



Effect of salinity on growth and yield of muskmelon (*Cucumis melo* L.) genotypes

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Abstract

In the present study we investigated the effect of different salinity levels (0, 50, 100, 150 and 200 mM NaCl) on growth and yield of two muskmelon genotypes. Regression analysis showed that salinity stress adversely affected the morphological and physiological attributes of both genotypes. Relatively, genotype 'T-96' showed more resistance and gave greater vegetative growth and yield as compared to 'Bukhara'. In both genotypes, leaf Na⁺ content increased, while K⁺ and K⁺/Na⁺ ratio decreased with the increase of salinity concentrations. Results also exhibited that genotype 'T-96' showed better tolerance to salinity stress, possibly due to accumulating maximum K⁺ and least Na⁺ ions, keeping higher photosynthetic rate and stomatal conduction and ensued greater biomass and yield.

Keywords: salinity stress, *Cucumis melo* L., physiological attributes, K⁺/Na⁺ ratio

Introduction

Soil salinity is one of the critical factors for agricultural production, and estimation says that by the year 2050; almost 50% of the arable land will be salt affected (Shrivastava and Kumar, 2015) [27]. Crops growing in arid and semi-arid regions are particularly at risk to salinity stress, because of low precipitation and high evapotranspiration in such areas (Hussain and Al-Dakheel, 2018) [11]. Salinity is a multidimensional factor, which creates water stress, ionic toxicity, imbalance the nutritional orders, and execute oxidative stress in plants (Machado and Serralheiro, 2017; Tavakkoli *et al.*, 2010) [20, 29]. However, the two distinct effects of salt on plant are osmotic and ionic stresses (Gupta and Huang, 2014) [9]. In addition to this, salt stress also exhibits oxidative stress in plant.

Salt stress hinders the physiological and metabolic functions of plant. As a result plant vegetative growth such as shoot root length, shoot root biomass and leaf area are reduced (Rahneshan *et al.*, 2018) [26]. Resistance of plants to salt stress is mainly depends upon its genetic makeup (Flower and Colmer, 2008) [8]. Most of the plant species do not have the ability to restrain the toxic salt ions going inside the body; which create osmotic pressure in cytosol. This interrupts the ionic (Na⁺, K⁺, Ca²⁺ etc) homeostasis in plant and ultimately reduces the normal physiological and biochemical functions and caused low growth and yield (Gupta and Huang, 2014; Asif *et al.*, 2020; Masood *et al.*, 2020) [5, 9, 22]. Under salt stress conditions, Na⁺ and K⁺ homeostasis has a critical role in progression and development of plant (Asif *et al.*, 2020; Nazir *et al.*, 2020) [5, 25]. Plants having the ability to maintain greater K⁺/Na⁺ ratio under salt stress conditions are measured as salt tolerant or vice versa (Khan *et al.*, 2009) [16]. Salinity stress also limit the photosynthetic process in plant; and it may be related to stomatal or non-stomatal factors. The stomatal factor is related to stomata closure in leaf; while non-stomatal factors relates to chlorophyll production, photosynthetic electron transport and others (Liu *et al.*, 2011) [19].

Muskmelon (*Cucumis melo* L.) is the important crop species from cucurbit family and is mostly grown in arid and semi-arid regions throughout the world. The fruit is famed for its nutritional values as it is a rich source of vitamins, carbohydrates, proteins and minerals. Beside these, it has great medicinal importance and work as an anti-cancer, anti-diabetic, and anti-microbial (Danish *et al.*, 2020; Ali *et al.*, 2020; Khalil *et al.*, 2020ab; Milind and Kulwant, 2011) [2, 7, 14, 15, 23]. Crops grown in arid and semi-arid regions are mostly threatened with high salinity (Allbed and Kumar, 2013) [1]. In general, muskmelon is considered moderately tolerant to salinity; but its tolerance depends upon the individual cultivar (Kusvuran *et al.*, 2007) [17]. There are various reports which endorse that there is great genetic diversity exists in melon cultivars regarding salt tolerance (Kusvuran *et al.*, 2007) [17]. It is therefore important to explore muskmelon cultivars with high capacity of salt tolerance. The present study was therefore, undertaken to investigate the salt tolerance potential of two important local muskmelon cultivars on the basis of some important morphological and physiological attributes.

