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Full Length Research Paper

The resulting 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			<0.001	<0.001	<0.001	<0.001
(S) 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 – Mixedapplicati on	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}
Saline Soil – I n g applicatio n	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 – MixedApplication	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}
Amended Soil – I n g 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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