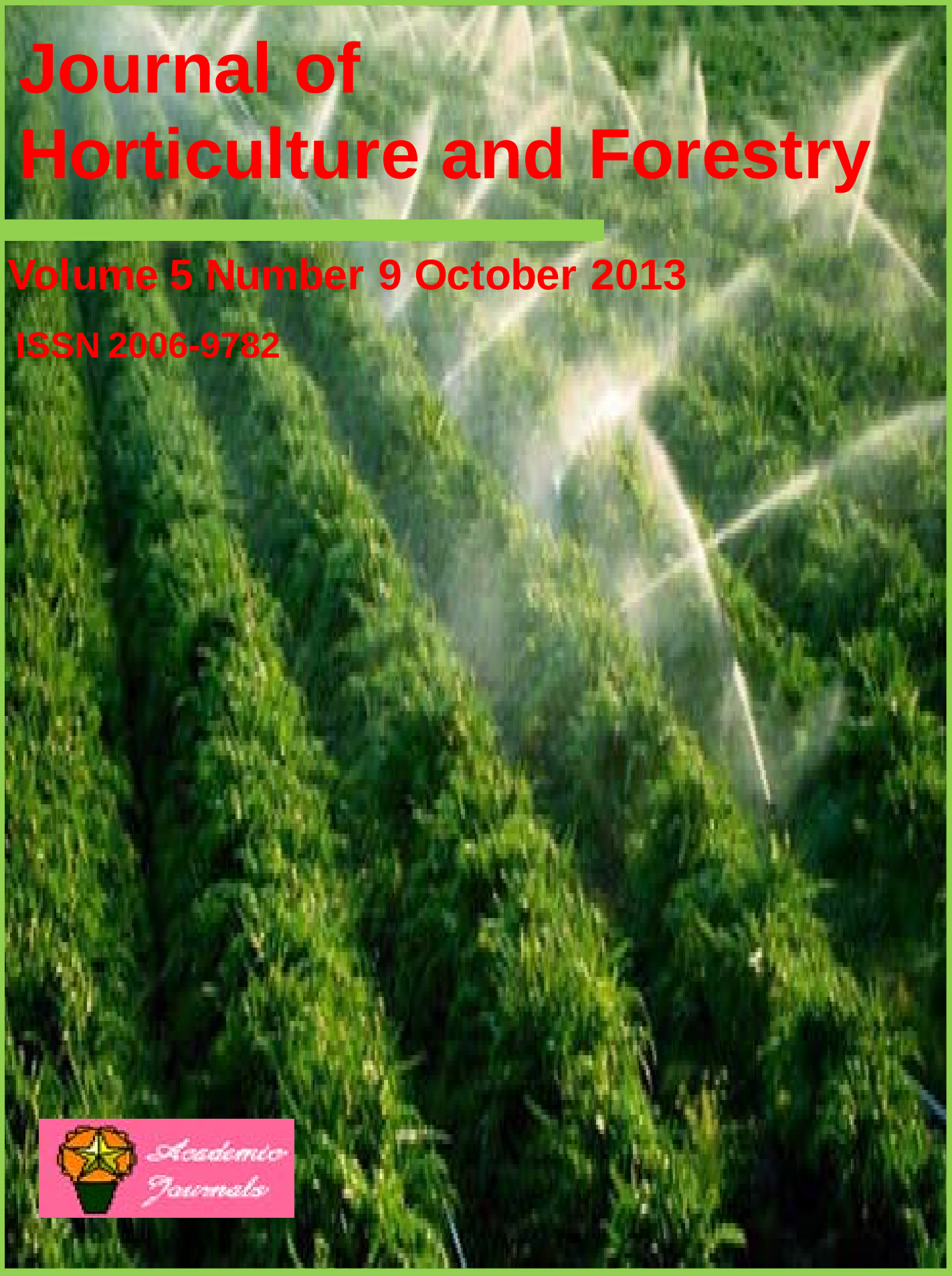

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Journal of Horticulture and Forestry

Full Length Research Paper

Studies on integrated nutrient management on growth and yield of banana cv. Ardhapuri (*Musa* AAA)

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Accepted 29 July, 2013

A field experiment was laid out in a randomized block design with 10 treatments and 3 replications consisting of recommended dose of fertilizers (RDF) and RDF was combined with organic manures and biofertilizers [Vesicular-arbuscular mycorrhizae (VAM), *azotobacter,* and Phosphate solubilising bacterial (PSB)] at different combinations to know their effect on growth and yield of banana. The vegetative growth parameters which are, plant height, plant girth, number of leaves per plant, leaf area and crop duration were influenced significantly due to different treatments. The maximum plant height (190.84 cm) and plant girth (81.34 cm) were recorded in treatment 50% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant) while the maximum leaves (32.30) per plant and leaf area (17.93 m^2) were recorded in Treatment T_3. The minimum number of days (211.03) for shooting after planting and number of days for harvesting after shooting (117.46) were recorded with 50% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *G. fasciculatum* (250 g/plant). Similarly, the yield parameters that is, bunch weight (19.31 kg) and per hectare (85.80 t/ha) were recorded in Treatment T_3. The application of 50% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *G. fasciculatum* (250 g/plant) was found beneficial for growth and yield of banana cv. Ardhapuri.

Key words: Banana, organic manures, shooting, biofertilizers.

INTRODUCTION

Banana (*Musa* spp.) is one of the most important staple foods in the globe. It is known for its antiquity and is interwoven with Indian heritage and culture. The plants are considered as the symbol of prosperity and fertility. In India, banana is the second largest growing fruit crop next to mango and the leading producer in the world contributes more than 20% of global production. Banana requires high amount of mineral nutrients for proper growth and production. One tone of banana requires 7 to 8 kg of Nitrogen (N), 0.7 to 1.5 kg of Phosphorous (P) and 17 to 20 kg of Potassium (K) (Anonymous, 2004). These nutrients must be replenished every year through different nutrient sources including organic manures, mineral fertilizers as well as bio-fertilizers in order to maintain soil fertility and to permit continuous production.

A thorough knowledge of the critical levels of different nutrient elements, time and method of application of nutrients is essential to get better growth, yields, and also to maintain optimum nutrient balancing, a prerequisite enhancing nutrient use efficiency (Basagarahally, 1996). In this scenario, efficient nutrient management plays an important role to better production of banana (Mustaffa et al., 2009a). Beneficial microbes increase nutrient availability, reduce disease, reduce nutrient losses, and help degrade toxic compounds (Subba, 1998). The present experiment was planned as an attempt in this direction.

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MATERIALS AND METHODS

The present investigation was carried out at farmer's field of Shri. Kalyan Kaldate of Bramangaon village, taluka Parbhani, during 2010 to 2011 and 2011 to 2012 entitled, "Studies on Integrated Nutrient Management in banana cv. Ardhapuri (*Musa* aaa)". The different treatment manipulated as follows: T_0 - 100% recommended dose of NPK (RDF) + FYM (Control), T_1-100% RDF + FYM + *Azotobacter* (50 g/plant) + Phosphate solubilising bacterial (PSB) (50 g/plant) + Vesicular-arbuscular mycorrhizae (VAM) *Glomus fasciculatum* (250 g/plant), T_2 - 75% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *G. fasciculatum* (250 g/plant), T_3 - 50% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *G. fasciculatum* (250 g/plant), T_4 - 100% RDF + FYM + *Azotobacter* (50 g/plant), T_5 - 100% RDF + FYM + PSB (50 g/plant) + VAM *G. fasciculatum* (250 g/plant), T_6 - 75% RD of N + 100% RD of PK + FYM + *Azotobacter* (50 g/plant), T_7 - 75% RD of N + 100% RD of PK + FYM + PSB (50 g/ plant) + VAM *G. fasciculatum* (250 g/plant), T_8 - 50% RD of N + 100% RD of PK + FYM + *Azotobacter* (50 g/plant), T_9 - 50% RD of N + 100% RD of PK + FYM + PSB (50 g/plant) + VAM *G. fasciculatum* (250 g/plant). The treatments were arranged in a randomized block design with 10 treatments in 3 replications. The required dose of organic and inorganic manures and biofertilizers as VAM, *azotobacter* and PSB was calculated and applied in 3 split doses at the 2nd, 4th, and 6th month after planting as per the treatments. The recommended dose of fertilizers followed for the experiment consisted of 200 g N, 160 g P_2O_5, and 200 g K_2O per plant (Anonymous, 2013).

RESULTS AND DISCUSSION

Growth parameters

Plant height (cm)

From the data given in the Table 1 it is revealed that, among the growth parameters, the maximum plant heights (127.48 cm) at 120 Days after planting (DAP) was observed in 100% RDF + FYM. The treatment receiving 50% RD of N + 100% RD of PK + FYM + PSB (50 g/plant) + VAM *G. fasciculatum* (250 g/plant) recorded maximum plant height of 156.99, 175.67, 187.76, and 190.84 cm, respectively at 150, 180, 210 DAP and at shooting stage. The increase in plant height could be attributed to the higher uptake of nutrients, particularly nitrogen. This fact is supported by the works of Pafli (1965) that the uptake of N, the chief constituent of chlorophyll, protein and amino acids is accelerated through its increased supply at appropriate time to the plants.

Plant girth (cm)

The data revealed that, plant girth was found to be non-significant at 60 and 90 DAP. The significantly maximum plant girth (52.56, 60.82, 68.20, 76.46 and 81.34 cm) respectively at 120, 150, 180, 210 DAP and at the shooting stage (Table 2) was recorded in Treatment T_3 containing 50% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *G. fasciculatum* (250 g/plant) and it was significantly superior over rest of the treatments. The minimum plant girth was recorded under control treatment. The beneficial response of biofertilisers on plant girth might be due to the accumulation of poly hydroxybutyric acid which gives rise to vegetative cells. Pigment production is one of the important characteristics of *Azotobacter sps.* These strains are also known to produce growth substances (Mohandas, 1996).

