

Original Research Paper

Correlation of trunk cross sectional area with fruit yield, quality and leaf nutrient status in plum under North West Himalayan region of India

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ABSTRACT

An experiment was conducted to study the correlation of trunk cross sectional area (TCSA) with fruit yield, quality and leaf nutrient status in plum at ICAR-Central Institute for Temperate Horticulture, Srinagar, Jammu and Kashmir during 2013-14. The TCSA (110.45, 118.23, 123.45, 131.67, 139.25, 146.82, 152.37 and 161.26 cm²) was based on their trunk girth at 15 cm above the ground. Maximum canopy volume (23.14m³ and fruit number 128/ tree) were recorded when TCSA was highest (161.26cm²). Maximum fruit weight (58.85g) was recorded with 123.45cm² TCSA. Fruit yield and productivity efficiency (59.47kg/ tree and 0.29kg/ cm²) were recorded with 152.37cm² TCSA. Fruit size (47.45 x 44.12mm), pulp weight (57.54g) and pulp/stone ratio (43.92) were recorded with 123.45cm² TCSA. Maximum TSS (19.45⁰B), total sugar (13.98%) and reducing sugar (11.46%) were recorded with 161.26 cm² TCSA. Non-reducing sugar (2.53%) was recorded with 118.23cm² TCSA. Higher leaf nitrogen, phosphorus and potassium content (2.38, 0.19 and 1.95%) was observed with 161.26 cm² TCSA. A positive and significant correlation was noticed between TCSA and canopy volume (0.995), fruit number (0.992), yield (0.968), pulp/stone ratio (0.903), TSS (0.977), total sugar (0.937), reducing sugar (0.920), non-reducing sugar (0.048), leaf N (0.971), leaf P (0.977) and leaf K (0.997) value in plum variety Santa Rosa under North West Himalayan region of India.

Keywords: TCSA, plum fruit yield, quality, leaf nutrient

INTRODUCTION

Plum (*Prunus domestica* L.) is one of the important stone fruits of temperate region of India, mainly grown in the states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand. The total area under plum cultivation is 22,000 ha with annual production of 82,000 tonnes and productivity is 3.72 t/ha (Anonymous, 2015) as compared to other apricot growing countries in the world. The chilling requirement of this crop ranges from 300 to 400 hours (chill unit) depending upon the variety (Japanese as well as European plum). The plum fruit are commonly used for fresh as well as for drying purposes. The processed products include candy, frozen fruit, jams, jelly products and traditional Serbian plum for alcoholic beverages (Milosevic *et al.*, 2010a). The ripe fruits are the rich source of Vitamin A, B (Thiamine), riboflavin and minerals like calcium, phosphorus and iron. The dried plums are

known as prunes and all plum cultivar cannot be used for drying purpose. The prunes have great Ayurvedic value for medicine. European plums are used both for drying and fresh markets, while Chinese plums are used mainly for fresh market (Kumar *et al.*, 2018).

The Trunk Cross sectional Area (TCSA) of fruit tree is a useful index for estimation of fruit yield and other parameters (Chapman *et al.*, 1986). Several variations have been observed in the TCSA of plum trees even when a single cultivar is planted on a large scale, which is mainly due to differences in root characteristics leading to nutrient uptake. The differences in tree size have shown differences in their performance in respect of growth and fruit yield (Oppenheimer, 1960). The TCSA of the tree is positively related to transport of nutrient from root to aerial parts of the plant and the distribution

of food materials from site of production to site of utilization (Hartmann and Kester, 1989), which ultimately influences the vegetative as well as reproductive growth of tree. An objective of our investigation was to determine the effect of trunk cross sectional area of trees on growth, fruit yield, quality and leaf nutrient status of plum under Kashmir conditions of Jammu and Kashmir.

