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Effect of tree architecture and variety on growth and yield attributes of apple under UHDP

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ABSTRACT

To find the efficient architecture type for apple under UHDP, experiment was carried out on 3-4 years old plants, results obtained revealed that maximum average yield (6.89 kg tree^{-1}) was noted in Coe Red Fuji irrespective of tree architecture and was minimum in cordon architecture. Maximum mean yield efficiency (0.67 kg cm^{-2} TCSA) was noted in Granny Smith (V2) and minimum in Spartan (0.37 kg cm^{-2} TCSA). Tree architecture had great influence on yield efficiency and quality. Maximum yield efficiency (0.67 kg cm^{-2} TCSA) was noted in vertical axis architecture and minimum (0.42 kg cm^{-2} TCSA) in cordon architecture. Positive correlation was recorded between fruit weight and yield efficiency under tree architecture. Though, color intensity (Chroma) was comparatively higher in cordon architecture and all the cultivars exhibited higher color intensity in cordon architecture.

***Keywords*:** Apple, cordon, Coe-Red –Fuji, Granny Smith, Spartan, tree architecture, vertical axis and yield efficiency

Apple (*Malus domestica* Borkh) is a very important fruit, occupies more than 70 per cent area and 60 per cent production of total temperate fruits in India. Apple productivity is a result of composite factors rootstock, planting density, pest and disease management, plant architectural techniques and variety in addition to orchard and floor management, irrigation, pollination and fruit numbers/tree. Dwarfing and semi-dwarf rootstocks have become widely acceptable by apple industry as effective tools to increase orchard efficiency (Barritt *et al*., 1995). Smaller and compact trees are more efficiently intercepting the solar energy (Green *et al.*, 2003). Tree height and canopy shape also affect the light interception, penetration and distribution in to the canopy. High yield and quality depends on light conditions, which can be further improved through designing the appropriate canopy shape (Ugolik, 1994; Buler *et al*., 1999; Gruca, 2001; Buler and Mika, 2004). Plant architecture with angled canopies have demonstrated better light relations and productivity than slender spindle on constant rootstock and spacing (Hampson *et al*., 2002; Robinson, 1997; 2000), tall trees have potential to intercept more light and yield than short statured tree at same spacing (Barrit, 2000; Callesen, 1993; Palmer, 1989; Wertheim *et al*., 2001). Tree size is generally expressed in trunk cross sectional area (TCSA), it is the most common and reliable factor to determine tree size and tree potential to produce fruit (Jimenez and Diaz, 2004; Wright *et al.*, 2006) and yield efficiency indicates the real potential of tree yield irrespective of the tree size. Annual extension growth exhibited the state of tree health; it is not affected by the training system (Hampson *et al*., 2004). The fruit weight, yield and fruit color depends on light interception, plant architecture, cultivars, density and rectangularity of planting, a square layout (1:1) is the most favorable for light interception and distribution (Wagenmakers, 1991; Wagenmakers and Callesen, 1995). Rectangularity affects both light interception, and distribution which influence the yield, tree size, alternate bearing, flowering density and fruit color in apple (Callesen and Wagenmakers, 1989; Cripps *et al*., 1975). The HDP in apple are being practiced with no definite canopy form, thus in order to harvest the potential productivity of apple, the present experiment was undertaken with an objective to standardize the ideal variety and efficient tree architecture under UHDP.

