J. Hortl. Sci.
Vol. 7(1):46-50, 2012

Yield and quality of passion fruit in relation to training systems

V.V. Sulladmath, K. Srinivas and R.H. Laxman[1]
Division of Fruit Crops
Indian Institute of Horticultural Research
Hessaraghatta Lake Post, Bangalore – 560 089
E-mail : vijay@iihr.ernet.in

ABSTRACT

Four different training systems, viz., Kniffin, High trellis, Tatura and Bower were evaluated in passion fruit cv. Kaveri. Kniffin system with 4 arms recorded highest cumulative yield of 67.22 t/ha with a cost:benefit ratio of 1:4.25, followed by Kniffin 2 arm and 6 arm, respectively. Kniffin system was also the most ideal system of training for passion fruit, facilitating easy cultural operations. Although Tatura system recorded highest cumulative yield/vine (43.57kg), it registered lowest yield/ha, largely due to lower plant population/ha (1250 vines/ha). Fruit quality parameters like TSS, Vit. C, carotene content and titrable acidity were not significantly influenced by different training systems. Similarly, interception of Photosynthetically Active Radiation (PAR) by the canopy did not differ significantly among training systems. Though photosynthetic rate did not differ significantly, shaded leaves in the canopy did not contribute photosynthates and were parasitic on the vine.

Key words: Passion fruit, Kniffin, high trellis, tatura, bower, Photosynthetically Active Radiation(PAR)

INTRODUCTION

Passion fruit (*Passiflora edulis* Sims.) is a native of Brazil and is highly valued for its juice. The juice has excellent aroma, blending qualities and has potential in tropical humid South Indian conditions. In the north-eastern states of India, it has attained the status of a commercial fruit crop. Area under cultivation of passion fruit in these regions is rapidly increasing. Traditionally, two cultivars of passion fruit, viz., 'Purple' (*Passiflora edulis*. Sims.) and 'Yellow' (*Passiflora edulis f. flavicarpa*) are grown. Lately, a hybrid between purple and yellow cultivars, 'Kaveri', released by Central Horticultural Experiment Station, Chettalli (IIHR), Kodagu, Karnataka, has become very popular in passion fruit growing regions of the country owing to its high yield and excellent fruit quality (Singh *et al*, 1991).

Passion fruit is a woody, herbaceous, perennial climber that essentially needs to be trained on a support system. In countries like Australia and Kenya, commonly, the trellis system with 'one wire' and 'three wires' is adopted in passion fruit cultivation (Melville, 1952; Gachanja and Gurnah, 1980 and Gurnah & Gachanja, 1980). These systems are cheap, simple to construct and should be erected at a height of 2m (Avent, 1958 and Malan, 1948). However, the three-wire trellis was considered to be better than single-wire trellis in South Africa and Queensland (Malan, 1948 and Wills, 1948). In this study, an attempt has been made to evaluate different training systems for 'Kaveri' passion fruit under mild tropics of South India.

MATERIAL AND METHODS

Field experiments were carried out during 2006-08 at the Indian Institute of Horticultural Research, Bangalore, on passion fruit cv. Kaveri. The trial was conducted using Randomised Block Design (RBD) with four training systems, viz., Kniffin (2 arm, 4 arm and 6 arm); High trellis (Single cordon and Double cordon); Tatura (4 arm, 8 arm and 12 arm) and Bower (2 cordons and 4 cordons). These 10 treatments were replicated 5 times with 4 vines / treatment. Three-month old cuttings were planted at a spacing of 3m x 2m under three systems of training, viz., Kniffin, High trellis and Bower (1666 vines/ha), while, in the case of Tatura, the spacing was 4m x 2m (1250 vines/ha). Recommended cultural practices were followed in toto and light pruning of extended laterals was carried out at the end of each harvest season. Vines were irrigated with drip system fitted with 2 emitters / vine (4 LPH). Mature fruits were harvested at weekly intervals and data on yield/vine were recorded. There were 28 pickings during 2006-07, and 30 pickings during 2007-08. Cumulative yield obtained in two years was analyzed.

[1]Division of Plant Physiology and Biochemistry, IIHR, Bangalore

Ten mature fruits in each treatment were sampled and the fresh weight and volume was recorded. Pulp from ripe fruits was extracted and pulp weight, juice weight, seed weight and peel weight were recorded.