MATERIALS AND METHODS

The experiment was conducted on eight year old trees of plum variety Santa Rosa, planted with 5m × 5m spacing at ICAR-Central Institute of Temperate Horticulture, Srinagar, Jammu and Kashmir, India during 2013 and 2014. The Research farm at Srinagar is situated at a latitude of 34° 05'N and longitude of 74° 50'E and at an altitude of 1640 m above mean sea level. The plum variety Santa Rosa is commercially grown in the region and requires 300-400 chill hours for proper fruiting. Fruits of are highly attractive shape and size with red in colour. The experimental field soils are silty loam with medium fertility levels (38.50% sand, 25.2.0% Silt and 36.30% clay; pH 6.8, 0.45% organic carbon, 358.5 kg N/ha, 10.45 kg P/ha and 281.35 kg K/ha).

There were eight different Trunk Cross Sectional Area of tree (110.45, 118.23, 123.45, 131.67, 139.25, 146.82, 152.37 and 161.26 cm²) based on their trunk girth at 15 cm above the ground. The experiment was laid out in randomized block design with three replications and two trees per unit with almost uniform trunk cross-sectional area were kept for recording the observations. The trees were trained in Central Modified Leader system and pruning was done during dormant (December-January) depending upon the climatic condition. The trunk cross-sectional area of tree was calculated by using formula $TCSA = \text{Girth}^2 / 4\pi$ (Westwood *et al.*, 1963). Observations on canopy volume, fruit number, size and yield were recorded during fruiting season. Fruits were harvested at maturity stage and yield per tree was calculated in kilogram. The productivity efficiency was calculated by formula:

$$\text{Productivity efficiency (kg/cm}^2 \text{ TCSA)} = \frac{\text{Fruit yield (kg/tree)}}{\text{TCSA (cm}^2 \text{)}}$$

The fruit, stone and kernel size were determined by observing the length and diameter and measured by digital Vernier calliper. Ten mature fruits were selected randomly from each tree and pooled as per replication in all treatments for quality analysis. The Total Soluble Solids (TSS) of fruits was estimated by Hand Refractometer (0-32 range) and expressed in terms of °Brix. To estimate TSS, fruit pulp was crushed in a pestle and mortar and then squeezed through a muslin cloth for extraction of juice. The titratable acidity expressed in terms of percentage of citric acid was recorded by titrating 2ml of juice against N/10 sodium hydroxide using phenolphthalein indicator. For nutrient analysis, leaf samples were collected as per the treatments from the middle portion of bearing shoots of the plum tree (Singh *et al.* 2007). Fully developed 30 number of leaf samples were collected from the tree and processed for estimation of nitrogen, phosphorus and potassium content. The leaf samples were kept in hot oven for drying at 60 °C for 48 hours (Bhargava and Raghupati, 1993). After drying the leaf samples ground to pass a 0.5 mm mesh and analysed for macro-nutrient content. Nitrogen, phosphorus and potassium were estimated by the modified micro-Kjeldahl Vanado-molybdate (Jackson, 1967) and flame photometric methods, respectively. The data were analysed statistically (Steel and Torrie, 1986) for interpretation of results.

RESULTS AND DISCUSSION

Data on canopy volume, fruit number, fruit weight, fruit yield and productivity efficiency as influenced by trunk cross sectional area of tree is given in **Table 1**. The canopy volume and fruit number increased with increase in the TCSA of tree and the parameters were positively correlated. Significantly maximum canopy volume (23.14m³) and fruit number (128/tree) were recorded when the TCSA was highest (161.26cm²) and minimum canopy volume (12.45m³) and fruit number (65/tree) were recorded with minimum TCSA (110.45cm²). This might be due to more uptake of nutrients from root to aerial part of the plants. These results are inconformity with the findings of Dhaliwal and Dhillon (2003) while working on guava. Maximum fruit weight (58.85g) was recorded when the TCSA (123.45cm²) was medium. The improvement in fruit weight with medium trunk cross sectional area might be attributed to the reduction in number of fruits/tree and yield, which in turn diverted more nutrients for the

