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Effect of different pruning levels and growth retardants on growth, yield and quality of cocoa (*Theobroma cacao* L.)

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Abstract
The experiment was conducted to study the effect of pruning and growth retardant on yield and quality of cocoa. Three different types of pruning and two growth retardant were taken up for the study. Observations were recorded on number of new laterals produced, length of new laterals, leaf area, number of pods per tree and quality parameters of bean like soluble protein, phenol and fat content. Hard pruning recorded highest number of new laterals produced (24.58) after imposition of treatments. Highest length of new laterals (112.07 cm) was recorded with medium pruning. Initially, light pruning recorded highest leaf area for 4th and 6th month (69.67 cm^2 and 152.09 cm^2) but later medium pruning reregistered highest leaf area for 8th and 10th month (225.72 cm^2 and 299.41 cm^2) respectively. Highest number of pods per tree (34) and yield parameters like soluble protein (16.40 mg/g) and fat content (42.63 %) of bean was also recorded in medium pruning. Total phenol in the bean was recorded highest in light pruning (67.57 mg/g).

Keywords: pruning, growth retardant, cocoa, paclobutrazol, cycocel

Introduction
Cocoa (*Theobroma cacao* L.) is an important plantation crop widely grown in tropical regions of the world. In India, cocoa is cultivated as an intercrop in already existing coconut and arecanut gardens and serves as an additional source of income to the farmers. Southern states of Kerala, Karnataka, Tamil Nadu and Andhra Pradesh are major cocoa growers in India. Tamil Nadu ranks first with an area of 26,969 hectares whereas Andhra Pradesh leads in production. Kerala with its favourable climatic condition have the highest productivity of 785 kg/ha. The national productivity of cocoa is 475 kg/ha.

Cocoa is hardly grown as a mono crop. Its imminent capacity to share the alley spaces of tall growing coconut and arecanut palms (Alvim and Nair, 1986) [1] and its compatibility with the microclimatic conditions available in such perennial gardens helps its cultivation in utilizing such areas without exacting for an independent growing climate of its own. Cocoa plants are grown under the shade of arecanut and coconut plantations in South India (Shama Bhat, 1988.) [9]. It is therefore necessary to regulate the canopy size and shape of the plants so that the main crop is not affected. Pruning becomes absolutely essential under such circumstances. Pruning for maintenance and rehabilitation is performed during cocoa life cycle (Mohd Yusoff, 1996) [8].

The growth habit and tree architecture are different in cocoa. The seedlings grow vertically until they jorquette to form three to five fan branches. The height at which seedlings jorquette varies considerably, the usual range being between one to two meter. There are two types of pruning practiced in cocoa *viz.,* formative pruning and maintenance pruning (Balasimha, 2002) [2]. The formative pruning is done to adjust the height of the jorquette and to control the vertical growth. Normally the height at which the jorquette is formed depends upon the shade condition in the garden. Low shade intensity leads to jorquette formation at lower height. When the jorquette is formed at lower height, it will be removed at an early stage to facilitate upward growth. This is practiced mainly in Malaysia to achieve a jorquette height of 1.6 m (Leach *et al.*, 1971) [6].

Apart from pruning, role of micronutrients in improving yield and quality of cocoa had been studied by many workers. But studies on effect of growth regulators on yield and quality of cocoa are limited. Growth regulators like GA_3, NAA, paclobutrazol, cycocel *etc*. has a great importance in improving yield and quilt of many fruit crops. The use of plant growth regulators by many researchers had shown reduce flowering drop, high flower retention, increased fruit yield in many fruit crops (Iqbal *et. al*., 2009) [5]. Hence, application of growth regulators also can be an important pre-harvest practice to improve yield and quality of cocoa.

With this brief background, effect of pruning and growth retardant on growth, yield and quality of cocoa was studied.

