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PRECISION FARMING APPROACH FOR CULTIVATION OF BANANA IN KONKAN REGION OF MAHARASHTRA

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ABSTRACT

Precision farming implies a management strategy to increase productivity and economic returns with a reduced impact on the environment. It is based on the application of information technology to a description of variability in the field, variable-rate operations and the decision making system. There are three technology levels and three strategies in development of precision farming. Precision farming practices can be used on small farms as well as big ones, and they play a core role in rural development programs which are integrated with industry. In Konkan region the lateritic soil with steep slope and heavy annual rainfall is the peculiarity. The climate and well drained soils of this region are favourable for banana crop and there is vast scope for increasing the area under this crop. Here in the present study an attempt was made to decide the spacing of banana crop along with the irrigation and fertilizer level on micro level in the field to get maximum productivity and returns with variable crop periods coupled with the drip irrigation system. An experiment on banana was conducted during 2007-08 to 2009-10 at Research Farm of College of Agricultural Engineering and Technology, Dapoli (M.S.). The maximum benefit : cost ratio of 2.34 was observed in planting density D_3 (1.75 m x 1.75 m) followed by 2.23 in planting density D_2 (1.50 m x 1.50 m). Hence, it was concluded that the combinations of planting density D_3 (1.75 m x 1.75 m) with I_2 level of irrigation (0.6PE) and F_3 (120 % RD through WSF) level of fertigation was found significantly superior over the other combinations of planting density, irrigation level and fertilizer level.

(Key words: Banana, drip irrigation, fertigation, B:C ratio)

INTRODUCTION

Precision farming provides a new solution using a system approach for today's agricultural issues such as the need to balance productivity with environmental concerns. It is based on advanced information technology. It includes describing and modeling variation in soils and plant species and integrating agricultural practices to meet site-specific requirements. It aims at increased economic returns, as well as at reducing the energy input and the environmental impact of agriculture.

This paper describes the concept of precision farming, and also its use in agriculture especially for cultivation of banana crop in lateritic soil (well drained soil and humid climatic conditions) in Konkan region of Maharashtra State.

The term "precision farming" or "precision agriculture" is capturing the imagination of many people concerned with the production of food and fiber. Precision farming management concept is based on observing, measuring and responding to inter and intra-field variability in crops.

Elements of the technology

Describing variability is the key concept. In particular, it is based on variation within each field. There are three fundamental elements in this technology (Shibusawa, 2001). Variability should be understood in at least three elements i.e. spatial, temporal and predictive. Variable rate technology (VRT) is used to adjust the agricultural inputs according to the site specific requirements in each part of the field.

Variable rate applications include correct positioning in the field, correct information at the location, timely operations at the site concerned and decision support systems offer a range of choices to farmers with respect to trade – off problems.

Information levels

Precision farming needs all stages of information in the agricultural system and also requires good linkage between the stages. In particular, information technology should be closely linked to farmers.

Banana is the most ancient fruit crop and grown in about 120 countries. In India banana is grown on 8.80 lakh hectares with the production of 30.008 million tones as

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against world production of 140 million tones. In India it is grown in the states of Kerala, Maharashtra, Andhra Pradesh, Tamilnadu, Karnataka, West Bengal, Gujarat and Bihar. It is one of the major crops grown in Maharashtra on an area of 61,310 ha and production of 3.55 million tons (Anonymous, 2016), more than 50% area and production is located in Jalgaon district. The average yield of banana is 34.10 t ha^{-1} of the country while it is 58.03 t ha^{-1} in Maharashtra. In India banana ranks first in production and third in area among fruit crops.

In Konkan region, the lateritic soils, which are well drained and climatic conditions are favourable for banana. By viewing the potential of banana crop for production, the experiment was intended to conduct to formulate the complete package for banana with precision in the input parameters to increase its productivity and profitability in Konkan region.

MATERIALS AND METHODS

Precise land preparation and planting technique are one of the most important components in Banana cultivation. Before plantation, two deep ploughings followed by disc harrowing for clod crushing and ridging with different spacings were performed. Plantation of Banana was done in pits of size 30 cm x 30 cm x30 cm at required plant spacing. The planting technique includes anchoring or supporting mechanism through soil by roots from all sides and to avoid the later supporting system of bamboos costing Rs. 33000 to 35000 $hectare^{-1}$. The proper earthing-up was carried out to provide sufficient and congenial soil and soil atmosphere and prevent lodging of plant and avoid the additional expenditure on supporting mechanism.

Considering the major role of different amount of irrigation water to be delivered to the crop, fertilizer application and planting densities, the present study was formulated with different treatment combinations as follows,

Irrigation levels : I_1 = 0.4 PE
I_2 = 0.6 PE
I_3 = 0.8 PE
(0.4, 0.6, 0.8 are the integrated factors determined by considering pan factor, crop factor/coefficient,wetted area etc.)

Fertigation levels : F_1 = 80 % of RD through WSF
F_2 = 100 % of RD through WSF
F_3 = 120 % of RD through WSF

Planting Density : D_1 = 1.25 x 1.25 m
D_2 = 1.50 x 1.50 m
D_3 = 1.75 x 1.75 m

Control : Recommended package of practices
Spacing = 1.5 m x 1.5 m
Fertigation = Recommended (200:100:100 NPK g $plant^{-1}$)
Irrigation = 3 cm depth of water after every 4 days

Design : Split plot

Treatment Combinations : 27

Replications : Two

Total plot size : 55.00 m X 36.00 m

Block size : Block –1 = 35.00 m X 11.25 m
Block –2 = 34.50 m X 13. 5 m
Block –3 = 35.00 m X 15.75 m
Block –4 = 34.50 m X 9.0 m

Number of plants under each block : Block –1 = 252
Block –2 = 207
Block –3 = 180
Block –4 = 138

Variety of crop : Grand Naine, G-9

Date of Plantation : 13th September 2007

Table 1. Monthly evaporation and depth of water applied (cm) to banana under different treatments (2006-07 and 2007-08)

Month	Evap	I_1	I_2	I_3	Control
Sep**	4.64	1.95	2.93	3.91	7.50
Oct	11.07	4.66	6.99	9.32	23.25
Nov	12.32	5.19	7.78	10.37	22.50
Dec	11.52	4.85	7.28	9.70	23.25
Jan	11.04	4.65	6.97	9.30	23.25
Feb	12.70	5.35	8.02	10.69	21.00
Mar	16.60	6.99	10.48	13.98	23.25
Apr	17.35	7.31	10.96	14.61	22.50
May	17.66	7.44	11.15	14.87	23.25
Jun*	4.04	1.70	2.55	3.40	6.00
Total	**118.94**	**50.08**	**75.12**	**100.16**	**195.75**
Water saving over control (%)		74.42	61.62	48.83	

*Water delivered up to onset of effective monsoon

** Water delivered whenever required.

Irrigation treatments were incorporated immediately after transplanting (September) after a week and the irrigation was terminated after the on-set of effective monsoon. The base irrigation was applied until settlement of crop; was not considered as the same quantity was applied to each treatment. The average water applied in two seasons under each treatment and water saving are tabulated in table 1.