Table 1. Effect of TCSA on growth and yield of plum cultivar Santa Rosa

| TCSA (cm ²) | Canopy Volume (m ³) | Fruit Number (/tree) | Fruit weight (g) | Fruit Yield (kg/ tree) | PE (kg/cm ² TCSA) |
|-------------------------|---------------------------------|----------------------|------------------|------------------------|------------------------------|
| 110.45 | 12.45 | 65 | 56.12 | 36.47 | 0.330 |
| 118.23 | 14.37 | 71 | 57.45 | 40.78 | 0.345 |
| 123.45 | 15.95 | 79 | 58.85 | 46.49 | 0.376 |
| 131.67 | 16.35 | 86 | 55.48 | 47.71 | 0.362 |
| 139.25 | 18.45 | 98 | 55.12 | 54.02 | 0.388 |
| 146.82 | 20.19 | 105 | 52.28 | 54.89 | 0.374 |
| 152.37 | 21.25 | 120 | 49.56 | 59.47 | 0.390 |
| 161.26 | 23.14 | 128 | 45.24 | 57.91 | 0.359 |
| SEm± | 1.81 | 12.5 | 3.02 | 2.31 | 0.45 |
| CD(P=0.05) | 4.27 | 29.4 | 7.12 | 5.45 | NS |

development of limited number of fruits on the tree. Significantly maximum fruit yield (59.47kg/tree) was recorded with 152.37cm² TCSA closely followed by 57.91kg/tree with 161.26cm² TCSA and 54.89 kg/tree with 146.82 cm² TCSA, respectively which were superior to other treatments. The productivity efficiency varied from 0.330 to 0.390 and maximum value 0.390 kg/cm² was recorded with 152.37cm² TCSA and lowest value 0.330kg⁻¹cm² was recorded with 110.45cm² TCSA in plum variety Santa Rosa. Similar results were reported by Kumar *et al.*, (2008) indicating that TCSA had significant and positive effect on fruit yield in guava and in Kinnow mandarin by Dalal and Brar (2012). The authors Westwood and

Roberts (1970) reported that cross-sectional area of trunk increases the fruit yield in apple.

Fruit attributes

A perusal of data on fruit size, L/W ratio, pulp weight, stone weight and pulp/stone ratio as influenced by different trunk cross sectional area of plum (**Table-2**) indicated that the fruit size varied from 40.18 x 39.24mm to 47.45 x 44.12mm under different treatments. Maximum fruit size 47.45 x 44.12mm was registered when the TCSA was 123.45cm². The length/width ratio (1.09) was higher with 110.45cm² and 131.67cm² TCSA. Maximum pulp weight (57.54g) was recorded with 123.45cm² TCSA and

Table 2. Effect of TCSA on fruit attributing characters of plum cultivar Santa Rosa

| TCSA (cm ²) | Fruit size (mm) | | L/W ratio | Pulp weight (g) | Stone weight (g) | Pulp/stone ratio |
|-------------------------|-----------------|-------|-----------|-----------------|------------------|------------------|
| | Length | Width | | | | |
| 110.45 | 46.45 | 42.35 | 1.09 | 54.12 | 1.32 | 41.00 |
| 118.23 | 47.11 | 43.93 | 1.07 | 56.15 | 1.30 | 43.19 |
| 123.45 | 47.45 | 44.12 | 1.07 | 57.54 | 1.31 | 43.92 |
| 131.67 | 45.23 | 41.24 | 1.09 | 54.08 | 1.40 | 38.62 |
| 139.25 | 44.05 | 41.08 | 1.07 | 53.71 | 1.41 | 38.09 |
| 146.82 | 42.15 | 41.15 | 1.02 | 50.90 | 1.38 | 36.88 |
| 152.37 | 41.89 | 40.02 | 1.05 | 48.22 | 1.34 | 35.98 |
| 161.26 | 40.18 | 39.24 | 1.02 | 43.89 | 1.35 | 32.51 |
| SEm± | 3.25 | 2.18 | 0.04 | 5.87 | 0.06 | 5.27 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |

minimum stone weight (1.30g) was recorded with 118.23 cm² TCSA. The highest pulp stone ratio (43.92) was recorded with 123.45cm² TCSA followed by 43.19 with 118.23cm² TCSA and 41.0 with 110.45cm² TCSA in plum variety Santa Rosa. An improvement in fruit size due to lower trunk cross sectional area might be attributed to the reduction in fruits/tree and yield which in turn diverted more nutrients for limited number of fruits. Similar findings on fruit yield and

quality in relation to crop load in apple were reported by Dhaliwal and Dhillon, 2003.

