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 programmes which are integrated with industry. The Konkan region is charcterised by the red and lateritic soils with steep slope and high annual rainfall. The climate and well-drained soils of this region are favourable for banana crop and there is a vast scope for increasing the area under this crop. 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 economic returns with variable crop periods coupled with the drip irrigation system. 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). It was concluded that the combinations of planting density D_3 (1.75 m x 1.75 m) with I_2 level of irrigation (0.6 Pan Evaporation) and F_3 (120% Recommemded Dose through water soluble fertilisers) level of fertigation is found significantly superior over the other combinations of planting density, irrigation level and fertilizer level.

Key words : Banana, drip irrigation, fertigation, B:C ratio.

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Introduction

Precision farming provides a new solution using a system approach for today's agricultural issues such as the need to balance productivity keeping in view the 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, reducing the energy input and the environmental impact on agriculture.

The term "Precision Farming" or "Precision Agriculture" is capturing the imagination of many people concerned with the production of food and fiber. It offers the promise of increasing productivity, while decreasing production costs and minimizing the environmental impact of farming (NRC 1997, SKY – Farm 1999). 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 2000 - 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.

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 which is grown in about 120 countries.

In India banana is grown on 4.66 lakh hectares with the production of 14.2 million tonnes as against World production of 86 metric tones (Anonymous, 2002). 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 59,700 ha with a production of 3.9 million tonnes (Anonymous, 2002), more than 50% area and production is located in Jalgaon district. The average yield of banana is 30.5 tha^{-1} of the country while it is 65.7 tha^{-1} in Maharashtra. In India, banana ranks first in production and third in area among fruit crops.

Land preparation and planting technique : Precise land preparation and planting technique are the most important components in Banana cultivation. Before plantation, two deep ploughings followed by disc harrowing for clod crushing and ridging with different spacings are necessary. 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 per hectare. 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.

The well drained red and lateritic soils of Konkan, Maharashtra provide a favourable climatic conditions for banana cultivation. Assuming the potential of banana crop for production, the experiment was intended to formulate the complete package for banana with precision in the input parameters to increase its productivity and profitability in Konkan region. The present paper describes the concept of precision farming, and its use in agriculture especially for cultivation of banana crop in lateritic soil (well drained soil and humid climatic conditions) in Konkan , Maharashtra .

Methodology:

Land preparation and planting technique: 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 are necessary. Plantation of Banana was done in pits of size 30 cm x 30 cm x 30 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 per hectare. 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.

Irrigation Management: 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. The treatments included different irrigation levels through drip irrigation system i.e. I_1 = 0.4 PE, I_2 = 0.6 PE and I_3 = 0.8 PE (0.4, 0.6, 0.8 are the integrated factors determined by considering pan factor, crop factor/coefficient, and wetted area); three different fertigation levels i.e. F_1 = 80% of RD using WSF, F_2 = 100% of RD using WSF, F_3 = 120% of RD using WSF through drip irrigation system and three different planting densities i.e. D_1 = 1.25 x 1.25 m, D_2 = 1.50 x 1.50 m, D_3 = 1.75 x 1.75 m. The influence of all these combinations on crop performance was compared with the existing package of practices being adopted by farmers (Recommended package of practices: Crop spacing = 1.5 x 1.5 m; Irrigation = water application through furrow irrigation system with 3 cm depth of water after every 4 days and fertilizer application = Recommended i.e. 200:100:100 NPK gm $plant^{-1}$). The experiment was conducted on *cultivar* G9 with 27 treatment combinations and replicated thrice.

Results and Discussion

Irrigation: Irrigation treatments were incorporated immediately after a week of transplantation (September) and were 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 total amount of water applied to banana under treatments 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 as 118.94 cm.

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

Month	Evaporation	I_1	I_2	I_3	Control
September**	4.64	1.95	2.93	3.91	7.50
October	11.07	4.66	6.99	9.32	23.25
November	12.32	5.19	7.78	10.37	22.50
December	11.52	4.85	7.28	9.70	23.25
January	11.04	4.65	6.97	9.30	23.25
February	12.70	5.35	8.02	10.69	21.00
March	16.60	6.99	10.48	13.98	23.25
April	17.35	7.31	10.96	14.61	22.50
May	17.66	7.44	11.15	14.87	23.25
June*	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.

Growth Parameters : Growth parameters and the yield contributing parameters were taken periodically and 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 tables 2, 4 and 6.

