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Performance of mango cultivars in eroded soils of Shiwalik foothills

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ABSTRACT

The present study describes the evaluation of six commercially important mango (*Mangifera indica* L.) cultivars namely 'Dashehari', 'Langra', 'Chausa', 'Lucknow Safeda', 'Ramkela', 'Sinduri' and two hybrids, namely 'Amrapali' (Dashehari × Neelam) and 'Mallika' (Neelam × Dashehari) being grown in the eroded soils of lower Himalayas. The experimental orchard was established in the year 2000 with plantation of uniform sized plantlets of different cultivars/hybrids under uniform edaphic conditions. The climate is sub-tropical humid with an annual average rainfall of 1118.8 mm. Comprehensive data for evaluation of horticultural traits of different cultivars and hybrids were recorded for three consecutive years (2008-2010). Maximum TCSA (477.2 cm^2), TCV (116.97 m^3) and CA (23.50 m^2) was observed in cultivar 'Ramkela'. Cultivar 'Sinduri' exhibited low growth vigour and the poorest total yields. Cumulative yield ranged from 28.7 kg $tree^{-1}$ (for the lowest yield cultivar 'Sinduri') to 91.1 kg $tree^{-1}$ (for the most productive hybrid 'Mallika'). The qualitative analysis indicated the superiority of hybrid 'Mallika' in terms of total soluble solids, titrable acidity, TSS: acid ratio, sugar content, low stone and peel content and high pulp attributes and low percent of physiological loss in weight of fruit compared to other cultivars and hybrids.

1. INTRODUCTION

Shiwalik foothills cover an area of 3.1 m ha in the States of Jammu and Kashmir, Himachal Pradesh, Punjab, Haryana and Uttarakhand and are experiencing rapid expansion in area under fruit cultivation (Prasad *et al.,* 2007). The regions receive an average annual rainfall of 1100 mm, out of which around 83% alone is concentrated in between the months of June to September during the monsoon season. The irregular distribution of rainfall causes soil erosion during four months of monsoon season and moisture stress during remaining eight months *i.e.* from October to May. The eroded soil of the foothills carries mineral nutrients and organic matter from soil profile and progressively turns the topography undulating. Soil erosion is a worldwide menace causing depletion of top soil at the rate of 0.38 mm yr^{-1} which is most serious in the southwest region of the world (Yang *et al.*, 2003). It is estimated that one-sixth of the world's soil has already been degraded by water and wind erosion. In India, approximately 45% of the total geographical area (130 m ha) is affected by soil erosion through ravines and gullies, shifting cultivation, cultivated wastelands, sandy areas, deserts and water logging (GoI, 2009). Under these adverse edapho-climatic conditions, selection of fruit tree species is very-very limited.

Mango (*Mangifera indica* L.) is one of the choicest and profitable fruit crops of tropical and sub-tropical regions of the world due to excellent flavour, attractive fragrance, delicious taste and high nutritive value. Its production is increasing in various subtropical zones throughout the world and is acclaimed as 'King of fruits' in the tropical world**.** The trees have strong frame work of branches and deep tap root system which can withstand several edaphic, biotic and abiotic extremes, and thus, have a better adoption compared to other fruit trees. Most of the cultivars hence, achieve their normal plant growth and development characteristics in the region but commercial fruit production requires some specific eco-geographical requirements for optimum growth and yield.

Comprehensive screening of mango cultivars for cropping behaviour and fruit production is the need of the hour and is yet to be studied for degraded soils of Shiwalik foothill region. In view of the above, the present study has been planned with the objective to evaluate the performance of different mango cultivars and hybrids under the agro-ecological conditions of Shiwalik foothills.

