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Effects of saline irrigation water on morphological characteristics of banana (*Musa spp.*)

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Abstract

Banana is one of the most important food crops after rice, wheat and corn around the world. It is susceptible to a wide spectrum of non-infectious problems such as abiotic stresses resulting in restricting growth and production. Studies were conducted to determine the effects of four salinity levels (0.17 (control), 3.0, 6.0, and 9.0 dS m^{-1}) on morphological characteristics of four banana cultivars at vegetative growth stage. Banana cultivars from the Cavendish group (Williams, Malindi) and plantains group (FHIA18 and Diwan) were grown in 61 x 76 cm polyethylene bags filled with soil mixture comprising of top soil, sand and peat moss (3:1:2 v/v), with pH ranging from 6 - 6.5 and EC 0.02 $mScm^{-1}$. The experiment was carried out under a rain-shelter in split-plot design with three replicates. Plants were irrigated manually. Data were collected at 3, 6 and 9 months after transplanting. The results revealed that, the number of leaves, stem height, stem girth and total leaf area were significantly affected by salinity, variety and plant age. Significant interaction was also found between salinity and variety, salinity and plant age, as well as variety and plant age. The morphological characteristics of banana were negatively affected by higher salinity levels (6.0 and 9.0 dS m^{-1}). Under similar salinity level, cultivar Malindi had higher number of leaves, stem height, stem girth and total leaf area as compared to cultivar Williams. Among plantains banana, cultivar FHIA18 was more tolerance to high salinity levels than Diwan cultivar, while Malindi from Cavendish group shows high salt tolerant than Williams. Therefore cultivars Malindi and FHIA18 could be grown in arid and semiarid environment depend on their tolerance to high salinity level above 1.0 dS m^{-1}.

Introduction

Banana is a vital source for food security and it represents the 4th main staple food crop after rice, wheat and corn and it is grown in over 130 countries around the world including tropical, sub-tropical regions and it is the most popular dessert fruit in industrialized and developing countries (FAO, 2013). It is considered as the main food source in tropical and subtropical areas, where the population is approximately exceeding 400 million people (FAO, 2013). From the economics point of view, many of the developing countries rely upon banana export to build up their foreign exchange. Banana, as an important element in food crops around the world, has various industrial, medical, ornamental and architectural uses. One of the difficulties facing banana growth in arid and semi-arid regions is soil and water salinity. As reported by (Miao *et al.*, 2014) it appears to be one of the main abiotic factors limiting growth and yield of most horticultural crops, vegetables, cereals as well as ornamentals and landscape plants. Increase in soil and water salinity depends on several factors such as salt concentration, phase of growth and susceptibility of plant to exposure, and other environmental attributes (Aishah *et al.*, 2011). Intercellular and intra-cellular toxicity are the consequences of high salt concentration in both irrigation water and/or

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Table 1: ANOVA of Mean Square on number of leaf, stem height, stem girth and leaf area of banana with saline irrigation water during period of May 2014 to Jan 2015.

Source	dF	No. of Leaf		Stem height		Stem girth		Leaf area	
Salinity	3	29.604	***	406.701	***	89.972	***	13108711.92	***
Variety	3	38.687	***	4983.955	***	90.928	***	8220826.85	***
Salinity*Variety	9	2.134	***	18.056	ns	4.975	*	614818.63	***
Month	2	221.168	***	2818.366	***	216.293	***	2967908.77	***
Salinity*Month	6	1.180	**	57.732	***	26.739	***	4268883.12	***
Variety*Month	6	1.923	***	98.355	***	10.475	***	152767.07	**
Salinity*Variety*Month	18	0.053	*	10.751	ns	2.495	ns	116193.93	*
Error	64	0.240		9.393		1.697		51121.6	
Corrected Total	143								
CV		5.278		3.73		6.391		9.054	

* and ** : significant at 5%; *** : significant at 1%; ns: non-significant

cultivated soils (Hasegawa *et al.*, 2000; Ghoulam, Foursy, and Fares, 2002). Banana plantation is a large scale aspect of gardening, found in both micro and macro-commercial farms worldwide, including the Sultanate of Oman, most of which are located in salt affected farm land (FAO, 2013). Banana plants require constant warm and moist soil of quality equal or less than 1.0 dS m^{-1} for optimum growth and yield. However, when the soil is saturated with water low quality, plant's growth, physiology and morphology become affected due to salt water stress (Carr, 2009). Salt tolerant mechanisms usually differ between plants species, nonetheless, plants can adapt mechanisms such as, minimizing the entry of Na+ or Cl^-ions into the organs by accumulating them in photosynthetic tissues and/or reducing intercellular concentration of salt ions (Kerepesi and Galiba, 2000; Munns, 2002; Zhu, 2003). Several *in vitro* studies of banana under different salinity showed growth reduction with increased in salt concentration of irrigation water above 1.0 dS m^{-1} (de Oliveira Gondim *et al.*, 2009; Haq *et al.*, 2011). However, there is a lack of information on the effect of salinity on banana plants growth in arid region under field conditions, which is becomes an essential in improving banana plantation in this area. The present study was undertaken to investigate the effects of different levels of salinity using irrigation water on morphological attributes of four banana cultivars during vegetative stages under Malaysian climate which is characterized by tropical climate with temperature ranges from 25ºC to 33ºC, light intensity of 1721.11 µmol m^{-2} s^{-1}, average monthly relative humidity was 92.7%, and frequent rainfall throughout the year approximately above 90.0 mm.

