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Tree architecture influenced productivity and quality attributes in apple under HDP

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ABSTRACT

The present experiment was conducted to develop efficient tree architecture in apple under high density planting systems. In this trial vertical axis tree and cordon tree architecture were validated first time in India viewing the success in horticultural advanced countries. Maximum annual extension growth (102.34 cm), trunk cross sectional area (23.66 cm^2), the highest yield per tree (10.92 kg), yield per hectare (84.63 t/ha) and yield efficiency (0.45 kg/cm$^{2)}$ were recorded in cultivar Coe Red Fuji under vertical axis tree architecture. Maximum fruit weight was observed in cultivar Coe Red Fuji under cordon tree architecture (167.14 h). The red colour intensity was recorded maximum (*a) (20.16) in cultivar Coe Red Fuji under vertical axis tree architecture, while, maximum yellow colour intensity (*b**) (28.44) were found in Granny Smith fruits under same architecture. Cultivar Coe Red Fuji has excelled on the overall vegetative growth, yield and quality attributes under HDP in vertical axis system.**

Key words: Apple, vertical axis, cordon tree, tree architecture, HDP, yield efficiency.

INTRODUCTION

Apple (*Malus domestica* Borkh.) is an important temperate fruit crop and its cultivation site falls geographically between 25-52°N or S latitudes. The apple productivity depends on canopy management, scion and rootstock behavior, fertilization, disease and pest management. Among all these factors canopy management plays a very vital role in production function. In apple, traditionally training system, *i.e.*, central leader, modified centre leader and open centre leader are being adopted with the advent of new growth controlling scion and rootstocks. The concept of high density led the development of modern tree architecture like vertical axis tree architecture (VATA) and cordon tree architecture (CTA), which had been found efficient in giving high yield and quality apple production. Training systems are the key factors for high yield and quality (Celik *et al*., 6). However, the selection of tree architecture depends on previous conducted studies (Celik *et al*., 5). Trees must be trained and pruned to achieve a manageable uniform size, a balance between growth and regular yield and also to permit good light and spray solution penetration to the inner most points of the centre canopy (Malavoeta and Cross, 13). Over the last 30-40 years, several tree architectures for the apple have been developed to attain high yields and quality (Ferree and Warrington, 8). Modern orcharding systems are based on high tree densities with a range from 1,000 to 6,000 trees and some upto 10,000 trees hectare^{-1} (Robinson, 14). Tree architecture involves the manipulation of planting arrangement and canopy geometry to improve the light interception and distribution of photosynthetic active radiation for the purpose of optimizing fruit quality and yield. Greene (9) reported the desired growth and yield of Granny Smith and Starking Delicious trees trained on 8 different ways and found no differences in leaf area and yield but systems did affect in fruit size and colour, the incidence of certain fruit defects and yield efficiency. Differences in fruit qualities were associated with difference in light interception and aeration in side canopy (Greene, 9; Ferree *et al*., 7).

MATERIALS AND METHODS

The present experiment was carried out during 2009-2013 at ICAR-CITH, Srinagar, Jammu and Kashmir situated at 34°, 45' N latitude, 74°, 50' E longitude at altitude of 1640 m above mean sea level. The average maximum and minimum temperature 19.63° and 6.52°C, respectively with total precipitation of 60.72 cm and relative humidity of 58.35%. Treatment comprised of three apple varieties, *i.e.*, Coe Red Fuji (V1), Granny Smith (V2) and Spartan (V3) on M9 rootstock on two architectures, namely, Vertical axis tree architecture (VATA) (T-1) and cordon tree architecture (CTA) (T-2) planted at 0.75 m × 1.5 m spacing. The experiment was laid in factorial randomized block design with three replications; uniform cultural practices were applied in all the trees under study. Data with respect to annual extension growth was measured by selecting four shoots randomly from each

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quadrant of the experimental tree and the average trunk cross-sectional area (TCA) was also worked out as per the procedure given by Westwood (19). The fruit weight was recorded using digital electronic balance and fruit yield was calculated at the time of harvesting and expressed as kg tree^{-1} and projected in tonnes hectare^{-1}. The yield efficiency was calculated by using the formula given by Westwood (19).

Colour measurements were recorded using Hunter Color Lab having the head 15 mm diameter and were expressed in the units of L^*, a^* and b^*. Chroma (C^*) and hue angle ($h°1$) were computed from L^*,a^* and b^* values. The colour meter was calibrated using the manufacturers' standard white tile (Lancaster and Lister, 12). The data were analyzed using SPSS statistical software.