The water application observations indicated that the total amount of water applied to banana under treatment I_1 (0.4PE), I_2 (0.6PE), I_3 (0.8PE) and control was 50.08 cm, 75.12 cm, 100.16 cm and 195.75 cm, respectively. It resulted in water saving over control irrigation treatment as 74.42, 61.62 and 48.83 per cent, respectively in I_1, I_2 and I_3 treatments. Total evaporation during the study period was recorded 118.94 cm. (Table 1)

Growth Parameters

The data of growth parameters, which yield contributing parameters of the crop were taken periodically and were analyzed statistically. These are plant height, number of leaves, stem girth (circumference) and leaf area. The observed data on growth parameters along with their statistical analysis are presented in table 2, 4 and 6.

RESULTS AND DISCUSSION

Plant height

The data in table 2 and table 4 indicated that the plant height was influenced by planting density upto 8 months of the age for the first season, while for the ratoon crop it was influenced by plant density upto entire season. The most prominent influencing parameter among planting density, irrigation and fertigation, was found to be plant density. Among planting densities, the treatments D_1 (1.25m X 1.25 m) and D_2 (1.5m X 1.5m) were found most significant over treatment D_3 (1.75m X 1.75m) up to 8th month for the first season, while for the ratoon crop upto 10th month. This indicated that the vertical growth was more in high densities as compared to the low-density plantation. Maximum height of plant attained after 10 months was 264.38 cm for the first season crop and 274.78 cm in treatment D_1 for ratoon crop.

The irrigation levels I_2 and I_3 resulted prominent but not significant as compared to I_1 throughout the growth period of banana influencing the plant height. Maximum height achieved in irrigation levels was 282.2 cm after 10 months for first season crop and 269.44 cm for ratoon crop.

The fertigation also influenced the height of banana plant after 4 months for both first season and ratoon crop and fertigation levels F_2 (100% RD through WSF) and F_3 (120% RD through WSF) were found higher height over level F_1 (80% RD through WSF) and they were at par with each other for most of the period. This indicated the more fertilizer is required for banana in lateritic soils.

Stem girth

The growth parameters like number of leaves, stem girth and leaf area were found initially influenced by planting density and this effect was nullified in the later growth stages. These parameters were also found influenced by the irrigation and fertigation levels throughout the plant's growth period. From table 2 and table 4 the stem girth during 10 months was found larger by 21.79 % due to decreased planting density (D_3), 22.91 % due to irrigation through drip system at 0.80 PE level (I_3) and 24.05 % due to application of water soluble fertilizers through drip irrigation in monthly splits at the level of 120% of RD (F_3) within the treatment, while it was 12.90 %, 9.12 % and 9.13 % for ratoon crop, respectively. This is the indicator that strength to plant was more by incorporating the advanced techniques, thus the loss of produce due to breakage/lodging of plant stem can be decreased as compared to traditional method of cultivation of banana.

Number of leaves

The effect of planting density was found to be up to 8 months; however, fertigation and irrigation levels did not have any significant impact on number of leaves for the first year crop, while the ratoon crop showed the significant impact after 4 months to the last month (up to harvest).

Leaf area

The leaf area, which is the indicator of health of plant, was also increased by 46.77 %, 42.74 % and 62.90 % by changing planting density, irrigation technique and fertigation as compared to the traditional method for the first year crop, while it was shown the increase of 14.1 %, 5.1 % and 10.1%, respectively for ratoon crop. As the leaf area is increased, the photosynthesis of plant is increased, thus the total health of plant is enhanced.

Quality parameters

The quality parameters like TSS, girth and length of banana finger were determined to evaluate the effect of treatments. These parameters are also included in table 3 and table 5. The TSS and finger girth were found to be significantly increased due to more application of fertilizers, however, the fertigation over 100% RD through WSF can not give significant effect. The length of finger was found to be significantly influenced by irrigation and fertigation levels. The irrigation treatments 0.6 PE (I_2) and 0.8 PE (I_3) were found to be most significant and were at par with each other to increase the length of banana fingers. The maximum TSS was observed in fertigation level 120 % RD through WSF (F_3) (21.37), whereas it was 20.92 and 20.98 in irrigation level 0.8 PE (I_3) and planting density 1.75m X 1.75m (D_3). The maximum girth of finger was observed in fertigation level 120 % RD through WSF (F_3) (13.54 cm), whereas it was 12.89 cm and 12.98 cm in 1.75m X 1.75m (D_3) and 0.8 PE (I_3), respectively. The maximum length of the finger was observed in 0.6 PE (I_2) (19.88 cm), whereas it was 19.62 cm and 19.77 cm in 1.75m X 1.75m (D_3) and 120 % RD through WSF (F_3), respectively.

Number of days to harvest

The number of days required for harvesting was also influenced by planting density 1.75m X 1.75m (D_3) (303)

Table 2. Biometric growth parameters of banana in different planting densities, irrigation and fertigation levels (2006-07)