Materials and methods

Two factorial experiments were conducted using a split-plot design replicated three times under an open rain-shelter at the Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia (02°N 59.476′ 101°E 2.867′, 51 m altitude). Seedlings of four tissue culture banana cultivars namely; Diwan and FHIA18 from plantains and Malindi and Williams from Cavendish group (sub-plot) were grown in 61x76 cm polyethylene bags filled with thoroughly sieved soil mixture of top soil, sand and peat moss in the ratio of 3:1:2 (v/v), with pH ranged from 6 - 6.5, EC 0.02 $mScm^{-1}$ and total dissolved salt of 0.08ppm. All plants were irrigated with water pH 6.6, EC 0.17 $mScm^{-1}$ and Na^+ 5.26 mg/l, and arranged at distance between plants of 1.5 x 1.5 m apart. At establishment period from February 2014 to April 2014, all banana plants were irrigated with tap water of EC 0.17dS m^{-1}. Thereafter they were manually irrigated with different levels of saline irrigation water 3.0, 6.0 and 9.0 dS m^{-1} for the main plot and 0.17 dS m^{-1} for the control from April 2014 to January of 2015. During this period, irrigation was affected when the soil tension reached 10-12 kPa measured using tensiometer. Chemical fertilizer containing 46% urea (CH_4N_2O), 52% triple super phosphate (P_2O_5) and 52% potassium oxide (K_2O) were applied on the 5th and 7th 104 month after final transplanting at the recommended rate (Al-Harthi and Al-Yahyai, 2009). Morphological measurement viz: plant height (cm), stem girth (cm) (was done at 30 cm above soil level), leaf area and number of functional leaf produced per plant, taken at 3rd (Initial), 7th and 9th month (end) of the experiment. Data were analyzed using SAS 9.4 software (SAS institute, Inc., Cary NC, USA). Mean comparison was applied using LSD test at 5% level of probability.

Table 2: Effect of saline irrigation water on banana morphological characters

Salinity level (dSm^{-1})	Leaf number	Stem height (cm)	Stem girth (cm)	Leaf area (cm^2)
0.17 (control)	10.53 a	86.08 ab	21.51 a	3206.6 a
3	10.80 a	87.81 a	21.79 a	2713.6 b
6	9.58 a	87.81 a	20.97 a	2302.0 c
9	8.00 b	81.94 b	18.91 b	1797.9 d
LSD	1.34	4.93	1.84	250.53
Banana varieties				
Diwan	8.22 c	98.69 a	18.24 c	3079.9 a
FHI18	9.83 b	93.67 b	20.93 b	2638.9 b
Malindi	10.72 a	76.86 c	23.28 a	2341.2 b
Williams	10.11 ab	73.61 c	20.73b	1960.1 c
LSD	0.8795	4.1028	0.9076	298.37
Plant age (month)				
5 (initial)	11.60 a	76.94 c	19.15 c	2714.92 a
7	9.33 b	88.52 b	21.09 b	2562.42 b
9 (end of experiment)	8.23 c	91.67 a	22.14 a	2237.77 c
LSD	0.56	1.57	0.35	87.8

Means with the same letter are not significantly different, (No. of observation: 36).

