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Effect of fertigation through drip and micro sprinkler on pod characters in cocoa (*Theobroma cacao* L.)

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Abstract

A field experiment to study the influence of fertigation through drip and micro sprinkler of N, P and K fertilizers on pod characters of cocoa (*Theobroma cacao* L.) was conducted at Coimbatore, India during January 2010 to December 2011. The experiment was laid out with thirteen treatments replicated three times in a randomized block design. The study revealed that, fertigation with 125 per cent RDF (Recommended Dose of Fertilizer) as water soluble fertilizer by drip irrigation (T_4) recorded the highest pod length (17.72 cm), pod girth (28.69 cm), pod weight (541.88 g), husk weight (387.83 g), pod volume (610.55 cc) and number of pods per tree per year (59.49) as against 12.98, 12.76, 31.69, 29.51, 34.66 and 21.05 % increase over the control (T_1), respectively. The same treatment (T_4) recorded the lowest number of cherelle's per tree (9.59) and pod value (16.11).

Key words: *Theobroma cacao* L., fertigation, drip, micro sprinkler, water soluble fertilizer, straight fertilizer, pod characters

Introduction

Cocoa (*Theobroma cacao* L.) the 'Food of Gods' is one of the most important plantation crops consumed worldwide and around 40-50 million people depend on cocoa for their livelihood (World Cocoa Foundation, 2011). Cocoa is cultivated mainly in Africa, Asia, Central America and South America. Major cocoa producing countries are Ivory Coast, Ghana, Indonesia, Nigeria, Cameroon, Brazil, Ecuador and Malaysia. The annual production is around 3 million tonnes with an estimated value of $ 5.1 billion (World Cocoa Foundation, 2010). Ivory Coast leads in production occupying 38 % of total world cocoa production followed by Ghana (21 %), Indonesia (13 %), Nigeria (5 %), Cameroon (5 %), Brazil (4 %), Ecuador (3 %), Malaysia (1 %) and others (10 %). West Africa alone contributes nearly 70 % of the world cocoa production.

Cocoa is a viable intercrop in coconut as well as arecanut plantation in India. Remunerative price, better market intervention and support given to the crop have brought fruitful results in area expansion under the crop. In India, four states *viz.*, Kerala, Andhra Pradesh, Tamil Nadu and Karnataka share the major cocoa production. The current area is estimated to be 46,318 ha with the production of 12,954 MT (metric tonnes). The average national productivity is 550 kg dry beans per ha. Kerala leads the production with an area of 11,044 hectares contributing 6344 MT of cocoa beans with a productivity of 592 kg per hectare. Tamil Nadu occupies third in cocoa cultivation and the area reported under this crop is 15,000 ha with an annual production of 350 MT (Directorate of Cashewnut and Cocoa Development, 2011).

Cocoa is cauliflorous and flowering cycle follows certain seasonal patterns. Flowering and fruit set are the most critical periods occurring after the establishment of a crop (Nainanayake *et al.*, 2008). Fertigation at proper time and dose will increase the pod yield constantly.

More than 80 % of active roots in cocoa are located within the radius of 30-60 cm. The surface applications of the required fertilizers are to be applied between 30-60 cm distances from the main trunk under conventional system of irrigation. Such a spot application of fertilizers often mismatch with meeting the nutrient requirement of the crop. The physical processes such as leaching, runoff, volatilization *etc.* leads to loss of applied nutrients besides affecting the environment. Fertigation has come in handy for this purpose. Fertigation not only supplies nutrients precisely and timely, but also provides monetary gain and ecological safety by avoiding pollution of ground water resources (Patel and Rajput, 2000).

In Tamil Nadu, a dose of 100:40:140 g NPK $tree^{-1}$ $year^{-1}$ is generally recommended (Anon, 2004) for cocoa. The tap roots (1.2 m deep) in cocoa acts as physical support and only lateral roots (20 - 30 cm) absorb the moisture and nutrients. As cocoa is very sensitive to moisture stress and water logging, irrigation should be given to optimum level for the better growth. Hence, the present study was aimed to evaluate the fertigation system involving drip, sprinkler irrigation methods; comparing the farmers practice (surface irrigation + soil application of RDF) and various level of fertilizer application on pod characters of cocoa.

