J. Hortl. Sci.
Vol. 17(2) : 00-00, 2022

Original Research Paper

Advancing fruiting season in *Annona* cv. Arka Sahan through pruning

Chander S.*$, Kurian R.M., Satisha J., Upreti K.K. and Laxman R.H.
ICAR-Indian Institute of Horticultural Research, Bengaluru - 560089, India
$Punjab Agricultural University, RRS, Abohar - 152116, India
*Corresponding author Email : subhashghorela@pau.edu

ABSTRACT

***Annona* cultivar 'Arka Sahan', an inter-specific hybrid of *Annona atemoya* × *A. squamosa* comes to harvest during August-September under mild tropical climate, which coincides with monsoon rains resulting in poor fruit quality and high susceptibility to anthracnose and fruit fly. An attempt was made to advance the fruiting in this hybrid through pruning during 2016-17 and 2017-18. The effect of three pruning levels (25, 50 and 75% of previous season's growth) at five different times (60, 75, 90, 105 and 120 days after final harvest of previous crop) on flowering and fruiting were compared. Early sprouting, flowering and fruit harvest were recorded in trees pruned to 75% of the past season's growth in both the years. Earliest fruits were harvested 271 (3rd week of June) and 268 (2nd week of June) days after pruning in trees pruned during first week of October in 2016-17 and 2017-18 respectively ($P<0.05$). Bigger fruits with lesser seeds per 100 g of pulp ($P<0.05$) were harvested from trees pruned to 75% and 25% levels in the first and second year, respectively, irrespective of pruning time. Tree canopy following pruning at 75%level recorded higher light interception and photosynthetic rate ($P<0.05$). Pruning time and levels significantly influenced the biochemical constituents of leaf and shoot. The fruiting in cultivar 'Arka Sahan' could be thus advanced by 8-9 weeks to June from the normal season of August-September with comparable or better fruit quality by pruning 75% of the last season's growth during October.**

Keywords : Annona, biochemical constituents, fruit quality, off-season and pruning

INTRODUCTION

Sugar apple (*Annona squamosa* L.), also known as sweet sop, sugar apple, sitaphal or sharifa and as custard apple in India is a native of tropical America and West Indies, introduced to India. The fruits are generally used fresh, while some products like custard powders and ice-creams are prepared from the fruits. 'Arka Sahan' is an inter-specific hybrid between *A. atemoya* (var. Island Gem) × *A. squamosa* (var. Mammoth). It is a vigorous plant. Its mature fruits take about 6-7 days to ripe. The creamy white colour flesh is juicy with mild pleasant aroma and tender with fewer seeds (9/100 g pulp) and large segments. The edible pulp is remarkable for its sweetness with 22.8 per cent total sugars and measures more than 30^0 B as against 24^0 B in Mammoth (Jalikop and Kumar 2007). Flowering in annona occurs on current season growth arising after natural leaf fall during late winter. In annona, flower bud formation is restricted to early shoot development, and is extra-axillary, borne opposite to leaves (George and Nissen 1991). The leaf imposed para-dormancy of axillary bud is present in annona (George and Nissen 1987). Soler and Cuevas (2008) reported off-season (winter season) fruit production through shoot pruning followed by tipping the newly emerged shoots in cherimoya. Normal fruiting time of 'Arka Sahan' grown under the mild tropical climate is August-September, which coincides with monsoon rains resulting in deterioration of fruit quality due to anthracnose incidence and fruit fly infestation during the rainy period. Flowering can be manipulated by modifying the timing of bud break in annona species to get fruit out of season. For this leaf fall is prerequisite to open up the sub-petiolar axillary bud residing under the leaf petiole. We attempted to make the annona hybrid 'Arka Sahan' to flower and fruit early through pruning, which could induce early defoliation, bud sprouting and formation of new shoots and flowers and thus advance fruiting season to summer months. The pruning techniques were standardized in terms of time and severity, keeping in view the flowering and fruiting behavior of the cultivar 'Arka Sahan'.