Results

The results of the experiment revealed the significant effects of salinity, variety as well as duration of growth (months) ($p\leq 0.01$), on number of leaves, plant height, pseudo-stem girth and leaf area. Highly significant ($p\leq 0.01$) interactions were also observed between varieties and salinity as well as between salinity and duration (months) of growth of the cultivars (Table 3). In respect to control (0.17 dS m^{-1}), the number of leaves, pseudo-stem height, stem girth and leaf area decreased by 24.03%, 4.8%, 12.09%, and 43.9% respectively with increase of NaCl in irrigation water to highest level 9 dS m^{-1} (Table 2). Cavendish cultivar (Malindi) had higher number of leaves (10.72) as shown in Figure1A, while plantain cultivar (Diwan) had the lowest number of leaves (8.22) (Table 2). Differences in plant height among all tested varieties showed that the average plant height were 98.69 cm and 93.67 cm among plantain types (Diwan, FHIA18) and 76.86 cm and 73.61 cm among the Cavendish cultivars (Malindi and Williams) respectively. The cultivars Diwan and Malindi were also found to be taller than other cultivars (Table 2). Malindi cultivar significantly ($p\leq 0.01$) had thicker stem girth (23.3 cm) followed by FHIA18 (20.9 cm), Williams (20.7 cm) and Diwan (18.2 cm). Stem girth was significantly affected in plants irrigated with high concentration of NaCl with a reduction of 12.08 % at 9 dSm-1 in relation to the control with low level of salinity (0.17 dSm-1) and 3.0 dS m^{-1}. This indicates significant ($p\leq 0.01$) interaction between salinity and banana cultivars. Similarly, both group of plantains (Diwan and FHIA18) and Cavendish banana (Malindi and Williams) showed considerable reduction in stem girth by 13.8, 17.66 and 20.6 and 15.9 at 9.0 dS m^{-1} respectively (Figure1B). The effect of cultivars on leaf area was also found to be more pronounced on Williams cultivar which had the lowest leaf area (1960.1 cm^2) than Malindi (2341.2 cm^2) and FHIA18 (2638.9 cm^2). While Diwan had the highest leaf area (3079.9 cm^2) as shown in (Table 2). Malindi cultivar as table fruit and Diwan as cocking types had the highest leaf area when compared to Williams and FHIA18. Correspondingly, high concentration of NaCl at 9.0 dSm^{-1}, 6.0 dS m^{-1} and 3.0 dS m^{-1} salinity reduced leaf area by 43.93%, 28.2% and 15.4% respectively in relative to control (0.17 dSm^{-1}). Plant age was also found to be negatively affected in leaf area by a reduction of 17.6% at the age of 9 month when compared to the first stages of plant growth. There was a significant interaction on leaf area between salinity and cultivars where the highest reduction in leaf area was observed at 6.0 and 9.0 dSm^{-1}. However there were noticeable differences in the reduction of leaf area with increasing salinity level between plantains banana (31.2 and 31.5%) and Cavendish group (57.6 and 62.1%) when they were irrigated with 9.0 dSm^{-1} (Figure 1C).

Table 3: Regressions equations and coefficients of determination of number of leaves, pseudostem girth and average leaf area of banana cultivars under different levels of saline irrigation water.

	Diwan	FHIA18	Malindi	Williams
Number of leaves	y = -0.175x + 8.73 R^2 = 0.9962	y = -0.415x + 10.97 R^2 = 0.9633	y = -0.197x + 11.25 R^2 = 0.8767	y = -0.1435x + 10.37 R^2 = 0.9294
Pseudostem girth (cm)	y = -0.297x + 19.57 R^2 = 0.966	y = -0.411x + 22.96 R^2 = 0.8055	y = -0.477x + 24.09 R^2 = 0.739	y = -0.4311x + 22.24 R^2 = 0.9493
Average leaf area (cm^2)	y = -141.2x + 3721.1 R^2 = 0.9397	y = -118.8x + 3163.1 R^2 = 0.8587	y = -181x + 3163.4 R^2 = 0.8475	y = -191.99x + 2816.9 R^2 = 0.962

Discussion

Studies have shown that plant metabolic processes and osmotic potential equilibrium between soil solution and plant water absorption may reduce the vegetative growth and development of some common plant species such as cereals, vegetables, fruits, forages and ornamental plants when grown under saline condition (Westcot, 2013). Similarly, leaf characteristics and stem growth have shown to exhibit low plant ability to grow and produce new leaves when exposed to high saline water (Romero-Aranda, Soria and Cuartero, 2001) The effect of salinity on the reduction of leaf area was also observed by several researchers on different banana genotypes (Gomes *et al.*, 2005). Irrigating plants with high NaCl level above 1.0 dS m^{-1} had caused banana plants to lose their functions to produce new leaves, and senesce earlier (Muscolo, Panuccio and Sidari, 2003). Irrigating banana plants with saline water of 3.0, 6.0 and 9.0 dSm^{-1} markedly caused death of affected leaves with faster expansion of brownish and necrotic tissues because of toxic effects due to salt accumulation in unfurled leaves and leaf apices as a result of missed function of stomatal and mesophyll conductance and enzymatic activities. It is therefore reasonable to suggest that salt stress and long course of exposure to the stress make plants to differ in energy assimilation and nutrients partitioning to other physio-chemicals processes such photosynthesis and metabolic responses. This contributes to reduction in growth and the emergence of new leaves (Lacerda *et al.*, 2001), and consequently producing shorter and smaller size pseudo-stems (Silva, 2009), thus resulting