Number of leaves per plant

The data at 60 and 90 DAP produced non-significant results (Table 3). Maximum number of leaves per plant (20.73) was produced by the plant treated with 50% RD of N + 100% RD of PK + FYM + PSB (50 g/plant) + VAM *G. fasciculatum* (250 g/plant) after 120 DAP. However, at 150,180, and 210 DAP and at shooting stage, the Treatment T_3 produced maximum number of leaves (23.57, 25.90, 30.63, and 32.30, respectively) per plant. Minimum number of leaves per plant was recorded in control. The increase in number of leaves might be due to the higher vegetative growth of VAM treated plants which may be due to the growth promotory effect of VAM that improves the phosphorus availability and thereby causing higher protein synthesis resulting in more morphological growth. The VAM compensations at reduced P application were very much effective in increasing the number of total leaves per plant. The number of leaves was managed at lower fertility (Singh and Singh, 2004).

Leaf area (cm^2)

The maximum leaf area (2.65, 7.31, 10.73, 11.93, 14.23, 17.79, and 17.93 cm^2 at 60, 90, 120, 150, 180, 210 DAP and at shooting stage, respectively) (Table 4) was recorded in Treatment T_3 containing 50% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *G. fasciculatum* (250 g/plant) and it was significantly superior over rest of the treatments. While significantly minimum leaf area was recorded in control. Increase in leaf area at any stages of growth is very critical in banana as it has a close bearing on photosynthetic efficiency which in turn influences the biomass production. Greater leaf area aids the plant to synthesize more metabolites, exhibiting high photosynthetic rate during the period of growth and development (Mahadevan, 1988).

Crop duration (days)

The early shooting, harvesting and total crop duration were recorded in Treatment T_3, which received 50% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *G. fasciculatum* (250 g/plant) (Table 5). It

Table 1. Effect of different treatments on plant height (cm) of banana cv. Ardhapuri at different days after planting (Pooled)**.**

Treatment no.	Treatment	Plant height (cm)						
		60 DAP	90 DAP	120 DAP	150 DAP	180 DAP	210 DAP	At shooting stage
T_0	100% Recommended dose of NPK (RDF) + FYM (control)	56.33	99.43	127.48	132.61	146.66	157.34	161.11
T_1	100% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	58.79	99.64	122.13	138.81	151.28	166.92	170.14
T_2	75% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/ plant) + VAM *Glomus fasciculatum* (250 g/plant)	53.25	98.73	124.68	152.44	166.11	178.97	182.47
T_3	50% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	53.89	98.33	121.50	156.99	175.67	187.76	190.84
T_4	100% RDF + FYM + *Azotobacter* (50 g/plant)	54.21	97.49	119.51	143.13	156.86	168.29	171.64
T_5	100% RDF + FYM + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	53.18	98.64	119.29	137.35	150.87	166.89	170.39
T_6	75% RD of N + 100% RD of PK + FYM + *Azotobacter* (50 g/plant)	54.50	97.76	119.64	147.66	161.67	173.45	181.14
T_7	75% RD of N + 100% RD of PK + FYM + PSB (50 g/ plant) + VAM *Glomus fasciculatum* (250 g/plant)	56.55	99.73	120.70	147.17	157.25	170.96	176.36
T_8	50% RD of N + 100% RD of PK + FYM + *Azotobacter* (50 g/plant)	53.20	99.44	120.50	150.53	161.62	176.57	181.67
T_9	50% RD of N + 100% RD of PK + FYM + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	57.27	100.66	126.28	142.63	152.79	166.81	171.63
	S.E. ±	0.91	0.80	0.75	0.83	0.70	1.12	0.51
	C.D. at 5%	NS	NS	2.16	2.39	2.02	3.23	1.48

RDF-Recommended dose of fertilizer, DAP-Days after planting, PSB-Phosphate solublising bacteria, VAM-Vesicular arbuscular mycorrhizae, NS-Non significant.

was observed that, minimum days required for shooting and (211.03 and 117.46 days) was recorded in the Treatment T_3, all the treatments were significantly superior over control which recorded maximum days (246.13 and 134.98 days), respectively for shooting after planting.

Table 2. Effect of different treatments on plant girth (cm) of banana cv. Ardhapuri at different days after planting (Pooled).

Treatment no.	Treatment	Plant girth (cm)						
		60 DAP	90 DAP	120 DAP	150 DAP	180 DAP	210 DAP	At shooting stage
T_0	100% Recommended dose of NPK (RDF) + FYM (control)	25.37	36.07	39.30	46.13	52.70	62.67	66.82
T_1	100% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/ plant)	25.26	37.35	45.95	52.49	58.71	69.57	74.47
T_2	75% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	25.34	37.78	50.96	57.84	66.32	74.74	80.20
T_3	50% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	25.54	38.66	52.56	60.82	68.20	76.46	81.34
T_4	100% RDF + FYM + *Azotobacter* (50 g/plant)	24.14	35.57	48.04	53.60	57.52	71.40	78.19
T_5	100% RDF + FYM + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	24.45	36.48	44.12	51.20	59.59	70.43	73.27
T_6	75% RD of N + 100% RD of PK + FYM + *Azotobacter* (50 g/plant)	23.82	35.90	48.45	56.22	65.95	72.68	79.44
T_7	75% RD of N + 100% RD of PK + FYM + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	25.54	37.80	48.32	54.57	59.91	71.31	79.53
T_8	50% RD of N + 100% RD of PK + FYM + *Azotobacter* (50 g/plant)	23.57	36.93	48.63	56.68	66.32	73.41	79.64
T_9	50% RD of N + 100% RD of PK + FYM + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	22.78	37.70	46.86	52.87	65.17	70.36	77.42
	S.E. ±	0.73	0.83	0.69	0.51	0.76	0.55	0.33
	C.D. at 5%	NS	NS	2.21	1.48	2.19	1.57	0.96

RDF- Recommended dose of fertilizer, DAP- Days after planting, PSB- Phosphate solublising bacteria, VAM- Vesicular arbuscular mycorrhizae, NS- Non significant.

Similarly, minimum total days required (328.49 days) were recorded in the Treatment T_3, which was statistically at par with Treatment T_2 (345.25 days). It was found that, the untreated control recorded maximum total crop duration (381.12 days) as a consequence of improved vegetative growth and high photosynthetic rate and CO_2 fixation.

The shooting (flowering) process is greatly

Table 3. Effect of different treatments on number of leaves per plant of banana cv. Ardhapuri at different days after planting (Pooled).

Treatment no.	Treatment	Number of leaves per plant						
		60 DAP	90 DAP	120 DAP	150 DAP	180 DAP	210 DAP	At shooting stage
T_0	100% Recommended dose of NPK (RDF) + FYM (control)	11.87	14.13	17.07	19.93	22.27	25.63	26.90
T_1	100% RDF + FYM + *Azotobacter* (50 g/ plant) + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	12.10	14.70	19.67	22.70	24.00	25.87	28.23
T_2	75% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	12.60	14.93	20.57	23.23	25.97	30.13	31.57
T_3	50% RDF + FYM + *Azotobacter* (50 g/ plant) + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	13.35	15.40	20.70	23.57	25.90	30.63	32.30
T_4	100% RDF + FYM + *Azotobacter* (50 g/ plant)	11.93	14.63	17.90	21.20	23.00	25.93	27.07
T_5	100% RDF + FYM + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	12.27	14.97	20.03	22.73	24.17	25.77	27.73
T_6	75% RD of N + 100% RD of PK + FYM + *Azotobacter* (50 g/plant)	12.07	14.70	19.73	22.00	25.17	26.60	29.47
T_7	75% RD of N + 100% RD of PK + FYM + PSB (50 g/ plant) + VAM *Glomus fasciculatum* (250 g/plant)	12.43	14.90	20.57	22.90	24.30	25.77	28.83
T_8	50% RD of N + 100% RD of PK + FYM + *Azotobacter* (50 g/plant)	12.00	14.30	17.97	20.90	25.13	29.10	30.93
T_9	50% RD of N + 100% RD of PK + FYM + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	12.17	15.40	20.73	23.53	24.47	26.13	28.93
	S.E. ±	0.40	0.47	0.31	0.31	0.25	0.39	0.43
	C.D. at 5%	NS	NS	0.90	0.89	0.73	1.12	1.24

RDF-Recommended dose of fertilizer, DAP-Days after planting, PSB-Phosphate solublising bacteria, VAM-Vesicular arbuscular mycorrhizae, NS-Non significant.

affected by the changed hormonal levels, that is, higher growth promoter/inhibitor ratio resulting in flower induction. Early flowering with higher number of flowers in mycorrhizal plants is dependent upon the genotype/workers through which mycorrhizal plants enter into the reproductive

Table 4. Effect of different treatments on Leaf area (m^2) of banana cv. Ardhapuri at different days after planting (Pooled).

Treatment no.	Treatment	Leaf area (m^2)						
		60 DAP	90 DAP	120 DAP	150 DAP	180 DAP	210 DAP	At shooting stage
T_0	100% recommended dose of NPK (RDF) + FYM (control)	1.88	5.69	8.22	9.93	10.98	13.86	14.06
T_1	100% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/ plant)	2.13	5.76	9.14	10.51	11.46	14.33	14.66
T_2	75% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/ plant)	2.59	7.07	9.30	11.64	13.36	17.60	17.73
T_3	50% RDF + FYM + *Azotobacter* (50 g/ plant) + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	2.65	7.31	10.73	11.93	14.23	17.79	17.93
T_4	100% RDF + FYM + *Azotobacter* (50 g/plant)	2.19	6.18	9.85	11.27	12.04	16.08	16.13
T_5	100% RDF + FYM + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/ plant)	1.92	5.71	8.87	10.18	11.46	14.06	14.43
T_6	75% RD of N + 100% RD of PK + FYM + *Azotobacter* (50 g/plant)	2.36	6.55	10.70	11.61	12.23	16.48	16.56
T_7	75% RD of N + 100% RD of PK + FYM + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	2.29	6.24	9.81	11.62	12.28	15.93	16.46
T_8	50% RD of N + 100% RD of PK + FYM + *Azotobacter* (50 g/plant)	2.49	6.80	10.76	11.68	12.24	16.76	16.81
T_9	50% RD of N + 100% RD of PK + FYM + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	2.18	6.13	9.76	10.75	11.70	15.13	15.24
	S.E. ±	0.03	0.05	0.17	0.15	0.17	0.15	0.14
	C.D. at 5%	0.08	0.13	0.50	0.42	0.56	0.43	0.41

RDF-Recommended dose of fertilizer, DAP-Days after planting, PSB-Phosphate solublising bacteria, VAM-Vesicular arbuscular mycorrhizae

Table 5. Effect of different treatments on crop duration of banana cv. Ardhapuri (Pooled).