Materials and methods

Field experiments were conducted at Department of Spices and Plantation Crops, Tamil Nadu Agricultural University, Coimbatore, India during January 2010 to December 2011 to find out the effect of fertigation on pod characteristics of cocoa. The age of cocoa trees was six years which were intercropped with coconut of 30 years old. Cocoa was spaced at 3 x 3 m between the two rows of coconut. Besides, one cocoa plant was planted in between two coconut trees within the coconut row (Fig.1). The population of cocoa trees maintained was @ 500 plants per hectare. Flowering in cocoa was throughout the year and

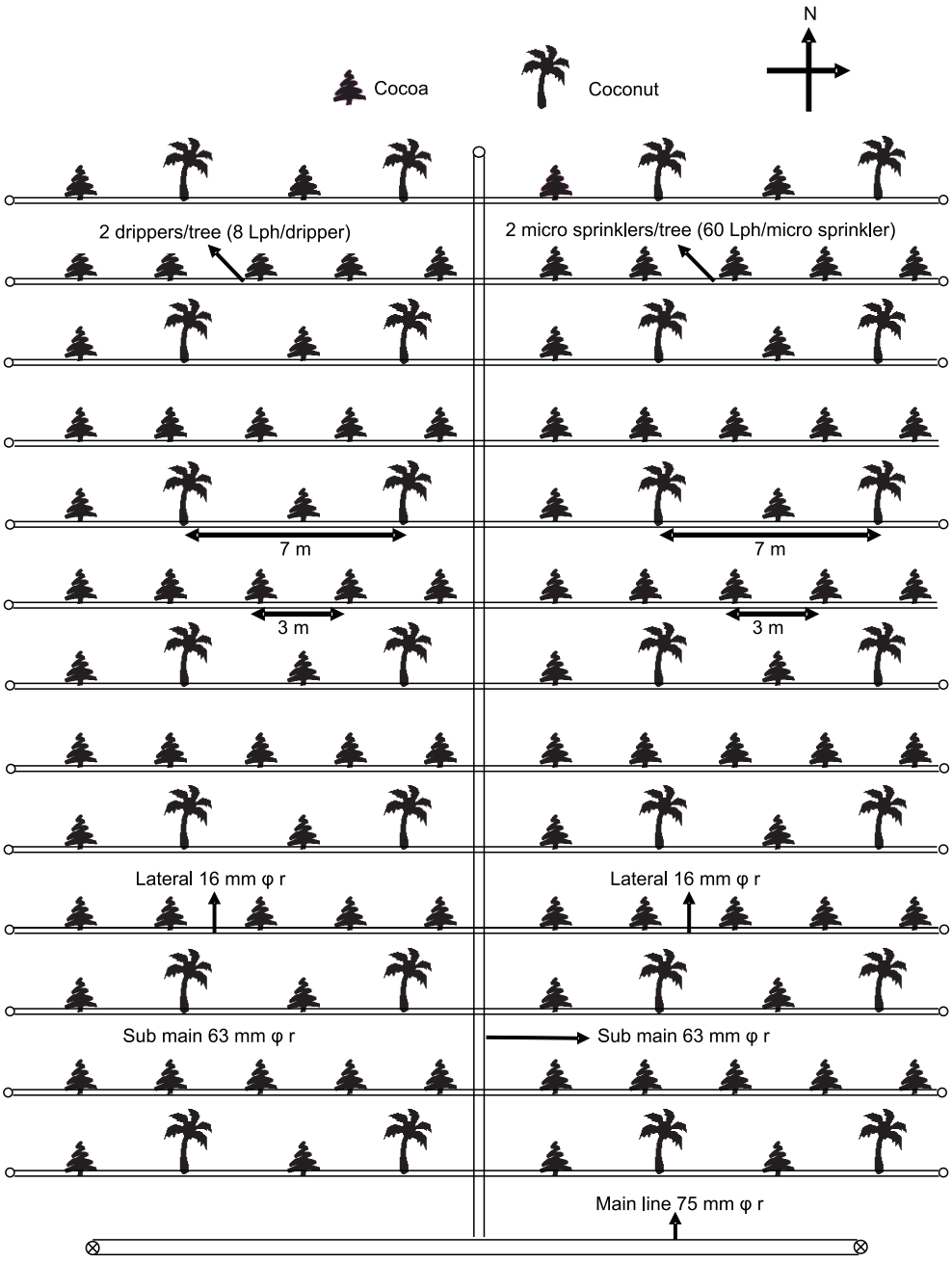

Fig. 1. Lay out of drip and micro sprinkler in cocoa

two peak harvest seasons *viz.*, March to May and September to November were observed. Among these two seasons, March-April (flowering) to July (pod harvest) season is considered as lean cropping period (1st season) while September (flowering) to December (pod harvest) season is considered as peak cropping period (2nd season).

The drip line was laid out as per the spacing of cocoa trees *i.e.* 3 x 3 m. In case of drip irrigation for each tree, two drippers were installed @ 8 Lph (litres per hour) dripper^{-1}. Two half sub circle micro sprinklers were installed per tree @ 60 Lph micro sprinkler^{-1} to cover the entire basin. The half sub circle micro sprinkler type with a height of 30 cm and it sprinkled an area of 60 cm. A venturi assembly was used for mixing fertilizer with irrigation water.

The experiment was laid out in Randomized Block Design (RBD) with thirteen treatments replicated thrice. The details of the treatments were as follows, T_1 - 100 % of RDF as surface application (100:40:140 g NPK plant^{-1} year^{-1}) with flood irrigation (control), T_2 - 75 % RDF as WSF through fertigation by drip irrigation, T_3 - 100 % RDF as WSF through fertigation by drip