MATERIALS AND METHODS

The experiment was conducted at ICAR - Indian Institute of Horticultural Research, Bengaluru (Karnataka state, India) during two consecutive years, 2016-17 and 2017-18. The experimental material consisted of eight-year-old one hundred and twenty uniform plants of *Annona* cv. Arka Sahan planted at a distance of 5m × 5m. The treatments comprised of five pruning times (T_1, T_2, T_3, T_4 & T_5) and three shoot pruning levels (L_1, L_2, & L_3). Pruning was performed after 60, 75, 90, 105 or 120 days after final harvest of the previous crop. Pruning levels consisted of removal of 25 per cent (one-fourth of shoot length), 50 per cent (half of shoot length) or 75 per cent (two-third of shoot length) of the previous season's growth. Each treatment was replicated four times in a factorial randomized block design. Two trees were observed in each replication under each treatment for collection of data. Eight trees that were not pruned and giving new shoot growth naturally by the end of March following leaf abscission during late winter served as external check for comparison of treatment effects against natural fruiting as these could not be fitted effectively into the factorial design involving pruning time and intensity. Standard package of practices were adopted for maintenance of all the trees during the experimentation.

The number of days required for sprouting and flowering was assessed by recording the days taken for the emergence of first sprout and flower respectively after the treatment imposition. The durations of the first and last harvest were calculated from the date of imposing the treatments to the first fruit harvest and the last fruit harvest respectively. The total fruit yield per tree was recorded at harvest by measuring the weight of fruits harvested and values were expressed in kilogram. Fruit weight (g) was recorded using electronic balance. The total soluble solids (TSS) were measured using digital refractometer and expressed as degree Brix. Titrable acidity was estimated by adopting the *titrametric* method of A.O.A.C (1975) using phenolphthalein indicator and the values were expressed in terms of percentage citric acid equivalent. Pulp content (%) of fruit was determined using the following formula:

$$\text{Pulp (\%)} = \frac{\text{Pulp weight}}{\text{Fruit weight}} \times 100$$

The number of seeds per 100 g of pulp was calculated by using the following formula:

$$\text{Number of seeds per 100 g of pulp} = \frac{\text{Number of seeds in fruit}}{\text{Pulp weight of fruit}} \times 100$$

Gas exchange parameters such as net photosynthesis (P_N, µmol m^{-2} s^{-1}), transpiration rate (E, mmolm^{-2} s^{-1}) and stomatal conductance (gs, mmol $m^{-2}s^{-1}$) were recorded in three fully expanded leaves of each plant using portable photosynthesis system (LCpro+, ADC BioScientific limited, UK) during morning hours of clear and sunny conditions between 09:30 h and 11:30 h at two stages *viz.,* fruit set (March, 2018) and rapid fruit growth (May, 2018) stage in the second year (2017-18) of study. Photosynthetically active radiation (PAR) below the tree canopy was measured using the LI-191SA Line Quantum Sensor (Li-Cor, Lincoln, NE) on uniformly overcast days between 12:00 h and 13:00 h at the fruit set and rapid fruit growth stages (FSS and RFGS) during 2017-18. The total leaf chlorophyll content was measured at FSS using spectrophotometer (UV 1650PC, Shimadzu, Japan) at wave lengths of 645 and 663 nm as per Hiscox and Isrealstam (1979). Total sugar in shoot was estimated after the harvest of fruits following the method of Somogyi, (1952).

Statistical analysis was done separately for the parameters studied for each year using OPSTAT (Sheoran *et al.,* 1998) and discussed at $P < 0.05$ for significance of difference between their mean values.

RESULT AND DISCUSSION

Physiological and biochemical characteristics: Pruning, especially its levels, significantly influenced the amount of light interception at both fruit set stage (FSS) in March and rapid fruit growth stage (RFGS) in May ($P<0.05$) (Table 2). Higher light interception in different treatments could be related to longer shoot length and higher number of leaves and leaf area in 75 per cent pruned trees ($P<0.05$). Differential light interception within tree canopies can also influence vegetative growth, flower initiation, fruit set, fruit size and fruit quality (Marini and Marini, 1983). Higher light interception was also associated with higher photosynthetic rate of leaves at both fruit set and rapid fruit growth stage. Pruning provided open canopy area and resulted in maximum interception of sunlight for