Photosynthetic rate was measured using a Portable Photosynthesis System LI-COR 6200 in (i)completely exposed, (ii)partially-shaded and (iii)shaded leaves in the canopy. Interception of Photosynthetically Active Radiation (PAR) under different canopy systems was measured using LI-COR line quantum sensor.

Total carotenoids were estimated as per Leskovar *et al* (2004). Two grams of the sample were ground with a mixture of 50ml hexane:acetone:ethanol (50:25:25) containing 0.05% (w/v) butylated hydroxytoluene. Extracted mixture was allowed to separate into 2 layers. The upper layer was collected, lower layer discarded and volume was made up. Absorbance was read at 470nm for calculating total carotenoids and expressed as beta carotene units using a standard curve.

Vitamin C content was estimated using modified method of Davis and Masten (1991). Samples were extracted in 3% metaphosphoric:acetic acid mixture using a set of chilled pestle and mortar. The homogenate was filtered and centrifuged at 4°C. Supernatant solvent (1ml) was mixed with 2ml of 1.7mM 2, 6-dichlorophenol-indophenol (2,6-DCPIP) in 3ml cuvettes. Absorbance at 520nm was recorded one minute after mixing the reagents. Metaphosphoric acid;acetic acid:mixture was used as a blank and reduction in absorbance was taken for calculating Vitamin C content and expressed as mg/100g fresh weight.

RESULTS AND DISCUSSION

A. Yield parameters

Cumulative fruit yield per vine was highest under Tatura system of training (43.57 kg/vine), followed by Kniffin (39.76kg/vine) and Bower system (38.03kg/vine). There was no significant difference in yield between Kniffin and Bower; but, between Tatura and high Trellis, differences were significant (Table 1). However, data on first year annual yields and also cumulative yields/vine, recorded under the treatments (i.e., number of arms under Kniffin and Tatura and number of cordons under High Trellis and Bower), did not show any significant difference, except for Tatura (8 arm) which recorded 25.54kg fruits in the second year. However, the general trend remained consistent during both years. This tendency could be due to the highly vigorous nature of 'Kaveri' passion fruit, which may have enabled the vines to cover the entire support system and yield to its full potential. Gachanja and Gurnah (1980) also reported similar results under Kenyan conditions for purple passion

Table 1. Effect of different training systems on fruit yield, photosynthetic rate and % light interception in passion fruit cv. Kaveri

Treatment	No. of fruits / vine			Fresh weight of fruits/vine (kg)			Cumulative fruit yield (t/ha)	Photosynthetic rate (μmol $m^{-2}s^{-1}$)	Per cent light interception
	2006-07	2007-08	Cumulative yield	2006-07	2007-08	Cumulative yield			
Kniffin system									
2 arms (T1)	338.70	312.30	671.00	19.29	39.89	20.60	66.45	10.07	82.72 (9.10)
4 arms (T2)	343.24	316.80	660.04	19.55	40.335	20.80	67.22	09.93	84.81 (9.15)
6 arms (T3)	319.30	310.80	630.10	19.57	39.05	19.48	65.05	10.58	84.22 (9.11)
Mean	333.74	319.96	653.70	19.47	39.76	20.29	66.24	10.19	83.92
High Trellis									
Single cordon (T4)	244.18	317.10	561.28	19.43	33.95	14.52	56.56	09.98	81.85 (9.28)
Double cordon (T5)	252.52	296.94	549.46	17.40	32.44	15.04	54.04	09.97	83.06 (9.07)
Mean	248.35	307.02	555.37	18.41	33.19	14.78	55.30	09.98	82.46
Tatura									
4 arms (T6)	275.44	425.48	700.92	26.60	43.10	16.50	53.87	09.99	82.54 (9.24)
8 arms (T7)	276.90	417.82	694.72	25.54	42.24	16.70	52.80	10.73	83.10 (9.13)
12 arms (T8)	277.84	454.84	732.68	28.54	45.37	16.83	56.71	09.67	83.99 (9.12)
Mean	276.72	432.71	709.44	26.89	43.57	16.67	54.46	10.13	83.21
Bower									
2 cordon (T9)	297.48	346.16	643.64	21.23	39.19	17.96	65.29	09.77	83.37 (9.20)
4 cordon (T10)	286.16	333.36	619.52	20.06	39.88	16.82	61.44	10.36	82.60 (9.09)
Mean	291.82	339.76	631.58	20.64	38.03	17.39	63.36	10.07	82.99
S Em±	12.58	15.86	24.80	0.91	1.25	0.89	1.91	0.75	0.09
CD *(P=0.05)*	36.11	45.52	71.19	2.61	3.59	2.55	5.48	NS	NS