irrigation, T_4 - 125 % RDF as WSF through fertigation by drip irrigation, T_5 - 75 % RDF as straight fertilizers through fertigation by drip irrigation, T_6 - 100 % RDF as straight fertilizers through fertigation by drip irrigation, T_7 - 125 % RDF as straight fertilizers through fertigation by drip irrigation, T_8 - 75 % RDF as WSF through fertigation by micro sprinkler irrigation, T_9 - 100 % RDF as WSF through fertigation by micro sprinkler irrigation, T_{10} - 125 % RDF as WSF through fertigation by micro sprinkler irrigation, T_{11} - 75 % RDF as straight fertilizers through fertigation by micro sprinkler irrigation, T_{12} - 100 % RDF as straight fertilizers through fertigation by micro sprinkler irrigation, T_{13} - 125 % RDF as straight fertilizers through fertigation by micro sprinkler irrigation.

For surface application and irrigation (T_1), an annual application of 100 g N, 40 g P_2O_5 and 140 g K_2O per tree per year in two split doses was made as per the recommendation. The fertilizers were applied in two equal splits, the first dose in first week of April and the second dose in first week of September. The surface irrigation was done once in seven days interval. For drip and micro sprinkler treatments (T_2 to T_{13}), the fertilizers were applied through drip and micro sprinkler irrigation system (fertigation) at weekly intervals and the irrigation was resorted once in a day (20 litres tree^{-1} day^{-1}).

The observations on pod characters were recorded as per standard procedures and analyzed statistically. The cherelle is referred to the elongation of immature pods from the pod set. The pod length was measured from stalk to apex and girth was measured at the centre of the pods by using thread. Volume of the pod was recorded in cubic centimetre by the water displacement method and pod value can be defined as the number of pods required to produce one kg of dry beans.

