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Effect of light interception and penetration at different levels of fruit tree canopy on quality of peach

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Peach trees were trained to four systems, viz. Y-shaped, Hedge row, Espailer and V trellis. Irrespective of the training system in upper canopy total PAR increased from January to July and then a decrease was recorded. However, in lower canopy an inverse trend was recorded. The total radiation intercepted during the year was maximum (59.99%) in Espailer system followed by V trellis (57.76%). Minimum radiation interception (49.05%) was recorded in trees trained to Hedge row. Upper canopy part of the tree received more PAR which influenced fruit quality in terms of size, weight, acidity, total sugars, firmness.

Keywords: Canopy management, quality improvement, Peach, PAR, training systems.

THE light environment in which a fruit develops will affect its size, shape and quality. Improvement of light penetration within tree canopies has been a constant objective of fruit tree architecture manipulation through the setting up of training systems. Quality peaches require more light exposure than many fruit crops to grow and mature. The achievement of an adequate yield and good quality of fruit and the setting of flower buds depend on light conditions, which can be improved through the formation of an adequate tree canopy[1,2]. Overall effects of shade on fruit quality are very clear, but the processes responsible for these effects are not. Shade reduces photosynthetically active radiation (PAR) and, therefore, reduces local photosynthetic activity, canopy temperature[3] and changes wavelength distribution of transmitted light. Recently, different training systems, i.e. Y-shaped, Espailer, Hedge row, and V-shaped were proposed to improve fruit size and colour as well as return-bloom as compared to conventional central leader trained trees with equivalent.

The experiment was conducted at the Fruit Research Farm of the Department of Fruit Science, Punjab Agricultural University, Ludhiana during 2014 and 2015. The trees were trained on to four different training systems, i.e. Y-shaped, Hedge row, Espailer and V trellis (Figure 1).

There were a total four treatments each with four replications and each replication consisted of 2 trees in a randomized block design.

PAR was taken at fortnightly intervals on clear days at three times (10 a.m., 1 p.m. and 4 p.m.) by recording the sensor output from a quantam sensor using a digital multi-voltmeter (Figure 2). Incoming solar radiation measurements (watt/m^2) were recorded one feet above the canopy and at the centre of upper and lower parts of the canopy by the quantam sensor facing upward. The quantam sensor was inverted one feet above the canopy to record the amount of reflected short wave radiation {albedo (A)} (ref. 4).

Radiation intercepted in the upper part =

$$\frac{I-(I_1+A)}{I}\times 100 = x\%,$$

radiation intercepted in the lower part =

$$\frac{I-(I_2+A)}{I}\times 100 - x\% = y\%,$$

total interception by the tree canopy = $x\% + y\%$,

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where I is the incoming solar radiation received above one feet of tree canopy, I_1 the incoming solar radiation received in the upper part of tree canopy, I_2 the incoming solar radiation received in the lower part of tree canopy and A is the reflected short wave radiation.

Fruit size length and diameter were measured across the cheeks of 10 randomly selected mature fruits. Weight was noted and the mean values were calculated. Fruit colour was estimated with the help of colour meter (Colour Flex, Hunter Lab, USA) (Figure 3) and expressed as L, a and b values.

Figure 4 shows that the mean total radiation intercepted during the year was maximum (59.99%) in Espailer system and was closely followed by radiation intercepted by trees trained to V trellis (57.56%). Higher radiation interception was due to two-dimensional form of Espailer system in which all paired horizontal branches are trained in the same plane. This allows more light to penetrate even the inner parts of tree canopy. Similarly, in V trellis it may be due to the openness of canopy in the centre which allows light penetration inside the canopy. As a result, less light falls on the orchard floor. Chenyl *et al.*[5] also found that V trellis intercepted more light (73%) as compared to slender spindle (53%) in apple. Radiation interception in the upper part of the canopy was highest (51.46%) in Espailer system followed by V trellis (49.41%) and Y-shaped trees (48.53%) and lowest in the Hedge row trees (43.41%). Similar trend was noticed in lower canopy. Singh and Kanwar[6] reported that more than 70% of total light was intercepted in the upper 1/3rd part of the canopy of plants during the growing season.

