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Impact of canopy management on flowering and yield attributes of cocoa (*Theobroma cacao* L.) under tropical condition of Tamil Nadu

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Abstract
The present investigation on canopy management of cocoa was carried out to study the influence of different pruning levels and growth retardant applications on growth, flowering and yield of cocoa. Three different levels of pruning *viz.,* light pruning, medium pruning and hard pruning and two growth retardant *viz.,* paclobutrazol and cycocel at different concentration was taken for the study and compared with farmer practice (control). The experiment was laid out in Randomized Block Design with eight treatments and three replications. Treatments were imposed on January of 2017 and various observations on growth, flower and yield attributing characters were recorded throughout the study period. The results of the experiment revealed that hard pruning recorded highest in canopy spread and light transmission ratio (%) at different stages. Medium pruning registered highest in number of flower cushions per tree (378.02), number of pods per tree (34), dry bean weight per pod (55.42 g), weight of the pod (540.58 g).

Keywords: pruning, canopy management, cocoa, paclobutrzol, cycocel

Introduction
Canopy management is one of the most important production factors confronting the burgeoning horticultural industry in India. Canopy management is the manipulation of tree canopy to optimize the production potential with excellent quality of produce. In many horticultural crops particularly fruit crops, increase in production with enhanced fruit quality is optimized by managing the canopies of short statured trees. In fact, small trees capture and convert sunlight into fruit production in a better way than larger ones. The main controlling factors are amount of incoming radiation and percentage of radiation intercepted by tree canopies.

Among the plantation crops, cocoa plants are grown under the shade of arecanut and coconut plantations in south India and it is necessary to regulate the canopy size and shape of plants so that the main crop is not affected. This warrants proper and systematic canopy management through pruning in cocoa cultivation which aid in ventilation, tree height maintenance and other horticultural practices (Lik and Hussein, 2001) [8]. Growth retardant like paclobutrazol had been of great importance in canopy management and improving yield and quilt of fruit crops like mango, guava, apple etc. The use of plant growth regulators by many researchers had shown reduced flowering drop, high flower retention, increased fruit yield in many fruit crops (Iqbal *et. al*., 2009) [7].

Pruning is an important operation in cocoa especially when it is grown as an intercrop. It is a regular practice in all cocoa growing countries except in West Africa. The main objective of pruning is to maintain the shape of the cocoa plant to make it more productive and efficient. Formative and maintenance pruning are the two types of pruning practiced in cocoa (Balasimha, 2002) [3]. He further stated that pruning of canopy is necessary for maintenance of optimum leaf area index in cocoa. Photosynthesis occurs on leaves exposed to light and leaves inside the canopy are considered parasitic as they import photosynthates from outer leaves. Thus pruning is absolutely necessary for productivity. Formative pruning is to adjust the height of the first jorquette and control of vertical growth. Generally first jorquette is formed at a height between 1 and 2 meters. For easy operations in the field, the preferable jorquette height is 1.5 to 2.0 meters.

Earlier works done on canopy management through pruning are pertaining to African countries and to Kerala conditions.

However, information on canopy management in cocoa under tropical condition of Tamil Nadu by pruning and growth retardant in coconut based cultivation is not validated. In the present investigation, attempts were made to compare pruning intensities and application of different growth retardant for growth, flowering and yield of cocoa.

Materials and Methods

The present investigation was carried out at farmer's field near Coconut Research Station, Tamil Nadu Agricultural University, Aliyarnagar situated in the foot hills of Western Ghats at the geographic co-ordinates of 10°N latitude and 77° E longitude, at an elevation of 260 m above MSL with an undulating topography. Uniform seedling trees of Forestero aged ten years were used as the materials for the study. The experiment was laid out in a randomized block design with eight treatments in three replications. Ninety six uniform sized trees spaced at 7.5 X 3 m were used for the study. Each treatment unit consisted of twelve trees. Observations were recorded for two seasons (January to June, 2017 as first season and July to December, 2017 as second season).

Pruning was carried out during January, 2017 after the end of final harvest of December, 2016 crop. Major pruning was carried only during first season crop (January, 2017 to June, 2017) and in second season crop (July, 2017 to December, 2017) only water shoots and some diseased branches were removed. Soil drenching of Paclobutrazol and foliar spray of Cycocel were carried out twice per season. In first season crop, first application was done on mid of January, 2017 and second application forty five days after first application. Similarly in second season crop, first application was done on mid of August, 2017 and second application forty days after first application.

