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Effect of fertigation schedules on flowering and yield characters of cocoa grown under coconut plantation in black soils

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Abstract
A field study was carried out to know the effect of fertigation on flowering characters of cocoa grown as intercrop in existing coconut garden in a farmer's field located in Ankampalem village of East Godavari District during 2019 to 2021. The experiment was laid out in randomized block design with seven treatments having three replications with different combinations of water soluble fertilizers applied through drip and soil application. The flowering characters like flowers per main stem, flowers per fan branches, total flowers per tree and cherelles per tree were recorded after fertigation from July to December for both the years. Based on the results, the highest number of flowers per main stem (1131.42 & 1087.36), flowers per fan branches (4117.44 & 4128.77) and total flowers per tree (5248.86 & 5227.46) were recorded in the trees treated with 125% RDF through fertigation in the year 2019 and 2020 respectively. The results regarding total number of cherelles per tree (67.69 & 66.43), total number of pods harvested (61.39 & 65.42) and percentage of pod set (2.50% & 2.55%) were recorded highest in the plants treated with 125% RDF through drip irrigation in the year 2019 and 2020 respectively. The above results indicated that application of 125% RDF as water soluble fertilizers through drip irrigation was recommended in black deltaic soils of coastal Andhra Pradesh to promote flowering characters of cocoa.

Keywords: Cocoa, coconut, flowering, fertigation, intercrop, schedules

Introduction
Cocoa (*Theobroma cacao* L.) popularly known as 'Food of Gods' is one of the most important plantation crop grown under coconut which was introduced into India from South America. Now, it had become one of the most important crops grown for the preparation of chocolates. In India, it is cultivated as intercrop crop mainly under arecanut, coconut and oilpalm plantations which accounts to an area of 1 lakh ha with production of 27 thousand MT of dry beans and with average productivity of 669 kg/ha (DCCD, 2021) [2]. It is cultivated in southern states mainly Kerala, Karnataka, Tamil Nadu and Andhra Pradesh. Andhra Pradesh recorded first in terms of area about 39, 714 ha and production of 10, 903 MT with average productivity of 950 Kg ha^{-1} which account a share of 40% in the country (DCCD, 2021) [2]. It is mainly a tropical crop grown under full sunlight to shade and produces pods throughout the year which can yield up to 40 years. In India, most of the farmers adopt soil application of fertilizers which causing lower yields of this crop. In the case of surface application, many physical processes such as leaching, runoff, volatilization *etc*. may leads to loss of applied nutrients besides affecting the environment (Krishnamoorthy and Rajamani, 2016) [6]. In order to increase the yields there is a need of frequent application of nutrients with sufficient moisture for better utilization (Noordiana *et al*., 2007) [4] because more than 80 per cent of active roots are located within the radius of 30-60 cm. Hence, Fertigation has come in handy for this purpose. In this method, fertilizers can be applied throughout the cropping season in appropriate concentration which results in higher yield and quality of cocoa (Krishnamoorthy *et al*., 2015) [5]. But fertigation schedules should be standardized in Andhra Pradesh to get good returns. Hence this experiment was carried out to study the effect of fertigation schedules on flowering and yield characters on cocoa grown under coastal Andhra Pradesh.

Materials and Methods
The experiment was carried out in a farmer's field near Ankampalem village, East Godavari