Quality attributes

The quality parameters viz, TSS, acidity, total sugar, reducing sugar and non-reducing sugars as influenced by different TCSA in plum is presented in **Table-3**. The Total soluble solids varied from 17.24 to 19.45⁰Brix. Maximum TSS (19.45⁰Brix)

Table 3. Effect of TCSA on fruit quality characters of plum cultivar Santa Rosa

| TCSA (cm ²) | TSS (°B) | Acidity (%) | Total sugar (%) | Reducing sugar (%) | Non reducing sugar (%) |
|-------------------------|----------|-------------|-----------------|--------------------|------------------------|
| 110.45 | 17.24 | 0.52 | 12.58 | 10.12 | 2.46 |
| 118.23 | 17.51 | 0.54 | 12.95 | 10.42 | 2.53 |
| 123.45 | 18.21 | 0.48 | 13.05 | 10.98 | 2.07 |
| 131.67 | 18.45 | 0.59 | 13.12 | 11.04 | 2.08 |
| 139.25 | 18.58 | 0.53 | 13.16 | 11.13 | 2.03 |
| 146.82 | 19.12 | 0.50 | 13.25 | 11.15 | 2.10 |
| 152.37 | 19.24 | 0.49 | 13.85 | 11.35 | 2.50 |
| 161.26 | 19.45 | 0.47 | 13.98 | 11.46 | 2.52 |
| SEm± | 0.43 | 0.02 | 0.29 | 0.26 | 0.08 |
| CD (<i>P</i> =0.05) | 1.02 | 0.05 | 0.69 | 0.62 | 0.21 |

was recorded with 161.26cm² TCSA. The total sugar and reducing sugar (13.98 and 11.46%) was maximum when the TCSA was highest 161.26 cm². The non reducing sugar (2.53%) was maximum with 118.23cm² TCSA in plum variety Santa Rosa. Similar results were also reported by Salvador *et al.*, (2006) in apples and Kumar and Pandey (2010). Smaller fruit size had higher TSS probably because of lower cell volume and lower proportion of intercellular spaces. The fruit acidity decreased due to increase in the TCSA, maximum acidity was estimated with medium TCSA. Similar relationship was also established by Kumar *et al.*, (2008) in guava and Kumar *et al.*, (2014) in apricot.

Leaf nutrient attributes

The leaf nitrogen, phosphorus and potassium content as influenced by different TCSA in plum is presented in **Table-4**. Significantly maximum leaf

nitrogen, phosphorus and potash content (2.38, 0.19 and 1.95%) were estimated when the TCSA (161.26cm²) was highest followed by 152.37 cm²(2.31, 0.17 and 1.89%) and 146.82cm² (2.28,0.17 and 1.82%), respectively in plum variety Santa Rosa. Higher leaf nitrogen, phosphorus and potassium contents recorded with highest TCSA might be due to more uptake of macro-nutrient from root to aerial part of the plants. Similar findings were reported by Dalal and Brar,(2012) in Kinnow.

Correlation between TCSA with yield and quality characteristics

Correlation coefficient among different traits studied were estimated in all possible combinations for growth, yield and quality parameters (**Table-5**). A positive and significant correlation was observed between trunk cross sectional area and canopy volume (0.995), fruit number (0.992),