RESULTS AND DISCUSSION

The data presented in Table 1 revealed that maximum trunk circumference (20.33 cm) and trunk cross sectional area (33.19 cm^2) was recorded in cultivar Coe Red Fuji, which was significantly superior to all other cultivars. Whereas, minimum trunk circumference (14.35 cm) and trunk cross sectional area (16.76 cm^2) were noticed in cultivar Granny Smith. Maximum annual shoot extension growth was noticed in cultivar Coe Red Fuji (98.55 cm), which was significantly superior to Granny Smith (84.17 cm). The effect of tree architecture on annual shoot extension growth was observed to be significant and annual shoot extension growth was recorded maximum (94.20 cm) with CTA, followed by VATA (90.72 cm). Interaction effect of cultivar and tree architecture on annual growth extension was observed to be significant. Cultivar Coe Red Fuji on VATA exhibited significantly maximum annual shoot growth (102.34 cm), which was superior to other architecture (Table 1). The system might be due to proper light penetration in canopy leading better to photosynthetic production. These findings are in accordance with those of Szczygiel and Mika (18) better on apple.

Tree vigour and growth habit varied, depending on the tree architecture (Table1), maximum trunk circumference (16.18 cm) and trunk cross sectional area (21.20 cm^2) were recorded in cultivar Coe Red Fuji, followed by Granny Smith. Significant effect of tree architecture was observed on trunk circumference and trunk cross sectional area. Maximum trunk circumference (14.32 cm), trunk cross sectional area (17.34 cm^2) were recorded in VATA. Interaction effect of cultivar and tree architecture on trunk circumference and trunk across sectional area were found to be non-significant. However, maximum trunk circumference (16.70 cm) and trunk cross sectional area (23.66 cm^2) were noticed in cultivar Coe Red Fuji

Table 1. Effect of cultivar and tree architecture on growth and yield of apple under HDP (pooled data 2011-13).

Cultivar	Annual extension growth (cm)	Trunk circum. (cm)	TCA (cm^2)	Yield (kg/ tree)	Yield (t/ ha)	Yield efficiency (kg/ cm^2)	Fruit wt. (g)
Coe Red Fuji (V1)	98.55	16.18	21.20	8.68	70.84	0.39	164.02
Granny Smith (V2)	84.17	13.72	15.46	3.19	28.34	0.18	137.73
Spartan (V3)	94.62	12.26	12.02	1.94	17.42	0.15	144.79
CD (P = 0.05)	5.57	0.81	2.67	2.88	8.88	0.08	20.82
Tree architecture							
VATA (T1)	90.72	14.32	17.34	5.97	48.96	0.31	143.74
CTA (T2)	94.20	13.97	15.12	3.26	28.72	0.17	153.95
CD (P = 0.05)	2.41	0.24	2.18	2.35	5.41	0.07	1.05
Interaction effect of cultivar and tree architecture							
Coe Red Fuji (V1) × VATA (T1)	102.34	16.70	23.66	10.92	84.63	0.45	160.91
Coe Red Fuji (V1) × CTA (T2)	94.77	15.66	18.75	6.44	57.06	0.33	167.14
Granny Smith (V2) × VATA (T1)	76.08	14.07	16.48	4.05	36.01	0.23	116.82
Granny Smith (V2) × CTA (T2)	94.27	13.39	17.43	2.32	20.61	0.13	158.64
Spartan (V3) × VATA (T1)	95.68	12.20	1.87	2.93	26.24	0.24	153.49
Spartan (V3) × CTA (T2)	93.56	12.33	12.18	0.96	8.60	0.06	136.09
CD (P = 0.05)	6.43	N.S	N.S	1.42	3.96	0.02	19.44

under VATA. The above findings are in consonance with Szczygiel and Mika (18) who reported stronger vegetative growth of trees expressed as trunk cross sectional area on M9. However, growth intensity was not significantly affected by the training and planting density of trees, although some tendency to stronger growth of trees planted at a lower density was observed. The cultivars had significant effect on yield attributes (Table 1). Maximum yield tree^{-1} (8.68 kg), yield hectare^{-1} (70.84 t/ha) and yield efficiency (0.39 kg cm^{-2}) were noticed in cultivar Coe Red Fuji. Similarly, the yield attributes were significantly influenced by the tree architecture with maximum yield tree^{-1} (5.97 kg tree^{-1}), yield hectare^{-1} (48.96 t ha^{-1}) and yield efficiency (0.31 kg cm^{-2}) under VATA, which was statistically superior to CTA. The interaction effects of cultivar and tree architecture on yield attributes were observed to be significant. Maximum yield tree^{-1} (10.92 kg), yield hectare^{-1} (84.63 /ha) and yield efficiency (0.45 cm^{-2}) were noted in Coe Red Fuji under VATA, which was significantly superior to all other systems. Yield efficiency was positively correlated with trunk cross sectional area, fruit weight, yield tree^{-1}; yield per hectare and yield efficiency. Yield is linearly related to light interception, which suggest that increase in light interception by tree architecture resulted in increased yields (Robinson, 15). Further, Antognozzi *et al.* (2) reported that the highest yield was obtained in slender spindle architecture having M9 and M26 as rootstocks for Gloden Delicious and M9 rootstock for Starking Delicious. Bielicki and Rozpara (3) obtained increased total yield in cherry grown on spindle architecture. Szczygiel and Milka (18) also reported that highest yield from tree on M9, trained on vertical axis tree architecture.