Figures in parentheses indicate square root transformation values
NS = Non-significant

Table 2. Effect of different training systems on physico-chemical parameters in passion fruit cv. Kaveri

Treatment	Physical parameters of the fruit								Chemical parameters of the fruit			
	Length (cm)	Diameter (cm)	Fresh weight (g)	Volume (ml)	Juice weight (g)	Juice (%)	Peel weight (g)	Seed weight (g)	TSS (%)	Titrable acidity (%)	Vit. C (mg/ 100g)	Carotene content (mg/100g)
Kniffin system												
2 arms (T1)	5.52	5.10	58.72	80.73	9.20	15.61	15.66	1.81	15.6	2.56	19.6	2.71
4 arms (T2)	5.59	5.25	59.25	84.73	9.77	16.35	17.60	1.67	15.6	2.37	19.5	2.76
6 arms (T3)	5.65	5.13	62.45	87.27	10.21	16.27	17.68	2.00	15.6	2.74	19.1	2.65
Mean	5.58	5.16	60.14	84.24	9.72	16.07	16.98	1.82	15.6	2.55	19.4	2.70
High Trellis												
Single cordon (T4)	6.07	5.83	73.31	94.12	13.89	18.98	24.66	3.37	15.6	2.68	19.1	2.74
Double cordon (T5)	6.15	5.89	71.02	88.74	14.28	20.18	24.02	2.99	15.6	2.40	19.6	2.83
Mean	6.11	5.86	72.16	91.43	14.08	19.58	24.34	3.18	15.6	2.54	19.4	2.78
Tatura												
4 arms (T6)	5.70	5.25	61.22	79.83	10.66	17.27	15.22	2.27	15.2	2.74	19.4	2.69
8 arms (T7)	5.68	5.11	60.89	78.99	10.47	17.16	15.28	2.17	16.0	2.86	19.6	2.85
12 arms (T8)	5.68	5.26	60.13	79.99	9.99	16.52	15.76	2.11	15.2	2.68	19.4	2.77
Mean	5.68	5.20	60.74	79.60	10.37	16.98	15.42	2.18	15.6	2.76	19.5	2.77
Bower												
2 cordon (T9)	6.02	5.56	69.10	96.59	12.70	18.42	28.50	3.39	14.8	2.53	18.9	2.60
4 cordon (T10)	6.03	5.64	68.41	95.99	12.06	17.61	25.74	3.30	15.0	2.71	19.6	2.83
Mean	6.02	5.60	68.75	96.29	12.38	18.01	27.12	3.34	14.9	2.62	19.3	2.71
SEm±	0.092	0.102	3.17	3.59	1.07	1.284	1.17	0.187	0.021	0.67	1.43	0.51
CD *(P=0.05)*	0.26	0.29	9.10	NS	3.08	NS	3.36	0.538	NS	NS	NS	NS

NS = Non-significant

fruit, wherein, single-wire trellis out-yielded three-wire trellis with low pruning; while, with selective pruning, three-wire trellis system out-yielded single-wire indicating a direct relationship between type of pruning and trellis system. Cumulative yield in terms of number of fruits/vine was non-significant among treatments within each training systems, but differences among training systems *per se* were significant (Table 1). Tatura recorded higher average cumulative number (709.44 fruits/vine), while, High Trellis recorded the least fruit number (555.37 fruits/vine). The Kniffin system recorded higher number of fruits/vine during its first year of bearing compared to that in the second year, while the other systems exhibited a reverse trend (with initial lower yields, followed by higher yields during the second year). Three-wire Kniffin system (6 arm) produced several lateral spreading on the ground, which possibly encourage incidence of soil-borne diseases. One-wire trellis is a commonly used system in Victoria, Australia and in Kenya (Melville, 1952; Ministry of Agriculture, 1976). Three-wire trellis was found to be better in Queensland and South Africa (Malan, 1948; Wills, 1948).

Cumulative yields were highest in the Kniffin system (66.24 t/ha), followed by Bower (63.36t / ha.) system (Table 4). However, Tatura system, which gave highest yield per vine (43.57kg/vine), recorded lowest yield per ha (54.46t/ ha), mainly due to lower plant population per hectare (1250 vines/ha) compared to other systems (1666 vines/ha). Costa *et al* (1991) also reported lowest yields in 'Kiwi' fruit under Tatura system compared to T-Bar, Free Spindle and GDC (Geneva Double Cordon) systems. In view of highest cumulative yield in Kniffin system and the benefits it offers (in term of easier and less cumbersome cultural operations), this is the most ideal training system tested by us for 'Kaveri' passion fruit.

