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Original Research Paper

Effect of cultivars on tree growth, yield and quality attributes of apple on espalier architecture under high density planting system

K.K. Srivastava, Dinesh Kumar, S.R. Singh and O.C. Sharma
ICAR-Central Institute of Temperate Horticulture, Old Air Field, Rangreth, Srinagar - 190 007 (J&K), India.
Email : kanchanpom@gmail.com

ABSTRACT

Annual extension growth (AEG), an indicator of tree vigor, was recorded maximum (145.63 cm) in Granny Smith and minimum (111.04cm) in Spartan, where as correlation matrix showed negative relation between trunk cross sectional area (TCSA) and AEG. Granny Smith exhibited maximum (184.09 g) fruit weight and it was minimum (128.68 g) in Spartan, the correlation matrix between fruit weight and yield efficiency exhibited significant positive correlation over the years. Yield tree^{-1} was maximum (29.45 kg tree^{-1}) in Coe red Fuji and minimum (16.04 kg/tree) in Spartan. Significant and positive correlation coefficient (0.870) observed between yield and TCSA. TCSA has positive correlation with fruit weight and yield efficiency, maximum mean yield efficiency (1.11 kg/cm^2) was recorded in Granny Smith. All the cultivars trained on this architecture had high chroma values (color intensity).

Key words: apple, tree architecture, espalier, high density planting, Coe-Red –Fuji, yield efficiency, chroma

INTRODUCTION

Apple (*Malus domestica* Borkh) is an important fruit, occupies more than, 70% area and 60% production of total temperate fruits in India. Apple productivity is a production function of rootstock, planting density, tree architecture and variety in addition to orchard and floor management. Dwarfing and semi-dwarf rootstocks have been widely accepted in apple industry as effective tools to increase orchard efficiency (Barritt *et al.*, 1995) as smaller and compact trees can more efficiently intercept the solar energy. High and early productivity in high density planting system is partly based on the greater leaf area ha^{-1}, resulting greater light interception of photosynthetically active radiations (PAR) (Jackson, 1980). Tree height and canopy shape also affect the light interception, penetration and distribution in the inner portion of the canopy. High density orchards have varied canopy architecture form, practiced all over world; however, the most common is the spindle form (Mika *et al.,* 1984; Mika *et al.,* 2001). Tall trees have potential to intercept more light and yield than short statured tree at the same spacing (Barrit, 2000, Callesen, 1993; Palmer 1989. The trunk cross sectional area in the HDP was 20% less than that of low density (Hampson *et al.,* 2004). The tree size is virtually expressed in trunk cross sectional area (TCSA), as it is the most common and reliable factor to determine tree size and yield potential (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 planting rectangularity. Square planting system (1:1) is the most favorable for light interception and distribution (Wagenmakers, 1991; Wagenmakers and Callesen, 1995). Espalier is like kniffin tree architecture of grape, comprising 4-5 layer of wires running parallel at 30-45 cm interval on which scaffold branches are trained on both directions.

MATERIALS AND METHODS

The present experiment was carried out during 2010 to 2014 at ICAR-Central Institute of Temperate Horticulture, Srinagar, J&K. The experiments includes 3 cultivars; Co-Red Fuji (V1), Granny Smith (V2), Spartan (V3) which were grafted on to M.9 rootstock. The planting was done at 1.5x 3.0 m (row to row and plant to plant). All the experimental trees were trained on 5 tier galvanized wires fixed on the iron angle of 1.5 m, the angles were fixed at 8 m distance. First wire fitted at 45 cm from ground level and rest 4 wires at 30cm intervals. The experiment was laid out in complete randomized block design with six replications and 2 plants/ replication; uniform cultural operations were practiced in all the trees under study, drip irrigation laid out for irrigation and fertigation. Trunk diameters were measured 15 cm above the graft union. The trunk cross sectional area was calculated by using standard formulae ($TCSA=Girth^2/4\pi$). 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 Hunter colour 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 Sheoran *et al* (1998), and are being presented in the table for interpretation of the results.