District, Andhra Pradesh of one acre land maintained with drip irrigation. The experiment was laid out in a randomized block design with 7 treatments in 3 replications having 6 trees in each replication of 14 years age planted as intercrop in coconut plantation with 40 years age having a spacing of 2.5 m x 2.5 m. The treatments contain different combinations of water soluble fertilizers, complex and straight fertilizers which are applied through soil and drip. The treatments combinations are T_1: 75% RDF as water soluble fertilizers through drip irrigation (75: 30: 105 g NPK/ plant/ year), T_2: 100% RDF as water soluble fertilizers through drip irrigation (100: 40: 140 g NPK/ plant/ year), T_3: 125% RDF as water soluble fertilizers through drip irrigation (125: 50: 175 g NPK/ plant/ year), T_4: 75% RDF as water soluble fertilizers through drip irrigation (150: 60: 210 g NPK/ plant/ year), T_5: 175% RDF as water soluble fertilizers through drip irrigation (175: 70: 245 g NPK/ plant/ year), T_6: 200% RDF as water soluble fertilizers through drip irrigation (200: 80: 280 g NPK/ plant/ year) and T_7: 100% RDF as soil application (control). Pruning was performed every year during the month of June- July to ensure adequate ventilation in the garden. Fertilizers were applied in three different stages *i.e.*, flowering stage, pod development stage and pod maturity stage in 30%, 40% and 30% respectively in weekly intervals. From treatment combination T_1 to T_6, water soluble fertilizers were applied through drip irrigation system and T_7, conventional fertilizers were applied to the soil. Conventional fertilizers were weighed and applied in three split doses during the months of June, October and February. The observations were recorded from July to December for flower characters in each treatment and statistical analyzed as per Panse and Sukhatme (1975). The number of flower cushions produced on main stem and fan branches was counted separately for every tree and total flowers per each cushion from July to December was counted. The old flowers were identified and excluded from counting by the appearance of dried stigmatic surface. The total number of flower cushions and number of flowers per each cushion were multiplied for main stem and fan branches, expressed in numbers. The total number of flowers per tree was calculated by adding total number of flowers in main stem and fan branches and expressed in number. The total number of cherelles and total number of pods harvested per tree was counted, expressed in numbers and the percentage pod setting was calculated by using the following formula.

$$\text{Pod set percentage} = \frac{\text{Total number of pods harvested (Healthy and Diseased pods)} + \text{Total number of cherelles per tree per year}}{\text{Total number of flowers per tree}} \text{ X } 100$$

The results of this study were analyzed and discussed in the paper

Results and Discussion

The results indicated significant differences among the treatments with respect to flowering and yield characters in cocoa. However, the trees treated with 125% RDF through fertigation had recorded highest number of flower cushions on main stem (36. 50 and 35.31) and fan branches (204.71 and 205.90) during 2019 and 2020 respectively (Table 1). The same treatment had recorded highest number of flowers per cushion on main stem (31.20 and 30.35) and fan branches (20.09 and 19.82) in the year 2019 and 2020 (Table 2). However the total flowers on main stem (1131.42 and 1087.36) and fan branches (4117.44 and 4140) were recorded highest in the plants treated with 125% RDF through fertigation (Table 3). The total number of flowers per tree (5248.86 and 5227.46) was recorded highest in the trees treated with 125% RDF through fertigation with a pooled mean value of 5238.16 and the lowest flowers per tree of 3260.93 was recorded in control (Fig 1). The total number of cherelles per tree (67.69 (2019) and 66.43 (2020)) was recorded highest in the trees applied with 125% RDF through fertigation with an average of 67.06 (Table 3). The treatment T_3 had recorded highest number of pods (61.39 and 65.42) in the year 2019 and 2020 respectively with pooled mean of 63.41. The lowest number of pods was harvested in control with a pooled mean of 43.46 (Table 3). The trees supplied with 125% RDF through fertigation had recorded highest percentage of pod set with pooled mean of 2. 53% and lowest pod set was in T_5 and T_6 (Table 3 & Fig 2).

The plants treated with 125% RDF through fertigation reported highest flowering characters especially total number of flowers per tree. The most important trait while considering higher yields in cocoa were flower cushions per tree and number of flowers per cushion. The climatic conditions existed in the previous year and soil nutrient conditions are the main factors will influence the flower number on the tree. The rapid differentiation of vegetative buds into reproductive ones may be due to fertigation treatment which accelerated the production of photo assimilates required for the tree to increase sink strength. The results were also reported by Krishnamoorthy *et al.*, 2015 [5], Krishnamoorthy and Rajamani, 2016 [6]. The highest pod set observed in the treatment (T_3) might be due to increased uptake of nutrients which resulted in synthesis of hormones like auxins and gibberellins. The continuous wetting in the root zone due to fertigation with desired schedules of fertilizers and irrigation will reduce moisture stress will increase the pod setting percentage in cocoa (Babou *et al*., 2017, Shanmugasundaram and Balakrishnamurthy, 2013) [1, 8]. However, the pod set was low during dry season and gradually reaches peak during September in cocoa. The highest number of pods harvested in 125% RDF through fertigation might be due to the fact that the treated trees supplied with exact nutrients uniformly in the active root zone with minimum nutrient leaching which ultimately increased the efficiency of overall fertilizers was also reported by Hendre *et al*., 2020 [3].