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

Sr. No.	Obser-vations	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	NS	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	NS	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	NS	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	NS	12.4	12.4	12.3	0.006	NS	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	NS	15.2
	8 months	17.2	16.3	17.1	0.328	NS	16.3	17.1*	17.1*	0.165	0.515	16.7	16.6	17.1	0.175	NS	14.9
	10 months	15.2	15.0	16.5	0.270	NS	14.7	15.6*	14.9	0.237	0.729	15.0	14.7	14.4	0.252	NS	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	NS	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	NS	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	NS	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	NS	58.65	59.36	60.62	0.873	NS	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	NS	1.15	1.36**	1.59**	0.018	0.054	1.07
	10 months	1.64	1.81	1.82	0.031	NS	1.77	1.73	1.77	0.017	NS	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	NS	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	NS	350	359	372	7.79	NS	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	96	95	100	2.020	NS	91	101**	99**	2.020	7.917	96	97	99	2.020	NS	73
2.	Yield/plant (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 (T/ha)	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 (qtl/kg)	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	NS	12.82	12.93	13.06	0.065	NS	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	NS	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.	Obser-vations	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*	4.286	N.S.	193.67	185.00	203.33	6.73	NS	211.60
	4 months	259.44**	248.11**	178.00	6.55	18.99	217.11	232.11**	236.33**	6.55	N.S.	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	N.S.	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	N.S.	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	NS	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	NS	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	NS	340	349	362	7.79	N.S.	359

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

Plant height : 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 during the entire season (Table 2 and 4). Out of the three parameters viz. planting density, irrigation and fertigation, the first one appeared as the most prominent. 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) till 8th month and 10th month for the first season and for the ratoon crop, respectively. 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 the first season and ratoon crop and fertigation levels F_2 (100% RD through WSF) and F_3 (120% RD through WSF) produced 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 more fertilizer requirement for banana in lateritic soils of Konkan, Maharashtra.

Stem girth: Growth parameters like number of leaves, stem girth and leaf area were initially influenced by planting density. This effect was, however, nullified later in the growth stages. These parameters were also influenced by the irrigation and fertigation levels throughout the growth period. Stem girth during 10 months was found larger by 21.79% due to decreased planting density (D_3), 22.91% and 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) Stem girth was 12.90%, 9.12% and 9.13% for ratoon crop (Tables 2 and 4). This indicates that plant strength can be influenced more by incorporating the advanced techniques of cultivation to reduce the loss of produce due to breakage/lodging.

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 during the first year, 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 showed the increase of 14.1%, 5.1% and 10.1%, respectively for ratoon crop. With the leaf area increase the photosynthesis of plant is increased to result in better plant health.

Quality parameters: The quality parameters like TSS, girth and length of banana finger were determined to evaluate the effect of treatments (Tables 3 and 5). The TSS and finger girth were significantly increased with increased fertilizer doses, however, the fertigation over 100% RD through WSF did not bring significant effect. The length of finger was found to be significantly influenced by irrigation and fertigation levels. The irrigation treatments I_2 and 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 F_3 (21.37), whereas it was 20.92 and 20.98 in irrigation level I_3 and planting density D_3. The maximum girth of finger was observed in fertigation level F_3 (13.54 cm), whereas it was 12.89 cm and 12.98 cm in D_3 and I_3, respectively. The maximum length of the finger was observed in I_2 (19.88 cm), whereas it was 19.62 cm and 19.77 cm in D_3 and F_3, respectively.

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	104	110	114	2.64	7.67	101	118	110	2.64	7.67	107	109	113	2.64	NS	94
2.	Yield/plant (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	NS	16.40
3.	Yield/ha (T/ha)	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	NS	72.90
4.	Fertilizer use efficiency (qtl/kg)	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	NS	12.50	12.70	12.90	0.065	NS	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	NS	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 biometric parameters of banana at different planting densities, irrigation and fertigation levels(06-07 & 07-08).

Sr. No.	Obser-vations	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*	4.286	N.S.	125.11	120.62	130.65	3.61	N.S.	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	N.S.	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	N.S.	8.37	8.63	8.37	0.14	N.S.	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	N.S.	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	N.S.	18.30	17.49	18.51	0.56	N.S.	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	N.S.	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	N.S.	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	N.S.	379

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

Table 7 : Average yield parameters of banana in different planting densities, irrigation and fertigation levels(2006-07 & 2007-08).