Table 1 : Details of timing and level of pruning

Treatments	Pruning level	Pruning time
T_1L_1 T_1L_2 T_1L_3	25% pruning 50% pruning 75% pruning	60 DAFH* (1st week of October)
T_2L_1 T_2L_2 T_2L_3	25% pruning 50% pruning 75% pruning	75 DAFH (3rd week of October)
T_3L_1 T_3L_2 T_3L_3	25% pruning 50% pruning 75% pruning	90 DAFH (1st week of November)
T_4L_1 T_4L_2 T_4L_3	25% pruning 50% pruning 75% pruning	105 DAFH (3rd week of November)
T_5L_1 T_5L_2 T_5L_3	25% pruning 50% pruning 75% pruning	120 DAFH (1st week of December)

*Days after final fruit harvest

higher rate of photosynthesis (Singh and Singh 2007). Similar results were recorded by Sharma *et al*. (2006) that the light interception was significantly influenced by pruning intensity in mango, being higher for pruned trees than for not pruned ones. The highest value of diffuse light availability below the canopy was recorded for severely pruned trees than for trees not pruned. Higher photosynthetic rate was recorded in trees pruned to 75 per cent level compared to 50 and 25 per cent levels ($P<0.05$) (Table 2). Higher photosynthetic rate reflects more metabolic activity in these leaves which could be attributed to interception of more light by the leaves. The trees pruned to 75 per cent produced longer shoots carrying more leaves, which harvested more light. Similar results were observed by Sharma *et al*. (2006) in mango where higher photosynthetic rate was recorded in leaves of pruned trees than trees not pruned. However, stomatal conductance was not affected much due to pruning in the present study (Data not presented). It ranged from 0.07 to 0.18 mmol m^{-2} s^{-1} among the treatments. The leaf chlorophyll content is considered as an important index of the metabolic activity of plants. At both FSS and RFGS, chlorophyll content exhibited differential pattern in response to different levels of pruning (Table 2). Accumulation of higher chlorophyll content in leaf could be related to the higher light interception which favoured the synthesis of more chlorophyll. Light interception by 75 per cent level pruned trees was higher at both fruit set and rapid growth stages. The lower chlorophyll content in the other treatments may be attributed to limited chlorophyll synthesis for want of conducible environmental conditions (Sritharan *et al*., 2010). Although, there was significant influence of pruning time and pruning levels on chlorophyll content at fruit set stage, no consistent results were evident over the years. At fruit set, the amount of chlorophyll content varied from 1.5 to 3.1 mg/g in the first year and from 1.2 mg to 3.2 mg/g in the second year. At rapid fruit growth stage, in the first year, pruning treatments did not influence the chlorophyll content while in the second year, significant influence was recorded with chlorophyll content varying from 2.0 to 2.8 mg/g ($P<0.05$). Sharma and Chauhan (2003) reported higher chlorophyll content in leaves of pruned peach tree leaves as compared to trees not pruned. However, total leaf chlorophyll content was recorded similar for both pruned and unpruned mango trees during April and July while during November it was recorded highest in pruned trees (Schaffer and Gaye 1989). Presence of higher amount of sugar in shoots of trees pruned at 25 per cent level in the present study, could be attributed to poor translocation of sugar for the growth of shoot or more towards the developing fruits which was also reflected in terms of relatively, smaller shoot and less number of leaves in 25 per cent pruned trees. However, sugar accumulation in shoot was recorded more in the second year (506.2 mg/100 g) over the first year (457.4 mg/100 g) which could be related to the favourable environmental condition prevailed including higher rainfall (average 2.41 mm per month), relative humidity (average 76.32%) and maximum temperature (average 29.74° C) in the second year (October to July) than the first year (rainfall 1.76 mm & relative humidity 68.47%). Shoots that emerged from 75 per cent pruning treatments were longer, which also reflected better translocation and utilization of sugar in the growth of shoot. Overall, total sugar content was affected by pruning levels, the results are in conformity with those of Bagchi *et al*. (2008) who observed that pruning up to 10 cm with complete removal of old leaves showed significant effect on increasing reducing sugars (36.7 mg/g) than other treatments and control.