2. MATERIALS AND METHODS

Experimental Material and Description of Site

The experimental material consisted of uniform sized one-year-old grafted plants of six mango cultivars namely, 'Dashehari', 'Langra', 'Chausa', 'Lucknow Safeda', 'Ramkela', 'Sinduri' and two regular bearing hybrids, Amrapali' (Dashehari × Neelam) and 'Mallika' (Neelam × Dashehari) were transplanted during the year 2000-2001. The investigations were undertaken at the laboratory and Research Farm of ICAR-Indian Institute of Soil and Water Conservation (earlier CSWCRTI), Chandigarh (U.T.), India located at latitude 30°43′36″ North and 76°51′35″ East longitude at an elevation of 371 m above msl. The climate of the region is sub-tropical humid with an annual average rainfall of 1118.8 mm (mean rainfall since 50 years). Planting pits measuring 1 × 1 × 1 m were dugout at 5 × 5 m and boulders were removed through sieving. Farm yard manure was mixed with sieved soil in proportion of 1:4 and filled in dugout pits followed by deep irrigation. The plants were grown under uniform agro-ecological conditions as per standard package of practices, spaced at 5 x 5 m and trained in modified central leader system.

The study was carried out during the period 2008-2010. The soil is sandy loam having suitable soil texture containing 74.08% sand, 8.00% silt and 17.92% clay. It represents neutral pH with electrical conductivity of 0.10 dS m^{-1} and 0.20% organic carbon.

Vegetative Growth and Leaf Area Measurements

The trunk girth (15 cm above graft union), plant height, the tree spread in both the directions *viz.,* east-west and north-south and current season's shoot growth were measured. Trunk cross-sectional area (TCSA), tree canopy volume (TCV) and crown area (CA) were calculated. TCV was determined by calculating total above ground volume of each tree from the height and tree spread method as suggested by Westwood (1988) Each foliage sample comprised 50 leaves from middle of the shoot (non-fruiting and non-flushing) from December flush taken during the month of April. Every 5th leaf from each tree was collected for estimating the total leaf area $tree^{-1}$ and subsequently, the leaf area constant was calculated from these measurements for the collected leaves by using formula Leaf area/(length of leaf x breadth of leaf) as suggested by Westwood (1988). Degree days or heat units were calculated using formula [(M-10) x N; where, M is mean monthly temperature and N is number of days in the month] as suggested by Jackson (2011).

Fruit Yield and Yield Efficiency

Total yields and cumulative yield (kg $tree^{-1}$) were computed from the harvest data. Yield efficiency was calculated as kg cm^{-2} TCSA, kg m^{-3} TCV and kg m^{-2} CA and kg m^{-2} leaf area (LA). Efficiency values based on TCSA, TCV and LA were calculated using the corresponding tree measurements for that season as well as for cumulative 3-years yield. An overall yield efficiency was also calculated by dividing the mean of 3-years yield by the respective TCSA, TCV and/or LA value determined after the final harvest.

Sampling of Fruits and Physico-chemical Analysis

Ten mature and ripe fruits of each cultivar were harvested randomly from the trees and then subjected for physico-chemical analysis. Maturity of the fruits was judged on the basis of total soluble solids (TSS, °Brix) and the appearance of prominent lenticels and off white colour (Chadha *et al.*, 2004). The pulp, stone and peel of the fruits were separated and weighed. Physical parameters like fruit length, width, thickness and weight and subsequently stone, peel and pulp characteristics were recorded independently. Digital vernier calliper was used to measure the dimensions of the fruit samples, whereas, fruit volume was recorded by using water displacement method. TSS was determined using hand refractometer (0-32°, ERMA); acidity by titration method by 0.1N NaOH solution using phenolphthalein; sugar content; ascorbic acid was determined titrimetrically using 2, 6-dichlorophenolindophenol dye method (Ranganna, 1986) and total carotenoids in the fruit samples were estimated using standard procedure (A.O.A.C., 1980).

Statistical Analysis

The experiment was laid out in Randomized Block Design with three replications. The data recorded was pooled and the statistical analysis was carried out using analysis of variance to evaluate the comparative performance among mango cultivars and hybrids (Panse and Sukhatme, 1985). The Least Significant Differences (LSD) was used to compare the means at 5% level of significance.