B. Physico-chemical parameters of fruit

Fruit parameters like fruit length, fruit breadth, fresh fruit weight, juice weight, peel and seed weight recorded significant variation with varying training systems (Table 2). Training system had a significant influence on linear dimensions of the fruit like fruit length and breadth, with High Trellis system recording highest values (6.11cm and 5.86cm, respectively). The same system also recorded highest values for fruit weight (72.16g), juice weight (14.08g) and juice % (19.58). High trellis and Bower Systems recorded higher peel weight compared to the other systems. Increase in fruit size parameters in High Trellis system was mainly due to restricted extension-growth of the laterals, which perhaps resulted in reduction in fruiting wood. In the present study, High trellis system was unable to fully support the highly vigorous 'Kaveri' passion fruit vines and their growth was restricted. This resulted in matting of the laterals

and a reduction in the number of fruiting axils. Buel (1956) and Gurnah and Gachanja (1980) opined that in passion fruit, reduction in fruiting wood was the main factor for increased fruit size. Reynold *et al* (1985) also reported significant effect of training system on berry number per cluster, cluster weight and berry weight in 'Seyal Blanc' grapes and ascribed the same to presence of perennial fruiting wood and greater leaf area.

C. Fruit quality

Training system, in general, had the least influence on fruit quality parameters. Kniffin and High trellis recorded higher TSS values (15.69°Brix), followed by Tatura. Bower system recorded the least TSS values (14.9°Brix). But, whether shading of fruits or lower Photosynthetically Active Radiation (PAR) observed under this system had any influence on reduced TSS values needs to be investigated. Tatura system recorded higher titrable acidity (2.76%) while High trellis recorded the least acidity (2.54%). Vitamin C content was almost equal in Kniffin, High trellis and Tatura, while Bower recorded the lowest values (19.25mg/100g). Carotene content was not significantly influenced by training system, and values ranged between 2.70 and 2.78mg / 100g. Similar results were reported by Avent (1958) and Gurnah and Gachanja (1980).

D. Light interception and photosynthetic rate

Interception of Photosynthetically Active Radiation (PAR) by the canopy did not differ significantly among training systems (Table 1). Overall, the canopy intercepted 82.46% to 83.92% of PAR among different training systems. Data on gas exchange of leaves exposed in the canopy and receiving PAR of around 1200µE $m^{-2}s^{-1}$ recorded photosynthetic rates ranging from 9.67 to 10.73µmol $m^{-2}s^{-1}$ across the training systems and did not differ significantly from each other (Table 1). Since, there were no significant differences in the photosynthetic rates of the exposed leaves training system wise, the quantification of the photosynthetic rates of the leaves exposed to different light regimes in the canopy was done at training system level. Results showed that in partially-shaded leaves receiving PAR of around 400µE $m^{-2}s^{-1}$, photosynthetic rate ranged from 2.0 to 2.86µmol $m^{-2}s^{-1}$ in Kniffin, High trellis and Tatura training systems, and were on par. Bower system recorded 0.94µmol $m^{-2}s^{-1}$ PAR (Fig 1). Shaded leaves in the canopy receiving PAR around 50µE $m^{-2}s^{-1}$ recorded a negative photosynthetic rate, ranging from –0.21 to –0.42µmol $m^{-2}s^{-1}$ under all the training systems meaning, that leaves were respiring but not contributing any photosynthate and were parasitic on the vine. Hence, shading within the canopy must be avoided to enhance light-use and encourage photosynthetic efficiency of the canopy. Similar trend was reported by Poni *et al* (2007) who reported in grapes, that canopy light-interception showed no convincing evidence of serving as a reliable predictor of yield, as observed by us in the present study. However, detailed studies are needed to quantify canopy photosynthesis under different training systems.