Higher radiation was intercepted by the upper canopy between March and July and after the interception decreases, whereas a reverse trend was recorded in lower canopy. This was due to the fact that during March–July higher leaf area and biomass absorbed more radiation in the upper tree part and less radiation penetrated in the lower part of the canopy. But, from August onwards, with the start of leaf fall under the experimental condition, more radiation reaches the lower canopy parts.

Tables 1 and 2 reveal that maximum mean fruit size (diameter and length) was found in trees trained to Espailer system in both upper and lower canopy (5.78, 5.52 cm diameter and 6.12 and 5.81 cm respectively)

Figure 1. Orchard layout of experimental block.

Figure 2. Quantum sensor (Sun Scan probe) used for measuring PAR.

Figure 3. Colour meter.

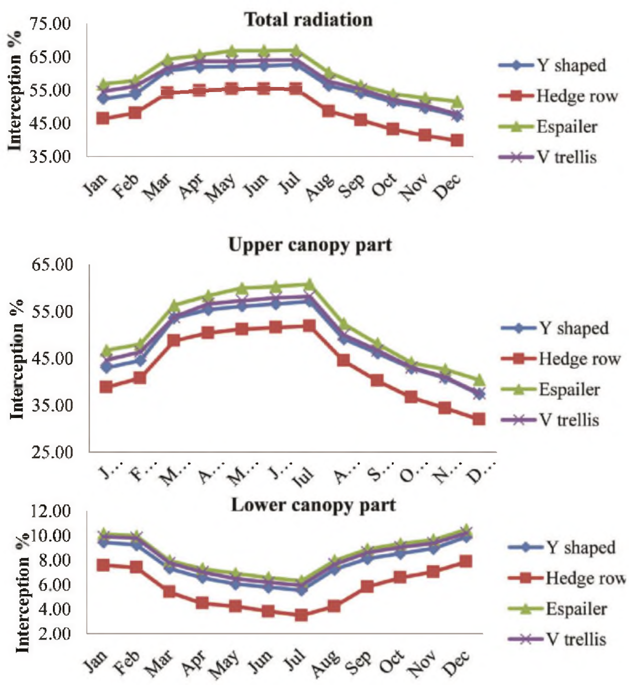

Figure 4. Average daily radiation intercepted during the year by peach tree at different training systems.

Table 1. Effect of training systems and spacings on fruit diameter (cm) of peach cv. Shan-i-Punjab

		Upper canopy part			Lower canopy part		
Training systems	Spacings (m)	2014	2015	Mean	2014	2015	Mean
Y-shaped	5 × 2	5.37	5.44	5.40	5.01	5.10	5.05
	5 × 3	5.45	5.57	5.51	5.11	5.24	5.17
	Mean	5.41[b]	5.50[c]	5.46[c]	5.06[c]	5.17[c]	5.11[c]
Hedge row	5 × 2	5.13	5.28	5.20	4.71	4.84	4.77
	5 × 3	5.27	5.47	5.37	4.86	4.99	4.92
	Mean	5.20[c]	5.38[d]	5.29[d]	4.78[d]	4.91[d]	4.85[d]
Espailer	5 × 2	5.68	5.82	5.75	5.48	5.62	5.55
	5 × 3	5.72	5.90	5.81	5.50	5.75	5.62
	Mean	5.70[a]	5.86[a]	5.78[a]	5.49[a]	5.68[a]	5.52[a]
V trellis	5 × 2	5.45	5.61	5.53	5.20	5.30	5.25
	5 × 3	5.55	5.71	5.63	5.34	5.41	5.37
	Mean	5.50[b]	5.66[b]	5.58[b]	5.27[b]	5.35[b]	5.31[b]
Spacing mean	5 × 2	5.40[b]	5.54[b]	5.47[b]	5.10[b]	5.21[b]	5.16[b]
	5 × 3	5.50[a]	5.66[a]	5.58[a]	5.20[a]	5.34[a]	5.27[a]
LSD 0.05	Training system	0.09	0.06	0.07	0.08	0.05	0.06
	Spacing	0.06	0.04	0.05	0.06	0.04	0.04
	TS × Spacing	0.12	0.09	0.11	0.12	0.08	0.09

Where a > b > c > d and these values are not at par with each other.