3. RESULTS AND DISCUSSION

Plant Growth Measurements

The data for plant growth characteristics of mango cultivars/hybrids for the three years (8th to 10th growing

season) are shown in Table 1. Maximum plant height (745 cm), tree spread of 530 cm (east-west) and 560 cm (north-south), and tree girth (77.3 cm) was observed in cultivar 'Ramkela', whereas, it was recorded minimum in cultivar 'Sinduri' with corresponding values of 281.7, 248.3, 246.7 and 30.7 cm, respectively. Maximum mean current season's shoot growth of 61.3 cm was noticed in 'Dashehari', whereas, minimum of 18.0 cm was observed in cultivar 'Sinduri'. Data on tree size and growth rate revealed large differences among cultivars/hybrids. The highest trunk cross-sectional area (TCSA=477.2 cm^2), tree canopy volume (TCV=116.97 m^3) and canopy area (CA=23.50 m^2) at the end of 10^{th} year was observed in cultivar 'Ramkela', whereas, the cultivar 'Sinduri' having smallest TCSA (75.33 cm^2), TCV (9.04 m^3) and CA (4.81 m^2). The small tree size of 'Sinduri' was also reflected in its overall low plant growth measurements in contrast with 'Ramkela', which produced the highest growth of the trees. Smith *et al.* (2008) reported that trees with larger TCSA, tended to have high TCV, CA, and suggested the need for caution to estimate tree size based solely on trunk measurements. Data regarding leaf measurements of the trees depicted that cultivar 'Chausa' followed by 'Ramkela' have the highest leaf area $tree^{-1}$. Generally, trees with high vigour have large leaf area and largely depend on the variety (Jackson, 1997). But the tree vigour indirectly influenced the leaf area through decrease of the TCV (James and Middlenton, 2001).

Table: 1
Vegetative growth characteristics of mango cultivars and hybrids in the eroded soils

Cultivar/hybrid	Plant height	Tree Spread (cm)			Tree girth	Current season's	TCSA	TCV	CA	Leaf parameter			
	(cm)	East-West	North-South	Mean	(cm)	growth (cm)	(cm^2)	(m^3)	(m^2)	Length (L)	Width (W)	LA (cm^2)	LA constant (LA/L x W)
Amrapali	386.7	396.7	320.0	358.3	37.7	35.0	113.17	26.22	10.14	24.0	5.3	90.9	0.72
Mallika	501.7	470.0	476.7	473.3	46.0	48.7	168.67	58.96	17.62	20.1	5.3	74.0	0.70
Dashehari	528.3	503.3	536.7	520.0	59.2	61.3	279.32	74.82	21.25	23.5	5.6	101.7	0.77
Langra	513.3	500.0	493.3	496.7	46.0	49.7	168.67	67.11	19.55	22.1	8.0	131.7	0.75
Chausa	536.7	413.3	410.0	411.7	45.0	51.3	161.62	47.79	13.45	22.5	7.6	126.4	0.74
Lucknow Safeda	455.0	346.7	363.3	355.0	40.7	41.3	131.83	30.37	9.98	18.4	6.4	82.3	0.70
Ramkela	745.0	530.0	560.0	545.0	77.3	37.7	477.20	116.97	23.50	24.9	6.4	130.3	0.82
Sinduri	281.7	248.3	246.7	247.5	30.7	18.0	75.33	9.04	4.81	25.9	6.0	125.4	0.81
C.V (%)	9.1	10.6	11.5	3.3	6.7	2.1	15.55	26.34	20.0	7.0	7.4	9.2	2.09
LSD 0.05	78.4	79.1	85.4	69.7	5.6	9.9	53.66	24.87	5.27	2.8	0.8	17.42	0.03

TCSA= trunk cross sectional area; TCV= tree canopy volume; CA= crown area; LA= leaf area; C.V.= coefficient of variation