Sr. No.	Obser-vations	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	100	103	108	2.3	7.0	96	110	105	2.3	7.0	102	104	106	2.3	N.S.	84
2.	Yield/plant (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 (T/ha)	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 (qtl/ kg)	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	NS	12.66	12.81	12.98	0.065	NS	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	NS	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

Table 8 : Quantification of micro-climatic parameters in banana plantations 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	

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) 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)	2,29,017	1,62,445	1,20,567	1,16,426
3.	Total cost of cultivation (1e + 2) (Rs./ha)	2,56,110	1,83,822	1,38,116	1,16,426
4.	Yield of produce (t/ha)	110.02	91.06	71.80	68.40
5.	Selling price (Rs./t)	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-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

Number of days to harvest: The number of days required for harvesting was also influenced by planting density D_3 (303) for the first season crop and for the ratoon crop planting density D_3 (296). Therefore, it is clearly indicating that within a period of 20 months it is possible to harvest two crops of banana. It is also observed that the fertilizer levels and irrigation levels could not produce any effect to decrease the days to banana harvest. The results are in close agreement with those of FAO (1997).

Yield per plant and yield per hectare: The yield per plant and per hectare for the first year crop was significantly influenced by the planting densities, fertilizer levels and irrigation levels. Maximum yield per plant (21.08 kg) is achieved with planting type shown in D_3treatment , 17.25 kg with I_2 irrigation level and 17.89 kg with fertigation level of F_2. The highest yield of 101.18 tha is achieved in the planting density of 1.25m x 1.25m (D_1). The maximum yield of 83.08 t/ha^{-1} is 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 is achieved as 63.84 t/ha^{-1} with the traditional method of cultivation. Thus, the yield of banana is increased by 30.12% in lateritic soil by applying the water at 0.60PE through drip irrigation and water soluble fertilizers. The same trends of results are reported in National Horticulture Board report on banana 2007 and by Goenaga *et al.* 1995.

The yield per plant and yield per hectare for ratoon crop was significantly influenced by the planting densities and irrigation levels. Maximum yield per plant (22.91 kg) is achieved with planting type shown in D_3treatment, 22.42 kg with I_2 irrigation level and 21.47 kg with fertigation level of F_3. The highest yield of 118.85 t ha^{-1} is achieved in the planting density of 1.25m X 1.25m (D_1). The maximum yield of 102.77 t ha^{-1} is 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. On the contrary, the maximum yield of banana is achieved as 72.90 t ha^{-1} with the traditional method of cultivation. Thus, the yield of banana is increased by 37.45 % in lateritic soil of Konkan, Maharashtra by applying the water at 0.60PE through drip irrigation and water-soluble fertilizers. These results find support from the observations made by Yuraj & Mahendran (2014).

The average yield per plant and yield per hectare was significantly influenced by the planting densities and irrigation levels. Maximum yield per plant (21.99 kg) is achieved with planting type shown in D_3treatment, 19.74 kg with I_2 irrigation level and 19.28 kg with fertigation level of F_3. The highest yield of 110.02 t/ha is achieved in the planting density of 1.25m X 1.25m (D_1). The maximum yield of 89.85 t/ha is fetched with 0.60PE irrigation level and the yield of 89.14 t/ha is obtained with 120% RD through application of water-soluble fertilizers. On the contrary, the average maximum yield of banana is achieved as 68.4 t/ha with the traditional method of cultivation. Thus, the yield of banana is increased by 30.84% in lateritic soil by applying the water at 0.60 PE through drip irrigation and water-soluble fertilizers. The results obtained are in close agreement with others (Patil *et al.* 2010; Ahmed *et al.* 2006).

Fertilizer use efficiency: The fertilizer use efficiency is achieved about 0.48 qtl kg^{-1} for ratoon crop and average of 0.46 qtl kg^{-1} by decreasing planting density (D_3), while with application of 0.60PE irrigation level it was 0.59 qtl ha^{-1} for ratoon and 0.51 qtl ha^{-1} on an average. The average of 0.39 qtl kg^{-1} fertilizer use efficiency was reported in the traditional method of cultivation. This suggests that the modified irrigation technique shown in this study can increase fertilizer use efficiency (Prajapati *et al.* 2013).

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 rain. The effect during morning, noon and evening are presented in figure 1 to 3.