MATERIALS AND METHODS

The present experiment was conducted during 2010 to 2013 on 3-4 years old trees of apple budded on dwarf rootstock (M.9) In case of cordon architecture, well feathered at ICAR-Central Institute of Temperate Horticulture, Srinagar, Jammu and Kashmir, located at 34^{0}45' N latitude and of 74^{0}50'E longitude and 1640 msl, received mean maximum and minimum temperature 19.63^{0} C and 6.52^{0}C, respectively and rainfall 60.72 cm annually. Three apple varieties *i.e*. Coe Red Fuji, Granny Smith and Spartan spaced at 1.5 m among row and 0.75 m among trees and were trained on Vertical axis (VA) and Cordon architecture (CA). Vertical axis is a single axis training system in which fruiting occurs on main trunk and primary and secondary scaffolds were allowed to grow 30 and 30-45 cm between rows. In case cardon architecture, well feathered budded plants were planted at 45^{0} angle; trees were supported by 4 wires erected on iron pole fixed at 7-8 m. The experiment was laid out in

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factorial randomized block design, replicated thrice, with two plants replication^{-1}, uniform cultural operations were carried out in all the trees under experiment. Trunk diameters of each variety were measured 15 cm above the graft union and trunk cross sectional areas were calculated with standard formulae (TCSA=Girth^2/4π). For fruit weight, 15 fruits were randomly harvested at maturity, weighted using digital electronic balance and fruit yield was calculated as total weight of fruit per unit TCSA (kg cm^{-2} of TCSA) at the time of harvest. The color was recorded using the head 15 mm in diameter of the Hunter color lab, it was calibrated using the manufacturers' standard white tile and were expressed in L*,a* and b* . The color intensity (chroma) was worked out using formula $(a^2+b^2)^{1/2}$). The data were analyzed statistically as per procedure given by Sheoran *et al*. (1998), and are being presented in the table for interpretation of the results.

RESULTS AND DISCUSSION

It is obvious from the table 1 that maximum mean AEG and fruit weight (119.08 cm and 186 g fruit^{-1}) were recorded in Granny smith and minimum (107.85cm and 109.87 g fruit^{-1}) in Spartan. Tree architecture has significant effect on AEG and fruit weight, maximum AEG and fruit weight (107.39 cm and 152.47 g fruit^{-1}) were recorded in vertical architecture (Table 2). Combined effect of architecture and variety were found significant on AEG and fruit weight, maximum AEG (132.16 cm) in V2 × T1 and minimum (106.0 cm) in V3 x T2 (Table 3). Similarly higher fruit weight was noted in Granny Smith (175.04 g fruit^{-1}) grown on vertical axis architecture over the years and minimum fruit weight in Spartan on all the tree architectures.

Yield is a function of variety, significantly maximum average yield tree^{-1} (6.89 kg tree^{-1}) was recorded in Coe Red Fuji irrespective of tree architecture (Table 4). Tree

Table 1: Effect of variety on annual extension growth and fruit weight during 2012-13

Variety	Annual extension growth (cm)				
	2010	2011	2012	2013	Mean
V_1= Coe-Red Fuji	115.67	109.16	124.00	123.67	118.12
V_2= Granny Smith	114.00	109.33	120.67	132.33	119.08
V_3= Spartan	88.20	106.88	116.50	119.83	107.85
LSD (0.05)	**13.96**	**NS**	**5.42**	**NA**	**-**
r with yield*	**0.87**	**0.90**	**0.99**	**0.04**	**-**
	Fruit weight (g)				
V_1= Coe-Red Fuji	168.0	154.80	158.17	161.33	160.75
V_2= Granny Smith	178.50	162.67	208.50	197.80	186.87
V_3= Spartan	128.0	102.67	106.67	98.83	109.87
LSD (0.05)	**12.55**	**17.41**	**11.10**	**11.10**	**-**
r with yield*	**0.980**	**0.935**	**0.789**	**0.786**	**-**
r with AEG	**0.726**	**0.843**	**0.970**	**0.868**	**-**

*Note: *r= Correlation coefficient*

Table 2: Effect of tree architecture on AEG and fruit weight during 2012-13

Treatment	Annual extension growth (cm)					Fruit weight (g)				
	2010	2011	2012	2013	Mean	2010	2011	2012	2013	Mean
T_1= Vertical Axis	124.67	122.33	131.78	130.78	107.39	154.44	157.89	131.78	165.78	152.47
T_2= Cordon system	87.11	94.59	109.00	119.78	102.62	140.90	140.33	133.44	160.11	143.69
LSD (0.05)	**11.39**	**5.19**	**4.43**	**9.81**	**—**	**NS**	**14.21**	**NS**	**NS**	**—**