The detailed treatments of the study are: T_1 - Control (Farmer practices); T_2 - Light pruning (Removal of 10% of total secondary branches); T_3 - Medium pruning (Removal of 20% of total secondary branches); T_4 - Hard pruning (Removal of 30% of total secondary branches); T_5 - Soil drenching of Paclobutrazol @ 0.5 g *a.i.* per tree (no pruning); T_6 - Soil drenching of Paclobutrazol @ 1.0 g *a.i.* per tree (no pruning); T_7 - Foliar spray of Cycocel @ 500 ppm (no pruning) and T_8 - Foliar spray of Cycocel @ 750 ppm (no pruning).

All the observations on growth and physiological characters like canopy spread, carbohydrate content of cocoa twigs, light transmission ratio were recorded throughout the study. Flowering and yield attributes were recorded for two seasons and then pooled mean values were calculated and presented in this paper.

Results and Discussions

Canopy spread

The hard pruning registered the maximum increment in canopy spread in both north – south (0.62 m)) and east-west (0.50 m) direction. The least increment was recorded by foliar spray of Cycocel @ 750 ppm in north – south direction (0.15 m) and by soil drenching of Paclobutrazol @ 0.5 g a.i per tree in east – west direction (0.18 m).

The result was as expected because among the eight treatments, removal of biomass was relatively higher in this treatment that would have forced the tree to grow and spread more than the rest of the treatments. In cocoa, maintenance of optimum canopy shape involves pruning of certain branches as it is known in cocoa that highly shaded leaves do not show photosynthetic activity and maintained at the cost of other exposed leaves. Increments in canopy sizes in both directions were lower in all treatments treated with growth retardant and among them soil drenching with Paclobutrazol @ 0.5 g *a.i* per tree recorded the lowest canopy spread. The reason may be due to lower vegetative growth in the treated trees. Shinde (2015) [15] similarly reported that vegetative growth *viz,* shoot length, shoot diameter and number of leaves were suppressed significantly by the Paclobutrazol application.

Total carbohydrate

Light pruning (10 %) was recorded with highest carbohydrate content in the twigs before (17.92 mg/g) and 10th month (13.17 mg/g) after treatment. Lowest carbohydrate content in cocoa twigs was recorded with foliar spray of Cycocel @ 500 ppm both before (16.71 mg/g) and 10th month (11.09 mg/g) after treatment. It could also be seen that in all the treatments the carbohydrate content in the twigs gets reduced at 10th month after treatment when compared to before treatment.

In a perennial crop like cocoa, carbohydrate reserves play a key role as they are related to yield. Carbohydrate content estimated before treatment (January, 2017) and ten month after treatment (December, 2017) revealed drastic reduction in its content in the twigs. In this study, carbohydrate content estimated ten month after treatment was done when harvesting was at peak. This may be the reason in decline of carbohydrate content indicating the utilization of reserve food material in the development of new canopy and pods. After harvesting of pods, the carbohydrate content may get increased again during gap of after harvesting and flowering. Gaveau *et al.* (2014) [5] reported similar result in grapevine where after removal of fruit, the results showed that carbohydrate reserves in the wood were elevated. A higher starch and soluble sugar accumulation was observed in whole plants. The increase of starch and soluble sugar content in the aerial organs could be explained by the lower needs of photoassimilates in the whole plant caused by sink fruit removal or by an increase of photoassimilate synthesis.

Light transmission ratio

Among the eight treatments, hard pruning (30%) recorded the highest light transmission ratio measured at different interval of 4th, 6th, 8th and 10th month after imposition of treatment (80.43, 65.93, 52.47 and 45.77%) respectively. Lowest light transmission ratio was recorded by foliar spray of Cycocel @ 500 ppm in all stages.

The more removal of the branches in hard pruning might had permitted the maximum light to fall on the ground. Comparing light transmission ratio (%) at different stages, light transmission ratio (%) slowly reduced in all the treatments after ten month of treatment which may be due to new laterals produced and growth of the laterals leading to canopy spread and shading of canopy.

Number of flower cushions per tree

In the present study, the different treatment imposed exhibited significant difference in the number of flower cushions per tree (Table 4). More number of flower cushions was reported with medium pruning (20 %) and on par with foliar spray of cycocel @ 750 ppm. Unlike growth parameters, higher flower cushions per tree were observed with trees treated with growth retardant. The results obtained are similar to the finding of Sonawane *et al.* (2016) [12] where he reported the effect of foliar sprays of paclobutrazol and cycocel on enhancing flowering behaviour of mango *cv.* Alphonso and found that foliar sprays of cycocel 1500ppm applied in the

month of October are better for early flower emergence and flowering.