Materials and Methods

The study was carried out at farmer's field near Coconut Research Station, Aliyar nagar, Tamil Nadu which is situated at 10°N latitude and 77°E longitude. 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 season (January to July, 2017 as season one and August to December, 2017 as season two).

Pruning was carried out during January, 2017 after the end of final harvest of December, 2016 crop. Major pruning was carried only in 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 was 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 treatments detailed are given below:

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)
T_8	Foliar spray of Cycocel @ 750 ppm (no pruning)

All the observations on growth parameters like number of new laterals produced after treatments, length of new laterals and leaf area were recorded throughout the study. Yield and quality characters were recorded for two seasons and then pooled mean values were calculated for the outcome of the study and presented in this paper.

Results and Discussions

Number of laterals produced on treated tree

Number of laterals produced significantly differed among the treatments. The data in Table 1 revealed that treatments involving hard pruning (30%) produced more number of laterals (24.58) followed by control (21.08) and the least by soil drenching of Paclobutrazol @ 0.5 g *a.i.* per tree (8.92). Among the pruned trees it was recorded that with an increase in severity of pruning, there was an increase in number of laterals on pruned branches.

Pruning always results in loss of biomass in plant system. But consequent to pruning the branches, new laterals are expected to grow as the result of removal of apical dominance. In the present study, it was observed that severe the pruning more was the number of laterals whereas treatments without pruning and application of growth retardant (T_5, T_6, T_7 and T_8) showed lower number of new lateral produced in the trees. The result purely highlighted the effect of apical dominance as expected in any other plants. More number of laterals produced following heading back of shoots in mango encouraged sprouting of more lateral buds (Suresh Kumar *et al*., 2003) [11] due to the removal of apical dominance, release of buds from correlative inhibition and well functioning of communication system within the trees (Mika, 1996) [4]. Reason for low number of laterals produced in all the growth retardant treated trees may be due to inhibition of growth by Paclobutrazol and Cycocel. Similar report on inhibition of vegetative growth with application of Paclobutrazol and cycocel was reported by Tahir *et al.* (2002) [12] in mango where intensity of flushing was minimized on treated plants due to application of growth retardants.

Table 1: Effect of pruning and growth retardant on number of laterals produced on pruned branches in cocoa.

T. No	Treatment	Number of laterals produced on pruned branches
T_1	Control (Farmer practices)	21.08
T_2	Light pruning (10%)	13.42
T_3	Medium pruning (20%)	19.42
T_4	Hard pruning (30%)	24.58
T_5	Soil drenching of Paclobutrazol @ 0.5 g	08.92
T_6	Soil drenching of Paclobutrazol @ 1.0 g	10.67
T_7	Foliar spray of Cycocel @ 500 ppm	11.08
T_8	Foliar spray of Cycocel @ 750 ppm	09.92
Mean		14.89
S.Ed		0.602
CD(P=0.05)		1.827

Length of new laterals

The light pruning (10%) registered the highest length of new laterals (Table 2) measured after 4th, 6th, 8th and 10th month of treatments (36.23, 87.83, 98.07 and 112.07 cm) respectively. Lowest length of new laterals was recorded mostly with foliar spray of Cycocel @ 750 ppm per tree after 3, 4 and 10 month (25.27, 64.00 and 82.07) after treatment except for the 8th month where soil drenching of Paclobutrazol @ 0.5 g *a.i* per tree recorded the lowest length of new lateral (74.23).

The length of the new laterals assessed in the present study showed that with the increase in severity of pruning, there was a decrease in length of new laterals. This may be due to competition between more of lateral buds forced to develop into new laterals following severe pruning. It was also observed that all the growth retardant treated trees recorded lower length of new laterals than pruned trees. Similar report on suppression of vegetative growth on application of growth retardant was reported by Tandel and Patel (2011) [13] in mango where vegetative growth was reduced by interrupting the biosynthesis of gibberellins because paclobutrazol act as an inhibitor of gibberellins bio-synthesis.