Table 3: Interaction effect of variety and tree architecture on growth and fruit weight during 2012-13

Variety	AEG (cm)							
	2010		2011		2012		2013	
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
V_1= Coe-Red Fuji	127.00	104.33	124.33	94.00	136.67	111.00	136.33	111.00
V_2= Granny Smith	142.67	129.00	129.00	89.67	138.00	165.00	138.00	126.00
V_3= Spartan	104.33	71.67	113.67	76.50	126.00	118.00	118.00	119.80
LSD (0.05)	**19.74**	**19.74**	**8.99**	**8.99**	**7.67**	**7.67**	**8.54**	**8.54**
	Fruit weight (g)							
V_1= Coe-Red Fuji	160.00	150.00	170.67	153.33	144.33	140.0	202.67	186.00
V_2= Granny Smith	165.00	155.00	192.00	173.03	150.0	156.0	210.67	198.67
V_3= Spartan	138.33	117.67	111.00	94.33	101.00	104.33	84.00	95.66
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 4: Effect of varieties and tree architecture on yield during 2012-13

Treatment	Yield (kg tree^{-1})				
	2010	2011	2012	2013	Mean
V_1= Coe-Red Fuji	3.19	8.06	7.17	9.15	6.89
V_2= Granny Smith	2.84	6.06	5.23	6.75	5.22
V_3= Spartan	1.38	2.80	2.05	3.20	2.35
LSD (0.05)	**0.33**	**2.27**	**1.70**	**2.12**	-
r with fruit weight	**0.951**	**0.803**	**0.831**	**0.880**	-
T_1= Vertical Axis	2.30	8.27	7.56	8.80	6.73
T_2= Cordon system	1.22	3.02	2.07	3.93	2.56
LSD (0.05)	**0.27**	**1.85**	**2.17**	**1.73**	-

Table 5: Interaction effect between variety and tree architecture on yield (kg tree^{-1}) during 2012-13

Variety	2010		2011		2012		2013	
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
V_1= Coe-Red Fuji	4.62	1.30	11.50	4.63	10.66	3.66	12.67	5.63
V_2= Granny Smith	2.68	2.18	9.47	2.67	8.33	2.13	9.30	4.20
V_3= Spartan	1.63	1.13	3.85	1.77	3.70	1.40	4.43	1.98
LSD (0.05)	**1.27**	**1.27**	**2.15**	**2.15**	**1.85**	**1.85**	**1.76**	**1.76**

architecture also affected tree yield significantly, maximum average yield tree^{-1}(6.73 kg tree$^{-1)}$ and it was lowest in cordon tree architecture (Table 4).

Yield efficiency and TCSA was also affected by variety, was noted in increasing trends over the years, maximum average yield efficiency (0.67 kg cm^{-2} TCSA) was noted in Granny Smith (V2), minimum in Spartan (0.42 kg cm^{-2} of TCSA) (Table 6). Positive correlation coefficient was observed between yield efficiency and annual extension growth (Fig. 1). Combined effect of varieties and tree architectures on yield efficiency were also affected were also found maximum (0.72 kg cm^{-2} TCSA) in V2 × T1 and minimum (0.27 kg cm^{-2}) in V3 × T2 (Fig. 1). Color intensity (chroma) was not influenced

Table 6: Effect of variety and tree architecture on yield efficiency (kg cm^{-2} of TCSA) during 2012-13