Fruit Yield and Yield Efficiency

Highest fruit yield (kg $tree^{-1}$) among mango cultivars/hybrids was obtained in 'Langra' in 2010. Maximum mean fruit yield was recorded in cultivar 'Langra', followed by 'Dashehari' and 'Mallika'. The mean of fruit yield obtained in the cultivars 'Lucknow Safeda', 'Ramkela', and hybrid 'Amrapali' was statistically at par to each other. Mango trees of cultivar 'Sinduri' with low growth vigour exhibited the poorest total yield (Table 2). Highest cumulative yield was noticed in hybrids 'Mallika', followed by 'Amrapali', and 'Lucknow Safeda', whereas, the lowest cumulative yield was recorded in cultivar 'Sinduri'. Similar observations were also noticed in apple varieties where an increase of the vigorousness of the tree is recorded to increase the cumulative fruit yield (McAfee and Rom, 2003). Conversely, hybrids 'Mallika' and 'Amrapali' produced the highest yields on the small trees. This diversity has important implications for different production systems in which it might be anticipated that low vigour cultivars are needed in higher-density plantations (Reddy *et al.*, 2003; Smith *et al.*, 2008) and more vigorous trees for traditional spacing.

Table: 2
Fruit yield, cumulative yield, yield efficiency and degree days between fruit set and maturity of mango cultivars and hybrids in the eroded soils at the end of 8th to 10th growing seasons

Cultivar/hybrid	Yield (kg tree^{-1})				Cumulative yield (kg tree^{-1})	Yield efficiency				Degree days between fruit set and maturity
	2008	2009	2010	Mean		Yield/TCSA (kg cm^{-2})	Yield/TCV (kg m^{-3})	Yield/CA (kg m^{-2})	Yield/LA (kg m^{-2})	
Amrapali	10.70	13.40	14.20	12.8	77.6	0.114	0.498	1.281	0.141	1659.4
Mallika	13.23	15.67	16.17	15.0	91.1	0.090	0.262	0.859	0.203	2101.5
Dashehari	16.67	5.53	26.17	16.1	69.2	0.057	0.215	0.757	0.158	2343.6
Langra	17.20	7.00	28.43	17.5	71.9	0.104	0.275	0.921	0.134	2163.3
Chausa	12.37	3.13	15.97	10.5	47.8	0.065	0.225	0.808	0.083	2346.2
Lucknow Safeda	12.73	14.73	15.90	14.5	73.4	0.110	0.497	1.500	0.176	2372.9
Ramkela	13.73	5.70	23.20	14.2	63.4	0.030	0.126	0.622	0.110	2298.7
Sinduri	5.37	3.20	5.67	4.7	28.7	0.066	0.532	0.988	0.038	2107.5
C.V (%)	9.9	11.6	9.0	7.9	7.2	14.99	23.7	19.35	11.57	2.20
LSD 0.05	2.21	1.74	2.87	1.8	8.2	0.02	0.136	0.328	0.026	83.6

TCSA= trunk cross sectional area; TCV= tree canopy volume; CA= crown area; LA= leaf area; C.V.= coefficient of variation

The best yield efficiency (kg cm^{-2}, Yield/TCSA) was found in hybrid 'Amrapali' which was significantly higher than all other mango cultivars/hybrids evaluated. In contrast, the lowest yield efficiency (Yield/TCSA) was recorded in cultivar 'Ramkela', which probably might be due to their high vigour, high TCSA, TCV and CA. The data recorded for yield efficiency (kg m^{-3}, Yield/TCV) and (kg m^{-2}, Yield/CA) are also presented in Table 2. Mango cultivars/hybrids 'Amrapali' followed by 'Lucknow Safeda' (Yield/TCV), 'Lucknow Safeda' followed by 'Amrapali' (Yield/CA) have best yield efficiency. Trees of 'Mallika' concerning yield efficiency expressed as kg m^{-2} LA have the highest value and the lowest value was found in trees of cultivar 'Sinduri'. In the present studies, the evaluated cultivars and hybrids showed that the decrease in the tree increased the yield efficiency of the trees. The cumulative yield showed a negative relationship with tree vigour which also confirms the strong negative correlations between tree size and yield efficiency of the cultivars. Similar findings have also been reported by Barritt *et al.* (1997) in apple.