Sr. No.	Observations	Planting densities					Irrigation levels					Fertigation levels					Control
		D_1	D_2	D_3	SE±	CD	I_1	I_2	I_3	SE±	CD	F_1	F_2	F_3	SE±	CD	
1.	**Plant height (cm) after**																
	2 months	116.38	122.33*	114.52	3.094	6.868	107.59	112.20	118.68*		13.544	114.00	114.42	116.96	2.526	--	102.60
	4 months	243.64**	236.45**	211.57	7.789	24.613	215.39	236.01**	236.78**	6.215	19.641	224.37	231.18	230.98	7.999	--	177.50
	6 months	256.93**	244.75**	220.43	2.596	8.150	239.04	262.03**	268.22**	4.458	12.936	244.39	262.66**	262.17**	4.458	12.936	211.16
	8 months	262.64**	253.69	232.89	7.788	23.36	255.84	275.52**	279.47**	5.487	16.321	253.82	273.93	274.76*	7.788	23.36	227.05
	10 months	264.38	258.80	238.99	12.331	--	258.87	278.41**	282.02**	3.429	10.49	255.71	278.77**	277.76**	4.866	15.23	233.39
2.	**Number of leaves after**																
	2 months	12.7**	12.9**	12.0	0.013	0.040	12.3	12.7	12.3	0.016	--	12.4	12.4	12.3	0.006	--	11.3
	4 months	16.3	16.0	16.0	0.004	0.008	15.5	16.5**	16.4	0.002	0.006	15.8	16.3*	16.3	0.014	0.0315	14.1
	6 months	16.5*	15.7	16.5*	0.199	0.577	15.7	16.5*	16.6*	0.199	0.577	16.0	16.2	16.5	0.199	--	15.2
	8 months	17.2	16.3	17.1	0.328	--	16.3	17.1*	17.1*	0.165	0.515	16.7	16.6	17.1	0.175	--	14.9
	10 months	15.2	15.0	16.5	0.270	--	14.7	15.6*	14.9	0.237	0.729	15.0	14.7	14.4	0.252	--	13.3
3.	**Stem girth (cm) after**																
	2 months	24.38	26.34**	25.74**	0.041	0.131	24.48	25.42	25.91*	0.118	0.262	24.97	25.09	25.69	0.165	--	22.10
	4 months	42.18	45.52**	43.35	0.132	0.416	41.47	46.46**	45.93	0.319	1.009	42.64	45.07**	45.03**	0.055	0.175	38.70
	6 months	48.46	49.27	47.83	0.690	--	45.53	49.16**	50.87**	0.690	2.706	46.95	48.82*	49.80*	0.690	2.004	43.04
	8 months	53.51	52.76	51.69	0.633	--	49.81	52.99*	54.33*	0.511	1.621	49.78	52.92*	54.12*	0.511	1.621	47.52
	10 months	59.19	60.07	57.68	0.927	--	58.65	59.36	60.62	0.873	--	56.78	59.51*	61.18*	0.621	1.932	49.32
4.	**Leaf area (m^2) after**																
	4 months	0.662	0.704	0.756*	0.0217	0.063	0.729*	0.747**	0.651	0.0217	0.0851	0.646	0.720*	0.761**	0.0217	0.0851	0.59
	6 months	0.923	1.032**	1.258**	0.0212	0.0831	0.894	0.911	1.101**	0.0212	0.0831	0.897	0.971*	1.038**	0.0212	0.0831	0.73
	8 months	1.09	1.37*	1.54**	0.035	0.210	1.37	1.35	1.38	0.018	--	1.15	1.36**	1.59**	0.018	0.054	1.07
	10 months	1.64	1.81	1.82	0.031	--	1.77	1.73	1.77	0.017	--	1.51	1.74**	2.02**	0.017	0.053	1.24
5.	**No. of days for panicle initiation**	242.94	227.22	210.2**	5.027	19.70	258.06	256.83	245.44	5.027	--	255.50*	265.06	279.94	5.027	19.70	301.51
6.	**No. of days to harvest**	339	321	303**	7.79	22.61	356	350	340	7.79	--	350	359	372	7.79	--	398

* Significant at 5% level, ** Significant at 1% level

Table 3. Yield and yield parameters of banana in different planting densities, irrigation and fertigation levels (2006-07)

Sr. No.	Observations	Planting densities					Irrigation levels					Fertigation levels					Control
		D_1	D_2	D_3	SE±	CD	I_1	I_2	I_3	SE±	CD	F_1	F_2	F_3	SE±	CD	
1.	No. of fingers bunch^{-1}	96	95	100	2.020	--	91	101**	99**	2.020	7.917	96	97	99	2.020	--	73
2.	Yield plant^{-1} (kg)	15.81	20.08**	21.08**	0.324	1.272	15.98	17.25**	17.06**	0.324	1.272	16.43	17.89*	16.49	0.324	0.942	14.36
3.	Yield ha^{-1} (Tha^{-1})	101.18**	89.24**	68.77	2.436	9.547	71.00	83.08**	75.26	2.436	9.547	72.22	83.06*	75.26	2.436	9.547	63.84
4.	Fertilizer use efficiency (q kg^{-1})	0.397	0.425**	0.44**	0.0086	0.0344	0.396	0.437**	0.429**	0.0086	0.034	0.506**	0.415**	0.343	0.0086	0.034	0.36
5.	Quality parameters																
a.	TSS (%)	20.92*	20.22	20.97*	0.049	0.297	20.62	20.67	20.82*	0.037	0.109	19.47	20.81*	21.84*	0.037	0.109	18.35
b.	Girth of finger (cm)	13.09	12.79	12.94	0.185	--	12.82	12.93	13.06	0.065	--	13.03	13.40	13.58	0.065	0.191	12.60
c.	Length of finger(cm)	19.13	19.48	19.74	0.220	--	18.68	19.86**	19.80**	0.2195	0.860	18.79	19.71**	19.84**	0.2195	0.860	18.66

* Significant at 5% level

** Significant at 1% level

Table 4. Biometric growth parameters of banana in different planting densities, irrigation and fertigation levels (ratoon crop)