Results and discussion

The impact of fertigation could be clearly observed from the increased pod characters as compared to conventional fertilizer application. Fertigation using water soluble fertilizers at 125 and 100 per cent recommended levels, significantly and consistently

proved better for these parameters. Though fertigation using straight fertilizers at 125 per cent level improved these parameters, fertigation using water soluble fertilizers proved to be still better.

Pod set is an important factor which decides the productivity in cocoa. In the present study, the highest pod set per cent was observed by application of 75 per cent RDF as WSF through fertigation by drip irrigation. It was higher than the 100 per cent RDF conventional method of fertilizer application (Table 1). This might be due to increased uptake of nutrients which resulted in enhanced synthesis of hormones like auxins and gibberellins. High pollen output, increased pollen germination are other factors contributing to increased set. Water applied through drip irrigation nearer to the root zone always maintains soil moisture in field capacity range and no moisture stress occur during the flowering and pod development stage and thereby the flower or premature pod drop was minimized. This might have resulted in higher per cent of pod set as evident from the lower percentage of cherelle in fertigated treatments (Table 2).

The plants which received 125 per cent RDF as WSF through fertigation by drip irrigation (T_4) recorded the maximum pod length (17.72 cm) and pod girth (28.69 cm) (Table 3 and 4). This increase in length and girth could well be attributed to the increased rate of photosynthesis which could have further led to the better partitioning of assimilates. Many characters of the pods like cell size, laticiferous canals, inter cellular spaces in different tissues of the pod contribute to the increase in length and girth of pod (Singh *et al.*, 2008).

Table 1. Effect of drip and micro sprinkler fertigation on percentage of pod set at various seasons

Treatments	2010			2011			Pooled
	1st season	2nd season	Mean	1st season	2nd season	Mean	
T_1	1.4	1.9	1.6	1.4	1.8	1.6	1.6
T_2	1.3	1.9	1.6	1.5	2.0	1.8	1.7
T_3	1.3	1.8	1.5	1.3	1.8	1.5	1.5
T_4	1.1	1.8	1.5	1.3	1.9	1.6	1.5
T_5	1.4	1.8	1.6	1.5	1.9	1.7	1.7
T_6	1.4	2.0	1.7	1.6	1.9	1.7	1.7
T_7	1.4	1.9	1.7	1.4	1.9	1.7	1.7
T_8	0.9	1.4	1.2	0.9	1.3	1.1	1.2
T_9	0.9	1.3	1.1	0.8	1.2	1.0	1.1
T_{10}	0.8	1.3	1.1	1.0	1.2	1.1	1.1
T_{11}	1.2	1.4	1.3	0.9	1.2	1.1	1.2
T_{12}	0.9	1.4	1.2	0.9	1.3	1.1	1.1
T_{13}	1.0	1.5	1.3	0.8	1.4	1.1	1.2
CD (0.05)	0.05	0.07		0.06	0.07		0.06
CD (0.01)	0.07	0.09		0.08	0.10		0.09

Table 2. Effect of drip and micro sprinkler fertigation on total number of cherelle's tree^{-1} at various seasons

Treatments	2010			2011			Pooled
	1st season	2nd season	Total	1st season	2nd season	Total	
T_1	41.4	37.4	78.8	34.3	30.2	64.4	71.6
T_2	8.3	8.8	17.1	8.0	7.4	15.4	16.2
T_3	6.9	6.7	13.6	6.1	5.5	11.6	12.6
T_4	5.3	5.1	10.4	4.7	4.1	8.8	9.6
T_5	10.1	10.0	20.1	10.1	10.2	20.2	20.2
T_6	9.4	9.1	18.5	8.5	8.0	16.5	17.5
T_7	9.2	9.0	18.2	9.0	8.2	17.3	17.8
T_8	20.1	23.9	44.0	20.3	18.7	38.9	41.5
T_9	19.3	11.4	30.7	11.3	10.2	21.5	26.2
T_{10}	11.8	27.3	39.1	15.9	11.3	27.2	33.1
T_{11}	24.9	23.6	48.5	19.0	21.5	40.5	44.5
T_{12}	16.9	12.3	29.2	13.6	18.4	32.0	30.6
T_{13}	15.7	10.6	26.3	10.0	14.6	24.6	25.4
CD (0.05)	1.81	1.81		1.47	1.39		3.13
CD (0.01)	2.46	2.46		2.00	1.89		4.27