Table 2: Effect of pruning and growth retardant on length of new laterals (cm) produced after treatments in cocoa.

T. No	Treatment	Length of new laterals (cm)			
		4 MAT	6 MAT	8 MAT	10 MAT
T_1	Control (Farmer practices)	34.6	80.17	91.77	98.30
T_2	Light pruning (10%)	36.23	87.83	98.07	112.07
T_3	Medium pruning (20%)	31.43	82.03	97.83	109.43
T_4	Hard pruning (30%)	32.33	83.80	95.67	105.53
T_5	Soil drenching of Paclobutrazol @ 0.5 g	25.30	67.07	74.23	82.50
T_6	Soil drenching of Paclobutrazol @ 1.0 g	25.73	66.40	80.87	84.10
T_7	Foliar spray of Cycocel @ 500 ppm	28.40	71.33	78.47	84.77
T_8	Foliar spray of Cycocel @ 750 ppm	25.27	64.00	77.83	82.07
Mean			29.91	75.33	86.84
S.Ed			0.478	1.380	0.500
CD(P=0.05)			1.451	4.185	1.517

*MAT – Months After Treatment

Leaf area

Leaf area (4th leaf from the tip of new flush) exhibited significant differences among the treatments at all stages of observation (Table 3). Among the treatments, light pruning (10%) recorded highest leaf area for 4th and 6th month (69.67 cm^2 and 152.09 cm^2) but medium pruning (20%) reregistered highest leaf area for 8th and 10th month (225.72 cm^2 and 299.41 cm^2) respectively. Lowest leaf area for 4th month was recorded with foliar spray of cycocel @ 750 ppm (53.25 cm^2) but for 6th, 8th and 10th month, foliar spray of cycocel @ 500 ppm recorded the lowest leaf area of 121.14 cm^2, 194.97 $cm^2$and 244.01 cm^2 respectively.

Pruning of canopy is necessary for maintenance of optimum leaf area index in cocoa as it affects the vegetative growth, consequently the photosynthetic activity leading to determination of yield. In the present study, the leaf area assessed on the 4th leaf from tip of new flushes showed considerable variation among the treatments observed at various stages of observation (table 4). Higher leaf area was observed in all pruning treatment after ten month of treatment imposition. All growth retardant treatment recorded lower leaf area than the pruned treatments. Suppression of vegetative growth by growth retardant may be the reason for lower leaf in growth retardant treatments. Yeshitela *et al.* (2004) [14] reported similar result of suppressed vegetative growth in mango with application of paclobutrazol when compared with the control

Table 3: Effect of pruning and growth retardant on leaf area (cm^2) in cocoa

T. No	Treatments	Leaf area (cm^2)			
		4 MAT	6 MAT	8 MAT	10 MAT
T_1	Control (Farmer practices)	60.23	133.45	202.36	250.59
T_2	Light pruning (10%)	69.67	152.09	223.12	292.23
T_3	Medium pruning (20%)	68.88	148.56	225.72	299.23
T_4	Hard pruning (30%)	64.29	137.92	206.86	278.15
T_5	Soil drenching of Paclobutrazol @ 0.5 g	54.29	125.74	200.00	251.63
T_6	Soil drenching of Paclobutrazol @ 1.0 g	55.32	126.33	199.70	254.55
T_7	Foliar spray of Cycocel @ 500 ppm	58.42	121.14	194.97	244.01
T_8	Foliar spray of Cycocel @ 750 ppm	53.25	122.63	196.31	247.73
Mean		60.54	133.47	200.13	264.16
S.Ed		3.465	4.616	3.076	5.274
CD(P=0.05)		10.510	14.123	9.330	15.997