Treatment no.	Treatment	Days for shooting after planting	Days to harvest after shooting	Total crop duration
T_0	100% recommended dose of NPK (RDF) + FYM (control)	246.13	134.98	381.12
T_1	100% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	243.10	124.07	367.17
T_2	75% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	224.05	121.20	345.25
T_3	50% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/ plant) + VAM *Glomus fasciculatum* (250 g/ plant)	211.03	117.46	328.49
T_4	100% RDF + FYM + *Azotobacter* (50 g/plant)	240.67	122.70	363.37
T_5	100% RDF + FYM + PSB (50 g/ plant) + VAM *Glomus fasciculatum* (250 g/plant)	245.30	123.90	369.20
T_6	75% RD of N + 100% RD of PK + FYM + *Azotobacter* (50 g/plant)	236.10	128.07	364.17
T_7	75% RD of N + 100% RD of PK + FYM + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	238.60	134.30	372.90
T_8	50% RD of N + 100% RD of PK + FYM + *Azotobacter* (50 g/plant)	235.00	129.17	364.17
T_9	50% RD of N + 100% RD of PK + FYM + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	239.90	125.67	365.57
	S.E. ±	1.90	1.70	2.42
	C.D. at 5%	5.46	5.42	6.93

RDF-Recommended dose of fertilizer, PSB-Phosphate solublising bacteria, VAM-Vesicular arbuscular mycorrhizae.

Table 6. Effect of different treatments on yield parameters of banana cv. Ardhapuri (Pooled).

Treatment no.	Treatment	Weight of bunch (kg)	Yield (t/ha)
T_0	100% recommended dose of NPK (RDF) + FYM (control)	10.64	47.30
T_1	100% RDF + FYM + *Azotobacter* (50 g/ plant) + PSB (50 g/ plant) + VAM *Glomus fasciculatum* (250 g/plant)	13.49	59.96
T_2	75% RDF + FYM + *Azotobacter* (50 g/ plant) + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/ plant)	18.08	80.35
T_3	50% RDF + FYM + *Azotobacter* (50 g/ plant)+ PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/ plant)	19.31	85.80
T_4	100% RDF + FYM + *Azotobacter* (50 g/plant)	12.66	56.25
T_5	100% RDF + FYM + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/ plant)	12.96	57.59
T_6	75% RD of N + 100% RD of PK + FYM + *Azotobacter* (50 g/plant)	12.48	55.45
T_7	75% RD of N + 100% RD of PK + FYM + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant)	15.57	69.19
T_8	50% RD of N + 100% RD of PK + FYM + *Azotobacter* (50 g/plant)	12.25	54.43
T_9	50% RD of N + 100% RD of PK + FYM + PSB (50 g/ plant) + VAM *Glomus fasciculatum* (250 g/plant)	14.18	63.03
	S.E. ±	0.47	2.08
	C.D. at 5%	1.35	5.98

RDF-Recommended dose of fertilizer, PSB-Phosphate solublising bacteria, VAM-Vesicular arbuscular mycorrhizae.

phase early because of the increased P nutrition and greater development of water conducting tissues (Chang, 1992).

Yield parameters

Weight of bunch (kg)

The highest weight of bunch (19.31 kg) was significantly recorded in (Table 6) Treatment T_3 containing 50% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *G. fasciculatum* (250 g/plant). This was obviously due to thevigorous plant growth character. In these treatments, increased number of leaves might have increased the photosynthetic activity resulting in higher accumulation of carbohydrates. Relatively higher amount of carbohydrate could have promoted the growth rate and in turn increased the weight of bunch. This was in accordance with the result of Hazarika and Ansari (2010).

The applied N, P, K and biofertilizers were utilized efficiently by the plant, which resulted in producing maximum photosynthates in terms of high biomass and translocating the assimilated material to the developing sink resulting in heavier weight of bunch. N is the chief constituent of chlorophyll. Protein and amino acids, the synthesis of which is accelerated through increased supply of N (Pafli, 1965; Mahadevan, 1988).

Yield per hectare (tones)

The maximum yield (85.80 t/ha) was noticed in (Table 6) Treatment T_3 containing 50% RDF + FYM + *Azotobacter*

(50 g/plant) + PSB (50 g/plant) + VAM *G. fasciculatum* (250 g/plant) which may be due to the maximum weight of bunch registered in that plot. Increase in yield in Treatment (T_3) could be attributed to the increase in morphological traits and also higher nutrient uptake by the plants. This is in confirmation with the findings of Agrawal et al. (1997) and Shakila (2000). Krishnan and Shanmugavelu (1979) found that, plants with thicker pseudostem are desirable as they reflect on bunch size and other related characters. Banana being an exhaustive crop, availability of more nutrients through the inorganic source might have helped to get better weight of bunch *vis a vis* yield per hectare (Athani et al., 1999).

Conclusion

The application of 50% RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *G. fasciculatum* (250 g/plant) was found beneficial for growth and yield of banana cv. Ardhapuri.

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Full Length Research Paper

Identification of the effect of different levels of activated charcoal and sucrose on multiplication shoots of date palm phenixdactylifera L.C.v. sufedy *in vitro*

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This study was conducted at the Laboratory of Plant Tissue Culture of the Palm Research Center / University of Basra from March 2010 to September 2011. The aim is to determine the effect of the use of activated charcoal and sucrose on the multiplication of shoots, rate of elongation, average number of roots and length of plantlets of date palms C.v Elsafada *in vitro*. Activated charcoal concentrations were zero, 0.5, 0.75, 1, and 1.25 g/l. Those of sucrose were 20 (control), 35, 50, 65, and 80 (g/l). Nutritional media were prepared with some other chemical substances as well as 3 mg/l Naphthalene acetic and 10 mg/l 2-Isopentenyl adenine (2iP). Transplants were incubated under illumination intensity lighting of 1000 Lux for 16 h a day and a temperature of 27 ± 1°C. A re-culture was done every four weeks. The use of 0.75 g/l of activated charcoal caused a significant improvement in the percentages of shoots multiplication (9.6%), rate of elongation (7.3 cm), number of roots (4.6 root/plantlets) and their length. However, the 0.5 concentration exceeded others in root length (5.3 cm). Use of 65 g/l sucrose increased the multiplication ratio (5.3%), elongation (7 cm) and number of roots (4.6 root/plantlet). While use of 80 g/l led to higher length of roots (5.8 cm) compared to the other concentrations. Results also showed that the use of 0.5 g/l activated charcoal and 65 g/l sucrose improved the multiplication ratio (9.2%), elongation (8.1 cm) and average number of roots (5.3 root/plantlet). Furthermore, the treatment of 0.75 g/l activated charcoal and 65 g/l sucrose significantly increased the average of root length (6.9 cm) compared to other treatments.

Key words: Date palm, elongation, activated charcoal.

INTRODUCTION

Tissue culture is a very important modern technology, which concentrates on planting various tissues of plants' parts. To obtain many plants genetically identical to the mother plant (AL-Maarri and Al-Ghamdi, 1998), propagation of date palm offshoots was done either by organogenesis from the shoot tip and auxiliary buds, or by configuring somatic embryogenesis during callus phase which makes embryos through the cultivation of plant tissues on industrial sterile nutritional medium (Abhman et al., 2001).

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Table 1. Concentrations of additives to the Nutritional media for the emergence of lateral shoots.

Quality (g/L)	Substrate
0.17	Sodium hydrogen ortho phosphates
0.1	Meso inositol
0.04	Adenine sulphates
0	Thiamine-Hcl
0	Biotin
0	Nicotine amide
6	Agar
0	NAA
0.01	2iP

The presence of activated charcoal in the nutritional medium balances plants' growth regulators and other materials inside the nutritional medium; it also helps to stimulate tissue cultivated, differentiated and modified (Zaid, 1993). The use of sucrose as an energy source has been indicated by many researchers who have obtained good response from plant parts cultivated from date palm *in vitro* (Rhiss et al., 1979; Omar et al., 1992).

The addition of sucrose is essential to the nutritional media as a source of carbon to all plant tissue cultivated including leaves of plantlets (Badr, 1982). Al-Maarri and Ghamdi (1997) stated that an increase in sucrose in the media of five cultivars of date palm from 30 to 70 g/L led to an increase in the proportion of plantlets' root to 90%. Al- Maarri and Alghamdi (1998) concluded that raising the proportion of sucrose led to an increase in the proportion of the side shoots from the tip developing on MS medium. They found that 60 g/L of sucrose increased the rate of the lateral buds and developed multiple buds from the tip compared to 30 g/L. However, Hamid (2001) found that using 45 g/L of sucrose has significantly affected the stimulation of elongation of buds from shoot tip of Maktoum cultivar. Taha et al. (2001) found in their study of the date palm, that addition of 40 g/L sucrose increased lengths of plantlets significantly like that of 30 g/l and also improved the number of leaves per plantlet.

The aim of this study is to investigate the effect of adding different levels of activated charcoal and sucrose on shoot multiplication, rate of elongation, number of roots and length of date palm plantlet *in vitro*.