Sr. No.	Observations	Planting densities					Irrigation levels					Fertigation levels					Control
		D_1	D_2	D_3	SE±	CD	I_1	I_2	I_3	SE±	CD	F_1	F_2	F_3	SE±	CD	
1.	**Plant height (cm) after**																
	2 months	232.56	204.11*	145.33	6.73	19.52	187.11	193.56	201.33*		--	193.67	185.00	203.33	6.73	--	211.60
	4 months	259.44**	248.11**	178.00	6.55	18.99	217.11	232.11**	236.33**	6.55	--	223.67	219.33	242.56**	6.55	18.99	224.50
	6 months	298.56**	273.33**	218.67	6.29	18.25	240.22	268.56**	281.78**	6.29	18.25	265.56	249.89**	275.11**	6.29	18.25	236.16
	8 months	274.78**	264.22	227.33	4.38	12.71	241.22	255.67**	269.44**	4.38	12.75	252.89	245.44	268.00*	4.38	12.71	251.05
	10 months	274.78**	264.22	227.33	4.38	12.71	241.22	255.67**	269.44**	4.38	12.75	252.89	245.44	268.00*	4.38	12.71	251.05
2.	**Number of leaves after**																
	2 months	6.00	8.00**	10.22**	0.16	0.46	8.56	7.67	8.00	0.16	0.46	7.78	8.44	8.00	0.16	0.46	7.1
	4 months	8.89	10.00	10.44	0.13	0.38	9.56	9.44**	10.33	0.13	0.38	9.67**	9.56*	10.11	0.13	0.38	8.1
	6 months	9.33*	9.22	9.77*	0.09	0.27	9.11	9.67*	9.56*	0.09	0.27	9.22	9.33	9.78	0.09	0.27	8.2
	8 months	9.00	8.44	8.56	0.07	0.22	8.67	8.56	8.78	0.07	--	8.44	8.56	9.00	0.07	0.22	9.3
	10 months	9.00	8.44	8.56	0.07	0.22	8.67	8.56	8.78	0.07	--	8.44	8.56	9.00	0.07	0.22	9.3
3.	**Stem girth (cm) after**																
	2 months	31.67	33.22**	45.89**	0.96	2.78	25.11	22.44	23.22*	0.96	N.S.	24.22	22.44	24.11	0.96	--	23.70
	4 months	31.33	43.33**	50.89	0.85	2.47	39.22	41.56**	44.78	0.85	2.47	41.33	40.22**	44.00**	0.85	2.47	39.8
	6 months	38.78	50.22	54.00	0.80	2.32	45.44	47.33**	50.22**	0.80	2.32	46.67	46.00*	50.33*	0.80	2.32	46.10
	8 months	43.56	53.44	55.67	0.67	1.93	48.56	50.33*	53.78*	0.67	1.93	50.67	48.11*	53.89*	0.67	1.93	49.60
	10 months	43.56	53.44	55.67	0.67	1.93	48.56	50.33*	53.78*	0.67	1.93	50.67	48.11*	53.89*	0.67	1.93	51.01
4.	**Leaf area (m^2) after**																
	4 months	0.05	0.23	0.41*	0.02	0.05	0.25*	0.18**	0.26	0.02	0.05	0.29	0.18*	0.22**	0.02	0.05	0.74
	6 months	0.36	0.79**	1.08**	0.04	0.11	0.68	0.74	0.80**	0.04	N.S.	0.73	0.67*	0.83**	0.04	0.11	0.96
	8 months	0.64	1.10*	1.26**	0.03	0.008	0.87	0.99	1.09	0.03	0.008	0.95	0.90**	1.11**	0.03	0.008	0.90
	10 months	0.70	1.10	1.13	0.02	0.06	0.91	1.04	0.99	0.02	0.06	0.95	0.90**	1.09**	0.02	0.06	1.12
5.	**No. of days for panicle initiation**	222	213	199**	5.027	19.70	248	246	235	5.027	--	245*	255	269	5.027	19.70	228.51
6.	**No. of days to harvest**	336	318	296**	7.79	22.61	346	340	330	7.79	--	340	349	362	7.79	--	359

* Significant at 5% level, ** Significant at 1% level

Table 5. Yield and yield parameters of banana in different planting densities, irrigation and fertigation levels (ratoon crop)

Sr. No.	Observations	Planting densities					Irrigation levels					Fertigation levels					Control
		D_1	D_2	D_3	SE±	CD	I_1	I_2	I_3	SE±	CD	F_1	F_2	F_3	SE±	CD	
1.	No. of fingers bunch^{-1}	104	110	114	2.64	7.67	101	118	110	2.64	7.67	107	109	113	2.64	--	94.00
2.	Yield plant^{-1} (kg)	18.57	20.91	22.91	0.40	1.17	19.27	22.42	20.69	0.40	1.17	20.24	20.67	21.47	0.40	--	16.40
3.	Yield ha^{-1} (T ha^{-1})	118.85	91.99	74.80	2.14	6.22	87.85	102.77	95.03	2.14	6.22	92.8	95.22	97.63	2.14	--	72.90
4.	Fertilizer use efficiency (q kg^{-1})	0.466	0.438	0.479	0.0089	0.036	0.396	0.589	0.437	0.0089	0.036	0.65	0.476	0.445	0.0089	0.036	0.42
5.	Quality parameters																
a.	TSS (%)	21.00*	20.00	21.00*	0.049	0.297	20.50	21.01	21.03*	0.037	0.109	19.50	21.00*	21.90*	0.037	0.109	18.40
b.	Girth of finger (cm)	12.90	12.80	12.85	0.185	--	12.50	12.70	12.90	0.065	--	13.00	13.03	13.50	0.065	0.191	12.50
c.	Length of finger (cm)	19.00	19.30	19.50	0.220	--	18.50	19.90**	19.50**	0.2195	0.860	18.40	19.60**	19.70**	0.2195	0.860	18.50

* Significant at 5% level

** Significant at 1% level

Table 6. Average (2006-07 & 2007-08) biometric parameters of banana in different planting densities, irrigation and fertigation levels

Sr. No.	Observations	Planting densities					Irrigation levels					Fertigation levels					Control
		D_1	D_2	D_3	SE±	CD	I_1	I_2	I_3	SE±	CD	F_1	F_2	F_3	SE±	CD	
1.	**Plant height (cm) after**																
	2 months	142.36	132.65*	101.35	3.61	10.49	120.69	125.40	130.27*		--	125.11	120.62	130.65	3.61	--	117.1
	4 months	185.04**	183.59**	142.92	4.18	12.14	162.21	171.47**	177.87**	4.18	12.14	167.82	165.44	178.29	4.18	--	147.6
	6 months	231.95**	232.36**	203.31	4.41	12.80	206.46	222.86**	238.29**	4.41	12.80	217.15	216.11**	234.36**	4.41	12.80	213.7
	8 months	269.20**	256.61	241.99	3.84	11.15	240.16	258.83**	268.81**	3.84	11.15	248.66	254.06	265.09*	3.84	11.15	229.1
	10 months	269.60	261.50	233.21	5.40	16.20	250.00	267.00	275.70	5.4	16.2	254.30	262.10	272.91	5.4	16.2	242.2
2.	**Number of leaves after**																
	2 months	7.37**	8.47**	9.53	0.14	0.40	8.59	8.29	8.50	0.14	--	8.37	8.63	8.37	0.14	--	7.2
	4 months	10.34	11.39	11.41	0.14	0.41	10.87	10.82**	11.44	0.14	0.41	10.99	10.95*	11.20	0.14	--	10.1
	6 months	12.07*	11.57	11.96*	0.12	0.36	11.49	12.02*	12.09*	0.12	0.36	11.65	11.71	12.23	0.12	0.36	11.7
	8 months	12.74	12.08	12.54	0.10	0.30	12.17	12.51*	12.69*	0.10	0.30	12.22	12.39	12.75	0.10	0.30	12.1
	10 months	12.10	11.70	12.50	0.20	0.60	12.70	12.10	12.80	0.20	0.60	12.30	12.60	13.70	0.20	0.60	12.8
3.	**Stem girth (cm) after**																
	2 months	12.26	18.70**	23.84**	0.56	1.61	18.63	17.53	18.14	0.56	--	18.30	17.49	18.51	0.56	--	16.20
	4 months	27.49	34.92**	38.14**	0.56	1.63	31.73	33.28	35.55	0.56	1.63	33.03	32.73**	34.79**	0.56	1.63	31.30
	6 months	37.54	43.77	44.41	0.76	2.21	39.91	41.51	44.30**	0.76	2.21	40.27	41.34*	44.11*	0.76	2.21	41.78
	8 months	46.01	51.36	51.75	0.52	1.51	47.04	49.74*	52.32*	0.52	1.51	48.81	48.46*	51.84*	0.52	1.51	45.33
	10 months	51.40	56.80	56.70	0.80	--	53.60	54.80	57.20	0.80	2.30	50.70	51.80	53.50	0.8	2.30	47.08
4.	**Leaf area (m^2) after**																
	4 months	0.40	0.50	0.60	0.02	0.05	0.52	0.45	0.53	0.02	0.05	0.31	0.42	0.38	0.02	0.05	0.70
	6 months	0.61	0.96	1.21	0.02	0.08	0.63	0.74	0.69	0.02	0.08	0.69	0.63	0.59	0.02	0.08	0.82
	8 months	0.68	0.92*	0.92**	0.02	0.06	0.76	0.84	0.92	0.02	0.06	0.80	0.79**	0.93**	0.02	0.06	1.00
	10 months	0.79	0.99	1.10	0.02	0.05	0.89	0.99	1.00	0.02	0.05	0.92	0.92**	1.05**	0.02	0.05	1.20
5.	**No. of days for panicle initiation**	222	213	199**	5.027	19.70	248	246	235	5.027	--	245*	255	269	5.027	19.70	265
6.	**No. of days to harvest**	337	319	299**	4.40	12.76	362	347	340	4.40	12.76	348	349	353	4.40	--	379