Materials and Method

Present experiment was conducted to investigate the salt tolerance capacity of two muskmelon genotypes at National Agricultural Research Centre, Islamabad, during the year 2011. Seeds of muskmelon genotypes (T-96 and Bukhara) were sown in earthen pots filled with 12 Kg sandy loam soils and evaluate for their vegetative growth and yield in response to various salinity levels (0, 50, 100, 150, and 200 mM NaCl). The pots were lined with good quality polyethylene sheet so as to restrict the soil solution seepage. Before sowing, seeds were surface sterilized with 10% hypochlorite solution for 5 minutes and then rinsed in distilled water thoroughly. Ten sterilized seeds in each pot were sown and irrigated daily with tap water for 12 days. After germination two uniform seedlings were maintained per pot. The pots were kept in an open field under natural light conditions. After 15 days of germination, the plants

were subjected to various salts stresses @ 50 mmol L⁻¹ NaCl daily till the desired level was achieved.

Na⁺ and K⁺ determination

Leaf was taken and dried in oven at 70 °C for 48 hours. Leaf sample of 0.5 g for each treatment was weighed and shifted to crucible. The crucible along with leaf samples placed in cool muffle furnace and ashes at 550 °C for 4 hours. The temperature was increased gradually. The furnace was stopped gently and the sample was keeping it there for a while, so as to achieve the room temperature. Afterward, 2N HCl was added to the ashed samples for 1 h. Samples were diluted to 50 mL with distilled water and then filtration was made. Na⁺ and K⁺ content were determined by flame photometer (Sherwood model 410, Japan) and the concentration expressed as (% DW). The procedure was carried out as prescribed by Chapman and Pratt, (1961) [6].

Gas Exchange attributes

Photosynthetic rate (A) and stomatal conductance (g_s) were recorded through Infrared Gas Analyzer (IRGA, LCA-4, ADC, Hoddesdon UK). The readings were taken from the fully expanded 4th leaf from the top of the muskmelon plants at morning (9:00 am to 11:00 am). Before taking the measurements, the instrument was adjusted to zero. The attributes noted three times for each treatment.

Total Chlorophyll content

Leaf chlorophyll content was determined using equation of Arnon, (1949) [4]. Leaf sample of 0.5 g was chopped in mortar and pestle using 80% acetone of 20 ml quantity. The given mixture was centrifuged thoroughly. The supernatants of samples were used for chlorophyll estimation. Readings were taken at 654 nm and 663 nm of wavelength for chlorophyll 'a' and 'b' and total chlorophyll was calculated by summation of chlorophyll 'a' and 'b', using spectrophotometer (Unico- UV 210 Japan).

Statistical analysis

The data collected on the above-mentioned parameters were subjected to regression analysis and presented in graphs. Regression analysis was performed on Microsoft Office Excel 2010 (Steel and Torrie, 1984) [28].

Results and Discussion

Vegetative growth and yield parameters

Regression analysis showed that various vegetative growth attributes of both muskmelon genotypes significantly ($p \leq 0.05$) and adversely affected by salinity stress and is presented in (Fig.1, 2 & Table 1). The trend line showed that different vegetative growth parameters such as vine fresh weight, vine length, leaf area and yield per plant linearly and steeply decreased with increase of salinity concentrations. Maximum values for all the vegetative growth parameters were recorded at control (0 mM NaCl), while minimum values were observed when plants were subjected to highest 200 mM NaCl level. When estimated at 200 mM NaCl level, the yield per plant was significantly decreased by 64% and 83% for T-96 and Bukhara respectively due to salinity stress on account of decrease in leaf area, vine fresh weight and vine length. When assessed at 200 mM NaCl concentration, vine length of T-96 decreased by 46% and Bukhara by 55% as compared to control. Similarly, in comparison to control, leaf area for T-