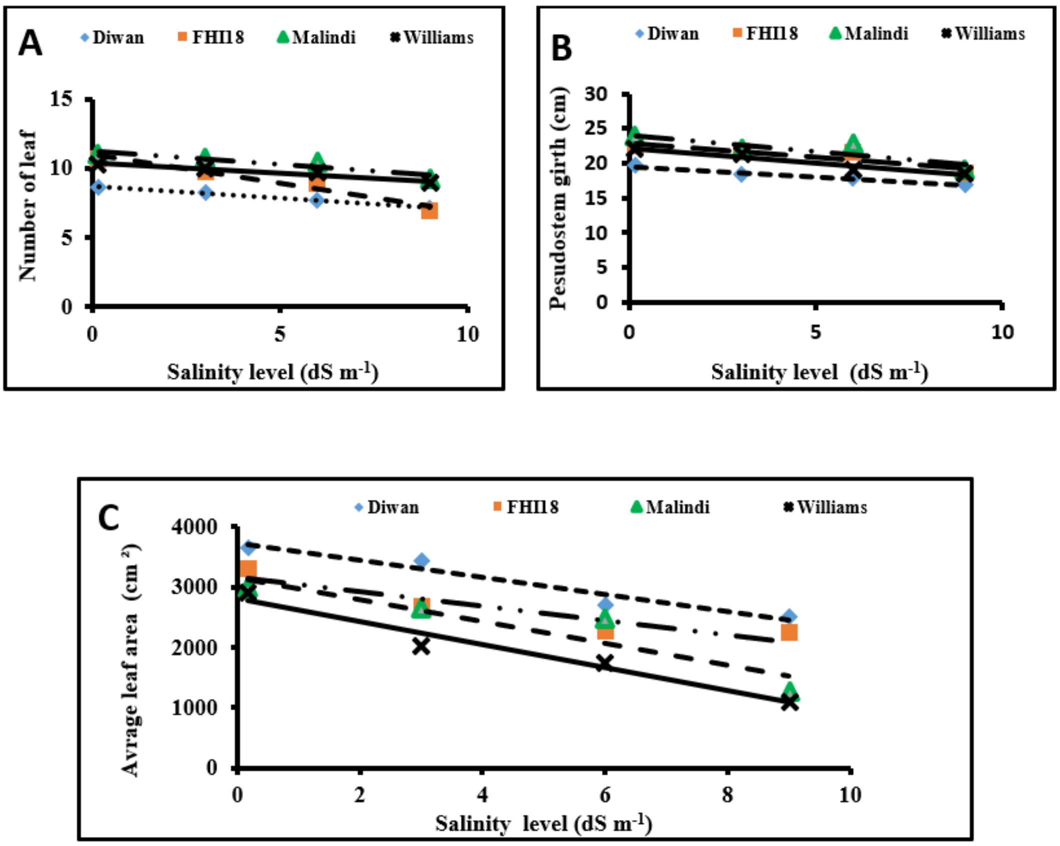

Figure.1: Interaction effect of salinity and variety on the number of leaf (A), pseudo-stem girth (cm) (B) and leaf area (cm^2) (C) of banana cultivars irrigated with different levels of salinity.

in low efficiency and encountering interferences with uptake of essential nutrients (Gomes *et al.*, 2005). The results of this study concur with several of previous in-vitro findings on different banana genotypes that producing short stature and smaller size under saline condition. For instance, decreased in plant height from 17 to 18% when compared to banana grown in non-saline as reported by (De Araujo Filho *et al.*, 1995; Macêdo *et al.*, 2005).

Conclusion

The present study revealed the negative effects of high salinity level on the morphological characteristics of banana causing plants to produce smaller pseudo-stem girth, smaller functional leaf area and limited new leaf production. Higher number of leaves and stem girth were maintained under Malaysian conditions as demonstrated for the first time by Malindi cultivar and Diwan cultivar. At higher NaCl concentration, banana leaf area was reduced from 15.4% at 3.0 dS m^{-1} to 43.93% at 9 dSm^{-1} relative to control 0.17 dSm^{-1}. Under saline irrigation, the number of leaves, pseudo-stem height and thickness of FHIA18 of that of Malindi were greater than Diwan and Williams, while Diwan and Malindi cultivars from different species had considerably greater leaf area. High salinity level noticeably caused serious leaf injury, necrosis and brownish toward the inner side of leaves. In conclusion, banana cultivars were found to be sensitive to salt osmotic potential as expressed in their morphological characteristics, however, Malindi and FHIA18 cultivars showed more tolerance to salinity conditions. The present study proposes that these latter cultivars (Malindi and FHIA18) be grown in moderate saline irrigated areas preferably after conducting specific investigation on physiological and biochemical responses.

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