Table 2. Effect of training systems and spacings on fruit length (cm) of peach cv. Shan-i-Punjab

		Upper canopy part			Lower canopy part		
Training systems	Spacings (m)	2014	2015	Mean	2014	2015	Mean
Y-shaped	5 × 2	5.72	5.76	5.74	5.36	5.45	5.40
	5 × 3	5.85	5.92	5.88	5.50	5.57	5.54
	Mean	5.78[c]	5.84[c]	5.81[c]	5.43[c]	5.51[c]	5.47[c]
Hedge row	5 × 2	5.44	5.64	5.54	5.00	5.23	5.11
	5 × 3	5.62	5.84	5.73	5.26	5.35	5.31
	Mean	5.53[d]	5.74[d]	5.64[d]	5.13[d]	5.29[d]	5.21[d]
Espailer	5 × 2	6.04	6.10	6.07	5.70	5.81	5.75
	5 × 3	6.10	6.23	6.17	5.85	5.92	5.88
	Mean	6.07[a]	6.16[a]	6.12[a]	5.77[a]	5.86[a]	5.81[a]
V trellis	5 × 2	5.85	5.90	5.88	5.53	5.61	5.57
	5 × 3	5.97	6.03	6.00	5.65	5.73	5.69
	Mean	5.91[b]	5.97[b]	5.94[b]	5.59[b]	5.67[b]	5.63[b]
Spacing mean	5 × 2	5.76[b]	5.85[b]	5.80[t]	5.43[b]	5.55[b]	5.44[b]
	5 × 3	5.89[a]	6.00[a]	5.94[a]	5.57[a]	5.64[a]	5.60[a]
LSD 0.05	Training system	0.10	0.06	0.07	0.10	0.07	0.06
	Spacing	0.07	0.04	0.05	0.07	0.05	0.04
	TS × Spacing	0.14	0.09	0.10	0.14	0.10	0.09

which was significantly higher than the trees trained to other systems. This may be due to comparatively higher radiation recorded in upper part of the trees which affected both cell division and size. Similar results are recorded by Farina *et al.*[7] in peach cv. 'Elegant Lady'. Bartolini *et al.*[8] reported that olive fruits located in shade developed at slow rate and were characterized by reduced size with oblong shape. According to Sharma *et al.*[9] strawberry plants grown under shade produced albino, smaller sized fruits and have lower fruit yield.

Table 3 shows that maximum fruit weight was recorded from upper part (94.92 g) of the canopy as compared to lower canopy (88.78 g) in Espailer trained trees. This discrepancy may be due to more efficient photosynthetic activity in upper canopy that results in higher availability of net photosynthates. These could be translated by the tree to produce more fruit weight. The results agree with previous observations[10,11].

Fruit colour, in terms of redness, was higher in upper canopy as compared to lower canopy (Table 4). Upper canopy of Espailer system showed *a* value of 26.62, whereas, the *a* value in lower canopy of the same tree was 24.39. Maximum *l* and *b* values (58.94 and 29.88 respectively) were obtained in lower canopy of Hedge row system. This was significantly higher than the trees trained to other systems. More redness and low brightness and

Table 3. Effect of training systems and spacings on fruit weight (g) of peach cv. Shan-i-Punjab