Treatments	2010	2011	2012	2013	Mean
V_1= Coe-Red Fuji	0.388	0.492	0.483	1.030	0.60
V_2= Granny Smith	0.50	0.578	0.412	1.175	0.67
V_3= Spartan	0.33	0.433	0.162	0.563	0.37
LSD (0.05)	**0.726**	**0.843**	**0.970**	**0.942**	-
r with AEG	**0.092**	**0.045**	**0.130**	**0.263**	-
T_1= Vertical Axis	0.526	0.559	0.474	1.126	0.67
T_2= Cordon system	0.312	0.443	0.230	0.720	0.42
LSD (0.05)	**NS**	**0.036**	**0.106**	**0.215**	-

by varieties, however, tree architectures had remarkable effect on chroma development, and maximum chroma (31.45) recorded on Cordon architecture (T2). No significant variation was noted on chroma with the combined effects of varieties and architecture (Fig. 2). The Scion growth was such a variable, which was not affected by the architecture, as it is innate property of the cultivars, similar trend in scion growth was also reported by Hampson *et al*., 2004, who observed that the scion growth was influenced by genetic constituents of cultivars not by training system. Coe Red Fuji is prolific bearing in habit, fruits are medium in size with large number of fruits per tree (2000-3000 thousand tree^{-1}) after 3 years, these results are in agreement with Srivastava *et al.* (2015) who reported high yields in Coe Red Fuji, Granny Smith and Spartan on espalier training system. Yield per tree and fruit weight are having positive correlation, (Costa *et al*., 1997). TCSA of the trees are accountable for the transporting and distribution of the photosynthates from source to sink, which ultimately affected the vegetative growth and fruit yield (Hartmann and Kester, 2002). Yield efficiency of the tree was increased with increased in TCSA. Similar relationship between TCSA with yield and AEG were reported by Dalal and Barar (2012) in Kinnow Mandarin, Dhaliwal and Dhillon (2003) in guava, Kumar *et al*., 2010 in Banana. In espalier, vertical axis and cordon architecture, initially no clear cut trend in fruit weight observed because of negligible competition among the fruit-lets for photosynthates, space, and light energy. Similarly, Palmer *et al.* (1997) reported that fruit weight was more with minimum competitions among fruit-lets. Initially yield tree^{-1} was recorded in increasing trends in this experiment, over the years, but the trend may change with the age of the trees.

The plant architecture determined the tree shape, but not overall tree size (Hampson *et al*., 2004). In T1 (Vertical axis), the overall annual extension growth was more than T2 (Cordon), the tree planted at 45^0 angle (T2) might have created obstacle in translocation of mineral nutrient from root to shoot and photosynthates from shoot to root. Further, horizontal growing shoots have lower auxin content as compared to upright shoots (Kato and Ito, 1962). Luckwill (1968) reported that the supply of nutrient to the apex is controlled by auxin in top meristem. In the T2 architecture earliest fruiting and heavy cropping started because the trees were trained at 45^o angle, which might have developed precocity, by impairing the apical dominance which has enhanced the floral development in the lateral shoots similarly, Srivastava *et al*. (2008) also reported that on 60 and 90^0 angle branch in Conian Itly apricot, minimum growth in shoot diameter were observed. The Granny Smith variety color was very intense and pure however, Costa *et al*. (1997) reported decrease in chroma values with tree density in Braeburn apple. Yield efficiency is reliable parameter for estimating the yield potential of varying tree size, AEG have positive correlation with yield efficiency, it may be due to more vegetative growth resulting more production of photosynthates due to which high partitioning of photo-assimilates occur towards growing fruit. Similarly Srivastava *et al.* (2008) recorded maximum yield in apricot trees in which branches were trained at 60^0 angle. Maximum color intensity (Chroma) recorded in T2 architecture, it may be due to the maximum exposed leaves to the solar radiations which results, more carbohydrate production, increased sugar content in fruits helps in the development of color intensity (Chadha, 2001).

TCSA showed positive correlation with fruit weight, yield efficiency and yield kg tree^{-1}. In the vertical axis architecture, higher fruit weight, yield efficiency and cumulative yield were observed as compared to Cordon. Yield efficiency was higher in Granny Smith in all the tree architecture; however, color intensity (Chroma) was higher in Cordon architecture. Coe Red Fuji, Granny Smith and Spartan exhibited high chroma value in cordon architecture.