Light intensity: The light intensity in the wide spaced banana (treatment D_3) was highest as compared to the other planting densities during morning, noon and evening throughout the observation period due to more open area provided in this treatment. 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 and 1.5m x 1.5m was quite more as compared to the control treatment. This might be the significant effect of the irrigation system. In treatment D_1 and 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.

Temperature: The temperature between the rows of 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.

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.

Quantification of micro-climatic parameters: To see the overall effect of planting density on micro-climate, the parameters were averaged for the observation period. The per cent fluctuation of these parameters due to planting density over ambient condition were determined (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 percent. This increase was very prominent during the noon period.

Cost economics: The detail cost economics for banana crop is 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^{-1}. 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 per unit 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 D1 (1.25 m x 1.25 m) i.e. Rs. 23.89 m^{-2}.

Conclusions:

Precision farming practices can be used on small farms as well as big ones, and they play a core role in rural development programmes. Konkan region's climate and well-drained soils are favourable for banana crop and there is a vast scope for increasing the area under this crop. It was concluded that the combinations of planting density D_3 (1.75 m x 1.75 m) with I_2 level of irrigation (0.6 Pan Evaporation) and F_3 (120% Recommemded dose through water soluble fertilisers) level of fertigation could be adopted for planting density, irrigation level, fertilizer level and maximum of BC ratio.