Maximum fruit weight was noticed in Coe Red Fuji (164.02 g), which was significantly superior to Granny Smith (137.73 g) but statistically at par with Spartan (144.79 g). Effect of tree architecture on fruit weight was observed to be significant (Table 1). Highest fruit weight was recorded on CTA (153.95 g). Combined effect of cultivar and tree architecture on fruit weight was found to be significant, maximum fruit weight (167.14 g) was observed in cultivar Coe Red Fuji under CTA, which was superior to Spartan under same architecture (136.09 g) and Granny Smith VATA (116.82 g). These results corroborate with the findings of Shengrui *et al.* (16) who obtained increased average fruit weight in apple cultivars on trellis architecture. Similarly, Bielicki and Rozpara (3) and Aleksander (1) noted higher, fruit weight in cherry after using the efficient tree architecture.

Interaction effect of cultivar and tree architecture was found to be significant. Maximum annual extension growth (102 cm) and minimum noted in Coe- Red Fuji and Granny Smith on VATA, respectively. Similarly TCA, yield tree^{-1}, yield, t ha^{-1} and yield efficiency were recorded highest in Coe Red Fuji in VATA, whereas fruit weight was found highest in same cultivar but in CTA (Table 1).

Maximum red colour intensity (a*) was recorded in cultivar Spartan (17.25) followed by Coe Red Fuji (15.70), however, it was negative (-a*) in cultivar Granny Smith (-7.45). The positive b*values were observed in all the cultivars and was maximum (27.46) in Granny Smith. Tree architecture had positive impact on red colour intensity (a*) in all the treatments with maximum (9.68) in VATA. However, effect of tree architecture on positive (b*) value (yellow colour intensity) on fruit was observed to be non-significant. Interaction effect of cultivar and tree architecture on red colour intensity (a*) was maximum (20.16) in Coe Red Fuji on VATA, followed by Spartan on CTA (17.29) and Spartan under VATA (16.22). Interaction effect of cultivar and tree architecture on yellow colour intensity (b*) on fruits were observed to be highest (28.44) in cultivar Granny Smith under VATA, which was significantly superior to other system (Table 2). Shengrui *et al*. (16) reported that the light penetration in the canopy was increased by tree architecture, which thereby improved colour of fruits with uniform size in apple. These results are in accordance with Hampson *et al.* (2002) who reported that fruit colour was improved on various tree architectures in apple.

Tree architecture for HDP is most influential factor for yield and quality. As the tree density increases, initially tree gives good quality yield, but with advancement in age shading affects both. For successful orcharding under HDP, suitable tree architecture is inevitable, which helps to control tree shape and canopy for better penetration of solar light, aeration and ease in targeted spray. The growth, productivity and quality were found superior in Coe Red Fuji trained on vertical axis tree architecture under intensive orchard system in apple.

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Table 2. Effect of cultivar and tree architecture on colouring pattern of fruits under HDP (pooled data 2011-13).

Cultivar	Color intensity/ Kind of colour				
	*L**	*a**	*b**	*Hue*	*Chroma*
Coe Red Fuji (V1)	54.25	15.70	20.91	57.97	25.62
Granny Smith (V2)	61.25	-7.45	27.46	-74.1	28.65
Spartan (V3)	43.35	17.25	12.00	69.60	20.46
CD (P = 0.05)	1.22	1.13	1.07	5.58	0.29
Tree architecture					
Vertical axis (T1)	54.43	9.68	19.75	24.22	25.65
Cordon tree architecture (T2)	54.31	5.65	20.49	11.40	24.17
CD (P = 0.05)	1.00	0.92	0.87	4.56	0.23
Interaction of cultivar and tree architecture					
Coe Red Fuji (V1) × VATA (T1)	56.70	20.16	19.27	43.61	27.71
Coe Red Fuji (V1) × CTA (T2)	56.35	7.25	22.56	72.34	23.53
Granny Smith (V2) × VATA (T1)	62.81	-7.33	28.44	-74.60	29.61
Granny Smith (V2) × CTA (T2)	65.11	-7.58	26.48	-73.68	27.61
Spartan (V3) × VATA (T1)	43.78	16.22	11.56	103.66	19.62
Spartan (V3) × CTA (T2)	41.46	17.29	12.44	35.55	21.31
CD (P = 0.05)	1.73	1.60	1.52	7.90	0.41

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