Numbers of flower cushions were higher in all the treatment of the second season crop than the first season crop; this may be due to environmental effect and rainfall prevailing during the period. In a crop like cocoa, flowering is conditioned by many factors such as effect of shade, distribution of rainfall and presence of larger quantities of pod having strong inhibitory effect on flowering (Alvim, 1981) [2]. Water stress inhibits flowering (Alvim, 1964; Hutcheon, 1977; Sale, 1970) [1, 6, 10] in cocoa.

Yields attributes of cocoa

In the present study, medium pruning (T_2) registered the maximum dry bean weight per pod and on par with light pruning (T_1) in number of beans per pod (Table 5). This is due to the maximum length, girth, weight and wet bean weight per pod in medium pruning (T_2) when compared to rest of the treatments. Average bean weight is expected to be 1.0 -1.2g with 1.0 g as a minimum. In the present study medium pruning (T_2) registered the maximum single bean dry weight and dry bean weight per tree when compared to rest of the treatments. Medium pruning (T_2) treatments had higher number of pods than rest of all treatments while foliar spray with cycocel @ 500 ppm (T_7) had lower number of pods per tree.

It can be observed that even though all treatments treated with growth retardant had high numbers of flower cushions per tree, the number of pods harvested at the end of the season was lower in all the growth retardant treatments. Exhaustion of carbohydrate stock during flowering and exhaustion of source due to presence of more numbers of less photo synthetically active old leaves surviving at the expense of other active leaves present in the trees may be the reason for the low yield. Sharma *et al.* (2011) [11] reported that pre-bloom paclobutrazol, cycocel and ethrel sprays induced flowering but did not affect fruiting significantly in mango *var*. Chausa.

In cocoa earlier studies showed that for optimum production, proper canopy management has to be maintained with optimum shape and size. Martin and Prasad (1983) [9] reported in a pruning experiment with three types of pruning *viz*., discretionary pruning, strict pruning and no pruning, the discretionary pruning showed higher yield. However, based on one year data in this study, one cannot conclude that medium (20%) or light pruning (10%) give better yield and the experiment has to be conducted for a minimum of two to three years to get a concordant result in a perennial crop like cocoa. This is true because pruning trials conducted in Ghana showed that during early years the pruned trees yielded slightly more than unpruned trees, but after ten years from planting, the unpruned trees started to yield more (Bonaparte, 1966) [4]. However, studies in cocoa revealed that trees with big canopy with spreading nature seem to be ideal for getting higher yield (Thomas and Balasimha, 1992) [13].

Table 1: Effect of pruning and growth retardant on canopy spread (m) in cocoa.

T. No.	Treatments	Canopy spread (m)					
		Before treatment		10 MAT		Increment in canopy spread	
		NS	EW	NS	EW	NS	EW
T_1	Control (Farmer practices)	4.25	4.49	4.70	4.90	0.45	0.41
T_2	Light pruning (10%)	4.94	4.98	5.23	5.27	0.29	0.35
T_3	Medium pruning (20%)	4.53	4.70	4.95	5.06	0.42	0.42
T_4	Hard pruning (30%)	4.85	4.90	5.47	5.40	0.62	0.50
T_5	Soil drenching of Paclobutrazol @ 0.5 g	4.19	4.60	4.35	4.78	0.16	0.18
T_6	Soil drenching of Paclobutrazol @ 1.0 g	4.25	4.30	4.43	4.50	0.17	0.20
T_7	Foliar spray of Cycocel @ 500 ppm	3.47	3.67	3.68	3.97	0.21	0.30
T_8	Foliar spray of Cycocel @ 750 ppm	4.01	4.19	4.17	4.43	0.15	0.24
Mean		4.31	4.48	4.62	4.80	0.31	0.32
S.Ed		0.198	0.153	0.200	0.168	0.049	0.055
CD(P=0.05)		0.602	0.464	0.607	0.508	0.150	0.167

*MAT – Months After Treatment

Table 2: Effect of pruning and growth retardant on carbohydrate content of the cocoa twigs (mg/g)

T. No.	Treatments	Carbohydrate content of the cocoa twigs (mg/g)	
		Before Treatment	10 MAT
T_1	Control (Farmer practices)	16.84	12.07
T_2	Light pruning (10%)	17.92	13.17
T_3	Medium pruning (20%)	17.66	13.16
T_4	Hard pruning (30%)	17.11	12.19
T_5	Soil drenching of Paclobutrazol @ 0.5 g	16.82	11.27
T_6	Soil drenching of Paclobutrazol @ 1.0 g	17.20	11.96
T_7	Foliar spray of Cycocel @ 500 ppm	16.71	11.09
T_8	Foliar spray of Cycocel @ 750 ppm	17.51	12.19
Mean		17.22	12.14
S.Ed		0.114	0.072
CD(P=0.05)		0.345	0.219

*MAT – Months After Treatment

Table 3: Effect of pruning and growth retardant on light transmission ratio (%) in cocoa.