* Significant at 5% level , ** Significant at 1% level

Table 7. Average (2007-08) yield parameters of banana in different planting densities, irrigation and fertigation levels

Sr. No.	Observations	Planting densities					Irrigation levels					Fertigation levels					Control
		D_1	D_2	D_3	SE±	CD	I_1	I_2	I_3	SE±	CD	F_1	F_2	F_3	SE±	CD	
1.	No. of fingers bunch^{-1}	100	103	108	2.3	7.0	96	110	105	2.3	7.0	102	104	106	2.3	--	84
2.	Yield plant^{-1} (kg)	17.19	20.49	21.99	0.36	1.22	17.36	19.74	18.97	0.36	1.22	18.34	18.98	19.28	0.36	1.22	15.38
3.	Yield ha^{-1} (Tha^{-1})	110.02	91.06	71.80	1.32	3.84	80.29	89.85	86.83	1.32	3.84	82.51	86.35	89.14	1.32	3.84	68.4
4.	Fertilizer use efficiency (q kg^{-1})	0.411	0.432	0.460	0.008	0.04	0.396	0.509	0.437	0.008	0.04	0.578	0.446	0.394	0.008	0.04	0.39
5.	Quality parameters																
a.	TSS (%)	20.96*	20.11	20.98*	0.049	0.297	20.56	20.84	20.92*	0.037	0.109	19.48	20.90*	21.37*	0.037	0.109	18.37
b.	Girth of finger (cm)	12.99	12.79	12.89	0.185	--	12.66	12.81	12.98	0.065	--	13.01	13.21	13.54	0.065	0.191	12.55
c.	Length of finger (cm)	19.06	19.39	19.62	0.220	--	18.59	19.88**	19.65**	0.2195	0.860	18.59	19.65**	19.77**	0.2195	0.860	18.58

* Significant at 5% level

** Significant at 1% level

for the first season crop and for the ratoon crop planting density 1.75m X 1.75m (D_3) (296), which is clearly indicating that within a period of 20 months it is possible to harvest two crops of banana, however, fertilizer levels and irrigation levels could not produce any effect to decrease the days to banana harvest in the present study.

Yield plant^{-1} and yield hectare^{-1}

The yield plant^{-1} and yield hectare^{-1} for the first year crop was significantly influenced by the planting densities, fertilizer levels and irrigation levels. Maximum yield plant^{-1} (21.08 kg) was achieved with 1.75m X 1.75m (D_3) planting, 17.25 kg with 0.6 PE irrigation level (I_2) and 17.89 kg with fertigation level of 100 % RD through WSF (F_2). The highest yield of 101.18 t ha^{-1} was achieved in the planting density of 1.25m X 1.25m (D_1). The maximum yield of 83.08 t ha^{-1} was fetched with 0.60 PE irrigation level and the same yield is obtained with 100% RD through application of water-soluble fertilizers. On the contrary, the maximum yield of banana was achieved as 63.84 t ha^{-1} with the traditional method of cultivation. Thus, the yield of banana was increased by 30.12 % in lateritic soil by applying the water at 0.60 PE through drip irrigation and water soluble fertilizers. Goenaga *et al.* (1995) reported that increasing the amount of applied irrigation in a 20 hectare banana plantation from a pan factor of 0.75 to 1.25 increased the number of banana fruit boxes by 6,747 in the plant crop, and by 18,009 in the first banana ratoon.

The yield plant^{-1} and yield hectare^{-1} for ratoon crop was significantly influenced by the planting densities and irrigation levels. Maximum yield plant^{-1} (22.91 kg) was achieved with 1.75m X 1.75m (D_3) planting, 22.42 kg with 0.6 PE (I_2) irrigation level and 21.47 kg with fertigation level of 120 % RD through WSF (F_3). The highest yield of 118.85 t ha^{-1} was achieved in the planting density of 1.25m X 1.25m (D_1). The maximum yield of 102.77 t ha^{-1} fetched with 0.60PE irrigation level and the yield of 97.63 t ha^{-1} can be obtained with 120% RD through application of water-soluble fertilizers (F_3). On the contrary, the maximum yield of banana was achieved as 72.90 t ha^{-1} with the traditional method of cultivation. Thus, the yield of banana increased by 37.45 % in lateritic soil by applying the water at 0.60PE through drip irrigation and water-soluble fertilizers. Yuvaraj and Mahendran (2014) reported that the treatments with subsurface drip fertigation of 100 per cent RDF levels resulted in higher availability of nutrients compared to surface irrigation with soil application of recommended dose of fertilizers. The increased availability of nutrients may be due to split application of fertilizers under drip fertigation that resulted in reduction in loss of nutrients thereby making them available continuously to the crop compared to soil application where these nutrients found to leach out to deeper layers and become unavailable to the crop.