RESULTS AND DISCUSSION

Espalier architecture

Annual extension growth (AEG) is the indicator of tree vigour, maximum AEG (145.63 cm) noted in Granny smith and minimum (111.04 cm) in Spartan while as correlation coefficient exhibited negative over the years between TCSA and AEG (**Table 1**). Similar trend in fruit weight with respect to variety was recorded in this experiment, Granny Smith showed maximum fruit weight throughout the studied period. Average fruit weight recorded maximum (184.09 g $fruit^{-1}$) in Granny Smith, while as minimum (128.68 g $fruit^{-1}$) in Spartan, the correlation matrix between fruit weight and yield efficiency exhibited significant positive correlation over the years (**Table 2**). Yield per tree was also influenced by the cultivars under espalier architecture, where in, maximum average yield (29.45 kg $tree^{-1}$) was recorded in Coe red Fuji and minimum (16.04 kg $tree^{-1}$) in Spartan. Significant and positive correlation coefficient (0.870) was observed between yield and TCSA (**Table 3**). The apple grafted on to dwarfing rootstocks, the tree exhibited precocity resulting fair yield in 2^{nd} year on wards. Coe Red Fuji has tendency to bear large number of fruits $tree^{-1}$ of medium sized in turn had maximum mean productivity (65.84 t ha^{-1}), while as, Spartan has comparatively low productivity over the years, 40.69 t ha^{-1}(**Fig.1**). TCSA is reliable criteria to estimate yield of the tree. Trunk cross sectional area was recorded maximum (33.01 cm^2) in Coe Red Fuji over the years which were on par to Granny Smith and Spartan, significant and positive correlations were noted, TCSA with fruit weight and yield efficiency (**Fig 2**).

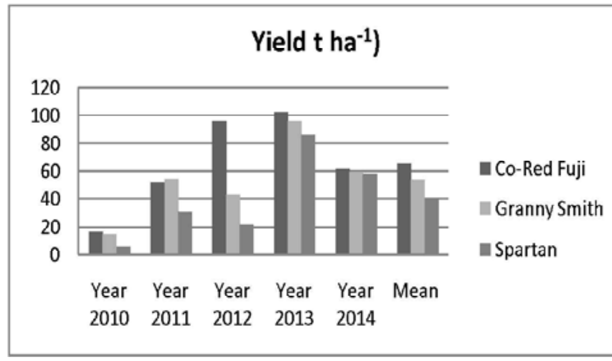

Fig. 1: Yield of apple varieties under espalier architecture

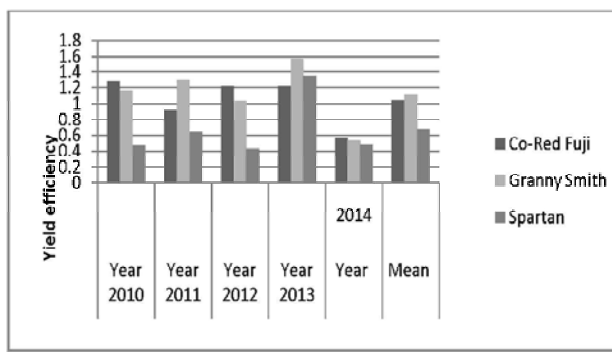

Fig. 2. Yield efficiency of apple under espalier architecture

Yield efficiency permits comparisons among the trees of varying vigor and was used as reliable criteria to estimate yield potential of different varieties grown under different spacing. Maximum average yield efficiency (1.11 kg cm^{-2}) recorded in Granny Smith followed by Coe Red Fuji (1.04 kg cm^{-2}), whereas, it was minimum (0.67 kg/cm^2) in Spartan. Chroma values were worked out to show the color intensity, all the studied varieties exhibited high color intensity as per their genetic constituents Hence, no considerable variations were observed on the chroma values among the studied varieties over the years (**Table 4**).

Table 1. **Varietal influence on annual extension growth under espalier architecture**

Variety	AEG (cm)					
	Year 2010	Year 2011	Year 2012	Year 2013	Year 2014	Mean
Co-Red Fuji	106.67	113.66	116.89	121.0	127.17	117.07
Granny Smith	139.66	142.50	145.50	148.17	152.33	145.63
Spartan	97.67	105.87	111.17	118.67	121.83	111.04
r with TCSA*	-0.368	-0.053	-0.325	-0.025	-0.035	-
CV (%)	8.90	8.91	7.10	6.15	6.17	-
LSD (p= 0.05)	13.31	16.95	10.75	9.73	10.75	-

*r= Correlation matrix (p=0.05)

Table 2. Effect of varieties on fruit weight under espalier architecture

Variety	Friut weight (g)					
	Year 2010	Year 2011	Year 2012	Year 2013	Year 2014	Mean
Co-Red Fuji	154.71	163.03	148.47	155.67	182.53	159.98
Granny Smith	176.14	172.76	160.58	208.28	207.68	184.09
Spartan86.28	125.67	94.62	166.97	171.86	128.68	
r with yield efficiency	0.933	0.988	0.919	0.985	0.602	0.950
CV(%) 3.0	2.41	4.90	1.92	2.50	1.50	
LSD(p= 0.05)	4.87	4.38	7.71	4.00	4.82	2.73