T. No.	Treatments	Light transmission ratio (%)			
		4 MAT	6 MAT	8 MAT	10 MAT
T_1	Control (Farmer practices)	76.13	55.30	41.83	36.23
T_2	Light pruning (10%)	69.90	50.63	39.43	32.30
T_3	Medium pruning (20%)	73.53	53.53	42.67	35.60
T_4	Hard pruning (30%)	80.43	65.93	52.47	45.77
T_5	Soil drenching of Paclobutrazol @ 0.5 g	51.53	42.40	35.63	26.60
T_6	Soil drenching of Paclobutrazol @ 1.0 g	55.70	40.53	31.40	25.37
T_7	Foliar spray of Cycocel @ 500 ppm	53.07	40.50	28.60	21.93
T_8	Foliar spray of Cycocel @ 750 ppm	54.63	45.10	35.73	25.60
Mean		64.37	49.24	38.40	31.18
S.Ed		0.733	0.620	0.503	0.633
CD(P=0.05)		2.222	1.881	1.526	1.919

*MAT – Months After Treatment

Table 4: Effect of pruning and growth retardant on number of flower cushions per tree in cocoa

T. No.	Treatments	Number of flower cushions per tree		
		Season I	Second II	Mean
T_1	Control (Farmer practices)	208.33	342.70	309.14
T_2	Light pruning (10%)	233.33	381.43	338.68
T_3	Medium pruning (20%)	257.83	413.25	378.02
T_4	Hard pruning (30%)	188.33	310.58	282.71
T_5	Soil drenching of Paclobutrazol @ 0.5 g	234.08	348.07	319.64
T_6	Soil drenching of Paclobutrazol @ 1.0 g	246.42	329.52	299.93
T_7	Foliar spray of Cycocel @ 500 ppm	229.75	324.08	300.50
T_8	Foliar spray of Cycocel @ 750 ppm	282.00	398.47	368.43
Mean		235.01	356.01	324.63
S.Ed		14.873	6.558	4.878
CD(P=0.05)		45.111	19.891	14.795

Table 5: Effect of pruning and growth retardant on yield attributing characters of cocoa (pooled mean values of two seasons)

Treatments	Number of pods	Pod length (cm)	Pod girth (cm)	Pod weight (g)	Wet bean weight (g)	Single dry bean weight (g)	Dry bean yield / pod (g)	Number of beans /pod	Dry bean yield / tree (kg)
T_1	25.88	20.08	28.13	511.00	159.50	1.16	46.43	40.08	1.19
T_2	30.51	20.48	29.78	518.58	162.17	1.19	51.95	43.85	1.60
T_3	34.00	22.60	31.63	540.58	169.50	1.27	55.42	43.68	1.88
T_4	27.13	19.35	28.03	511.83	152.83	0.91	37.67	41.72	1.02
T_5	25.32	21.72	29.03	529.67	157.80	1.09	45.22	41.26	1.14
T_6	25.13	19.87	28.27	496.13	116.50	1.16	40.13	35.05	0.99
T_7	24.42	18.87	26.02	436.80	121.50	0.98	35.74	36.93	0.88
T_8	26.96	20.48	28.20	524.60	129.90	0.86	34.25	39.95	0.92
Mean	27.42	20.43	28.73	508.62	146.18	1.07	43.35	40.31	1.20
S.Ed	0.645	0.446	0.549	12.025	9.587	0.077	3.073	0.900	0.069
CD(P=0.05)	1.957	1.354	1.667	36.475	29.078	0.234	9.32	2.710	0.209

Conclusion

Thus the overall study has indicated the beneficial effect of pruning particularly the medium pruning (20%) in enhancing the higher production in cocoa. However, being a perennial crop and based on earlier experience by the other workers the flowering and fruiting are dependent on environmental factors, study has to be continued for more years continuously to assess the real effect of pruning for ideal canopy management to sustain the optimum production and quality.

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