96 decreased by 47% and Bukhara by 64%. The present results are in accordance of Tavakkoli *et al.* (2010) [29] and Jahan *et al.* (2019) [13], who reported that vegetative growth of plants decreases when expose to salinity stress. Previous studies also confirm that plants with greater length and fresh weight ensued in improved yield production (Al-Zubaidi, 2018; Jahan *et al.*, 2019) [3, 13] and these reports confirm the present findings. Nawaz *et al.* (2010) [24] reported that biomass production of plants is linked with ionic and osmotic adjustments, and ionic imbalances impair the selectivity of K⁺ uptake which results in low growth and ultimately low yield. All these reports confirm and support the findings given in the present work.

Na⁺, K⁺, K⁺/Na⁺ ratio and Total Chlorophyll content

Regression analysis depicted that salinity stress altered the Na⁺, K⁺ and total chlorophyll content of both genotypes as shown in (Fig. 3, 4 and Table 1). Various salinity levels increased the Na⁺ leaf content of both T-96 and Bukhara and the increase was severe with the increase of NaCl concentration. Therefore, minimum (0.34 and 0.39 % DW) Na⁺ content was noted down at control, while maximum (1.52 and 2.11 % DW) was recorded at 200 mM NaCl level for T-96 and Bukhara respectively. When estimated at 200 mM NaCl level, the Na⁺ content of T-96 increased by 3.5-fold and Bukhara by 4.5-fold as compared to control. In contrast, the K⁺ leaf content of both genotypes decreased with the increases of NaCl concentration. Hence, maximum (2.38 and 2.23 % DW) K⁺ content was recorded at control, and minimum (1.64 and 0.89 % DW) was observed at highest 200 mM NaCl for both T-96 and Bukhara respectively. When evaluated at 200 mM NaCl, the K⁺ content of T-96 decreased by 27% and Bukhara by 60% as compared to control. Similarly, K⁺/Na⁺ ratio of both genotypes decreased with the increase of salinity stress. Maximum K⁺/Na⁺ ratio for both genotypes was recorded at control while minimum was observed at highest 200 mM NaCl level. When assessed at 200 mM NaCl level, K⁺/Na⁺ ratio for T-96 decreased by 85% and Bukhara by 93% as compared to control. Similar adverse effects were observed for total chlorophyll content in both genotypes due to salinity stress. Total chlorophyll content of both genotypes decreased with the increasing of salinity concentration. Hence, both T-96 and Bukhara possessed maximum chlorophyll content at control while minimum was observed when plants were subjected to 200 mM NaCl concentration. When evaluated at 200 mM NaCl level, the leaf chlorophyll content of T-96 declined by 33% and Bukhara by 65% as compared to control. The present results showed that ionic hemostasis of muskmelon plants disturbed when exposed to salinity stress. Na⁺ content increased, while K⁺ and K⁺/Na⁺ ratio decreased as the salinity concentrations increased. Ionic hemostasis has crucial role to discriminate between the salt tolerance potential of any plant (Ibrarullah *et al.*, 2019; Tavakkoli *et al.*, 2010) [12, 29]. Plants having the ability to refuse Na⁺ and attract greater K⁺ are considered as salt tolerant. Higher accrual of Na⁺ in plants under salt stress is always inversely proportional to plant growth rate (Li *et al.*, 2014) [18]. Na⁺ is considered the most toxic ion of salts. In saline condition, Na⁺ suppress the entry of beneficial ions such as K⁺ and Ca²⁺ (Ibrarullah *et al.*, 2019; Tavakkoli *et al.*, 2010) [12, 29] and such findings support the present results, as K⁺ content decreased when Na⁺ increased in leaf of muskmelon. Though the present results showed that