MATERIALS AND METHODS

Preparation of nutritional medium

The nutritional medium consists of a group of inorganic salts described by Murashige and Skoog (1962) and known as MS salts. It was prepared in the form of salt stock solution, which consists of five groups. Stock solution was prepared by weighting element of each group separately and dissolved in volumetric flask capacity of 150 cm^3. Each volumetric flask contains 50 cm^3 of distilled water. For the purpose of preparing ten liters , elements of each group were multiplied by 10, weighed and dissolved in distilled water; the volume was completed to 100 cm^3 and kept in the refrigerator.

Stimulating multiplication, elongation and root of shoots

For the purpose of stimulating multiplication, elongation and root of shoots resulting from lateral shoots, the following experiments were made:

1. Activated charcoal was added to the nutritional medium and led to different concentrations: 0, 0.5, 0.75, 1 and 1.25 g/L. Nutritional media contain materials listed in Table 1 plus sucrose concentration of 30 g/L,
2. After selecting the appropriate concentration of the activated charcoal, the different concentrations of sucrose (20, 35, 50, 65 and 80 g/l) was added to the media in Table 1,
3. After determining the best concentrations of each activated charcoal and sucrose, their interaction effect was studied.

Test tube size of 2.5 x 18 cm was used; it contained 20 ml of nutritional media and set at PH of 5.7. Experiment included planting lateral bud (ten replicates per treatment). Transplant was incubated at a temperature of 27 ± 1°C under the intensity of 1000 lux illumination for 16 h a day. Replanting was done every four weeks.

Statistical analysis

Each experiment was carried out separately in a simple experiment by completely randomized design (CRD) either in one or two way experiment. Significant difference among treatment means was done by using Revised Least Significant Differences Test (RLSD), at a significant level of 5% (Alrawy and Khalaf Allah, 1980).

RESULTS AND DISCUSSION

Percentage of multiplication, the rate of elongation and root of shoots

Results shown in Table 2 revealed that the addition of activated charcoal to the nutritional media helped to raise the percentage of multiplication shoots consisting of lateral buds of date palms cultivar Elsofydi. Adding 0.75 g/L concentration gave the highest proportion of

Table 2. Effect of different concentrations of activated charcoal on the percentage of multiplication and the rate of elongation and rooting shoots resulting from lateral shoots.

% vegetative shoots	Root length (cm)	No. of root/plantlets	Rate of elongation (cm)	Concentration of activated charcoal (g/l)
2.3^{d}	1.6^{c}	2.6^{b}	2.9^{c}	Zero
7.6^{b}	5.3^{a}	4.3^{a}	6.9^{a}	0.5
9.6^{a}	4.3^{b}	4.6^{a}	7.3^{a}	0.75
3.6^{c}	2.6^{d}	0.7^{c}	5.3^{b}	1
2.3^{d}	2.3^{d}	0.4^{c}	3.3^{c}	1.25

Different letters denote significant differences at the 0.05 level of probability.

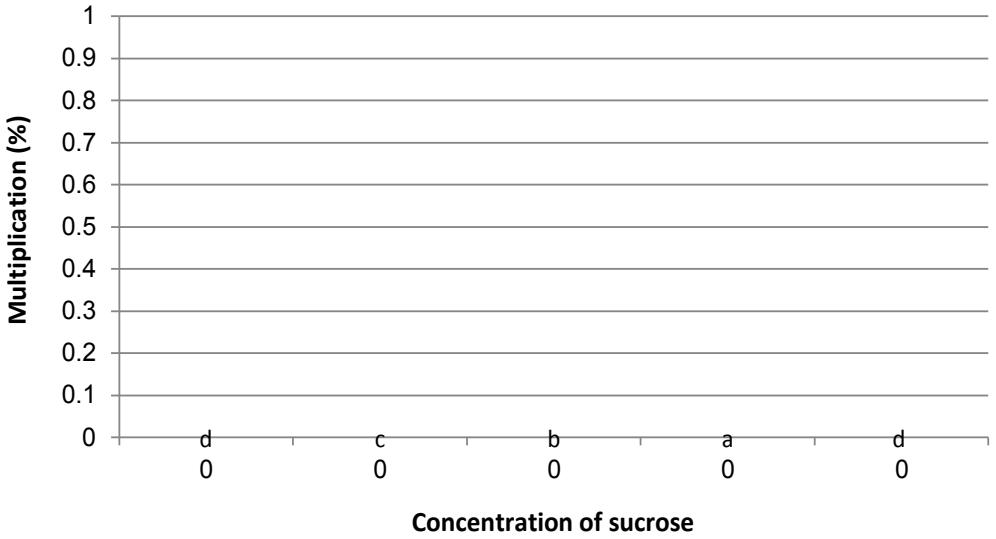

Figure 1. The effect of different concentrations of sucrose on the percent of shoots multiplication. *Different letters denote significant differences at the 0.05 level of probability.

multiplication (9.6%), which was significantly different from the other concentrations. Percentage of multiplication got to its lowest level (2.3%) when 1.25 g/l concentration was used. However, this result was not significantly different from the control group. Table 2 also showed that the rate of elongation of the branches of vegetative reached the highest rate at concentrations of 0.75 g/l (7.3 cm) and 0.5 g/l (6.9 cm); while the rate of elongation decreased at zero concentration (control treatment, 2.9 cm), with no significant difference from that of 1.25 g/l treatment (3.3 cm). The average number of roots in concentrations of 0.75 g/l and 0.50 g/l was the highest (4.6 and 4.3 root/plantlets, respectively). 0.5 g/l concentration gave the highest ($p<0.05$) mean of roots length (5.3 cm). The lowest length of roots was shown by 1.25 g/l concentration (2.3 cm). Superiority of 0.75 and 0.5 g/l of activated charcoal in both percentage of multiplication shoots arising from lateral bud as well rate of elongation and number of roots may be due to inhibition act of toxic phenolic compounds and lack of adsorption material useful for growth regulators; also other nutritional components of media which help plant parts to absorb these materials, leading to a good response (El-Shafey et al., 1999). The presence of activated charcoal in the nutritional media balanced plant growth regulators and other materials in the nutritional media and helped stimulate and supply the transplanted tissue; it also helped in differentiation and modification (Zaid, 1993). Rhiss et al. (1979) pointed out that the use of activated charcoal helped to reduce secretions of phenols and simulate budding and multiplication.

The effect of different concentrations of sucrose on the percentage of shoots multiplication

Results shown in Figure (1) indicated that there was significant difference ($P<0.05$) in the percentage of shoots multiplication arising from lateral buds of date palm Elsofydi cultivar *in vitro*. It also showed a highest

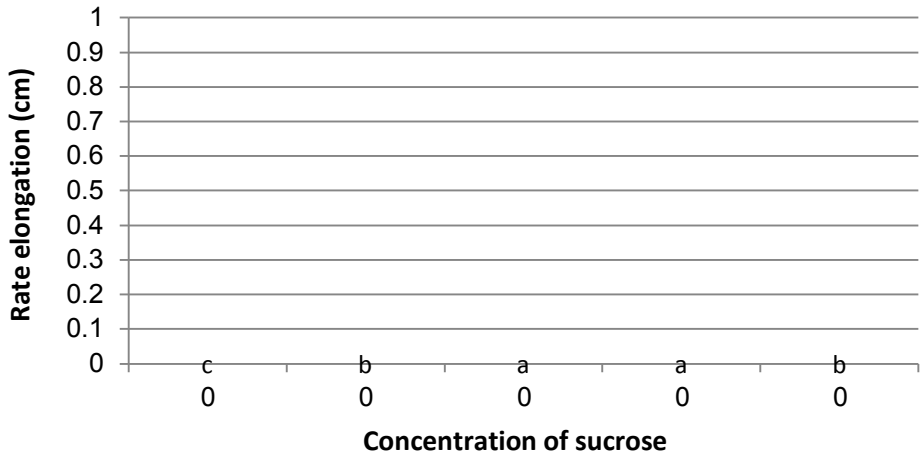

Figure 2. The effect of different concentrations of sucrose in the rate of elongation shoots. Different letters denote significant differences at the 0.05 level of probability.

Table 3. Effect of different concentrations of sucrose in the average number of roots / plantlet and lengths.

Average of root number/plantlets	Average of root length (cm)	Sucrose concentration g/l
2.3^{b}	1.6^{c}	20
2.6^{b}	2.1^{c}	35
4.3^{a}	5.6^{b}	50
4.6^{a}	5.9^{b}	65
2.6^{b}	6.8^{a}	80

Different letters denote significant differences at the 0.05 level of probability.

(P<0.05) multiplication percent due to the addition of 65 g/l of sucrose (5.3%) in comparison with other concentrations. There was a decline in the ratio (1.2%) of 20 g/l concentration (control), which was not significantly different from that of 80 g/L (2.5%).

The effect of different concentrations of sucrose on the rate of elongation shoots

There were significant (P<0.05) differences in the rate of elongation of shoots arising from lateral bud of Elsofydi cultivar (Figure 2). Superior concentration (65) g/L gave the highest elongation (7 cm) and the difference was not significant from that of 50 g/L concentration, which was 6.8 cm. While, low rate was noticed at concentrations of 20, 35 and 80 g/L (2.2, 4 and 4.3 cm, respectively).

The effect of different concentrations of sucrose on the average number of roots and length

Table 3 shows that the addition of sucrose concentration of 65 g/l resulted in the highest number of roots/plantlets (4.6 roots). Difference was not significant from that of 50 g/L concentration (4.3 roots). The number of roots reached the lowest level at a concentration of 20 g/L (2.3). Root difference was not significant than those of 40 and 70 g/L concentrations.

The concentration of 80 g/l gave the highest root length (6.8 cm) and was significantly different from those of other concentrations. 20 g/L concentration gave the lowest rate of root length (1.6 cm) and the difference was not significant from that of 35 g/l concentration.