Physical and Biochemical Characteristics of Fruits

Data recorded on physical characteristics of mango cultivars/hybrids showed that fruit dimensions had significant differences to each other (Table 3). The hybrid 'Mallika' had the superiority in terms of fruit measurements such as length, width, and thickness among all other cultivars/hybrids. Cultivar 'Ramkela' produced the smallest fruits. 'Mallika' had maximum dimension of fruits and hence, is being considered as a desirable cultivar. In the case of fruit weight and volume, 'Mallika' was followed by 'Langra' and 'Lucknow Safeda', and the lowest value was noticed in the cultivar 'Dashehari'. Bihari *et al.* (2012) also recorded heavier fruit of the cultivar 'Mallika'. No significant difference could be noticed between varieties in terms of specific gravity. 'Mallika', 'Chausa' and 'Sinduri' had a specific gravity of 1.07 g cc^{-1} each, whereas, it was least in the hybrid 'Amrapali' (1.04 g cc^{-1}). The results of the qualitative analysis of the fruits indicated the superiority of hybrid 'Mallika' in terms of total soluble solids (21.1 $^{\circ}$B), lowest titrable acidity (0.17%), higher contents of reducing sugars (2.60%), non-reducing sugars (14.53%) and total sugars (17.91%) as compared to other cultivars. TSS to acid ratio ranged from 57.83 to 104.38 among the different cultivars/hybrids. Cultivar 'Chausa', followed by hybrid 'Mallika' had the maximum TSS to acid ratio. TSS: acid ratio in 'Amrapali' was 95.89. The hybrid 'Amrapali' registered the highest ascorbic acid (34.5 mg 100^{-1} g of pulp) and total carotenoids (13.68 µg 100^{-1} g of pulp), followed by hybrid 'Mallika' with corresponding values of 33.7 mg 100^{-1} g of pulp and 8.75 µg 100^{-1} g of pulp, respectively.

Post Ripening Quality Attributes

Data on the physical attributes *i.e.* fruit weight, and stone weight, peel and pulp characteristics are presented in Table 4. Maximum fruit weight was recorded by hybrid 'Mallika', followed by the cultivars 'Langra', 'Lucknow Safeda', 'Dashehari' and 'Chausa'. The results also inferred that 'Chausa' recorded maximum (9.3%) loss in physiological weight during post ripening period, whereas, it was minimum in hybrid 'Amrapali' (3.2%). All the cultivars/ hybrids statistically differed in stone characteristics. Maximum stone weight was recorded in hybrid 'Mallika' (34.0 g) followed by the cultivars 'Sindhuri', 'Chausa', 'Amrapali' with corresponding values of 31.7, 30.4, 24.2 g, respectively. Maximum percent of stone in ripe fruit was assessed in 'Sindhuri' (20.1%), whereas, the cultivar 'Lucknow Safeda' recorded it the least (6.7%). Similarly, all the cultivars/hybrids recorded a

Table: 3
Physical and biochemical quality characteristics of fresh mango fruits at maturity stage

Cultivar/hybrid	Fruit Dimensions (cm)			Fruit weight	Fruit volume	Specific gravity	TSS	Acidity	TSS: acid	RS	NRS	TS	Ascorbic acid	Total Carotenoids
	Length	Breadth	Thickness (cm)	(g)	(cc)	(g cc-1)	(°Brix)	(%)	ratio	(%)	(%)	(%)	(mg 100^{-1} g of pulp)	(µg100^{-1} g of pulp)
Amrapali	10.0	5.9	5.5	171.7	165.0	1.04	20.3	0.19	95.89	2.59	13.72	17.04	34.5	13.68
Mallika	12.3	7.6	7.0	360.0	336.7	1.07	21.1	0.17	100.41	2.60	14.53	17.91	33.7	8.75
Dashehari	10.9	7.4	6.9	157.0	145.9	1.06	19.2	0.20	90.98	2.53	13.00	16.21	26.2	6.67
Langra	10.2	6.1	5.8	298.7	281.7	1.06	18.4	0.23	79.53	2.32	12.07	15.02	29.2	4.53
Chausa	10.2	7.1	5.8	221.0	206.7	1.07	19.1	0.22	104.38	2.24	13.18	16.11	30.4	7.13
Lucknow Safeda	10.3	6.7	6.4	286.3	270.0	1.06	17.3	0.23	77.00	2.21	11.23	14.03	25.7	5.28
Ramkela	7.4	6.1	5.0	168.0	158.3	1.06	18.3	0.30	61.07	2.19	12.38	15.22	26.2	4.34
Sinduri	7.8	6.0	6.1	168.3	156.7	1.07	16.9	0.26	57.83	2.04	11.55	14.20	28.1	3.95
C.V. (%)	6.2	3.7	4.2	12.5	12.1	2.9	5.5	8.77	9.71	3.07	3.19	2.99	7.57	9.63
LSD 0.05	1.1	0.4	0.5	51.7	47.3	NS	1.7	0.03	14.17	0.13	0.71	0.82	3.9	1.14