Growth and yield characteristics: Pruning led to leaf fall followed by sprouting of sub petiolar axillary buds on the shoot. Irrespective of pruning time, the number of days required for sprouting has become shorter with the increase of pruning levelduring both the years with minimum number of days to sprout for those pruned in December first week and October first week in first and second years, respectively ($P<0.05$) (Table3). Early sprouting in trees pruned to 75 per cent level

Table 2 : Effect of pruning time and pruning levels on light interception, photosynthetic rate, total leaf chlorophyll and total sugar in *Annona* cv. Arka Sahan

Treatments	Light interception (%) 2017-18		Photosynthetic rate (µmol $m^{-2} s^{-1}$)	Total leaf chlorophyll (mg g^{-1})		Total sugar (mg/100 g)	
	FSS	RFGS	2017-18	2016-17	2017-18	2016-17	2017-18
T_1L_1	21.8	65.1	7.9	3.1	3.2	399.3	480.0
T_1L_2	41.5	82.6	7.7	2.5	2.5	352.0	415.0
T_1L_3	58.8	92.0	10.8	2.9	3.1	181.5	249.3
T_2L_1	19.6	66.3	5.7	2.3	2.2	372.0	410.8
T_2L_2	40.6	75.9	5.8	2.9	3.0	427.8	504.0
T_2L_3	55.7	90.6	7.2	2.3	2.3	182.5	299.0
T_3L_1	24.4	71.9	4.5	2.3	2.4	467.5	531.0
T_3L_2	32.5	80.2	4.8	2.0	1.8	408.8	472.0
T_3L_3	59.4	85.2	8.7	2.2	2.1	278.8	327.8
T_4L_1	21.0	70.4	7.6	1.7	1.2	589.5	698.0
T_4L_2	47.4	76.9	8.0	1.5	2.9	570.5	573.0
T_4L_3	58.4	84.1	8.7	2.0	3.1	326.5	539.0
T_5L_1	24.6	73.4	6.8	1.8	2.6	458.8	411.0
T_5L_2	40.6	80.5	6.4	1.6	2.5	427.0	498.0
T_5L_3	58.7	92.7	7.5	1.9	1.8	364.0	431.0
External Check	20.3	60.2	7.6	3.0	3.1	350	465
$\mathbf{T}_{C.D.\ (P=0.05)}$	-	3.00	1.11	0.03	0.04	6.71	8.39
$\mathbf{L}_{C.D.\ (P=0.05)}$	2.81	2.33	0.86	0.03	0.03	5.20	6.50
$\mathbf{T \times L}_{C.D.\ (P=0.05)}$	6.28	5.20	1.92	0.06	0.07	11.62	14.53

T: Time of pruning; L: Level of pruning

Table 3 : Effect of pruning time and levels on sprouting, flower initiation, fruit yield and its pattern of *Annona* cv. Arka Sahan

Treatments	Sprouting (days)		Flower initiation (days)		First harvest (days)		Final harvest (days)		Fruit yield per tree (kg)		Fruit yield per TCSA (kg/cm^2)	
	2016-17	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**
T_1L_1	85.3	104.7	100.6	132.8	297.5	307.5	307.5	320.0	12.0	20.2	0.10	0.14
T_1L_2	57.5	60.7	75.7	74.5	285.0	279.5	302.0	306.3	10.1	14.9	0.07	0.09
T_1L_3	23.3	13.7	42.9	26.3	271.0	268.9	299.5	302.5	11.1	16.1	0.09	0.11
T_2L_1	60.5	104.6	77.7	126.1	290.0	291.0	305.0	301.8	10.2	17.7	0.08	0.13
T_2L_2	28.0	90.1	45.4	105.3	277.5	266.0	296.3	295.0	11.2	15.7	0.09	0.10
T_2L_3	17.5	20.0	35.3	33.9	271.0	245.0	287.0	295.0	11.3	17.0	0.08	0.10
T_3L_1	41.6	44.9	54.2	54.8	269.0	276.8	279.0	285.5	9.0	18.9	0.08	0.14
T_3L_2	25.5	32.6	42.9	55.6	269.8	265.8	278.0	284.5	10.0	19.4	0.09	0.14
T_3L_3	16.3	17.6	48.2	42.2	271.3	235.0	287.3	281.0	10.1	16.8	0.09	0.11
T_4L_1	31.5	62.9	44.4	76.1	269.0	261.5	284.0	266.8	8.7	20.5	0.07	0.13
T_4L_2	19.2	39.6	33.8	55.7	270.8	252.5	284.0	276.0	9.3	16.4	0.07	0.10
T_4L_3	16.2	18.4	56.8	44.0	276.3	236.8	285.0	271.5	10.8	15.2	0.08	0.10
T_5L_1	25.2	45.1	38.5	59.8	270.0	246.8	283.0	258.3	9.8	20.6	0.07	0.12
T_5L_2	20.9	33.5	37.8	45.6	271.0	236.5	283.0	255.0	10.5	19.1	0.07	0.12
T_5L_3	14.7	17.3	50.8	40.6	274.5	222.5	283.0	244.8	11.3	16.4	0.08	0.09
External Check	118	135	133	145	321	329	335	338	14.2	20.1	0.09	0.14
$\mathbf{T}_{C.D. (P=0.05)}$	3.06	5.10	4.39	5.07	3.98	2.55	3.25	4.78	0.21	1.27	0.01	0.01
$\mathbf{L}_{C.D. (P=0.05)}$	2.37	3.95	3.40	3.93	3.08	1.98	2.52	3.70	0.16	0.98	-	0.01
$\mathbf{T \times L}_{C.D. (P=0.05)}$	5.29	8.84	7.61	8.78	6.89	4.42	5.64	8.28	0.36	2.20	-	-