Table 1: Effect of different fertigation schedules on total number of flowers on main stem of cocoa in different years

Treatments	Total number of flowers on main stem						
	2019-20			2020-21			Pooled mean
	Number of cushions on main stem	Number of flowers per cushion on main stem	Total flowers on main stem	Number of cushions on main stem	Number of flowers per cushion on main stem	Total flowers on main stem	
T_1	27.28	25.03	685.32	29.35	24.76	730.29	707.80
T_2	32.49	29.19	927.75	33.72	28.27	972.94	950.35
T_3	36.50	31.20	1131.42	35.31	30.35	1087.36	1109.39
T_4	26.68	27.45	744.51	30.94	27.10	842.60	793.56
T_5	29.14	27.31	773.84	29.93	27.40	815.51	794.68
T_6	30.18	28.47	866.77	31.86	27.70	894.61	880.69
T_7	26.24	24.38	638.75	28.32	23.39	662.18	650.47
SEM ±	1.78	1.17	67.68	1.21	1.25	58.44	56.41
CD at 5%	5.51	3.62	208.57	3.74	3.88	180.07	173.81
CV%	10.40	7.38	14.22	6.71	8.08	11.79	11.61

T_1: 75% RDF as water soluble fertilizers through drip irrigation (75: 30: 105 g NPK/ plant/ year)
T_2: 100% RDF as water soluble fertilizers through drip irrigation (100: 40: 140 g NPK/ plant/ year)
T_3: 125% RDF as water soluble fertilizers through drip irrigation (125: 50: 175 g NPK/ plant/ year)
T_4: 150% RDF as water soluble fertilizers through drip irrigation (150: 60: 210 g NPK/ plant/ year)
T_5: 175% RDF as water soluble fertilizers through drip irrigation (175:70: 245 g NPK/ plant/ year)
T_6: 200% RDF as water soluble fertilizers through drip irrigation (200: 80: 280g NPK/ plant/ year)
T_7: Control- 100% RDF as soil application (100:40:140 g NPK/ plant/ year)

Table 2: Effect of different fertigation schedules on total number of flowers on fan branches of cocoa in different years

Treatments	Total number of flowers on fan branches						
	2019-20			2020-21			Pooled mean
	Number of cushions onfan branches	Number of flowers per cushion on fan branches	Total flowers onfan branches	Number of cushions onfan branches	Number of flowers per cushion on fan branches	Total flowers on fan branches	
T_1	186.93	16.74	3079.54	183.87	15.87	2944.81	3012.18
T_2	200.43	18.67	3740.99	199.72	17.38	3482.94	3611.97
T_3	204.71	20.09	4117.44	205.90	19.82	4140.10	4128.77
T_4	197.24	18.50	3708.08	195.50	16.83	3315.24	3511.66
T_5	199.13	17.70	3526.89	197.48	18.87	3684.33	3605.61
T_6	196.08	17.69	3519.14	194.51	16.03	3122.94	3321.04
T_7	165.71	14.85	2435.75	168.82	16.14	2785.17	2610.46
SEM ±	7.60	0.95	310.53	7.08	0.88	246.90	253.42
CD at 5%	23.41	2.93	956.84	21.84	2.71	760.80	780.87
CV%	6.82	9.30	15.60	6.38	8.82	12.75	12.90

T_1: 75% RDF as water soluble fertilizers through drip irrigation (75: 30: 105 g NPK/ plant/ year)
T_2: 100% RDF as water soluble fertilizers through drip irrigation (100: 40: 140 g NPK/ plant/ year)
T_3: 125% RDF as water soluble fertilizers through drip irrigation (125: 50: 175 g NPK/ plant/ year)
T_4: 150% RDF as water soluble fertilizers through drip irrigation (150: 60: 210 g NPK/ plant/ year)
T_5: 175% RDF as water soluble fertilizers through drip irrigation (175:70: 245 g NPK/ plant/ year)
T_6: 200% RDF as water soluble fertilizers through drip irrigation (200: 80: 280g NPK/ plant/ year)
T_7: Control- 100% RDF as soil application (100:40:140 g NPK/ plant/ year)