The average yield plant^{-1} and yield hectare^{-1} was significantly influenced by the planting densities and irrigation levels. Maximum yield plant^{-1} (21.99 kg) was achieved with 1.75m X 1.75m (D_3) planting, 19.74 kg with 0.6 PE (I_2) irrigation level and 19.28 kg with fertigation level of 120 % RD through WSF (F_3). The highest yield of 110.02 t ha^{-1} was achieved in the planting density of 1.25m X 1.25m (D_1). The maximum yield of 89.85 t ha^{-1} fetched with 0.60PE irrigation level and the yield of 89.14 t ha^{-1} was obtained with 120 % RD through application of water-soluble fertilizers (F_3). On the contrary, the average maximum yield of banana was achieved as 68.4 t ha^{-1} with the traditional method of cultivation. Thus, the yield of banana increased by 30.84 % in lateritic soil by applying the water at 0.60 PE through drip irrigation and water-soluble fertilizers. Ahmed (2006) obtained the percentage increase in total yield equal to 23% and 34% for the treatments 100% and 120% of ETc, respectively as compared to the surface irrigation

Fertilizer use efficiency

The fertilizer use efficiency was achieved about 0.48 q kg^{-1} for ratoon crop and average of 0.46 q kg^{-1} by decreasing planting density 1.75m X 1.75m (D_3), while with application of 0.60PE irrigation level it was 0.59 q ha^{-1} for ratoon and 0.51 q ha^{-1} on average level. The average of 0.39 q kg^{-1} fertilizer use efficiency was reported in the traditional method of cultivation. This reveals that more fertilizers were wasted in the traditional method. Prajapati *et al.* (2013) obtained the yield level ranging from 76 to 89 t ha^{-1} with drip + fertigation + mulching as against 69 to 79 t ha^{-1} with drip alone.

Effect of planting densities on micro-climate

The temperature, relative humidity and light intensity were recorded daily three times for three months to see the effect of planting density on micro-climate and were compared with these ambient climatic parameters. The recording of data was terminated after the on-set of monsoon, when the prominent effect of these parameters was nullified due to the rain. The effect during morning, noon and evening are presented in Fig. 1 to Fig. 3.

Light intensity

The light intensity in the wide spaced banana (treatment 1.75m X 1.75m (D_3)) was highest as compared to the other planting densities during morning, noon and evening through the observation period, which indicates more open area in this spacing. As the open area is more, the effectiveness of the micro-climate in this spacing is less. The consistency of micro-climate in 1.25m x 1.25m (D_1) and 1.5m x 1.5m (D_2) was quite more as compared to the control treatment. This might be the significant effect of the irrigation system. In treatment 1.25m X 1.25m (D_1) and 1.50m X 1.50m (D_2), banana was grown on drip irrigation, where the moisture content was maintained near to optimum as per the incorporated treatments; thus, the plants were healthy in these treatments as compared to the control treatment. It co-relates the results obtained on biometric parameters in the present study.

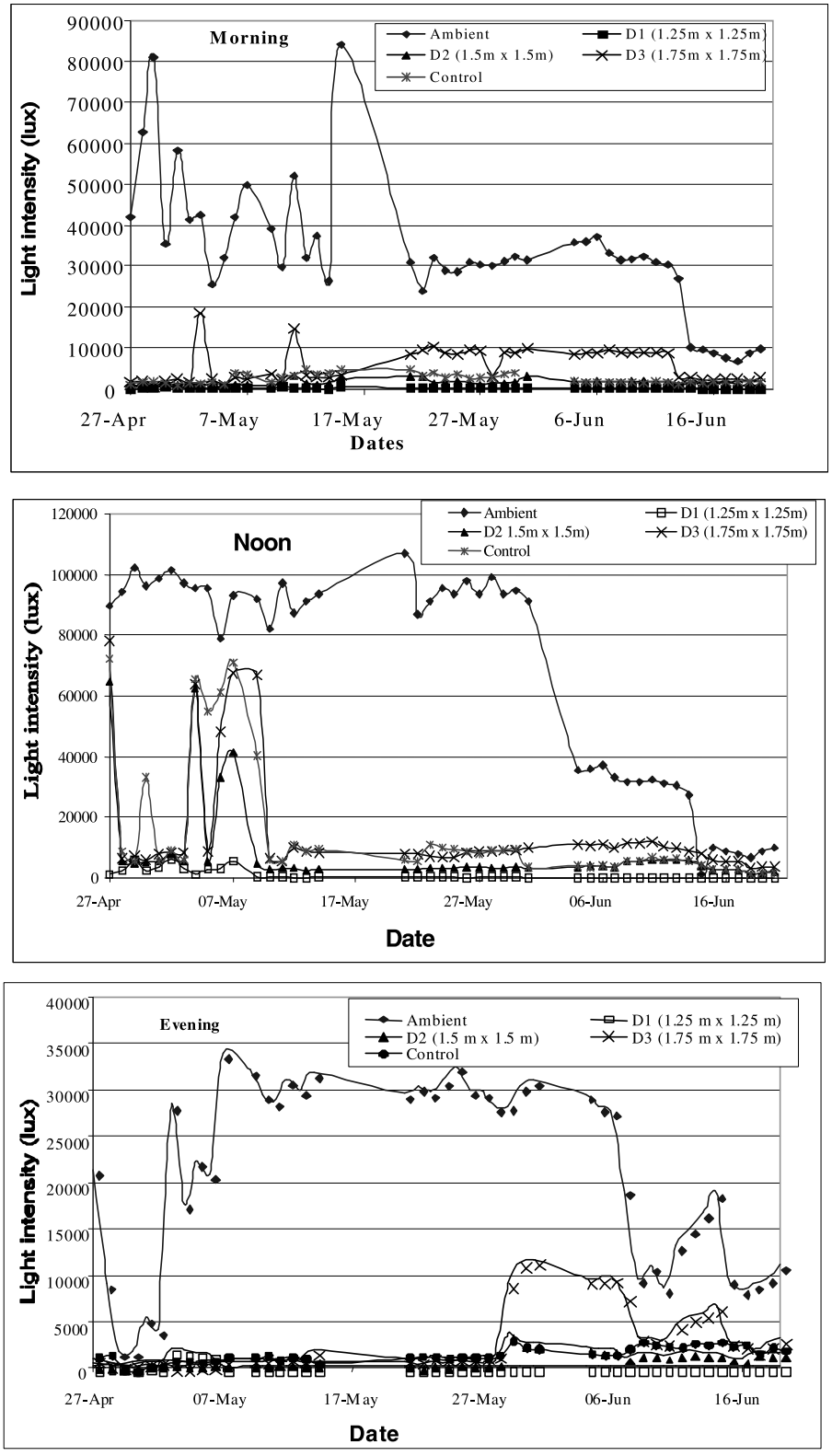
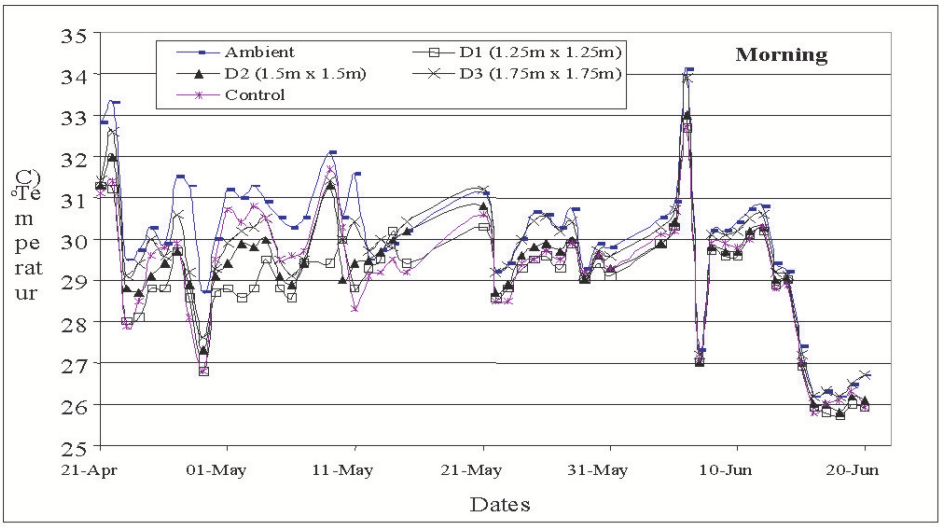
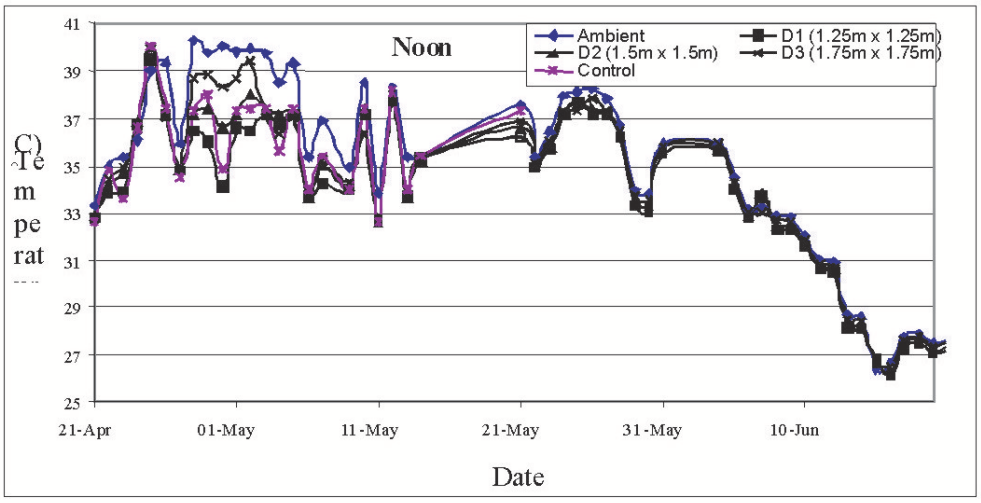