Table 3. Effect of drip and micro sprinkler fertigation on pod length (cm) at various seasons

Treatments	2010			2011			Pooled
	1st season	2nd season	Mean	1st season	2nd season	Mean	
T_1	15.4	15.8	15.6	15.5	14.9	15.2	15.4
T_2	16.6	16.4	16.5	17.6	16.6	17.1	16.8
T_3	17.2	17.4	17.3	17.4	17.1	17.2	17.3
T_4	17.6	17.9	17.8	17.9	17.4	17.7	17.7
T_5	16.8	16.6	16.7	16.4	16.9	16.7	16.7
T_6	17.0	16.4	16.7	16.9	16.0	16.5	16.6
T_7	17.0	17.3	17.1	17.0	16.7	16.9	17.0
T_8	16.8	16.3	16.6	16.4	15.9	16.1	16.4
T_9	16.1	17.0	16.6	16.9	16.6	16.8	16.7
T_{10}	16.7	15.9	16.4	15.9	16.3	16.2	16.3
T_{11}	15.7	16.3	15.9	15.9	15.9	15.9	15.9
T_{12}	15.9	16.1	16.1	16.8	16.4	16.6	16.3
T_{13}	16.9	15.9	16.4	16.1	16.8	16.5	16.5
CD (0.05)	0.55	0.55		0.56	0.54		0.55
CD (0.01)	0.75	0.75		0.77	0.74		0.75

Table 4. Effect of drip and micro sprinkler fertigation on pod girth (cm) at various seasons

Treatments	2010			2011			Pooled
	1st season	2nd season	Mean	1st season	2nd season	Mean	
T_1	25.8	24.9	25.3	25.7	23.7	24.7	25.0
T_2	27.1	26.1	26.6	27.3	26.8	27.1	26.8
T_3	27.1	27.3	27.2	28.9	29.9	29.4	28.6
T_4	28.8	27.6	27.7	29.3	29.9	29.7	28.7
T_5	26.7	26.3	26.5	27.2	26.0	26.6	26.6
T_6	26.7	25.9	26.3	27.8	27.2	27.5	26.9
T_7	27.4	26.1	26.7	28.0	27.7	27.8	27.3
T_8	25.9	25.5	25.7	26.2	26.8	26.5	26.1
T_9	26.1	26.4	26.3	28.1	27.2	27.7	26.9
T_{10}	26.7	26.8	26.8	27.4	28.3	27.9	27.3
T_{11}	25.9	25.1	25.5	27.1	25.1	26.1	25.8
T_{12}	25.9	25.3	25.6	26.9	26.9	26.9	26.2
T_{13}	26.8	25.9	26.4	26.9	27.9	27.5	26.9
CD (0.05)	0.88	0.86		0.92	0.95		0.89
CD (0.01)	1.20	1.18		1.25	1.29		1.22

Pooled mean values of pod weight and husk weight showed that 125 per cent RDF as WSF through fertigation by drip irrigation (T_4) registered the highest pod weight (541.88 g), husk weight (387.83 g) and pod volume (610.55 cc) (Table 5, 6 and 7). Many physiological activities like increased uptake of water and nutrients, photosynthetic rate contribute to more protoplasm, cell division and cell enlargement complementing vigorous growth (Veeranna *et al.*, 2000). This in turn increased the biometric traits like pod weight, husk weight and pod volume.

