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 (111.04 cm) 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/cm²) 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 (Barritt, 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 30 cm 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=Girth²/4π). 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/cm² 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 (a²+b²)½. 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 2nd 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 cm²) 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](image1.png)

![Fig. 2. Yield efficiency of apple under espalier architecture](image2.png)

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/cm²) 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  | Year  | Year  | Year  | Year  | Mean  |
|               | 2010  | 2011  | 2012  | 2013  | 2014  |       |
| 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       | Fruit weight (g)          |
|---------------|---------------------------|
|               | Year  | Year  | Year  | Year  | Year  | Mean  |
|               | 2010  | 2011  | 2012  | 2013  | 2014  |       |
| 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|
| Spartan       | 86.28 | 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  | Year  | Year  | Year  | Year  | Mean  |
|               | 2010  | 2011  | 2012  | 2013  | 2014  |       |
| 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)
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 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 | r with yield efficiency | CV (%) | LSD (p= 0.05) |
|--------------------------|---------------------|-------------------------|--------|---------------|
|                          | 0.321               | 0.639                   | 14.47  | 3.45          |
|                          | 0.246               | 0.592                   | 9.20   | 2.4           |
|                          | 0.135               | 0.511                   | 8.5    | 2.47          |
|                          | 0.552               | 0.385                   | 9.90   | 3.2           |
|                          | 0.392               | 0.956                   | 4.67   | 1.8           |
|                          | 0.990               | 0.638                   | 2.5    | 0.75          |

*r= Correlation matrix (p=0.05)

### 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     | 27.85     | 26.90 |
| Spartan         | 25.25     | 25.71     | 25.71     | 28.00     | 27.85     | 26.30 |
| r with AEG      | -0.822    | 0.853     | -0.014    | -0.660    | -0.185    | 0.760 |
| CV (%)          | 9.07      | 1.33      | 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° 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 photoassimilates to developing fruits, thus increased in yield efficiency. Similarly Srivastava et al (2008) recorded maximum yield in apricot tree branched at 60° 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.

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