The presence of sucrose in the nutritional media is one of the most important factors in plant tissue culture and its importance lies on its carbon content, which is a source of energy for tissue division and different growth stages (Hennigar, 1990; Trigian and Gray, 1999).

Taha et al. (2001) concluded that the concentration of sucrose in the nutritional media of date palm tissue culture had great effect on plantlet growth when it was added at a level of 50 g/L, It caused an increase in plantlet height and leaves number compared to 30 g/L where plantlets roots were weak (verifications). The plantlets tissue response differs due to the difference of variety, sucrose concentration and genetic factor of the plant (Singh and Shymal, 2001).

Table 4. Effect of interaction between the activated charcoal and sucrose on the ratio of multiplication and elongation rate and the number and length of roots.

Multiplication (%)	Rate of root length (cm)	Number root/plantlets	Rate of elongation (cm)	Activated charcoal (g/l)	Sucrose (g/l)
6.3[c]	4.1[c]	3.9[b]	5.8[b]	0.5	50
7.8[b]	4.3[c]	4.9[a]	7.9[a]	0. 75	
9.2[a]	5.1[b]	5.3[a]	8.1[a]	0.5	65
5.1[d]	6.9[a]	5.1[a]	6.1[b]	0.75	

Different letters denote significant differences at the 0.05 level of probability.

Image 1. Multiplication shoots on the medium is equipped with 65 g/L sucrose and 0.5 activated charcoal.

Image 2. Multiplication shoots on the medium is equipped with 50 g/L sucrose and 0.75 activated charcoal.

The effect of interaction between the activated charcoal and sucrose

It was noted from the results shown in Table 4 that there was a significant effect of the interaction between the concentration of activated charcoal and sucrose. The use of activated charcoal concentration of 0.5 g/l and sucrose concentration of 65 g/L led to the highest rate of shoot multiplication (9.2%, Image 1) followed by the impact of the use of 0.75 g/L of activated charcoal and 50 g sucrose/l (7.8%, Image 2). These were more significant than the effect of other treatments. The use of the same treatment also showed the highest shoot elongation (8.1 cm, Image 3). in the average number of roots and length, the result indicated a significant effect 0.5 g concentration of activated charcoal and 65 g/L sucrose. However, treatment of 0.75 g/L activated charcoal and 65 g/L sucrose resulted in highest rate of root length (6.9 cm), which is significantly different from other treatments (Images 4, 5 and 6). It can be concluded that adding 0.5 g/l of activated charcoal and 65 g/L sucrose to nutrient media gave the best results in cultivated Elsofydi date palm cultivar *in vitro*.

Image 3. Shoots elongation on the medium is equipped with 65 g/L sucrose and 0.5 activated charcoal.

Image 4. Shoots elongation on the medium is equipped with 50 g/L sucrose and 0.75 activated charcoal.

Image 5. Rooting shoots on the medium is equipped with 65 g/L sucrose and 0.5 activated charcoal.

Image 6. Rooting shoots on the medium is equipped with 65 g/L sucrose and 0.75 activated.

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Effects of organic and inorganic fertilizers addition on growth and yield of banana (*Musa* AAA cv. Malindi) on a saline and non-saline soil in Oman

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Water availability and soil salinity limit crop productivity in arid and semiarid regions such as Oman. The objective of this study was to examine the effects of amending a saline plant root zone soil with a non-saline sandy loam soil of organic and inorganic fertilizers, and of different placement methods on growth and yield of banana (*Musa* AAA cv. 'Malindi'). A total of 24 treatments comprising six fertilizer amendments, two soil types and two different application methods were tested. The amendments included four organic amendments versus un-composted dairy cow manure (FDM); composted dairy cow manure (CDM); CDM + 10% date palm straw (CDM + 10%DPS) by weight, and CDM + 30% date palm straw (CDM + 30% DPS) and two inorganic amendments (NPK and NPK plus foliar micronutrient spray, NPK+micro). The results revealed that neither soil amendments, fertilizer applications methods nor fertilizer composition significantly affected pseudostem height or girth, or leaf area. There was significant difference (P<0.05) in the number of leaves at flowering between Saline-Ring-NPK plants (8.2 leaves/plant) and Amended-Mixed-NPK and Amended-Ring-NPK+micro plants (14.0 and 13.8 leaves/plant, respectively). Amended-Ring-NPK+micro was significantly early flowering (267 days) compared to the other treatments. Amended-Ring-NPK+micro plants were harvested significantly earlier (in 339 days) than plants on saline soil. Amended-Ring-NPK+micro produced significantly higher average bunch fresh weight (9.5 kg/bunch/cycle) than all other treatments followed by Amended-Mixed-NPK+micro (5.9 kg/bunch/cycle).

Key words: Dwarf cavendish, amendments, application methods, manure types, mineral fertilizers, yield components.

INTRODUCTION

Banana is one of the most important tropical fruit crops. In 2010, banana and plantain (*Musa* spp.) were grown on over 10 million hectares worldwide and total production was about 138 million tons (FAOSTAT, 2010). In Oman, bananas are the second most important fruit crop after date palm (*Phoenix dactylifera* L.) in terms of area harvested and production. Countrywide bananas are grown on 3,720 ha and typically planted at a distance of 2 x 1.5 m resulting in a plant density of 3,333 plants/ha, with a total annual production of 56,700 tonnes (15.2 tonnes/ha) (FAOSTAT, 2010). The Dwarf Cavendish (*Musa* AAA) cultivar 'Malindi' is one of the most important cultivars grown in Oman due to its short stature and the sweetness of its fruit. It is a major source of income for a

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large number of farmers, particularly in the regions of Al-Batinah and Dofar.

Bananas need large quantities of mineral nutrients for high yields when grown in humid tropical areas with light soils and low fertility (Robinson, 1996). Under such conditions, nitrogen (N) should be added up to eight times per cycle to compensate for leaching losses. In Oman, chemical fertilizers alone or in combination with either dairy cow manure (MAF, 1993) or other ruminant manures (Schlecht et al., 2011; Siegfried et al., 2011) are used to provide nutrients to intensively managed banana. Bolaños et al. (2003) found that application of inorganic fertilizers and different sources of organic matter to the mother plants of plantain cv. 'Dominico hartón' positively affected pseudostem height and girth, but treatments were not significantly different. Similarly, Navarro (2001) observed no statistical differences in plant height, plant girth or bunch weight when comparing non-fertilized control cv. 'Cachaco' plantain with plants fertilized either with only organic fertilizer, only inorganic fertilizers or with a combination of organic and inorganic fertilizers. Al-Harthi and Al-Yahyai (2009) noticed that leaf number, leaf area, psedoustem height, and stem circumference of non-fertilized control plants were neither significantly different nor produced better vegetative growth when compared to fertilized plants. However, fertilized plants produced better total bunch weight and total fruit than non-fertilized control plants.

Mostafa (2005) found that fertilizing cv. 'Williams' banana with 500 g N per plant as ammonium sulphate applied at seven intervals and 600 g K per plant as potassium sulphate at 4 intervals increased pseudostem height, girth, number of leaves, leaf area and bunch weight, and reduced time to flowering and harvest compared to unfertilized plants. Abdel Moneim et al., (2008) found that fertilizing cv. 'Williams' banana plants with the recommended N rate from organic and mineral sources enhanced yield and weight of banana hands and fingers. Sibaja (1991) observed that semi-circular application of fertilizers around suckers of *Musa* AAA produced the highest yield as compared to other application methods tested. Baiyeri and Tenkouano (2008) found no significant differences between manure placement methods for specific leaf area (SLA) of the whole plant or leaf-3 at 5 months after transplanting (MAT) using a PITA 14 plantain hybrid. However, in the same experiment manure application significantly increased SLA at 3 MAT as compared to unmanured plants. In Oman, little research has been done on organic and inorganic banana fertilization and application methods.

Recently, the use of date palm (*P. dactylifera*) residues as an organic soil amendment has been intensively studied in the Middle East, where large amounts of this material is produced as a by-product of date cultivation (Khiyami et al., 2008; Al-Shaikh et al. 2009; Alkoaik et al., 2011; Ghehsareh et al., 2011; Yusuf, 2011). According to Khiyami et al. (2008) and Alkoaik et al. (2011), date palm produces about 20 kg of dry leaves per year. Hence, in arid regions like Oman where date palms are extensively cultivated, the use of these residues to improve soil properties makes economic and environmental sense. However, low N and high concentration of lignin in this substance may be an obstacle to soil microbial activity and derived substrate decomposition (Pankhurst et al., 2001; Sardinha et al., 2003). This may be particularly significant in low fertility soils, as predominating in the Oman Al-Batinah lowlands with their low organic matter content and high salinity. The soils on half of the farms in this region are saline (MAF, 1993). As no alternative land is available, the reclamation of salt-affected soils via simple mechanisms is of paramount importance.

The most common method of reclaiming saline soils is their flooding with sweet water, allowing the salts to be leached beyond the root zone of plants (Donahue et al., 1983). However, it is difficult to use this method in Oman where there is little water to begin with, and the water that is available is not always of sufficient quality. Amending the soil in the initial rooting zone of plants may be an alternative form of reclaiming saline soils. To explore this option, we tested the effects of amending the soil in the planting hole on the growth and productivity of the first crop cycle of *Musa* AAA cv. 'Malindi'. Our hypothesis was that replacing the plant root zone in saline soil by a non-saline sandy loam soil and adding fertilizer combinations will improve the growth and production of *Musa* AAA cv. 'Malindi'.

MATERIALS AND METHODS

Experimental site

The field experiment was conducted at the Agricultural Research Station, Rumais (23°41'15" N, 57°59'1" E) in the South of Al Batinah Governorate, Oman from October 2007 to July 2009. In this region, the average daily temperature ranges from 19.5°C in January to 41.0°C in July, with an annual precipitation of 100 mm.