The treatment combination of 125 per cent RDF as WSF through fertigation by drip irrigation (T_4) recorded the highest number of pods per tree (23.50 and 34.17, 25.95 and 35.36) during first and second season of 2010 and 2011, respectively (Table 8). The minimum number of pods per tree was reported by the control (100 per cent RDF as surface application) might be due to the poor availability of nutrients, resulting in lower efficiency of

Table 5. Effect of drip and micro sprinkler fertigation on pod weight (g) at various seasons

Treatments	2010			2011			Pooled
	1st season	2nd season	Mean	1st season	2nd season	Mean	
T_1	366.4	399.3	382.8	341.4	373.6	357.5	370.2
T_2	481.3	485.0	483.2	483.7	460.4	472.0	477.6
T_3	520.6	513.2	516.9	514.0	535.8	524.9	520.4
T_4	534.0	546.6	540.3	541.3	545.6	543.4	541.9
T_5	473.0	476.9	475.0	471.5	483.2	477.4	476.2
T_6	487.6	509.8	498.7	493.8	484.1	488.9	493.8
T_7	506.2	497.6	501.9	504.2	519.3	511.8	506.9
T_8	434.5	458.8	446.7	441.8	445.1	443.4	445.1
T_9	444.1	491.5	467.8	465.4	495.5	480.5	474.1
T_{10}	492.6	485.7	489.1	500.1	506.3	503.2	496.2
T_{11}	435.2	451.7	443.5	421.3	444.9	433.1	438.3
T_{12}	469.1	475.2	472.2	425.8	468.2	447.0	459.6
T_{13}	486.4	484.9	485.7	482.6	493.5	488.1	486.9
CD (0.05)	17.24	16.99		17.77	17.61		17.29
CD (0.01)	23.49	23.17		24.21	23.99		23.56

Table 6. Effect of drip and micro sprinkler fertigation on husk weight (g) at various seasons

Treatments	2010			2011			Pooled
	1st season	2nd season	Mean	1st season	2nd season	Mean	
T_1	279.0	294.6	286.8	246.6	273.4	259.9	273.4
T_2	362.2	351.8	356.9	354.7	339.7	347.2	352.1
T_3	366.9	374.4	370.1	363.5	374.3	368.9	369.5
T_4	371.8	404.0	387.9	379.2	396.3	387.7	387.8
T_5	346.7	347.9	347.4	330.1	356.2	343.2	345.3
T_6	348.7	376.9	362.8	366.8	345.4	356.1	359.5
T_7	370.2	365.9	368.0	356.4	378.5	367.5	367.7
T_8	334.7	340.9	337.8	341.5	334.7	338.1	337.9
T_9	325.1	366.5	345.8	337.0	372.9	354.9	350.4
T_{10}	358.3	365.8	362.1	360.4	372.0	366.2	364.2
T_{11}	336.6	340.2	338.4	321.8	325.2	323.5	330.9
T_{12}	348.9	335.9	342.4	302.4	359.3	330.9	336.6
T_{13}	354.2	356.1	355.1	347.4	355.8	351.6	353.4
CD (0.05)	12.13	12.56		12.74	12.71		12.39
CD (0.01)	16.53	17.12		17.36	17.33		16.89

photosynthesis accumulation of assimilates and less dry matter production. Similar results were also reported by Oliveira *et al.* (2006) in cashew.

The pod value contributes the realizable produce for the farmer and lower pod value contributes to higher bean yield. In the present study, these parameters were directly influenced by the fertigation treatments. The minimum pod value (16.29 and 15.58, 16.66 and 15.87 during first and second season in 2010 and 2011) was recorded in T_4 (Table 9). Fertigation with higher nutrient level (125 per cent) resulted in higher availability of required nutrients in soil which obviously led to increased growth, leaf area; higher uptake of nutrients, better photo assimilation and better translocation of assimilates from source to sink which in turn increased the pod yield.

Studies taken up in fertigation with cocoa indicated that a dosage of 125 per cent RDF as water soluble fertilizer through fertigation by drip irrigation (T_4) remarkably improved the pod characters.