T: Time of pruning; L: Level of pruning

could be attributed to very few leaves or no leaf left on such shoots and with less number of buds available on the shoot, the reserve metabolites from trunk could have contributed to early release of these buds. Similar results were observed in cherimoya (Soler and Cuevas, 2008) and guava (Shaban and Haseeb, 2009), where severely pruned trees gave early sprouting. Also, early flowering occurred in trees pruned to 75 per cent level (P<0.05). In a less vigorous cultivar of sugar apple, Balanagar, early shoot growth during winter could be induced under similar climatic condition through chemical defoliation (Chander *et al.,* 2019). Since flowering is on current season growth in *Annona* and concomitant with the shoot growth, early sprouting resulted in early flowering in both the years. However, in the first year, flowering was earlier on trees pruned to 50 per cent level during November and December despite early sprouting in those pruned to 75 per cent level. It was observed that there was continuous vegetative growth in 75 per cent pruned trees. Similar results were reported in custard apple (George and Nissen, 1987), cherimoya (Soler and Cuevas, 2008) and atemoya (Olesen and Muldoon, 2012). Pruning treatments significantly influenced the flowering and fruiting period of *Annona* cv. 'Arka Sahan' (Table 3). Earliest fruits were harvested from the treatments imposed in 1st week of October, at 75 per cent pruning level (T_1L_3) with minimum days (271) to harvest by 2nd week of June in first year (P<0.05). A consistent result was recorded for early harvest (2nd week of June) with 75 per cent pruned trees in second year for all pruning time. Early harvest from 75 per cent pruned trees could be attributed to advanced flowering and fruit set in these trees. Observations recorded on final harvest exhibited significant differences with pruning time and pruning level (Table 3). In both the years, the final harvest extended longer for the 25 per cent pruned trees (P<0.05). Final harvest in case of 75 per cent pruning was completed earlier than 25 per cent or 50 per cent pruning. Early harvest in these trees could be attributed to earlier induction of flowering and pollination than the other treatments. The results are in conformity with those reported by Vinay *et al.* (2014) in custard apple and Adhikari and Kandel (2015) in guava. Higher yield was obtained from trees pruned during 1st week of October at 25 per cent level (T_1L_1) while for rest of the pruning treatments greater yield was recorded from 75 per cent pruned trees in the first year. However, in the second year, maximum yield per tree was obtained from 25 per cent pruned trees (Table 3). Higher yield in respective years could be attributed to bearing of larger size of fruits and occurrence of prevailing congenial environmental conditions during the fruit growth. Also, accumulation of more sugars in the shoot of 25 per cent pruned trees at harvest reflect more availability of assimilates to fruits on these trees. Fruits were harvested near to normal season from trees pruned to 25 per cent level which could have advantage of prevailing congenial environmental condition than other treatments. The results are in conformity with Kumar *et al.* (2010) in peaches and Choudhary and Dhakare (2018) in sugar apple, where heavy pruning (90 cm) gave lesser yield than light or trees not pruned but medium pruning (30-45 cm) recorded higher yield per tree. The yield per TCSA was not influenced much with pruning treatments, which could be attributed to lesser effect of pruning treatments on trunk growth (Table 3). In the second year, comparatively higher yield per tree was recorded although there was not much improvement in trunk growth. Higher yield in second year could be more related to the increase of yield per tree rather than trunk circumference.