In September 2007, large planting holes (70 × 70 × 70 cm) were dug to apply organic amendments and/or replace saline soil with non-saline sandy loam soil (soil amendments). In October 2007, banana plants were transplanted into the field in holes of approx. 30 × 30 × 30 cm in the centre of the larger holes previously dug. Inorganic fertilizers were then applied and a bubbler irrigation system (discharge: 4 L per minute of a water with an electrical conductivity of 0.6 dS m^{-1}) was installed. Taking in the consideration the age of the plant and weather conditions, all plants were irrigated every two days in winter and daily in summer. Each plant received 16 L per irrigation event for the first 4 months (October to January), thereafter, the quantity increased to 20 L until the end of the experiments, as recommended by the Omani Ministry of Agriculture and Fisheries. Every week, newly emerged suckers around the mother plant were cut to the soil surface using a knife. The experimental plants were managed according to the recommendations of the Omani Ministry of Agriculture and Fisheries.

Soil analysis

To determine soil type, electrical conductivity (EC_e) and pH of soils,

composite soil samples were collected from 0 to 20 cm depth of the experimental field and from the pile of imported non-saline sandy loam soil prior to establishing the experiment. The EC_e was measured using a soil-to-water suspension of 1:5. Soil pH was measured using a soil-to-water ratio of 1:2.5.

Planting material

Suckers from the highly productive 'Malindi' plants were used as planting material. The suckers were removed from mother plants in September 2007, roots and a corm cut and shoots trimmed. They were initially planted in pots (30 cm × 30 cm) filled either with field soil or imported sandy-loam soil for one month before being transplanted into the field in October 2007.

Treatments

For the experiment conducted from October 2007 to July 2009, a completely randomized design was used with 6 replicates and 24 treatments (2 soil amendments × 6 fertilizer combinations × 2 fertilizer application methods).

Soil amendments

As the soil of the research station was saline, half of the treatments consisted in amending the soil in the planting hole (70 × 70 × 70 cm) dug one month prior to transplanting the banana plants into the field. These large planting holes were dug 3 x 3 m apart, to yield a planting density of 1,111 banana plants/ha. Half the holes were then refilled with non-saline sandy loam soil imported from another part of Oman ('Amended soil'). The other planting holes were refilled with original soil ('Saline soil').

Fertilizer combinations and application methods

Samples of fresh and composted manure and of date palm straw were collected and analyzed for basic chemical properties. These data was used to calculate the amount of manure necessary to provide each banana plant with 400 g N, as recommended by the Omani Ministry of Agriculture and Fisheries (MAF, 1995).

The six fertilizer combinations, four organic and two inorganic comprised:

i. FDM: 100% un-composted (fresh) dairy cow manure (39.0 kg dry weight),
ii. CDM: 100% composted dairy cow manure (22.2 kg dry weight),
iii. CDM+10%DPS: 100% composted dairy cow manure and 10% date palm straw by weight (2.2 kg dry weight),
iv. CDM+30%DPS: 100% composted dairy cow manure and 30% date palm straw by weight (6.7 kg dry weight),
v. NPK: urea (N), triple super phosphate (P) and potassium sulphate (K),
vi. NPK+micro: urea (N), triple super phosphate (P), potassium sulphate (K) and foliar micronutrients.

All organic fertilizers used (FDM ,CDM and DPS) were applied only once, either mixed in with the top 20 cm of the soil in the planting hole ('Mixed application') or in a ring at a depth of 20 cm in the planting hole ('Ring application'), one month prior to transplanting of banana suckers. The holes were then irrigated once to allow for initial release of nutrients.

Inorganic fertilizers (N: urea; P: triple super phosphate; and K: potassium sulphate) were applied either by spreading on the soil surface around the plant at a distance of approx. 30 cm from the base of the plant and mixed into the top layer of the soil by hand ('Mixed application') or by burying it under 5 to 10 cm of soil that had been removed in a ring around the plant at a distance of 30 cm from the base of the plant ('Ring application').

The quantity of urea applied was calculated such as to provide the plant with 400 g N. The quantity of triple super phosphate and potassium sulphate applied was calculated to provide the plant with the same amount of P and K available in 39 kg of fresh dairy manure (FDM), that is, the amount of FDM necessary to provide the plant with 400 g N. Micronutrients were applied onto the banana leaves using a backpack sprayer containing a solution of the foliar micronutrient fertilizer Fertilon® Combi 2 (Münster, Germany: Zn: 4.0%; Fe: 4.0%; Mn: 3.0%; Cu: 0.5%; B: 1.5%; Mo: 0.05%; Mg: 1.3%; S: 1.3%) at a concentration of 1 g/l water. The doses and application dates of organic, inorganic and micronutrient fertilizers are presented in Table 1.

Data collection

Vegetative growth

Dates of planting, flowering and harvest were collected to calculate days from planting to flowering (DTF) and to harvest (DTH) and from flowering to harvest (FF: Fruit Filling). At flowering, pseudostem height from the soil level up to the last two leaves (V-shaped) and girth (cm) at 10 cm above the soil level were measured and the number of leaves per plant was counted. To calculate leaf area (m^2), the length and width of the third fully expanded leaf were measured at flowering as described by Al-Harthi and Al-Yahyai (2009).

Yield parameters

At harvest, fresh bunch weight (kg) was measured. The number of hands per bunch and total number of fingers per bunch was counted. Three individual middle fingers of the second hand were used to measure average fruit weight as recommended by Alvarez et al. (2001). Total yield (kg/ha/cycle) was calculated based on bunch weight and the number of plants per hectare (1,111 plants/ha).

Data analysis

All data were tested for normal distribution using the Shapiro-Wilk test. Analysis of variance (ANOVA) was done on normally distributed data (plant growth parameters, fruit weight, bunch weight, total yield, total number of fruits per bunch and DTF) using GenStat Release 11.1 (VSN International, Hemel Hempstead, UK). Data of DTH, FF and number of hands per bunch were Ln-transformed to normalize distribution of residuals. The Tukey-test was used to test mean separation between factors.

RESULTS AND DISCUSSION

Soil and manure analysis

An experimental soil is classified as saline if its EC_e is > 4 dS m^{-1} (Al-Busaidi and Cookson, 2003). The saline field soil in our experiment was characterized by an EC_e of 11.9 dS m^{-1}, while the imported non-saline soil had an EC_e of 1.8 dS m^{-1}, but the pH of both soils was alkaline. The saline and non-saline soils had a $CaCO_3$-

Table 1. Doses and dates of ring and mixed applications of organic and inorganic fertilizers to soils and of foliar applications of micronutrients to leaves of *Musa* AAA cv. 'Malindi' plants in a banana soil salinity experiment in Al-Batinah of Oman.

Date of application	FDM	CDM	CDM+10%DPS	CDM+30%DPS	NPK	NPK+micro
Sep-07	FDM: 39.0 kg	CDM: 22.2 kg	CDM: 22.2 kg DPS: 2.2 kg	CDM: 22.2 kg DPS: 6.7 kg	-	-
Oct-07	-	-	-	-	P: 100 g	P: 100 g
Dec-07	-	-	-	-	N: 70 g P: 50 g K: 50 g	N: 70 g P: 50 g K: 50 g
Feb-08	-	-	-	-	N: 100 g P: 50 g K: 75 g	N: 100 g P: 50 g K: 75 g micro: 5 L
Apr-08	-	-	-	-	N: 120 g P: 69 g K: 120 g	N: 120 g P: 69 g K: 120 g
Jun-08	-	-	-	-	N: 150 g P: 68 g K: 140 g	N: 150 g P: 68 g K: 140 g micro: 7 L
Aug-08	-	-	-	-	N: 150 g K: 210 g	N: 150 g K: 210 g
Sep-08	-	-	-	-	N: 140 g K: 300 g	N: 140 g K: 300 g micro: 11 L
Oct-08	-	-	-	-	N: 140 g K: 315 g	N: 140 g K: 315 g
TOTAL	FDM: 39.0 kg	CDM: 22.2 kg	CDM: 22.2 kg DPS: 2.2 kg	CDM: 22.2 kg DPS: 6.7 kg	N: 870 g P: 337 g K: 1210 g	N: 870 g P: 337 g K: 1210 g micro: 23 L

†FDM: Fresh Dairy Manure, CDM: Composted Dairy Manure and DPS: Date Palm Straw - applied to planting hole before transplanting plants; N: urea [$CO(NH_2)_2$], P: triple super phosphate [$Ca(H_2PO_4)_2.H_2O$] and K: potassium sulphate [K_2SO_4] - applied to surface soil; micro: Fetrilon® Combi 2 soluble foliar micronutrient fertilizer solution - applied to leaves at a concentration of 1 g/L H_2O using a backpack sprayer.

Table 2. Basic physical and chemical properties of the experimental soils used for a banana soil salinity experiment in Oman.

Properties	Non-saline soil	Saline soil
EC_e (dS m^{-1})	1.8	11.9
pH (1:2.5)	8.5	7.9
Sand (%)	54	84
Silt (%)	37	6
Clay (%)	9	10
$CaCO_3$ (%)	26	31

Table 3. Basic chemical properties of fresh and composted dairy cow manure and of date palm straw used in a banana soil salinity experiment in Oman.

Properties	Composted dairy manure (CDM)	Fresh dairy manure (FDM)	Date palm straw (DPS)
ECe (dS m-1)	8.4	4.6	0.90
pH (1:2.5)	8.1	7.8	5.3
Total N (mg kg^{-1})	18	10.3	4.1
Total P (mg kg^{-1})	6.2	3.97	0.3
Total K (mg kg^{-1})	25.0	15.5	7.7
Lignin (mg kg^{-1})	145	100	84
Cellulose (mg kg^{-1})	289	277.2	450
Acid detergent fibers (mg kg^{-1})	434	377.2	534

concentration of 26 and 31%, respectively. While the saline field soil had a sandy texture, the imported non-saline soil was a sandy loam (Table 2).