TSS= total soluble solids; RS= reducing sugars; NRS= non- reducing sugars; TS= total sugars; NS= non-significant; C.V.= coefficient of variation

Table: 4
Physical and biochemical quality characteristics of fresh mango fruits at maturity stage

Cultivar/hybrid	Weight (g)	Physiological loss in weight (%)	Stone					Peel			Pulp	
			Weight (g)	Dimensions			Percentage in ripe fruit	Weight (g)	Thickness (cm)	Percentage in ripe fruit	Weight (g)	Percentage in ripe fruit
				Length (cm)	Width (cm)	Thickness (cm)						
Amrapali	166.0	3.2	24.2	8.7	3.0	1.8	14.6	28.7	1.2	17.3	113.7	68.4
Mallika	331.7	7.8	34.0	10.5	4.1	1.9	10.2	44.0	1.6	13.4	252.0	76.4
Dashehari	210.0	4.2	23.8	9.6	3.1	1.7	11.3	36.3	1.2	17.3	149.8	71.3
Langra	280.7	6.0	20.3	7.6	3.5	1.5	7.4	36.0	1.1	12.9	224.3	79.7
Chausa	200.3	9.3	30.4	8.9	3.2	1.6	15.2	24.5	1.2	12.2	145.4	72.6
Lucknow Safeda	278.3	2.8	18.7	8.3	4.1	1.6	6.7	35.0	1.1	12.7	224.7	80.6
Ramkela	161.7	3.8	23.0	5.5	3.6	2.1	13.7	30.3	2.6	18.9	109.3	67.4
Sinduri	156.0	7.5	31.7	6.8	5.1	2.2	20.1	22.0	1.1	14.2	102.3	65.7
C.V. (%)	12.4	14.3	18.8	8.8	5.6	12.7	10.6	12.7	5.3	10.0	13.7	2.8
LSD 0.05	48.5	1.4	8.5	1.3	0.4	0.4	2.3	7.2	0.1	2.6	39.6	3.6

C.V.= coefficient of variation

significant statistical difference in peel attributes. The hybrid 'Mallika' ranked first in pulp weight (252.0 g) among all cultivars/hybrids. However, the cultivars 'Lucknow Safeda', 'Langra', 'Dashehari' also showed good pulp weight with corresponding values of 224.7, 224.3, 149.8 g, respectively. 'Sindhuri' recorded the lowest pulp weight (102.3 g) due to smaller fruit dimension. Maximum pulp percent of ripe fruit was assessed in 'Lucknow Safeda (80.6%) followed by 'Langra' (79.7%), whereas, the cultivar 'Sindhuri' recorded the minimum (65.7%).

4. CONCLUSIONS

Six cultivars and two hybrids of mango have been evaluated in the present study. Overall, it is concluded that cultivar 'Ramkela' performed the best in terms of largest trunk cross-sectional area, tree canopy volume and crown area of the trees and hybrid 'Mallika' recorded maximum cumulative yield during first 10 years of growth. On the basis of quality characteristics, hybrid 'Mallika' showed superiority and needs to be considered as a desirable cultivar for the region.

REFERENCES

A.O.A.C. 1980. Official Methods of Analysis of the Analytical Chemists. Association of Official Analytical Chemistry, Washington D.C. 83: 617-623.

Barritt, B.H., Konishi, B.S. and Dilley, M.A. 1997. Tree size. Yield and biennial bearing relationships with 40 apple rootstocks and tree scion cultivars. *Acta Hortic*., 451: 105-112.