*MAT – Months After Treatment

Table 4: Effect of pruning and growth retardant on number of pods per tree

T. No.	Treatments	Number of pods per tree		
		Season I	Season II	Mean
T_1	Control (Farmer practices)	22.5	29.27	25.88
T_2	Light pruning (10%)	24.5	36.52	30.51
T_3	Medium pruning (20%)	28.33	39.67	34.00
T_4	Hard pruning (30%)	22.5	31.77	27.13
T_5	Soil drenching of Paclobutrazol @ 0.5 g	23.5	27.13	25.32
T_6	Soil drenching of Paclobutrazol @ 1.0 g	19.08	31.17	25.13
T_7	Foliar spray of Cycocel @ 500 ppm	20.83	28.00	24.42
T_8	Foliar spray of Cycocel @ 750 ppm	22.92	31.00	26.96
Mean		23.02	31.81	27.42
S.Ed		1.010	0.847	0.645
CD(P=0.05)		3.060	2.569	1.957

Yield of pods per tree

Medium pruning (20%) recorded highest number of pods per tree (28.33 and 39.67) followed by light pruning (10%) treatment (24.5 and 36.52) in both the seasons respectively. Soil drenching of Paclobutrazol @ 1.0 g recorded lowest number of pods per tree (19.08) in the first season and foliar spray of Cycocel @ 500 ppm recorded lowest (28.00) in the second season.

The pooled data showed that medium pruning (20%) recorded highest number of pods per tree (34.00) and foliar spray of Cycocel @ 500 ppm recorded the lowest number of pods per tree (24.42). It was observed that the second season recorded higher number of pods per tree than the first season in all treatments. More leaf area and production of new laterals and active leaf in the medium pruning (20%) may be the reason for higher yield of pods per tree. Whereas, 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 in the growth retardant treated trees of cocoa. Sharma *et al.* (2011) [10] reported that pre-bloom paclobutrazol, cycocel and ethrel sprays induced flowering but did not affect fruiting significantly in mango *var*. Chausa.

Quality of the cocoa beans

The quality of cocoa bean in the present investigation showed that medium pruning (20%) registered the maximum soluble protein (16.40 mg/g) and fat content (42.63%) when compared to rest of the treatments (Fig. 1). Highest phenol content of the bean was recorded with light pruning (67.57 %). Similar results were reported by Govindaraj and Jansirani (2017) [4] in cocoa. However, it is too early to predict the effect of treatment on quality of bean with one year data since qualities of cocoa beans are also largely influenced by other environmental conditions and post-harvest handlings at the farm level. Early studies showed a decline in fat content due to rainfall and also the bean developed during dry season had low fat content (Doyne and Volecker, 1939) [3].

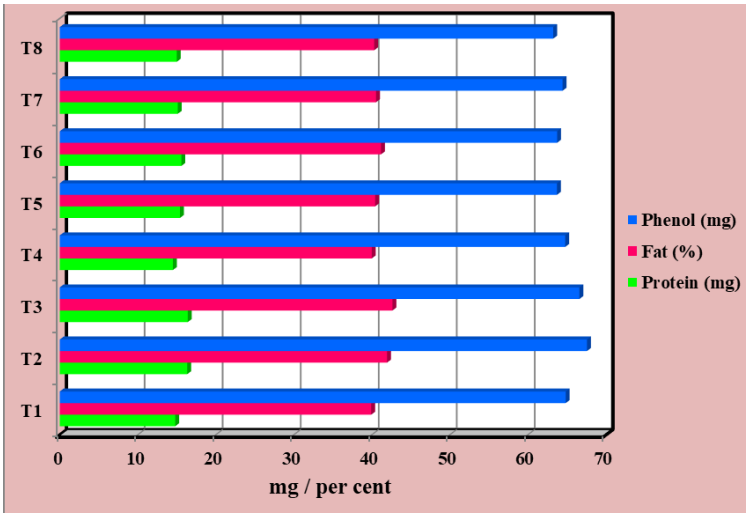

Fig 1: Effect of pruning and growth retardant on Phenol, Fat and Protein content of cocoa beans

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