		Upper canopy part			Lower canopy part		
Training systems	Spacings (m)	2014	2015	Mean	2014	2015	Mean
Y-shaped	5 × 2	89.06	90.78	89.92	84.50	84.86	84.68
	5 × 3	90.51	91.65	91.08	85.17	85.86	85.52
	Mean	89.70^{c}	91.21^{c}	90.50^{c}	84.83^{c}	85.36^{c}	85.10^{c}
Hedge row	5 × 2	87.27	86.05	86.66	82.42	82.73	82.57
	5 × 3	88.00	87.31	87.65	83.18	83.41	83.29
	Mean	87.63^{d}	86.68^{d}	87.16^{d}	82.80^{d}	83.07^{d}	82.93^{d}
Espailer	5 × 2	94.27	94.61	94.44	88.29	88.33	88.31
	5 × 3	95.33	95.47	95.40	89.12	89.39	89.25
	Mean	94.80^{a}	95.04^{a}	94.92^{a}	88.70^{a}	88.86^{a}	88.78^{a}
V trellis	5 × 2	90.69	91.41	91.05	86.62	87.27	86.95
	5 × 3	92.087	92.39	92.24	87.35	87.55	87.45
	Mean	91.39^{b}	91.90^{b}	91.64^{b}	86.98^{b}	87.41^{b}	87.20^{b}
Spacing mean	5 × 2	90.32^{b}	90.7^{b}	90.52^{b}	85.53^{b}	85.72^{b}	85.63^{b}
	5 × 3	91.48^{a}	91.70^{a}	91.59^{a}	86.26^{a}	86.49^{a}	86.38^{a}
LSD 0.05	Training system	0.53	0.49	0.35	0.65	0.43	0.37
	Spacing	0.38	0.34	0.25	0.46	0.30	0.26
	TS × Spacing	0.75	0.69	0.50	0.92	0.61	0.53

Table 4. Effect of training systems and spacings on fruit colour of peach cv. Shan-i-Punjab

		Upper canopy part			Lower canopy part			Mean		
Training systems	Spacing (m)	l	A	b	l	A	b	l	A	b
Y-shaped	5 × 2	54.62	24.38	24.48	56.76	22.02	26.76	55.69	23.2	25.62
	5 × 3	52.21	24.79	24.02	54.4	22.6	26.15	53.31	23.7	25.08
	Mean	53.41^{b}	24.59^{c}	24.25^{b}	55.8^{b}	22.31^{c}	26.45^{b}	54.50^{b}	23.45^{c}	25.35^{b}
Hedge row	5 × 2	58.19	21.76	27.36	60.35	19.59	29.62	59.27	20.68	28.49
	5 × 3	55.31	21.58	28.05	57.53	19.34	30.15	56.42	20.46	29.1
	Mean	56.75^{a}	21.6^{d}	27.70^{a}	58.94^{a}	19.46^{d}	29.88^{a}	57.85^{a}	20.57^{d}	28.79^{a}
Espailer	5 × 2	49.93	25.97	20.7	51.8	23.58	22.78	50.86	24.78	21.74
	5 × 3	43.6	27.26	20.26	45.74	25.2	22.3	44.67	26.23	21.28
	Mean	46.76^{d}	26.62^{a}	22.48^{d}	48.77^{d}	24.39^{a}	22.54^{d}	48.77^{d}	25.50^{a}	21.51^{d}
V trellis	5 × 2	50.92	25.3	21.82	52.87	23.3	23.89	51.88	24.3	22.86
	5 × 3	47.02	25.56	20.99	49.04	23.34	23.08	48.03	24.45	22.04
	Mean	48.97^{c}	25.43^{b}	21.40^{c}	50.95^{c}	23.32^{b}	23.49^{c}	49.96^{c}	24.37^{b}	22.45^{c}
Spacing mean	5 × 2	53.42^{a}	24.35^{b}	25.76^{a}	55.44^{a}	22.12^{b}	25.76^{a}	54.43^{a}	23.24^{b}	24.68^{a}
	5 × 3	49.55^{b}	24.80^{a}	25.42^{b}	51.68^{b}	22.62^{a}	25.42^{b}	50.61^{b}	23.71^{a}	24.37^{b}
LSD 0.05	T.S	1.09	0.42	0.2	1.08	0.46	0.2	1.09	0.43	0.22
	Spacing	0.72	0.3	0.14	0.76	0.32	0.14	0.77	0.3	0.15
	TS × Spacing	1.5	0.6	0.29	1.53	0.65	0.29	1.54	0.61	0.31