Fruit quality characteristics: There was consistent significant effect of pruning levels on fruit weight and pulp content in both the years (P<0.05) (Table 4). Higher fruit weight and pulp content in 75 per cent pruned trees could be attributed to the better growth of shoot with higher number of leaves which resulted in higher synthesis of photosynthates in these shoots. The higher amount of accumulated photosynthates could have contributed for bigger size of fruits. Similar results were reported in custard apple (Olesen and Muldoon, 2009; Choudhary and Dhakare, 2018) and ber (Gupta and Gill, 2015). However, in the second year, trees pruned at 25 per cent level recorded the maximum fruit weight and pulp content which could be due to availability of sufficient stored carbohydrates, confirmed with the estimation of higher sugar in the developed shoot. Similar trend was observed on other fruit quality parameters including fruit volume, fruit length, fruit width and fruit circumference with the pruning treatments imposed over two years (data not presented). Results indicated that irrespective of pruning time, comparatively fewer seeds per 100 g of pulp were recorded in 75 per cent and 25 per cent pruning levels in the first and second years, respectively (P<0.05). As the fruit size including fruit weight, volume, and pulp content was recorded more in these treatments this could have lowered the proportion of seed per unit of pulp. Similar findings were also observed by Chander and Kurian (2019) in sugar apple and Teaotia and Singh (1971) in guava where lesser percentage of seed was recorded in

Table 4 : Effect of pruning time and pruning levels on fruit quality attributes of *Annona* cv. Arka Sahan

Treatments	Fruit weight (g)		Pulp content (%)		Seeds per 100 g of Pulp		TSS (ºB)	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
T_1L_1	248.1	432.9	59.9	80.1	29.1	12.4	36.3	33.9
T_1L_2	301.5	350.8	69.5	70.5	22.7	15.4	35.2	32.0
T_1L_3	316.5	363.6	64.2	76.2	21.9	16.1	34.5	31.8
T_2L_1	257.9	394.0	63.6	80.3	24.1	12.1	37.0	33.6
T_2L_2	265.6	361.5	66.3	75.2	25.6	15.2	35.4	33.0
T_2L_3	310.7	421.4	67.7	73.3	20.3	15.0	32.8	31.8
T_3L_1	278.9	468.7	65.8	79.0	27.1	12.4	35.5	33.8
T_3L_2	308.9	452.8	66.8	78.6	24.2	15.4	36.7	32.8
T_3L_3	289.7	394.5	68.2	66.2	22.2	18.2	35.0	31.3
T_4L_1	262.5	456.0	66.5	80.0	26.1	13.5	36.3	32.6
T_4L_2	250.8	402.7	68.5	77.4	24.2	13.4	36.1	32.4
T_4L_3	275.0	385.8	70.8	74.3	19.2	15.5	35.3	31.7
T_5L_1	262.9	451.2	62.3	79.1	25.7	13.5	36.0	33.5
T_5L_2	273.1	408.7	65.8	69.7	28.6	13.1	35.7	32.9
T_5L_3	278.7	441.4	66.6	73.9	23.9	16.1	35.9	32.2
External Check	300	375	61.4	66.1	23.2	15.8	31.8	30.2
$\mathbf{T}_{C.D.\ (P=0.05)}$	-	36.73	2.72	-	-	-	0.60	-
$\mathbf{L}_{C.D.\ (P=0.05)}$	18.23	28.45	2.11	2.34	2.62	1.39	0.47	0.54
$\mathbf{T \times L}_{C.D.\ (P=0.05)}$	-	-	-	5.22	-	-	1.04	-