Table 7. Effect of drip and micro sprinkler fertigation on pod volume (cc) at various seasons

Treatments	2010			2011			Pooled
	1st season	2nd season	Mean	1st season	2nd season	Mean	
T_1	399.2	420.2	409.7	375.8	400.3	388.1	398.9
T_2	519.0	499.7	509.3	540.4	523.7	532.0	520.7
T_3	600.4	605.3	602.9	560.8	584.5	572.7	587.8
T_4	623.2	609.4	616.3	599.2	610.3	604.8	610.6
T_5	550.2	532.3	541.2	483.1	541.6	512.4	526.8
T_6	534.7	561.8	548.2	544.1	492.9	518.6	533.4
T_7	571.1	568.3	569.7	581.3	563.0	572.2	570.9
T_8	495.4	487.3	491.3	473.5	457.7	465.6	478.5
T_9	531.9	500.8	516.3	498.6	500.3	499.5	507.9
T_{10}	592.0	538.6	565.3	541.6	522.2	531.9	548.6
T_{11}	448.6	478.5	463.6	444.3	497.4	470.8	467.2
T_{12}	496.4	507.3	501.9	500.7	488.3	494.5	498.2
T_{13}	522.9	544.6	533.7	518.7	540.7	529.7	531.7
CD (0.05)	20.26	19.55		20.08	19.21		19.51
CD (0.01)	27.61	26.64		27.36	26.17		26.59

Table 8. Effect of drip and micro sprinkler fertigation on number of pods per tree at various seasons

Treatments	2010			2011			Pooled
	1st season	2nd season	Total	1st season	2nd season	Total	
T_1	19.3	28.6	47.9	19.7	26.4	46.1	46.9
T_2	22.7	33.7	56.4	24.1	33.2	57.4	56.9
T_3	23.3	34.0	57.3	24.3	33.7	57.9	57.6
T_4	23.5	34.2	57.7	25.9	35.4	61.3	59.5
T_5	22.2	30.9	53.2	23.8	30.8	54.6	53.9
T_6	22.0	33.2	55.2	23.7	31.4	55.1	55.1
T_7	22.9	33.5	56.4	25.2	33.9	59.1	57.7
T_8	19.4	29.9	49.3	22.3	28.1	50.4	49.8
T_9	23.9	30.7	54.6	22.0	32.1	54.1	54.4
T_{10}	21.7	32.7	54.4	25.1	31.2	56.3	55.4
T_{11}	20.8	29.2	50.0	20.3	28.0	48.3	49.1
T_{12}	21.0	29.7	50.8	21.3	31.2	52.4	51.6
T_{13}	22.2	31.1	53.3	20.4	32.5	52.9	53.1
CD (0.05)	0.77	1.12		0.82	1.15		1.90
CD (0.01)	1.04	1.52		1.12	1.57		2.59

Table 9. Effect of drip and micro sprinkler fertigation on pod value at various seasons

Treatments	2010			2011			Pooled
	1st season	2nd season	Mean	1st season	2nd season	Mean	
T_1	32.5	31.4	31.9	28.5	28.3	28.4	30.2
T_2	21.56	22.0	21.8	20.3	19.1	19.7	20.8
T_3	17.1	16.6	16.9	16.7	16.8	16.8	16.8
T_4	16.3	15.6	15.9	16.7	15.9	16.3	16.1
T_5	24.4	22.7	23.6	21.8	21.8	21.8	22.7
T_6	18.3	20.0	19.1	20.2	19.8	19.9	19.6
T_7	17.9	17.7	17.9	18.1	17.7	17.9	17.9
T_8	24.3	23.4	23.8	22.2	22.3	22.3	23.1
T_9	21.3	20.4	20.9	22.4	23.9	23.2	22.0
T_{10}	18.3	18.5	18.4	19.9	18.6	19.3	18.8
T_{11}	26.9	23.6	25.2	24.6	21.4	23.0	24.1
T_{12}	20.8	20.9	20.9	21.3	21.8	21.6	21.2
T_{13}	20.2	20.6	20.4	20.7	19.0	19.9	20.1
CD (0.05)	1.04	0.97		0.88	0.88		0.93
CD (0.01)	1.42	1.32		1.20	1.19		1.26

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