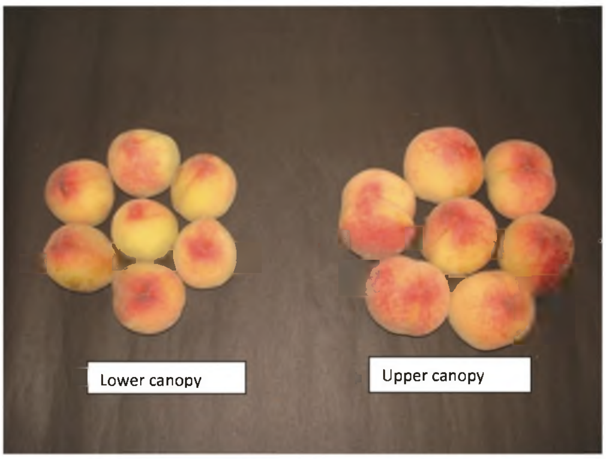

Figure 5. Fruits of lower and upper canopy

Table 5. Effect of training systems and spacings on fruit maturity (%) of peach cv. Shan-i-Punjab

		Upper canopy part			Lower canopy part		
Training systems	Spacings (m)	2014	2015	Mean	2014	2015	Mean
Y-shaped	5 × 2	67.17	70.8	68.99	34.69	37.86	36.27
	5 × 3	70	74.44	72.22	37.62	40.06	38.84
	Mean	68.58[b]	72.62[c]	70.60[b]	36.15[c]	38.96[c]	37.56[c]
Hedge row	5 × 2	43.07	48.96	46.01	23.11	24.15	23.63
	5 × 3	44.72	50.3	47.51	24.11	25.81	24.96
	Mean	43.90[c]	49.63[d]	46.76[c]	23.61[d]	24.98[d]	24.29[d]
Espailer	5 × 2	70.85	76.65	73.75	39.08	45.32	42.2
	5 × 3	73.28	77.87	75.57	40.65	46.55	43.6
	Mean	72.07[a]	77.26[a]	74.66[a]	39.87[a]	45.94[a]	42.90[a]
V trellis	5 × 2	68.24	75.09	71.66	37.16	42.67	39.92
	5 × 3	69.3	76.07	72.69	39.91	43.99	41.95
	Mean	68.77[b]	75.58[b]	72.18[b]	38.54[b]	43.33[b]	40.93[b]
Spacing mean	5 × 2	62.33[b]	67.88[b]	65.10[b]	33.51[b]	37.50[b]	35.50[b]
	5 × 3	64.32[a]	69.67[a]	67.00[a]	35.57[a]	39.10[a]	37.34[a]
LSD 0.05	Training system	0.65	0.6	2.19	0.59	0.85	1.7
	Spacing	0.46	0.43	1.55	0.42	0.6	1.2
	TS × Spacing	0.92	0.86	3.1	0.84	1.2	2.4

greenness in upper canopy may be due to canopy architecture which allows maximum light penetration in inner parts of the tree canopy as compared to other training system (Figure 1). Farina *et al.*[7] reported that fruit peel colour in peach decreased linearly from canopy top to bottom. Fruit from the more sun exposed parts of canopy is reported to have better red colouration in different apple cultivars[12]. Heinicke[13] found that apples which received less than 30% of full sunlight were less coloured due to less dry matter and sugars as compared to fruits which received full sunlight.

It is evident from Table 5 and Figure 5 that fruits from upper part of the canopy matured earlier. Delay in maturity in the lower part may be due to reduced radiation penetration in lower canopy. Higher percentage of mature fruit (74.66%) was recorded from upper canopy compared to lower canopy (42.9%) in Espailer system. It was found that trees trained to Espailer system and V trellis had better light distribution within the tree canopy as compared to other systems which caused early ripening in peach fruits during the present study (Figure 1).

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