Table 3: Effect of different fertigation schedules on percentage of pod set in different seasons

Treatments	Total number of flowers per tree			Total number of cherelles per tree			Total number of pods harvested			Percentage of pod set (%)		
	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean
T_1	3764.86	3675.10	3719.98	32.32	31.99	32.16	42.16	49.10	45.63	1.96	2.23	2.10
T_2	4668.74	4455.88	4562.31	43.58	40.26	41.92	55.49	60.79	58.14	2.15	2.26	2.21
T_3	5248.86	5227.46	5238.16	67.69	66.43	67.06	61.39	65.42	63.41	2.50	2.55	2.53
T_4	4452.59	4157.84	4305.22	41.19	31.43	36.31	53.33	58.06	55.70	2.23	2.30	2.26
T_5	4300.73	4499.84	4400.29	41.52	34.92	38.22	48.69	55.71	52.20	2.16	2.00	2.08
T_6	4385.91	4017.55	4201.73	37.88	27.15	32.52	51.96	55.32	53.64	2.11	2.06	2.08
T_7	3074.50	3447.35	3260.93	22.16	26.55	24.36	40.10	46.81	43.46	2.09	2.15	2.12
SEM ±	303.58	240.67	241.91	4.16	4.97	3.94	2.07	2.52	1.90	0.07	0.09	0.05
CD at 5%	935.44	741.58	745.42	12.84	15.33	12.16	6.38	7.78	5.87	0.21	0.28	0.17
CV%	12.31	9.89	9.88	17.65	23.31	17.56	7.11	7.82	6.21	5.54	7.20	4.50

T_1: 75% RDF as water soluble fertilizers through drip irrigation (75: 30: 105 g NPK/ plant/ year)
T_2: 100% RDF as water soluble fertilizers through drip irrigation (100: 40: 140 g NPK/ plant/ year)
T_3: 125% RDF as water soluble fertilizers through drip irrigation (125: 50: 175 g NPK/ plant/ year)

T_4: 150% RDF as water soluble fertilizers through drip irrigation (150: 60: 210 g NPK/ plant/ year)
T_5: 175% RDF as water soluble fertilizers through drip irrigation (175:70: 245 g NPK/ plant/ year)
T_6: 200% RDF as water soluble fertilizers through drip irrigation (200: 80: 280g NPK/ plant/ year)
T_7: Control- 100% RDF as soil application (100:40:140 g NPK/ plant/ year)