Fig. 1 Light intensity in banana during morning, noon and evening

Temperature

The temperature between the rows of 1.25m X 1.25m (D_1) treatment was found to be more or less constant as compared to the other treatments. The same trend was found in the fluctuation of temperature as the light intensity.





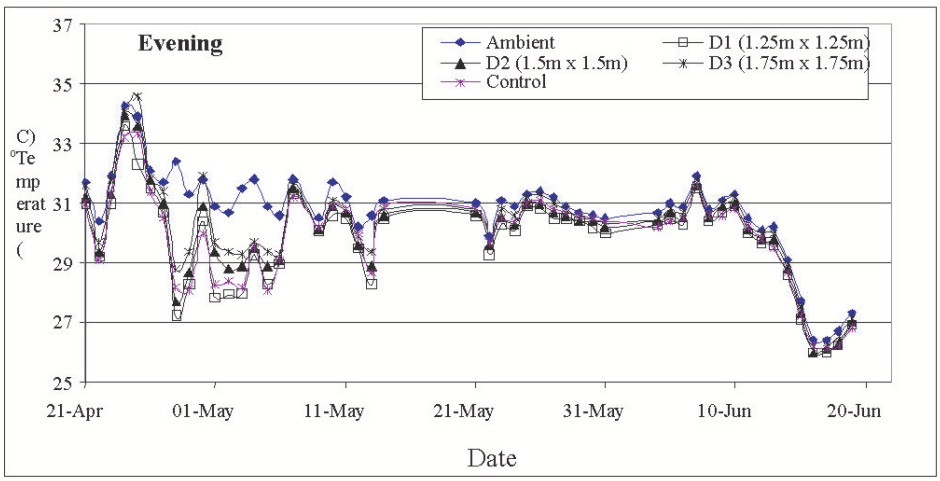


Fig. 2. Temperature in banana during morning, noon and evening

Humidity

The humidity in dense plant population was high throughout the observation period. The trend of the fluctuation in relative humidity was exactly reverse of light intensity and temperatures. The increased humidity throughout the growing season is the indicator of conductive atmosphere for plant growth. This trend of micro-climate also supports the results obtained on growth parameters of banana crop under this study.