salinity decreased K^+ and increased Na^+ , however, genotype T-96 showed tolerance and subdue the Na^+ and increase the K^+ uptake and hence gave greater yield and biomass production. These results are in accordance of (Ibrarullah *et al.*, 2019; Mahlooji *et al.*, 2018) ^[12, 21] who reported that genotypes retaining greater K^+ and less Na^+ are considered salt tolerant. The decrease in chlorophyll content might be attributed to decrease in water uptake due to salt stress and slowdown of other physiological functions like photosynthetic rate and stomatal conduction.

Photosynthetic rate (A) and Stomatal conductance (g_s)

Regression analysis revealed that various salinity levels considerably ($p \leq 0.05$) decreased the leaf photosynthetic rate and stomatal conductance of both genotypes (Fig. 5 & Table 1). The trend line displayed that leaf photosynthetic rate of both T-96 and Bukhara decreased gradually with the increase of salinity concentration. Therefore, maximum photosynthetic rate for both genotypes was recorded at control, while minimum was detected when plants subjected to highest 200 mM NaCl stress. As compared to control plants, the photosynthetic rate of T-96 decreased by 55% and Bukhara by 66% when assessed at 200 mM NaCl level. Likewise, stomatal conductance of leaf of both genotypes decreased with the increase of salinity concentrations. Thus, better stomatal conductance for T-96 and Bukhara was

noted at control and less was observed when plants subjected to highest 200 mM NaCl salinity stress. When evaluated at 200 mM NaCl, the stomatal conduction for T-96 decreased by 45% and Bukhara by 57% as compared to control. The present results showed that these important physiological attributes such as photosynthetic rate and stomatal conductance decreased when plants subjected to salinity stress and decrease was more as the salinity concentrations increased. There are previous findings who elaborate that salt stress reduces the photosynthetic rate, stomatal conduction and chlorophyll content of plant when exposed to salinity stress (Ibrarullah *et al.*, 2019; Liu *et al.*, 2011) ^[12, 19]. The present results showed that decrease in photosynthetic rate and stomatal conduction of muskmelon leaf was slight in T-96 as compared to Bukhara and such finding are in accordance of (Mahlooji *et al.*, 2018) ^[21] who reports that tolerant genotypes showed greater photosynthetic rate and stomatal conduction. The decrease in photosynthetic process and chlorophyll content might be attributed to decrease in water uptake due to salt stress. Also, toxic ions of salt (Na^+ and Cl^-) injuries to soft tissues of plant and decrease the cell division and disrupt the whole metabolic processes. All these factors collectively negatively affect the physiological mechanism of plant and ultimately reduced the plant growth and yield.

Table 1: Regression coefficients for different parameters studied, where a, b & r^2 are the intercept, linear coefficient and coefficient of determination respectively and the values in parenthesis are the standard errors