Table 4. Effect of TCSA on leaf nutrient content of plum cultivar Santa Rosa

| TCSA (cm ²) | Leaf nutrient content | | |
|----------------------------|-----------------------|-------|-------|
| | N (%) | P (%) | K (%) |
| 110.45 | 1.75 | 0.12 | 1.51 |
| 118.23 | 1.79 | 0.12 | 1.59 |
| 123.45 | 2.02 | 0.14 | 1.64 |
| 131.67 | 2.11 | 0.15 | 1.71 |
| 139.25 | 2.17 | 0.15 | 1.78 |
| 146.82 | 2.28 | 0.17 | 1.82 |
| 152.37 | 2.31 | 0.17 | 1.89 |
| 161.26 | 2.38 | 0.19 | 1.95 |
| SEm± | 0.12 | 0.01 | 0.08 |
| CD (<i>P</i> =0.05) | 0.29 | 0.03 | 0.21 |

yield (0.968), pulp/stone ratio (0.903), TSS (0.977), total sugar (0.937), reducing sugar (0.920), leaf N (0.971), leaf P (0.977) and leaf K (0.997). Similarly positive correlation was observed between canopy volume and fruit number (0.990), fruit yield (0.966), TSS (0.976), total sugar (0.841), reducing sugar (0.923), nitrogen (0.966), phosphorus (0.973) and potassium (0.993). The fruit number was positively correlated with yield (0.957), TSS (0.961), total sugar (0.955), reducing sugar (0.900), leaf N(0.953), leaf P(0.966) and leaf K(0.991). Significant and positive correlation was noticed between fruit weight and fruit length (0.954), width (0.901), L/W ratio (0.759) and pulp/stone ratio (0.094). A positive relationship was noticed between yield and TSS (0.974), total sugar (0.894), reducing sugar (0.956), leaf N(0.975), leaf P(0.925) and leaf K(0.974). Positive correlation was observed between fruit length and fruit width (0.930), L/W ratio (0.810) and pulp weight (0.948). Positive correlation between fruit width and pulp weight (0.948) and P/S ratio (0.980). Positive correlation was observed between L/W ratio and pulp weight (0.742), P/S ratio(0.680) and acidity. Similarly positive correlation between pulp weight and pulp/stone ratio (0.949) and total sugar (0.854).

Positive correlation was noticed between pulp/stone ratio and leaf K (0.888). Positive and

significant correlation between TSS and total sugar (0.900), reducing sugar (0.963), leaf N(0.996), leaf P(0.979) and leaf K (0.978) was noticed. Similarly there was significantly positive correlation between total sugar and reducing sugar (0.872), leaf N(0.878), leaf P (0.903) and leaf K (0.942). Significant positive correlation between reducing sugar and leaf N(0.967), leaf P(0.917) and leaf K(0.935) was noticed. Significant correlation was observed between leaf N and leaf P(0.974) and leaf K(0.973). Whereas, significantly negative correlation coefficient was observed between TCSA and fruit weight(-0.885) and pulp weight(-0.865). Similarly negative correlation between fruit number and fruit weight(-0.908) and pulp weight(-0.892) was noticed. Negative correlation between fruit yield and fruit size (-0.867 and -0.773). Similar results were reported by Kumar *et al.*, (2014) while working on apricot.

It is concluded that trunk cross sectional area of tree is important and useful index for prediction of fruit yield and quality traits. It is evident from the results that the TCSA of tree had a pronounced effect on the canopy volume, fruit yield and quality of plum variety Santa Rosa under North West Himalayan region of India.