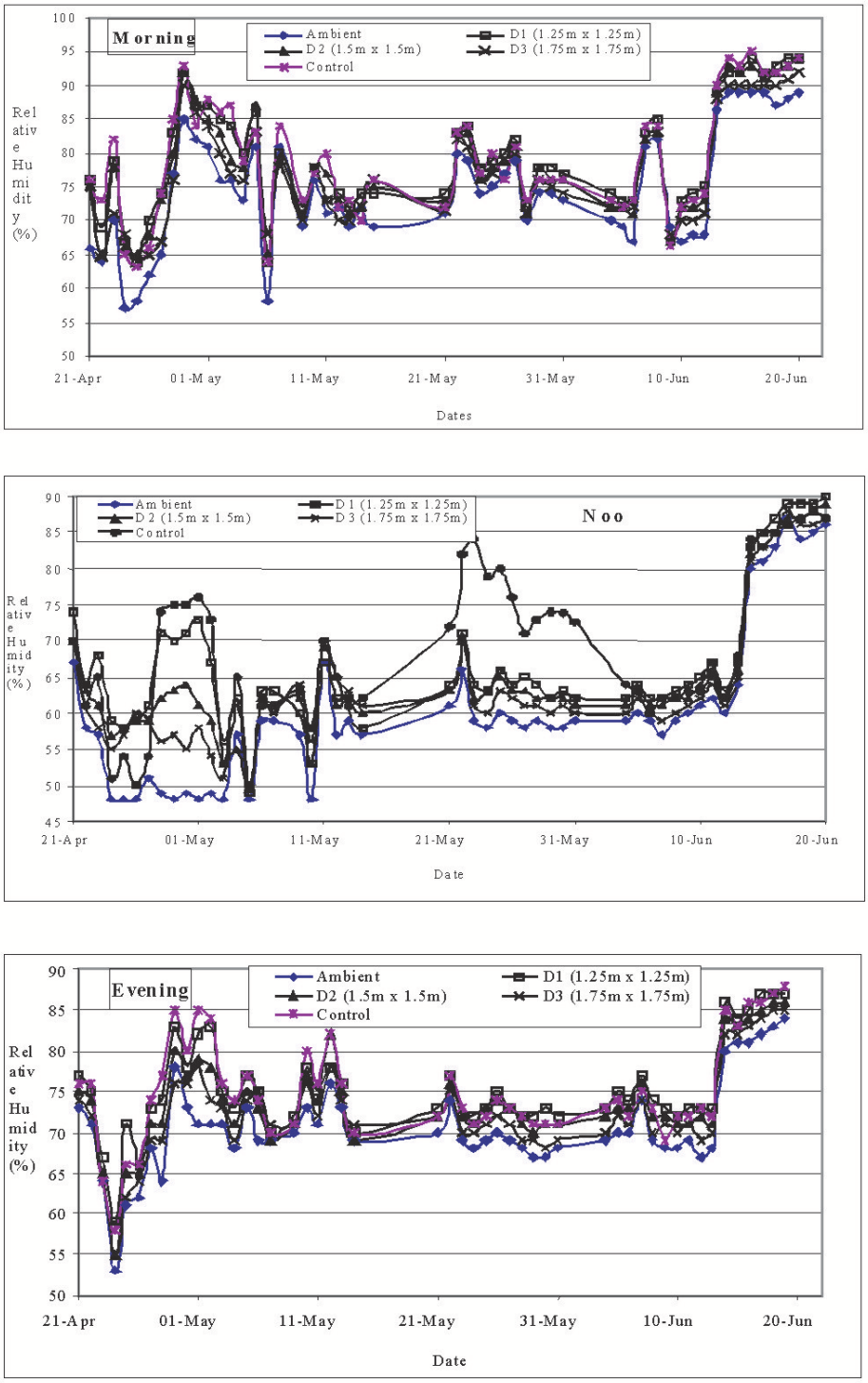


Fig. 3. Relative humidity in banana during morning, noon and evening

Quantification of micro-climate parameters

To see overall effect of planting density on micro-climate, the parameters were averaged for the observation period and per cent fluctuation of these parameters due to planting density over ambient condition were determined and are presented in table 8. The maximum reduction in light intensity and temperature was found to the tune of 99 and 4.2 per cent respectively. The increase in relative humidity over the ambient condition was 14 per cent. This increase was very prominent during the noon period.

Table 8. Quantification of micro-climatic parameters in banana during morning, noon and evening

Treatment	Average light intensity (lux)	% decrease compared to ambient	Average temperature (°C)	% decrease compared to ambient	Average relative humidity (%)	% increase compared to ambient
Morning observations						
D_1	273.90	99.31	29.20	4.24	77.40	6.82
D_2	1479.00	96.25	29.58	2.99	76.49	5.56
D_3	5736.72	85.47	29.98	1.68	74.97	3.47
Control	2822.46	92.85	29.57	3.08	77.04	6.32
Ambient	39472.41		30.49		72.46	
Noon observations						
D_1	1443.93	98.46	35.64	3.91	63.47	14.12
D_2	10586.43	88.72	35.98	2.99	61.16	9.97
D_3	17983.21	80.85	36.19	2.43	60.12	8.09
Control	20130.36	78.56	35.95	3.07	62.18	11.81
Ambient	93896.43		37.09		55.62	
Evening observations						
D_1	377.25	98.45	29.99	4.19	73.85	6.85
D_2	808.82	96.68	30.35	3.06	72.32	4.64
D_3	1979.14	91.87	30.68	2.00	70.97	2.68
Control	1547.07	93.65	30.20	3.53	73.94	6.98
Ambient	24343.21		31.31		69.12	

Cost economics

The data regarding cost economics for banana crop are given in table 9. The economic analysis of various treatment combinations showed the maximum benefit : cost ratio of 2.34 in planting density D_3 (1.75 m x 1.75 m) with net seasonal income of Rs. 1,84,984/- ha. The maximum cost of production of Rs 2,56,110 ha^{-1} i.e. Rs 25.61/m^2 was observed in planting density D_1 (1.25 m x 1.25 m) due to more number of plants $unit^{-1}$ area and minimum in control treatment Rs. 1,16,426 ha^{-1} i.e. Rs. 11.64/m^2. The maximum gross monetary returns of Rs. 4,95,090 ha^{-1} i.e. Rs. 49.51 / m^2 was observed in planting density D1 (1.25 m x 1.25 m). The minimum gross monetary returns of Rs 2,05,200 ha^{-1} i.e. Rs. 20.52 /m^2 was obtained in control. The maximum net income was gained from planting density D_1 (1.25 m x 1.25 m) i.e. Rs. 23.89 /m^2.

Table 9. Cost analysis for banana crop (average of 2006-07 & 2007-08)

Sr. No.	Cost economics	D_1 (1.25m X 1.25m)	D_2 (1.5m X 1.5m)	D_3 (1.75m X 1.75m)	Control (1.5m X 1.5m)
1.	Fixed cost (Rs. ha^{-1}) for drip irrigation system	1,09,000	86,000	70,600	---
	a) Life (year)	7	7	7	---
	b) Depreciation	14,013	11,057	9,077	---
	c) Interest @ 10%	10,900	8,600	7,060	---
	d) Repairs & Maintenance @ 2%	2,180	1,720	1,412	---
	e) Total (b + c + d)	27,093	21,377	17,549	---
2.	Cost of cultivation (Rs. ha^{-1})	2,29,017	1,62,445	1,20,567	1,16,426
3.	Total cost of cultivation (1e + 2) (Rs. ha^{-1})	2,56,110	1,83,822	1,38,116	1,16,426
4.	Yield of produce (t ha^{-1})	110.02	91.06	71.80	68.40
5.	Selling price (Rs.t^{-1})	4,500	4,500	4,500	3,000
6.	Income from produce (4 X 5) (Rs.)	4,95,090	4,09,770	3,23,100	2,05,200
7.	Net seasonal income (6 – 3) (Rs.)	2,38,980	2,25,948	1,84,984	88,774
8.	B : C ratio (6/3)	1.93	2.23	2.34	1.76
9.	Water applied (cm)	75.61	75.61	75.61	195.75
10.	WUE (t ha^{-1}-cm)	1.46	1.20	0.95	0.35
11.	Income per cm depth of water applied	3160.69	2988.33	2446.55	453.51

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