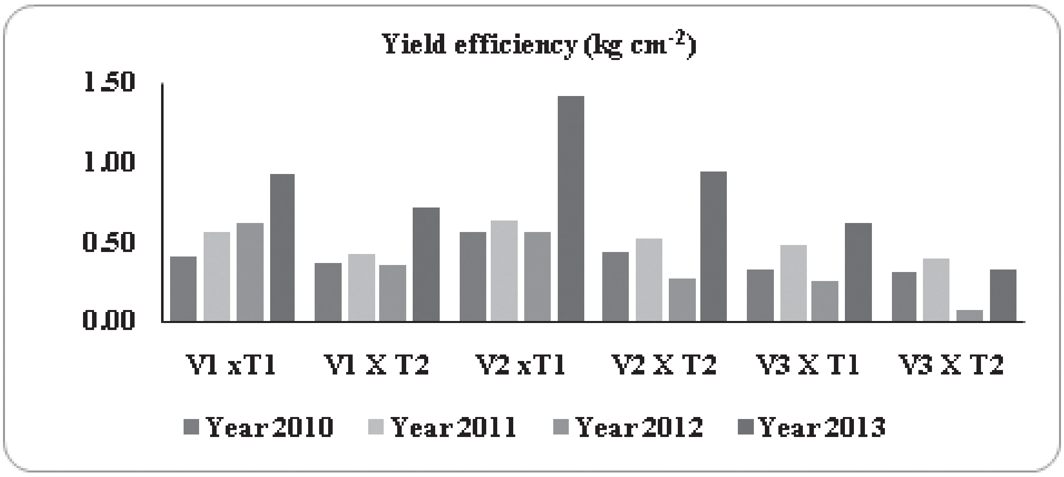

Fig. 1: Effect of variety and tree architecture on yield efficiency

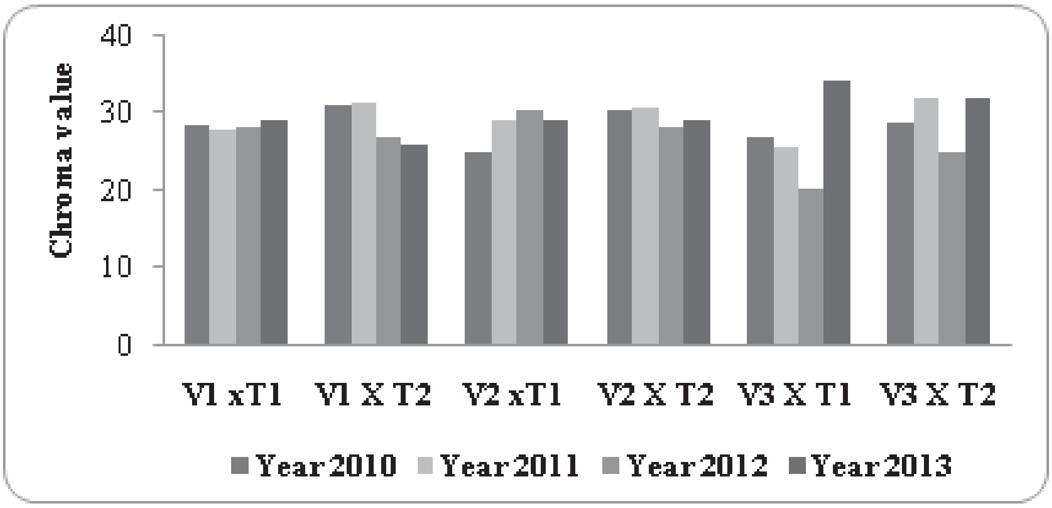

Fig. 2: Combined effect of architecture and varieties on chroma value of apple

The study unveiled that tree architecture had great influence on yield and quality attributes. The vertical axis tree architecture was found better with respect to yield and its associated attributes, while as cordon architecture have bright skin color and overall appearance.

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