T: Time of pruning; L: Level of pruning

heavier fruit obtained from pruned trees. Pruning influences quality of the fruits by regulating carbohydrate allocation to the developing fruits (Palanichamy *et al*., 2011). Early pruning during October-November resulted in increased level of total soluble solids (TSS) of the fruit than the later or trees not pruned ($P<0.05$) (Table 4). The prevailing congenial temperature during fruit growth and maturation could have contributed for accumulation of more sugar in the developing fruits as the fruits come to harvest earlier in these pruned trees. In both the years, comparatively higher value of prevailing average maximum temperature (31.11, 31.50°C) was recorded from flowering to fruit maturity (February to June) for October-November pruned trees than the late pruned trees wherein lesser average maximum temperature (30.73, 30.33°C) was recorded from flowering to fruit maturity (April to August). The results are in conformity with those of Kadam *et al*. (2018) in custard apple cv. Dharur-6 where fruits from light pruned (20 cm) trees recorded maximum TSS content. In contrast, heavy pruning resulted in accumulation of more TSS in grapes (Zabadal *et al*., 2002) and peach (Chitkara *et al*., 1991). There were no consistent trends of acidity content of fruit pulp although higher level of acidity was observed in trees pruned to 75 per cent level (data not presented). Chitkara *et al*. (1991) and Kumar *et al*. (2010) recorded increased acidity level with the increase of pruning severity in peaches. Similar results were obtained by Mehta *et al*. (2012) in guava and Kadam *et al*. (2018) in custard apple cv. Dharur-6.

Induction of off-season crop with better quality is a new technique in sugar apple production that could enable the growers to get better market and profitability. Fruiting could be advanced by 8-9 weeks to June with pruning at 75 per cent level during October in *Annona*cv. Arka Sahan from the normal fruiting season of August - September.

ACKNOWLEDGEMENT

We are thankful for the requisite facility providedby the Director, ICAR - Indian Institute of Horticultural Research, Bengaluru (India). The first author is also grateful for the financial support provided to him by University Grants, Commission, New Delhi (India).

REFERENCES

Adhikari, S. and Kandel, T. P. 2015. Effect of time and level of pruning on vegetative growth, flowering, yield, and quality of guava. *International Journal of Fruit Science,* **15(3):** 290-301.

A.O.A.C. 1975. Official methods of analysis. *Association of the Official Analytical Chemists, Washington D.C.* 8th Edn.

Bagchi, T. B., Sukul, P. and Ghosh, B. 2008. Biochemical changes during off-season flowering in guava (*Psidium guajava* L.) induced by bending and pruning. *Journal of Tropical Agriculture,* **8**: 64-66.

Chander, S. and Kurian, R. M. 2019. Effect of crop load, fruit position and shoot vigour on yield and quality of *Annona atemoya* × *Annona squamosa* in India. *The Journal of Horticultural Science and Biotechnology,* **94(4)**: 507-512.

Chander, S., Kurian, R. M., Satisha, J., Upreti, K. K. and Laxman, R. H. 2019. Chemical interventions for advancing the fruiting season of sugar apple (*Annona squamosa* L.) cv. Balanagar.*International Journal of Chemical Studies,* **7(1)**: 774-781.

Chitkara, S. D., Arora, R. K. and Sharma, R. K. 1991. Effect of various levels of pruning on physio-chemical characters of fruit in Flordasun peach. Haryana *Journal of Horticultural Sciences,* **20(3):** 189–192.

Choudhary, K. and Dhakare, B. B. 2018. Influence of pruning intensities on growth, yield and fruit attributes of custard apple. *International Journal of Current Microbiology and Applied Sciences,* **7**: 5311-5315.

George, A. P. and Nissen, R. J. 1987. Effects of cincturing, defoliation and summer pruning on vegetative growth and flowering of custard apple (*Annona cherimola* x *Annona squamosa)* in subtropical Queensland. *Australian Journal of Experimental Agriculture,* **27(6):** 915-918.

George, A.P, Nissen, R. J. and Campbell, J. A. 1991. Pollination and selection in *Annona* species (cherimoya, atemoya and sugar apple). *Frontier in Tropical Fruit Research,* **321:** 178-185.

Gupta, N and Gill, M S. 2015. Effect of intensity of pruning on yield and fruit quality of ber (*Ziziphus mauritiana* L.) cv. Umran. *International Journal of Agriculture, Environment and Biotechnology,* **8(1):** 69-73.

Hiscox, J. D. and Israelstam, G. F. 1979. A method for the extraction of chlorophyll from leaf tissue without maceration. *Canadian Journal of Botany,* **57(12):** 1332-1334.

Jalikop, S. H. and Kumar, R. 2007. Pseudo-xenic effect of allied *Annona* spp. Pollen in hand pollination of cv. 'Arka Sahan' [(*A. cherimola* × *A. squamosa*) × *A. squamosa*]. *HortScience,* **42(7):** 1534-1538.