Parameters	Genotypes	R ²	a	b	Probability
Vine Fresh Wight (g)	T-96	0.996	467.91 (± 12.26)	2.11 (± 0.069)	0.0001
	Bukhara	0.944	323.69 (± 32.77)	1.32 (± 0.185)	0.005
Vine Length (cm)	T-96	0.992	415.42 (± 16.21)	3.70 (± 0.185)	0.0003
	Bukhara	0.988	353.19 (± 16.00)	3.05 (± 0.186)	0.0005
Leaf area (cm ²)	T-96	0.968	417.26 (±33.88)	2.57 (± 0.268)	0.0024
	Bukhara	0.987	295.12 (± 13.47)	1.78 (± 0.115)	0.0005
Yield /Plant (g)	T-96	0.954	302.64 (± 26.85)	0.140 (± 0.005)	0.0002
	Bukhara	0.994	233.91 (± 6.37)	0.116 (± 0.005)	0.0002
Na ⁺ content	T-96	0.957	33.43 (±18.36)	158.47 (±19.36)	0.0038
	Bukhara	0.988	32.70 (± 9.31)	111.33 (± 6.90)	0.0005
K ⁺ content	T-96	0.944	662.13 (± 79.55)	271.29 (± 38.11)	0.0036
	Bukhara	0.987	336.27 (± 16.23)	148.22 (± 9.76)	0.0003
K ⁺ /Na ⁺ ratio	T-96	0.949	211.46 (± 17.50)	31.56 (± 4.21)	0.0049
	Bukhara	0.869	176.22 (± 22.51)	33.05 (± 7.38)	0.0207
Total chlorophyll content	T-96	0.943	576.30 (± 68.46)	409.89 (± 58.31)	0.005
	Bukhara	0.984	293.22 (± 14.71)	208.66 (± 14.93)	0.0008
Photosynthetic rate	T-96	0.990	359.27 (± 14.78)	20.14 (± 1.11)	0.0004
	Bukhara	0.997	302.68 (± 5.59)	18.43 (± 0.481)	0.0001
Stomatal conductance	T-96	0.979	424.69 (± 27.67)	1.49 (± 0.124)	0.0012
	Bukhara	0.977	334.56 (± 21.24)	1.23 (± 0.107)	0.0014

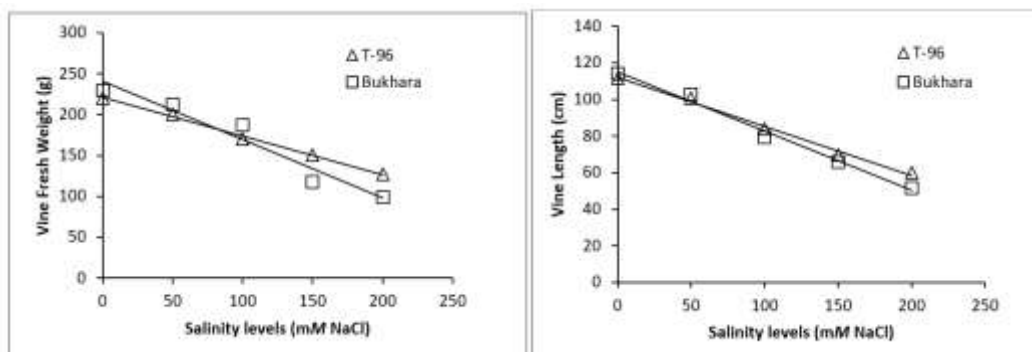


Fig 1: Effect of different levels of salinity on Vine fresh weight and Vine length of muskmelon genotypes

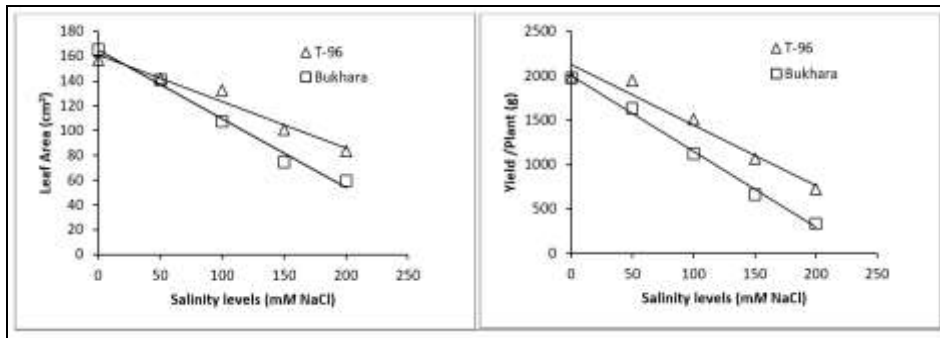


Fig 2: Effect of different levels of salinity on Leaf area and Yield per plant of muskmelon genotypes