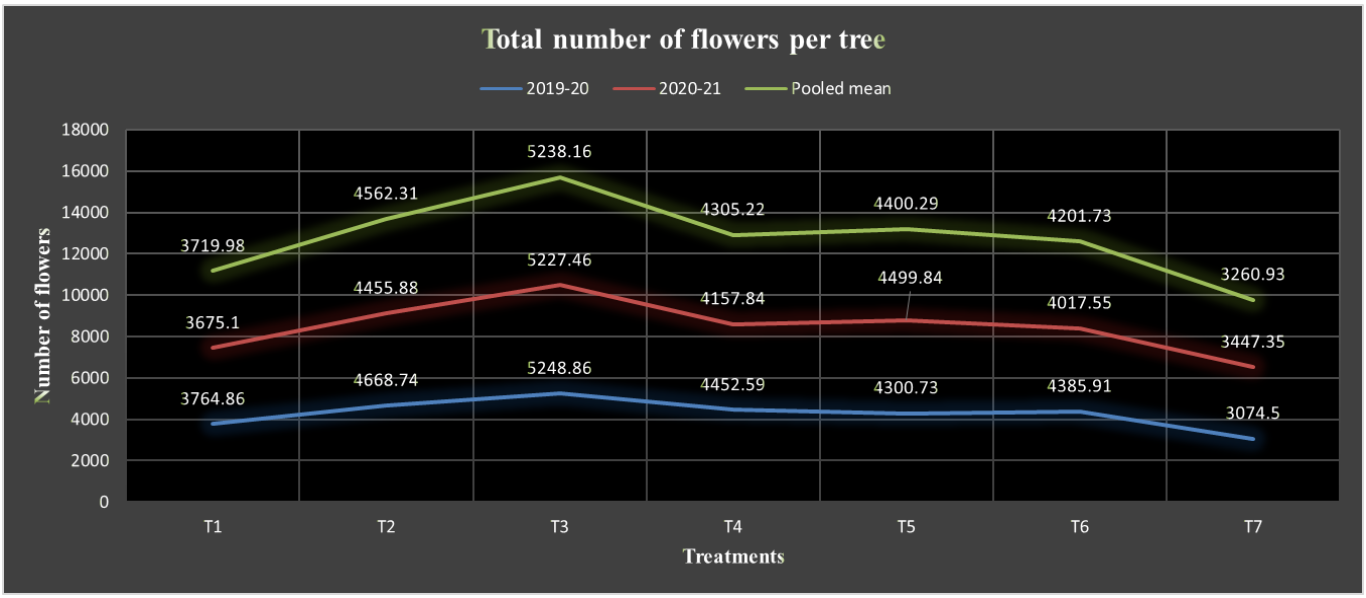

Fig 1: Effect of different fertigation schedules on total number of flowers per tree of cocoa in different

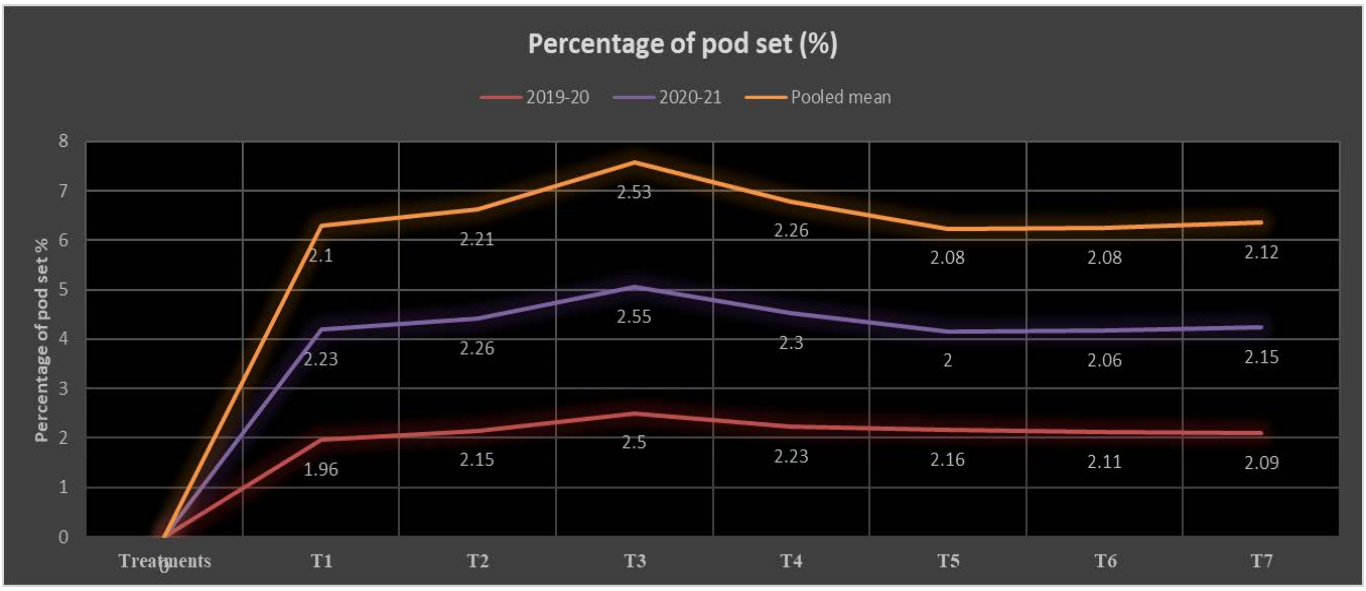

Fig 2: Effect of different fertigation schedules on percentage of pod set (%) of cocoa in different years

Conclusion

The present study concluded that application of fertilizers through fertigation in proper dosage at appropriate schedules will increase flowers characters of cocoa which ultimately improves the yield. The above results indicated that application of 125% RDF through fertigation was recommended in black deltaic soils of coastal Andhra Pradesh for higher returns.

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