Table 3. Cost-benefit ratio of different training systems in passion fruit cv. Kaveri

Treatment	Expenditure (Rs./ha)		Cumulative yield (t/ha)	Income in	Cost benefit
	Non-Recurring	* Recurring (2006-08)	during 2006-08	lakhs(Rs./ha)#	ratio
Kniffin system					
2 arms (T1)	1,73,824	89,973	66.45	3,80,700	4.22
4 arms (T2)	1,92,453	89,973	67.22	4,03,320	4.25
6 arms (T3)	2,10,082	89,973	65.05	3,90,300	4.09
Mean	—	—	66.24	—	—
High Trellis					
Single cordon (T4)	2,62,183	89,973	56.56	3,39,360	3.51
Double cordon (T5)	2,62,183	89,973	54.04	3,24,240	3.36
Mean	—	—	55.30	—	—
Tatura					
4 arms (T6)	2,66,432	83,333	53.87	3,23,220	3.59
8 arms (T7)	3,13,380	83,333	52.80	3,16,800	3.47
12 arms (T8)	3,36,328	83,333	56.71	3,40,260	3.70
Mean	—	—	54.46	—	—
Bower					
2 cordon (T9)	2,96,760	89,973	65.29	3,91,740	4.02
4 cordon (T10)	2,96,760	89,973	61.44	3,68,640	3.78
Mean	—	—	63.36	—	—

*Total life span of the training structures is taken as 40 years and land rent @ Rs. 20,000/- per ha/year
Cost of passion fruit = Rs. 6/kg

F. Cost:benefit ratio of different training systems

Kniffin training system was the most efficient with cost-benefit ratio ranging from 4.09 to 4.25 (Table 3), whereas, the other systems recorded lower cost-benefit ratios, viz., Bower (3.78 – 4.02) and Tatura (3.47 – 3.70). High trellis system was the least efficient and, therefore, unsuitable for 'Kaveri' passion fruit.

ACKNOWLEDGEMENT

The authors express their gratitude to Director, Indian Institute of Horticultural Research, Bangalore, for providing support and facilities for undertaking this work and to Shri K.N. Ramachandran, Technician, for assistance in the field.

REFERENCES

Avent, K.I. 1958. Growing passion fruit in Victoria. *Fruit World and Market Grower*, **10:**33-37

Buel, E.P. 1956. Training and pruning the passion vine. *Trop. Agri.*, **3:**18-12

Costa, G., Biasi, R., Guilian, R. and Succi, F. 1991. Comparison of kiwifruit training systems. *Acta Hort.*, **297:**427-434

Davis, S.H.R., and Masten, S.J. 1991. Spectrophotometric method for ascorbic acid using dichlorophenolindophenol: elimination of the interference due to iron. *Anal. Chim. Acta,* **248:** 225-227

Gachanja, S.P. and Gurnah, A.M. 1980. Pruning and trellising purple passion fruit. I. Yields and seasonal trends. *J. Hortl. Sci*., **55:**345-349

Gurnah, A.M. and Gachanja, P. 1980. Pruning and trellising purple passion fruit, II Disease incidence, fruit size and quality. *J. Hortl. Sci*., **55**:351-354

Leskovar, D.I., Haejeen, B., Crosby, K.M., Maness, N. Franco, J.A. and Perkins–Veazie, P. 2004. Lycopene, carbohydrates, ascorbic acid and yield components of diploid and triploid watermelon cultivars are affected by deficit irrigation. *The J. Hortl. Sci. & Biotech.,* **79:**75-81

Malan, E.F. 1948. Granadilla Production. *Farming in South Africa*, **23**:625-626

Melville, F. 1952. Passion fruit cultivation in Western Australia. *J. Agri. of Western Australia* (3rd series) pp 737-742

Ministry of Agriculture. 1976. Horticulture Handbook 3. Passion fruit. Agril. Info. Centre, Nairobi, Kenya

Poni, S., Bernizzoni, F. and Civardi, S. 2007. The issue of canopy efficiency in the grape vine : Assessment and Approaches for its Improvement. Proc. Int'l. Workshop on grapevine. *Acta Hort.*, **754:**163-173

Reynolds, A.G., Pool, R.M. and Mattick, L.R. 1985. Effect if training system on growth, yield, fruit composition and wine quality of Sauvignon Blanc. *Amer. J. Enol. Vitic.,* **26:**156-164

Singh, H.P., Yadav, I.S. and Jalikop, S.H. 1991. Studies on improvement of passion fruit. *South Ind. Hort*., **39**:12-17

Wills, J.M. 1948. Passion fruit growing in Southern Queesnland. *Queensland Agril. J*., **66:**325-50

(MS Received 6 January 2011, Revised 30 January 2012)