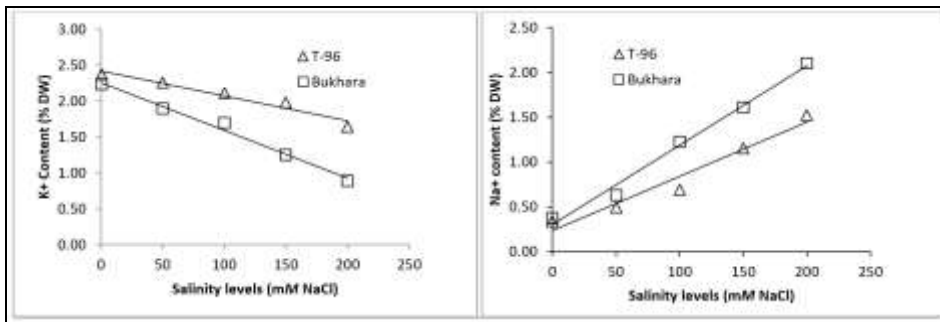


Fig 3: Effect of different levels of salinity on K⁺ content and Na⁺ content of muskmelon genotypes

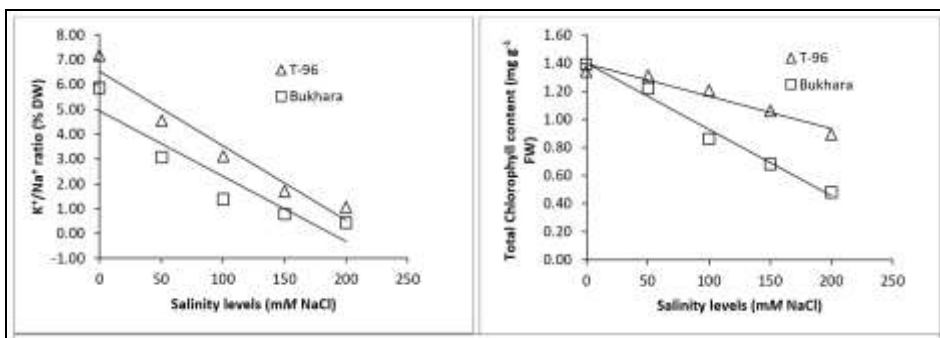


Fig 4: Effect of different levels of salinity on K⁺/Na⁺ ratio and Total chlorophyll content of muskmelon genotypes

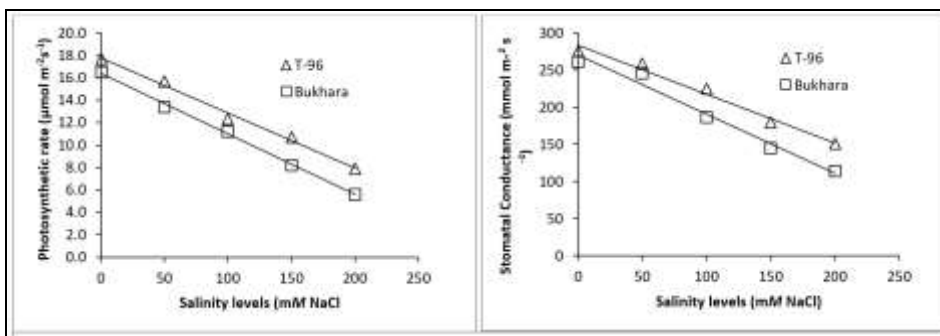


Fig 5: Effect of different levels of salinity on Photosynthetic rate and stomatal conductance of muskmelon genotypes

Conclusion

The instant results revealed that salinity stress negatively affected all the morphological and physiological attributes of both muskmelon (*Cucumis melo* L.) genotypes. The ionic homeostasis of muskmelon plant changed when exposed to salinity, as Na⁺ content increased and thereby decreased K⁺ and K⁺/Na⁺ ratio. However, genotype T-96 exhibited tolerance performance and inhibited the toxic effect of salt as gave greater vegetative growth and yield and maintained controlled physiological functions under salinity stress conditions.

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