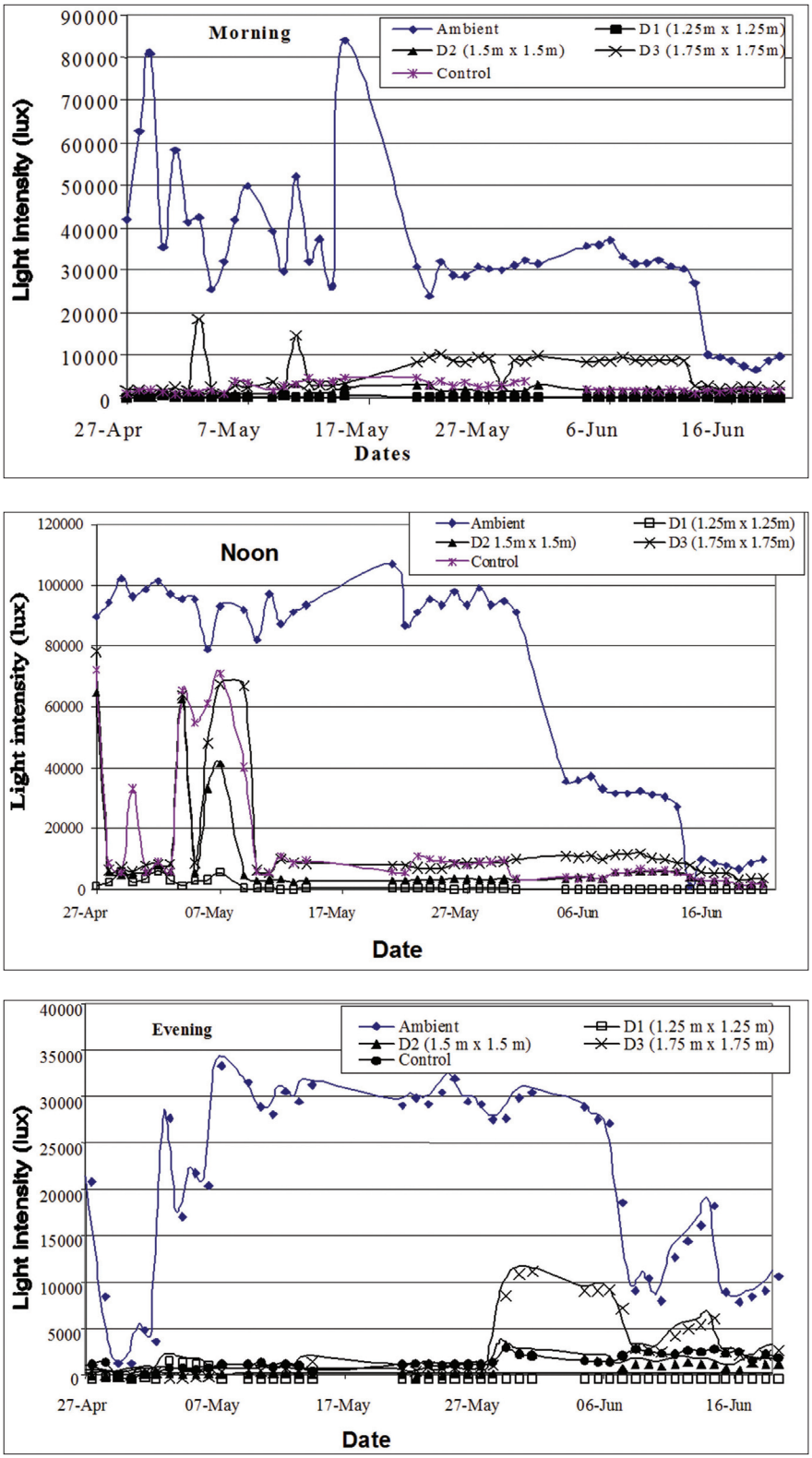

Fig. 1 : Light intensity in banana during morning, noon and evening

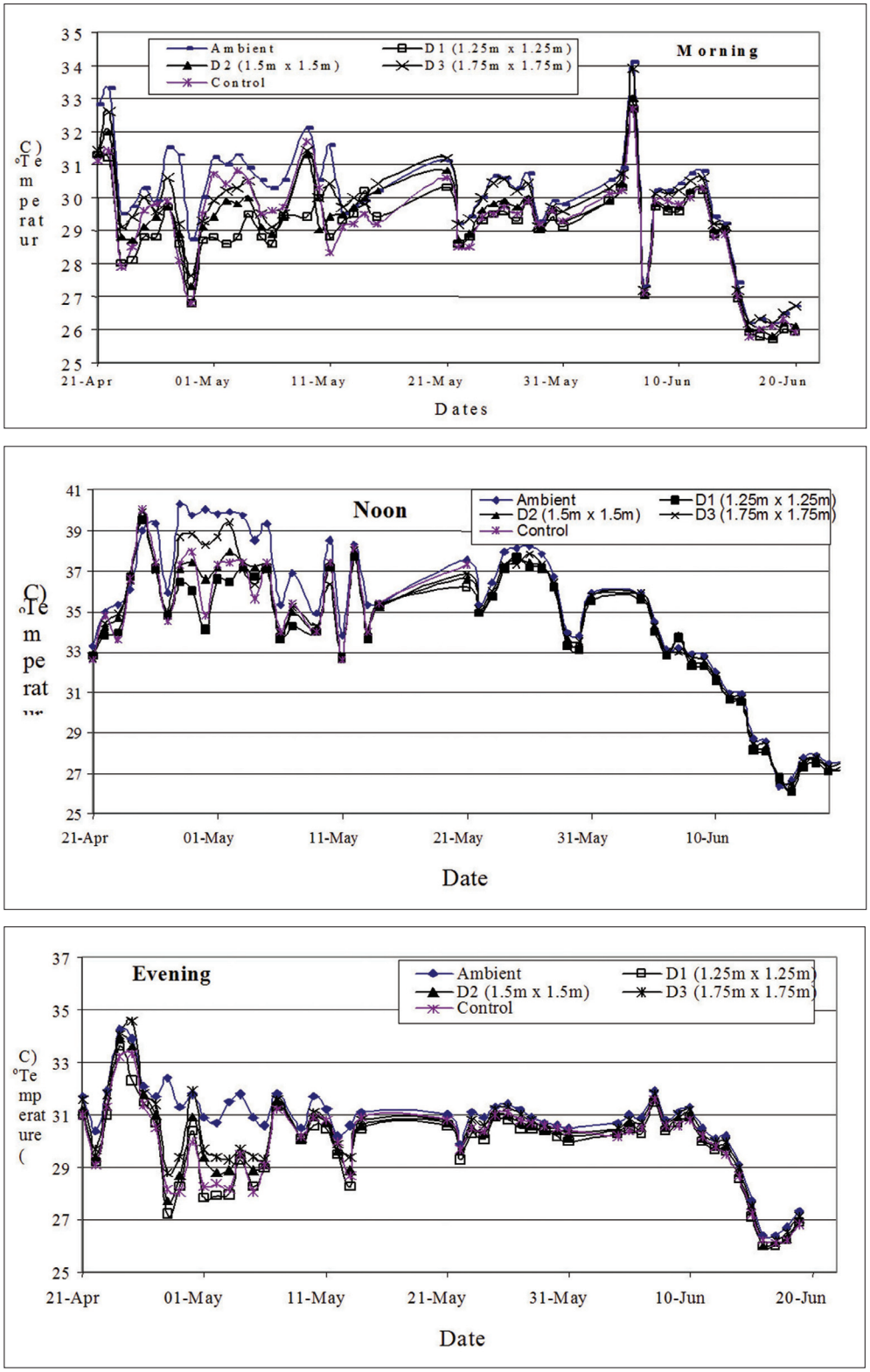

Fig. 2 : Temperature in banana during morning, noon and evening