The composted manure had an EC_e of 8.1 dSm^{-1} compared to fresh dry manure (4.3 dS m^{-1}), while date palm had an EC_e of 0.90 dS m^{-1} (Table 3). Both manures are alkaline, while date palm was acidic. Lignin was high in fresh and composted manure compared to date palm straw. The macronutrient concentrations (N, P and K) in organic amendments were relatively low. The amounts of N, P and K contained in the manures were used to calculate their quantities applied to the plants in non-manure treatments. Manure and date palm straw had high contents of lignin, cellulose and acid detergent fibre.

Vegetative growth

Neither soil amendments, fertilizer applications methods nor fertilizer compositions had a significant effect on pseudostem height or girth, or on leaf area at flowering (Table 4). Treatment effects were only significant for the number of leaves at flowering between Saline-Ring-NPK plants (8.2 leaves/plant) and Amended-Mixed-NPK and Amended-Ring-NPK+micro plants (14.0 and 13.8 leaves/plant, respectively). Replacing the saline field soil in the root zone with non-saline soil improved the growth of ‘Malindi’ plants compared to those planted in saline soil. However, replacement soil plants did not reach the average size of ‘Malindi’ plants grown under optimum conditions in Oman (psedoustem height, 180 cm; MAF, 1995). The maximum height attained by our plants was 129.3 cm for the amended Saline-Ring-NPK+micro plants. For optimum yield, the number of functional leaves at flowering stage should be 10 to 15 leaves (Robinson, 1996). The plants grown on the amended soil had 10 to 14 leaves, while those on saline soil had 8 to 11 leaves.

In studies on non-saline soil where the effects of different inorganic fertilizers on cv. ‘Williams’ were studied, the number of leaves ranged from 12 to 13.6 leaves (Mostafa, 2005; Al-Harthi and Al-Yahyai, 2009). In general, plant growth on amended soil was better than on saline soil, suggesting that our fertilizer amendments alone were not able to improve plant growth sufficiently to offset the negative effects of salinity. In a study on cv. 'Sindhri' banana, leaf area, plant biomass and water contents decreased significantly due to NaCl stress (Ul-Haq et al., 2011). Under saline soil conditions, growth of plants is inhibited by ion cytotoxicity, osmotic stress and unbalanced nutrients, which may the retard metabolic activity inside the plant (Allakhverdiev et al., 2000; Zhu, 2002) and inhibit photosynthetic activity (Parida and Das, 2005). These effects of salts on plants may explain the observed general weaker growth of cv. ‘Malindi’ plants on saline soil compared to those plants on amended soil.

Table 4. Effects of soil amendments, fertilizer application methods and fertilizer composition on vegetative growth of *Musa* AAA cv. 'Malindi' in a soil salinity experiment in Oman.

Treatments			Pseudostem height (cm)	Pseudostem girth (cm)	Leaf area at flowering (m^2)	No. of leaves at flowering
Saline soil	Mixed application	FDM*	117.4^{NS}	45.2^{NS}	3.70^{NS}	11^{abc}
		CDM*	88.8	34.5	2.9	10^{abc}
		CDM+10%DPS*	108.8	40.0	3.2	9^{ab}
		CDM+30%DPS	108.5	41.8	3.3	10^{abc}
		NPK	95.8	34.8	3.3	11^{abc}
		NPK+micro	108.0	41.1	4.0	10^{abc}
	Ring application	FDM	110.2	43.3	3.7	10^{abc}
		CDM	101.7	38.1	3.4	11^{abc}
		CDM+10%DPS	99.7	38.3	3.2	10^{abc}
		CDM+30%DPS	106.7	38.3	3.2	11^{abc}
		NPK	92.0	33.8	3.1	8^{a}
		NPK+micro	107.4	38.0	3.4	10^{abc}
Amended soil	Mixed application	FDM	123.0	50.2	4.0	12^{abc}
		CDM	115.7	44.8	4.1	11^{abc}
		CDM+10%DPS	127.7	44.0	4.1	11^{abc}
		CDM+30%DPS	117.7	44.8	3.8	12^{abc}
		NPK	127.8	48.8	4.6	14^{c}
		NPK+micro	128.2	51.2	4.7	13^{abc}
	Ring application	FDM	124.2	47.5	4.5	14^{bc}
		CDM	127.5	47.0	4.4	11^{abc}
		CDM+10%DPS	119.2	45.3	4.3	12^{abc}
		CDM+30%DPS	128.7	47.2	4.4	14^{bc}
		NPK	125.3	49.3	4.7	11^{abc}
		NPK+micro	129.3	51.3	5.2	14^{c}
			Probability values			
Soil Amendment (S)			<0.001	<0.001	<0.001	<0.001
S x F			0.003	<0.001	0.042	0.481
S x M			NS	NS	NS	NS
S x F x M			NS	NS	NS	0.046
CV %			10.4	10.3	18.5	18.2

*FDM=Fresh dry manure; CDM=compost dry manure; DPS=date palm straw, Means in columns with similar letters are not significantly different ($P<0.05$).

Yield parameters

None of the treatments significantly affected fruit filling (FF), fruit weight, number of hands/bunch or fingers/bunch (Table 5). However, a significant difference was observed in days to flowering (DTF) between Amended-Ring-NPK+micro (267 days) plants and Ring-NPK+micro, NPK, Ring-CDM, Mixed-NPK+micro, Mixed-NPK and Mixed-CDM plants in saline soil (405, 387, 340, 333, 372 and 365 days, respectively). On both soils, all plants, except Amended-Mixed-NPK (93 days) plants, needed less than 3 months from flowering to harvest (fruit filling: FF), which is unusual. In saline soil, Ring-FDM plants flowered significantly earlier (286 days) than Mixed-CDM, Mixed-NPK, Ring-NPK+micro and Ring NPK plants (372, 372, 387 and 405 days, respectively). In amended soils, fertilizer combinations and application methods did not significantly affect DTF. Amended-Ring-NPK+micro plants were harvested significantly earlier (339 days) than those Ring-NPK+micro, Ring-NPK, Mixed-NPK and Mixed-CDM plants on saline soil (494, 465, 457 and 453 days, respectively).

In saline soil, a significant difference in DTH was only observed between Mixed-FDM plants (354 days) and Mixed-CDM, Mixed- NPK, Ring-NPK+micro and Ring NPK plants (453, 457,465, and 494 days, respectively). In contrast in the amended soil, no interaction between fertilizer combinations and application methods was detected.

Aside from high yields, early flowering and bunch harvest are important for banana farmer because these dates determine when harvesting activities take place. In general, time to flowering was faster on the amended soil than on the saline soil. Under Omani conditions, using optimum cultural practices, DTH of cv. 'Malindi' banana is 330 days (MAF, 1995). In our study, Amended-Ring-NPK+micro and Amended-Mixed-FDM plants needed 339 and 346 days, respectively. Despite the unusual experimental pot conditions, our results seem reasonable. In their study on the effect of inorganic fertilizers on growth and yield of cv. 'Williams' in Oman, Al-Harthi and Al-Yahyai (2009) recorded crop-cycles (DTH) ranging between 423 and 450 days and days to fruit ripening between 107 to 119 days.

In our study, crop development for the plants receiving inorganic fertilizer and CDM treatments in both application methods on the saline soil were within this range. However, the general crop development in other treatments was much slower, while it was within the range for the same variety grown under optimum conditions in Oman. The number of days for fruit filling was the only unusual period (less than 3 months). In a study on the effect of salinity on different varieties of rice, Khatun et al. (1995) determined that salinity delayed flowering. Similarly, Peter et al. (2002) found that 4 g/l NaCl delayed flowering of *Iris hexagona* (Iridaceae). In our study, plants on the amended soil flowered earlier and were generally harvested earlier than those on saline soil, indicating that salinity may also delay flowering of banana.

Amended-Ring-NPK+micro plants produced signify-cantly heavier bunches (9.5 kg/bunch/cycle), followed by Amended-Mixed-NPK+micro (5.9 kg/bunch/cycle). The general trend was that plants on amended soil produced heavier bunches compared to those on saline soil. Neither soil amendments, fertilizer applications methods nor fertilizer compositions significantly affected fruit weight, number of hands/bunch and number of fingers/bunch (Table 5). Amended-Ring-NPK+micro plants were significantly more productive (10.6 tonnes/hectare) than all other plants, followed by Amended-Mixed-NPK+micro plants (6.6 tonnes/hectare). Despite of our experiment having been carried out on a nutrient poor saline soil, the two highest yielding treatments (Amended-Ring-NPK+micro and Amended-Mixed-NPK+micro, with yields of 9.5 and 5.9 kg/bunch, respectively) exceeded the average bunch weight per plant in Oman (4.6 kg/bunch/cycle at the typical density of 3,333 plants ha^{-1}) and FAO production data (FAOSTAT, 2010). The significant interaction between soil amendments, fertilizer application methods and fertilizer composition in this study revealed that replacing the saline soil around young banana with a non-saline sandy loam and ring-applying inorganic fertilizers can counteract the negative effects of salinity on banana yields during the first cycle, though not those on plant growth. However, even with these amendments, banana yields were still lower than those on the non-saline soil with good cultural practices.

For optimum yield, number of leaves at flowering should be no less than 10 (Robinson, 1996). It was observed that Amended-Ring-NPK+micro plants, which had the greatest average bunch weight also had the greatest number of leaves at flowering and leaf area. This may be the reason for the high average bunch weight of plants in this treatment. The yield effects of organic fertilizer amendments were much lower than those of NPK+micro. The high contents of lignin in manures may have retarded the decomposition of dry matter and nutrient release (Alexander, 1977). Also, the low macronutrient content of manures and their high EC_e and pH may have contributed to this weak performance. In contrast, quick dissolution of applied chemical fertilizers and their distribution in the soil solution enables the plant root system to absorb the nutrients easily (Polat et al., 2008).