Table 5. Correlation coefficient for 19 characters of plum

| Particular | TC SA | CV | Fruit number | Fruit wt | Yield | PE* | Fruit length | Fruit width | L/W ratio* | Pulp wt | Stone wt | P/S ratio* | TSS | Acidity | Total Sugar | RS | NRS | Leaf N | Leaf P | Leaf K |
|--------------------|-------|-------|--------------|----------|--------|--------|--------------|-------------|------------|---------|----------|------------|--------|---------|-------------|--------|--------|--------|--------|--------|
| TCSA | 1.00 | 0.995 | 0.992 | -0.885 | 0.965 | 0.607 | -0.951 | -0.853 | -0.809 | -0.865 | 0.448 | 0.903 | 0.977 | -0.441 | 0.937 | 0.920 | 0.048 | 0.971 | 0.977 | 0.997 |
| CV | | 1.00 | 0.990 | -0.870 | 0.966 | 0.625 | -0.933 | -0.808 | -0.840 | -0.849 | 0.387 | -0.868 | 0.976 | -0.514 | 0.941 | 0.923 | 0.051 | 0.966 | 0.973 | 0.993 |
| Fruit number | | | 1.00 | -0.908 | 0.957 | 0.595 | -0.953 | -0.864 | -0.793 | -0.892 | 0.382 | -0.905 | 0.961 | -0.496 | 0.955 | 0.900 | 0.126 | 0.953 | 0.966 | 0.991 |
| Fruit wt | | | | 1.00 | -0.754 | -0.215 | 0.954 | 0.901 | 0.759 | 0.998 | -0.223 | 0.094 | -0.799 | 0.477 | -0.876 | -0.669 | -0.422 | -0.783 | -0.879 | -0.865 |
| Yield | | | | | 1.00 | 0.793 | -0.867 | -0.773 | -0.727 | -0.730 | 0.494 | -0.799 | 0.974 | 0.423 | 0.894 | 0.956 | -0.106 | 0.975 | 0.925 | 0.974 |
| PE | | | | | | 1.00 | -0.409 | -0.339 | -0.339 | -0.184 | 0.472 | 0.313 | 0.696 | -0.252 | 0.538 | 0.788 | -0.482 | 0.713 | 0.548 | 0.643 |
| Fruit length | | | | | | | 1.00 | 0.930 | 0.810 | 0.948 | -0.434 | 0.973 | -0.894 | 0.428 | -0.856 | -0.767 | -0.188 | -0.889 | -0.935 | -0.933 |
| Fruit width | | | | | | | | 1.00 | 0.544 | 0.905 | -0.569 | 0.980 | -0.791 | 0.193 | -0.763 | -0.690 | -0.157 | -0.809 | -0.843 | -0.844 |
| L/W ratio | | | | | | | | | 1.00 | 0.742 | -0.099 | 0.680 | -0.780 | 0.674 | -0.724 | -0.648 | -0.161 | -0.743 | -0.810 | -0.780 |
| Pulp wt | | | | | | | | | | 1.00 | -0.218 | 0.949 | -0.776 | 0.474 | 0.854 | -0.639 | -0.436 | -0.762 | -0.862 | -0.844 |
| Stone wt | | | | | | | | | | | 1.00 | -0.514 | 0.483 | 0.393 | 0.187 | 0.505 | -0.622 | 0.545 | 0.442 | 0.459 |
| P/S ratio | | | | | | | | | | | | 1.00 | -0.836 | 0.288 | -0.810 | -0.723 | -0.184 | -0.844 | -0.899 | 0.888 |
| TSS | | | | | | | | | | | | | 1.00 | -0.430 | 0.900 | 0.963 | -0.109 | 0.996 | 0.979 | 0.978 |
| Acidity | | | | | | | | | | | | | | 1.00 | -0.498 | 0.359 | -0.281 | -0.398 | -0.467 | -0.422 |
| Total Sugar | | | | | | | | | | | | | | | 1.00 | 0.872 | 0.268 | 0.878 | 0.903 | 0.942 |
| Reducing sugar | | | | | | | | | | | | | | | | 1.00 | -0.237 | 0.967 | 0.917 | 0.935 |
| Non reducing sugar | | | | | | | | | | | | | | | | | 1.00 | -0.162 | -0.011 | 0.029 |
| Leaf N | | | | | | | | | | | | | | | | | | 1.00 | 0.974 | 0.973 |
| Leaf P | | | | | | | | | | | | | | | | | | | 1.00 | 0.968 |
| Leaf K | | | | | | | | | | | | | | | | | | | | 1.00 |

*PE-Productivity Efficiency; *L/W ratio-Length/Width ratio; *P/S ratio-Pulp/Stone ratio

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(MS Received 24 October 2018, Revised 01 April 2019, Accepted 11 June 2019)