*r= Correlation matrix (p=0.05)

Table 3. Effect of varieties on yield potential

Variety	Yield kg $tree^{-1}$					
	Year 2010	Year 2011	Year 2012	Year 2013	Year 2014	Mean
Co-Red Fuji	7.52	26.09	43.26	46.22	24.18	29.45
Granny Smith	6.80	22.83	20.19	43.91	15.67	21.88
Spartan	2.70	13.50	10.72	38.40	14.90	16.04
r with TCSA	0.782	0.643	0.875	0.638	0.977	0.870
CV (%)	5.18	12.87	9.1	5.08	12.16	4.25
LSD(p= 0.05)	1.20	3.15	2.70	2.60	2.61	1.30

*r= Correlation matrix (p=0.05)

Table 4. Trunk cross sectional area of apple varieties

Treatment	TCSA					
	Year 2010	Year 2011	Year 2012	Year 2013	Year 2014	Mean
Co-Red Fuji	25.99	27.90	33.31	37.02	40.83	33.01
Granny Smith	17.54	19.87	21.70	24.97	28.13	22.44
Spartan	17.22	19.49	22.03	25.97	28.93	22.72
r with fruit weight	0.321	0.246	0.135	0.552	0.392	0.990
r with yield efficiency	0.639	0.592	0.511	0.385	0.956	0.638
CV (%)	14.47	9.20	8.5	9.90	4.67	2.5
LSD (p= 0.05)	3.45	2.4	2.47	3.2	1.8	0.75

*r= Correlation matrix (p=0.05)

The scion growth is not affected by the tree architecture as it is due to genetic constituents of the cultivars; similarly Hampson *et al*. (2004) also reported that scion growth was affected by genetic constituents of cultivars not by tree architecture. The Coe Red Fuji which has prolific in bearing habit are medium sized and large number of fruit set per tree (4-5 thousand) after 3 years, these results are in agreement with Ahmed *et al*. (2015) who also reported higher yields in Coe Red fuji, Granny Smith and Spartan on espalier architecture. Fruit weight has direct correlation with yield; it decreased with increasing planting density (Costa *et al*., 1997). TCSA of the tree was positively correlated with the transporting and distribution of the photosynthates from source to sink, which ultimately affects the tree growth and fruit yield. The productivity efficiency of the tree increased with increase in TCSA (**Table 5**). Similar growth pattern in TCSA with yield and TCSA with AEG were reported by, Kumar and Kumar *et al* (2011) in Banana. In general, fruit weight is negatively correlated with tree density, where in higher tree density has low fruit weight. In espalier architecture, initially no clear cut trend in fruit weight was observed because of negligible competition among fruit-lets for photosynthates, space, and light energy. Similarly, Palmer *et al.* (1997) reported that fruit weight was greatest when there were minimum competition between fruits. The yield per tree was observed increasing trends, since the observations were taken on the 3 years after plants, the trend may change in future with the age of the trees.

Tree architecture determined the tree shape, but not overall tree size (Hampson *et al*., 2004). Further, horizontal growing shoots have lower auxin content as compared to upright shoots (Kato and Ito, 1962). Luckwill (1968) reported that the supply

Table 5. Chroma value of apple on espalier architecture

Variety	Year 2010	Year 2011	Year 2012	Year 2013	Year 2014	Mean
Treatment	Year 2010	Year 2011	Year 2012	Year 2013	Year 2014	Mean
Co-Red Fuji	26.53	27.14	26.35	25.67	29.68	27.07
Granny Smith	23.27	28.47	28.37	26.70	27.70	26.90
Spartan	25.25	25.71	25.71	28.00	27.85	26.50
r with AEG	-0.822	0.853	-0.014	-0.660	-0.185	0.760
CV (%)	9.07	1.90	10.16	11.53	8.20	5.80
LSD (p= 0.05)	NS	1.33	NS	NS	NS	NS

*r= Correlation matrix (p=0.05)

of nutrient to the apex is controlled by auxin in top meristem. Srivastava *et al* (2008) also reported that minimum growth in shoot diameter noted at 60 and 90^0 branch angles in Conian Itly apricot. The color was very intense in Granny Smith, 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, more production of photosynthates resulting high partitioning of photo-assimilates to developing fruits, thus increased in yield efficiency. Similarly Srivastava *et al* (2008) recorded maximum yield in apricot tree branched at 60^0 angle. Maximum color intensity (chroma) was recorded in espalier architecture, which may be due to the maximum exposed leaves to the solar radiations which results in more carbohydrate production and increased sugar content in fruits helped in the development of color intensity (Chadha, 2001).