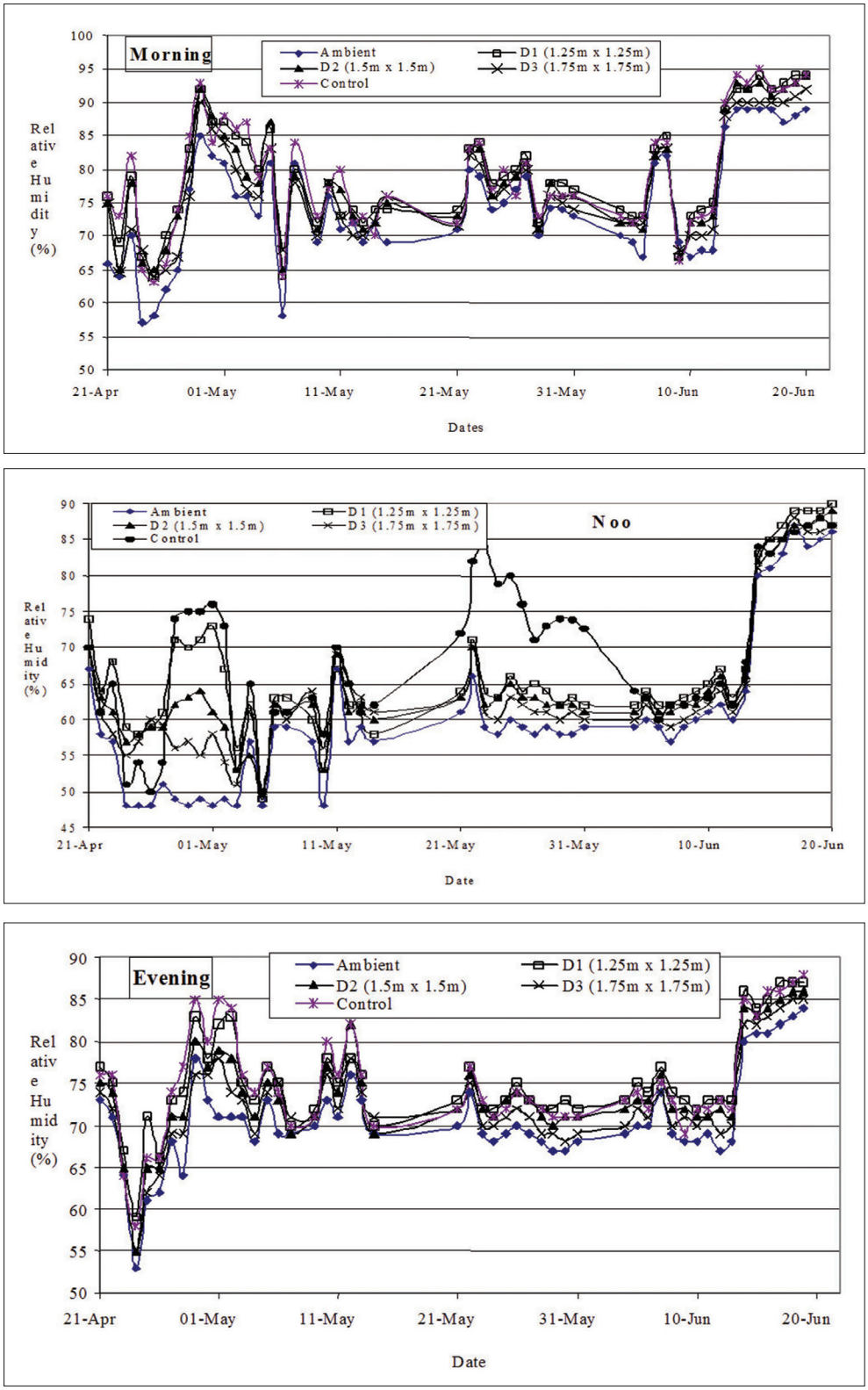

Fig. 3 : Relative humidity in banana during morning, noon and evening

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