Generally, the incorporation of fertilizers into the soil with the 'Ring method' gave better yields than mixing fertilizers with the top 20 cm of soil in the 'Mixed method'. This may be due to increased N use efficiency via reduced N volatilization losses, leaching and denitrifica-tion (Reiman et al., 2009). High soil salinity and sodicity affects the movement of nutrients from soil to plants and thus reduces crop yields (Al-Busaidi and Cookson, 2003).

Table 5. Effects of soil amendments, fertilizer application methods and fertilizer composition on yield and yield components of Musa AAA cv. 'Malindi' in a soil salinity experiment in Oman.

Treatments			DTF (days)	FF (days)	DTH (days)	Bunch weight (kg)	Fruit weight (g)	No. of hands	No. of fingers	Yield (kg/ha)
Saline Soil	Mixed application	FDM*	288^{abc}	66^{NS}	354^{ab}	3.8^{abcd}	55.9^{NS}	6.4^{NS}	65^{NS}	4193^{abcd}
		CDM*	365^{defg}	88	453^{cde}	2.7^{abc}	57.8	4.5	42	3030^{abc}
		CDM+10%DPS*	309^{abcde}	70	378^{ab}	3.6^{abcd}	61.2	6.0	56	4043^{abcd}
		CDM+30%DPS	314^{abcde}	74	388^{abc}	3.0^{abc}	53.3	5.0	49	3278^{abc}
		NPK	372^{efg}	85	457^{cde}	2.3^{ab}	58.2	4.3	37	2581^{ab}
		NPK+micro	333^{bcdef}	74	407^{abcd}	3.3^{abcd}	56.6	6.3	57	3704^{abcd}
	Ring application	FDM	286^{abc}	82	368^{ab}	3.3^{abcd}	56.8	5.8	56	3622^{abcd}
		CDM	340^{cdef}	75	415^{bcd}	2.7^{abc}	59.8	4.7	40	3031^{abc}
		CDM+10%DPS	318^{abcde}	72	390^{abcd}	2.7^{abc}	59.2	4.7	44	2952^{abc}
		CDM+30%DPS	305^{abcd}	69	374^{ab}	2.9^{abc}	54.9	5.2	49	3256^{abc}
		NPK	387^{fg}	78	465de	2.2^{a}	57.6	3.9	34	2399^{a}
		NPK+micro	405^{g}	89	494^{e}	4.2^{abcd}	92.1	5.0	43	4706^{abcd}
Amended Soil	Mixed Application	FDM*	269^{ab}	77	346^{ab}	5.0^{abcd}	68.7	6.6	73	5591^{abcd}
		CDM*	304^{abcd}	70	374^{ab}	4.0^{abcd}	61.3	6.7	63	4450^{abcd}
		CDM+10%DPS*	309^{abcde}	58	367^{ab}	5.2^{bcd}	62.6	6.3	58	5744^{bcd}
		CDM+30%DPS	303^{abcd}	58	361^{ab}	3.8^{abcd}	57.0	5.8	59	4261^{abcd}
		NPK	273^{ab}	93	366^{ab}	4.3^{abc}	62.5	6.0	71	4750^{abcd}
		NPK+micro	279^{abc}	62	341^{ab}	5.9^{d}	77.7	7.5	80	6591^{d}
	Ring application	FDM	272^{ab}	76	347^{ab}	5.6^{cd}	74.7	7.0	79	6187^{cd}
		CDM	290^{abcd}	64	353^{ab}	5.5^{cd}	69.5	6.8	78	6120^{cd}
		CDM+10%DPS	298^{abc}	59	356^{ab}	4.4^{abcd}	62.0	6.0	67	4883^{abcd}
		CDM+30%DPS	297^{abc}	59	356^{ab}	5.0^{abcd}	66.1	6.3	70	5585^{abcd}
		NPK	274^{ab}	83	357^{ab}	4.6^{abcd}	63.4	6.0	75	5050^{abcd}
		NPK+micro	267^{a}	72	339^{a}	9.5^{e}	89.5	8.0	122	10576^{e}
Probability values										
Soil amendment (S)			<0.001	0.007	<0.001	0.001	<0.006	<0.001	<0.001	<0.001
S x F			<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001
S x M			0.239	0.890	0.236	0.006	0.086	0.001	0.045	0.006
S x F x M			0.046	0.462	0.019	0.034	0.231	0.568	NS	0.034
CV %			9.6	22.9	9.0	33.1	25.3	16.9	24.1	33.1

*FDM=Fresh dry manure; CDM=compost dry manure; DPS= date palm straw. Means in columns with similar letters are not significantly different ($P < 0.05$) according to Turkey-test, NS= not significant.

An interesting effect of combined application of date palm straw and composted manure is the observed increase in plant size, as well as earlier fruit ripening and subsequent harvest. This could be due to the ability of DPS to increase soil microbial biomass and lower the microbial C turnover (Scheller and Jorgensen, 2008; Heinze et al., 2010) and therefore increase the release of nutrients necessary for vegetative growth. This confirms the role of date palm straw as a soil conditioner, as suggested by earlier work (Hegazi et al., 2007; Khiyami et al., 2008; Alkoaik et al., 2011; Ghehsareh et al., 2011; Ghehsareh and Kalbasi, 2012). This effect of date palm straw requires further research.

CONCLUSIONS AND RECOMMENDATIONS

Replacing the saline soil in the initial root zone of banana plants with a non-saline sandy loam soil and adding a combination of NPK mineral fertilizer with micronutrients incorporated at 5 to 10 cm depth 30 cm from the base of the plant (Ring application) is a favourable practice to alleviate the effects of salt-affected soil on banana in Oman. This led to increased plant growth and productivity of *Musa* AAA cv. 'Malindi'. Application of mineral fertilizers alone to a saline soil did not improve growth or productivity of banana cv. 'Malindi'. The poor quality of the dairy manures used likely minimized their expected positive effects on banana growth and yield. Chicken manure may be a better alternative organic fertilizer. The combined effect of date palm straw and composted manure on plant growth of field-grown banana requires further study.

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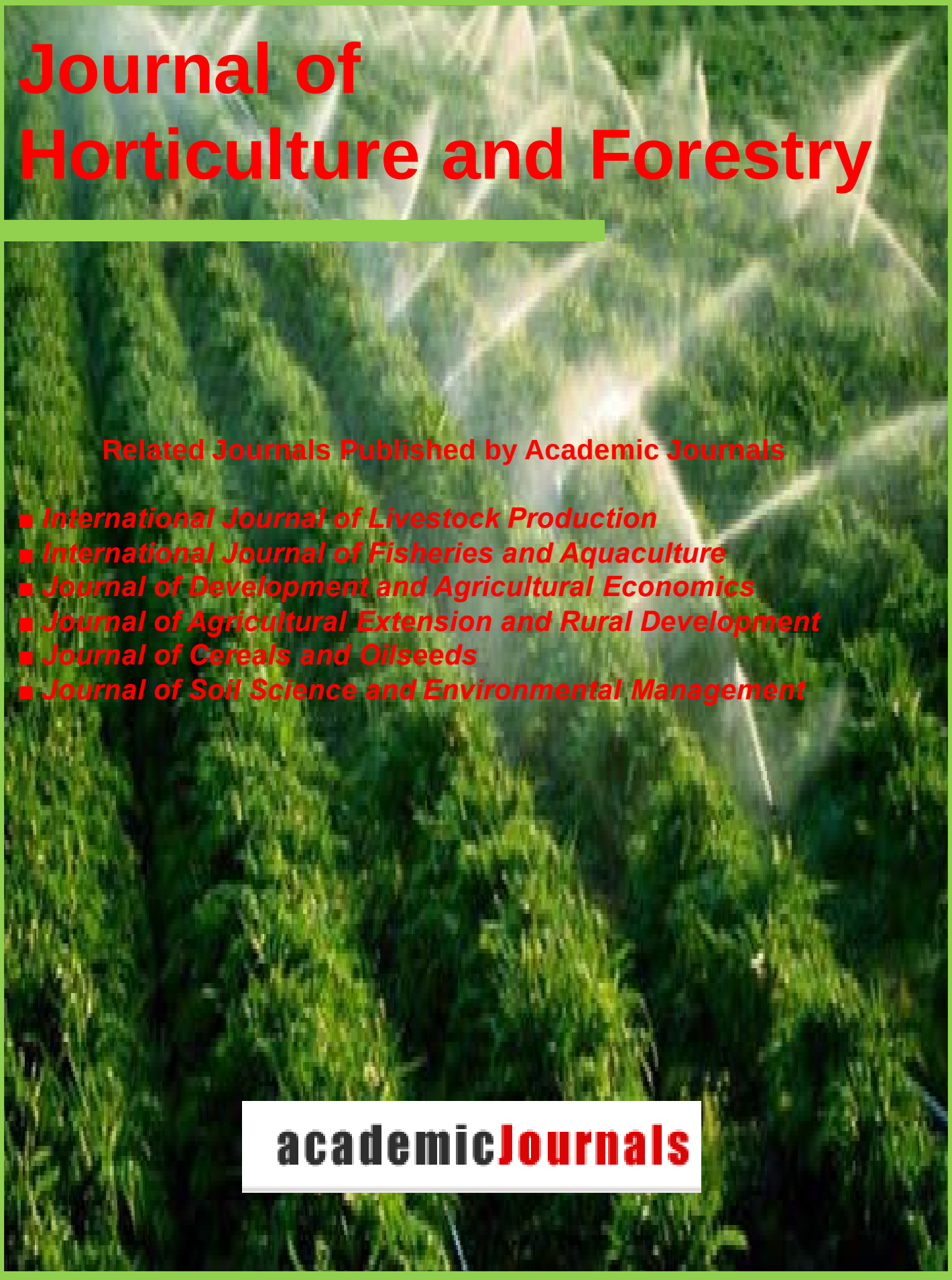
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