The Coe Red Fuji and Granny Smith have better performance on espalier architecture, though the initial cost for erection of the training structure was high. Yield efficiency and quality on espalier tree architecture were high. Further, ease in tree branch, shoot and leaf positioning are added advantage and low wastage of inputs are additional advantage. The AEG might be an indicator for assessing tree vigour. Granny Smith exhibited high growth and fruit weight but overall productivity was recorded high in Coe red Fuji on espalier architecture. TCSA showed positive correlation with fruit weight, yield efficiency, and yield kg $tree^{-1}$. Chroma value in all the varieties were found on par, as trees on espalier architecture have all the leaves well illuminated to the solar radiations.

REFERENCES

Ahmed N., Srivastava, K.K., Kumar Dinesh, Lal Shiv. (2015). Managing tree architecture for quality apples. *Indian Hort*. 60(4):6-8.

Barritt, B.H., Konishi, A.S.,Dilley, M.A. 1995 Intensive orchard management performance of three apple cultivars with 23 dwarfing rootstocks during 8 seasons in Washington. *Fruit Var. J*.**49**: 158-170.

Callesen, O.1993 Influence of apple tree height on yield and fruit quality. *Acta Hort.*, **349:** 111-115.

Chadha, K.L. 2001. Handbook of Horticulture Indian Council of Agricultural Research New Delhi, 291-296.

Costa, G. Testolin, R. and Sansavini S. 1997. Increasing plant density in peach: physiological aspects, cropping and orchard management. *XXII Convegno Peschicolo Cesena*,28-30.

Hampson, C., Quamme, H.A., Kappel, F., and Brownlee, R.T. 2004. Varying density with constant rectangularity: II. Effects on apple tree yield, fruit size and fruit color development in three training systems over ten years. *J. Hort. Sci.*, 39 **(3):** 50-51.

Jackson, J. E. 1980 Light interception and utilization by orchard systems. *Horticultural Revie*ws **2:**208-267.

Jimenez, C. M., and Diaz, J B R. (2004). Stastical model estimates potential yields in Golden Delicious and Royal Gala apples before bloom. *J. Amer. Soc. Hort. Sci*.129 **(1):**20–25.:741–746.

Kato, T. and Ito, H. 1962. Physiological factors associated with the shoot growth of appletrees. *Tohoku J. Agric. Res*. **13:** 121.

Kumar,S. and Kumar, A. 2011. Effect of high density planting on performance of banana. *J. Hort*. **1:**54-56.

Luckwill, L.C. (1968). The effect of certain growth regulator on growth on growth and apical dominance on young apple tree. *J.Horti.Sci*.**43:**91-101.

Mika, A. Buler, Z. and Chlebowska, D. 2001 Effects of within row spacing and training systems of plum trees grafted on vigorous and semi-dwarf root stocks. *Acta Hort* **557**: 275-80.

Mika, A.D., Chlebowska, and J. Kosmala. 1984. Effects of long term spacing trials with apple trees. *Fruit Sci. Rpt.* **8:**101-113.

Palmer, J. W., Giuliani, R. and Adams, H. M. (1997). Effects on crop load on fruit and leaf phosynthesis of Braeburn/M26 apple trees. *Tree Phy,* **17:** 741-746.

Palmer, J.W. 1989 The effect of row orientation, tree height, time of year and latitude on light interception and distribution in model apple hedgerow canopies *J .Hort. Sci.*, **62:** 137-145.

Sheoran, O. P. Tonk, Kaushik, D. S., Hasija, L. S. and Pannu, R. S. 1998. Statistical Software Package for Agricultural Research Workers. Recent Advances in Information Theory, *Statistics and Computer Application*. 139–143.

Srivastava, K.K., Sundouri, A.S., Sharma, M.K., and Banday**,** F.A. (2008). Inflance of breanch angles on gradients of shoot extention, shoot diameter and yield in apricot (*Prunus armeniaca*) cultivars. *Indian J. Plant Physiol.* **13** (4): 381-386.

Wagenmakers, P. S. 1991. Simulation of light distribution in dense orchards systems. *Agri. FoMeterol*.**57:** 13-25.

Wagenmakers, P. S. and Callesen, O. (1995) Light distribution in apple orchard systems in relation to production and fruit quality. *J Hort. Sci* **70**: 935-48.

Wright H., Nichols D., Embree C. 2006. Evaluating the accountability of trunk size and canopy volume models for determining apple tree production potential across diverse management regimes. *Acta Hort.* **707** : 237-243.

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