Bihari, M., Kumar, R., Singh, K., Kumar, A., Prasad, A., Narayan, S. and Pandey, S.K.N. 2012. Quality parameters studies on *Mangifera genus* and varieties. *Ind. J. Hort.,* 69(2): 272-276.

Chadha, K.L., Singh, S.K., Asrey, R., Patel, V.B. and Sethi, S. 2004. Maturity standards in fruits and vegetables. pp. 795-796. In: *Post-harvest management marketing and trade in horticultural crops-Vol-II* (Eds. K.L. Chadha, R.N. Pal, S.K. Singh and K.V. Prasad). Proc. First Indian Horticultural Congress, 6-9 Nov., 2004, The Horticultural Society of India, New Delhi.

Government of India. 2009. State of Environment Report-2009. In: *Ministry of Environment and Forest. http://www.moef.gov.in, http://envfor.nic.in*

Jackson, E.J. 1997. Light interception and canopy characteristics at low latitudes in relation to orchard system design. *Acta Hortic.,* 451: 417-425.

Jackson, D.I. 2011. Climate in Fruit Plants. pp. 11-17. In: *Temperate and subtropical fruit production-3rd Edition* (Eds. D.I. Jackson, N.E. Looney, Michael Morley-Bunker and Graham Thiele) CABI International.

James, P.A. and Middlenton, S.G. 2001. Apple cultivar and rootstock performance at lenswood, South Australia. *Acta Hortic.,* 557: 69-76.

Jones, J.W., Hoogenboom, G., Porter, C.H., Boote, K.J., Batchelor, W.D., Hunt, L.A., Wilkens, P.W., Singh, U., Gijsman, A.J. and Ritchie, J.T. 2003. DSSAT Cropping System Model. *European J. Agro.,* 18: 235-265.

Majumdar, P.K. and Sharma, D.K. 1985. Mango. pp. 69-123. *In: Fruits of India Tropical and Subtropical.* (Ed. T.K. Bose), Naya Prokash, Calcutta-6, India.

McAfee, J.D. and Rom, C.R. 2003. Evaluation of size-controlling apple rootstocks for high-density 'Gala' apple orchards in Arkansas: final year results of the 1994 NC-140 Uniform Apple Rootstock Trail. *Hortic. Stud.*: 21-23.

Panse, V.G. and Sukhatme, P.V. 1985. *Statistical Methods for Agricultural Workers, 4th ed.* Indian Council of Agricultural Research, New Delhi, India.

Prasad, R., Yadav, R.P., Aggarwal, R.K., Agnihotri, Y., Mittal, S.P., Tiwari, A.K. and Samra, J.S. 2007. *Prospects of aonla cultivation on degraded shivalik lands.* Tech. Bulletin no. T-55/C-13. Central Soil and Water Conservation Research and Training Institute, Research Centre, Chandigarh (U.T.). 133 p.

Ranganna, S. 1986. *Handbook of analysis and quality control for fruits and vegetable products, second edition*. Tata McGraw-Hill Publishing Company Limited, New Delhi, India. 1112 p.

Reddy, Y.T.N., Kurian, R.M., Ramachander, P.R., Gorakh, S. and Kohli, R.R. 2003. Long-term effects of rootstocks on growth and fruit yielding patterns of 'Alphonso' mango (*Mangifera indica* L.). *Scientia Hortic*., 97: 95-108.

Smith, M.W., Bright, J.D., Hoult, M.D., Renfree, R.A. and Maddern, T. 2008. Field Evaluation of 64 rootstocks for growth and yield of 'Kensington Pride' mango. *Hort. Sci.,* 43 (6): 1720-1725.

Westwood, Melvin, N. 1988. Temperate Zone Pomology. Timber Press, 9999 S.W. Wilshire, Portland, Oregon. 428 p.

Yang, D., Kanae, S., Oki, T., Koike, T. and Musiake, K. 2003. Global potential soil erosion with reference to land use and climate changes. *Hydrol. Process.,* 17: 2913-2928.