Kadam, S R, Dheware, R M. and Urade, P S. 2018. Effect of different levels of pruning on quality of custard apple (*Annona squamosa* L.). *International Journal of Bio-resource and Stress Management,* **9(5):** 573-575.

Marini, R. P. and Marini, M. C. 1983. Seasonal changes in specific leaf weight, net photosynthesis, and chlorophyll content of peach leaves as affected by light penetration. *Journal of the American Society for Horticultural Science,* **108:** 600-605.

Mehta, S., Singh, S. K., Das, B., Jana, B. R. and Mali, S. 2012. Effect of pruning on guava cv. sardar under ultra high-density orcharding system. *Vegetos,* **25(2):** 192-195.

Olesen, T. and Muldoon, S. J. 2012. Effects of defoliation on flower development in atemoya custard apple (*Annona cherimola* Mill. × *A. squamosa* L.) and implications for flower-development modelling. *Australian Journal of Botany,* **60(2):** 160-164.

Olesen, T. and Muldoon, S. J. 2009. Branch development in custard apple (*Annona cherimola* Miller× *A. squamosa* L.) in relation to tip-pruning and flowering, including effects on production. *Trees,* **23(4):** 855-862.

Palanichamy, V., Mitra, B., Srivastav, M. and Singh, S.K. 2011. Studies on various grape genotypes through development of bearing zones and pruning severity. *Journal of Pharmacy Research,* **4(10):** 7-10.

Schaffer, B. and Gaye, G. O. 1989. Effects of pruning on light interception, specific leaf density and leaf chlorophyll content of mango. *Scientia Horticulturae,* **41(1-2):** 55-61.

Shaban, A. E. A. and Haseeb, G. M. M. 2009. Effect of pruning severity and spraying some chemical substances on growth and fruiting of guava trees. *American-Eurasian Journal of Agricultural and Environmental Science,* **5(6):** 825-831.

Sharma, D.P. and Chauhan, J.S., 2003. October. Response of pruning intensities and fertilizer treatments on yield, fruit quality and photosynthetic efficiency of peach. In *VII International Symposium on Temperate Zone Fruits in the Tropics and Subtropics* ***662*** pp. 237-241.

Sharma, R. R., Singh, R. and Singh, D. B. 2006. Influence of pruning intensity on light penetration and leaf physiology in high-density orchards of mango trees. *International Journal of Fruit Science,* **61(2):**117-123.

Sheoran, O. P., Tonk, D. S, Kaushik, L.S., Hasija, R. C. and Pannu, R. S. 1998. Statistical software package for agricultural research workers. Recent Advances in Information Theory, Statistics & Computer Applications by D.S. Hooda & R.C. Hasija Department of Mathematics Statistics, CCS HAU, Hisar (139-143).

Singh, V K. and Singh, G. 2007. Photosynthetic efficiency, canopy micro climate and yield of rejuvenated guava trees. *Acta Horticulturae,* **735:** 326-331.

Soler, L and Cuevas, J. 2008. Development of a new technique to produce winter cherimoyas. *HortTechnology,* **18(1):** 24-28.

Somogyi, M. (1952). Notes on sugar determination. *Journal of Biological Chemistry,* **200:**245-247.

Sritharan, N, Vijayalakshmi, C. and Selvaraj, P. K. 2010. Effect of micro-irrigation technique on physiological and yield traits in aerobic rice. *International Journal of Agriculture, Environment and Biotechnology,* **3(1):** 26-28.

Teaotia, S. S. and Singh, R. D. 1971. The effect of training on growth, cropping and physico-chemical properties of guava cv. Allahabad Safeda. *Progressive Horticulture,* **2:** 5-20.

Vinay, G. M. and Chithiraichelvan, R. 2014. Induction of off-season flowering in custard apple (*Annona squamosa* L.) cv. Balanagar. *Journal of Horticultural Sciences,* **10(1):** 13-17.

Zabadal, T. J., Vanee, G. R., Dittmer, T. W. and Ledebuhr, R.L. 2002. Evaluation of strategies for pruning and crop control of concord grapevines in Southwest Michigan. *American Journal of Enology and Viticulture,* **53:** 20-24.