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Effects of Salinity Sources on Growth, Physiological Process, Yield, and Fruit Quality of Grafted Rock Melon (*Cucumis melo* L.)

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ABSTRACT

There is an increase in demand for high-quality rock melon for the local market. Supplementing salt with a nutrient solution is a viable approach that can be implemented to improve fruit quality. Therefore, this study aims to determine the best salt treatment that can be utilized to increase fruit quality without reducing growth, yield, and physiological process. The study is conducted by grafting (DAG) rock melon/bottle gourd at 18 days with four sources of salinity: basic nutrient solution (BNS) (2.5 dS m^{-1}), sodium chloride (NaCl) (50 mM) + BNS (7.1 dS m^{-1}), potassium nitrate (KNO_3) (50 mM) + BNS (7.1 dS m^{-1}), and high strength nutrient solution (NS) (7.1 dS m^{-1}). The plants were arranged in a randomized complete block design (RCBD) with four replications. Salinity induced using KNO_3 + BNS sustained most growth variables, fruit quality, relative water content, and leaf gas exchange compared with control. However, applying NaCl + BNS and high strength NS could sustain all physiological processes and increase fruit quality components, such as total soluble solid and sugar-acid ratio compared to control. Fruit weight had reduced regardless of salinity sources than those grown in control with their respective fruit weight reduction of 28.8%, 28.26%, and 27.72%. To conclude, incorporating NaCl at 50 mM

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is the most feasible approach to be applied on grafted rock melon/bottle gourd even though the fruit weight had reduced. It is due to the high fruit quality measured, capable of sustaining all physiological processes, provides lower cost, and is easily accessible than other sources of salinity.

Keywords: Fruit quality, grafted rock melon, salinity sources, salinity stress, salt-tolerant rootstock

INTRODUCTION

Rock melon, also known as muskmelon (*Cucumis melo* L.), is a short-term horticultural crop and belongs to the Cucurbitaceae family. It is one of the most important crops commonly cultivated for whole fruit consumption. Generally, melons are used as vegetables, desserts, salads, and pickles (Pitrat, 2016). The fruits are highly nutritious and rich in antioxidants, including phenolic compounds, ascorbic acid, and carotenoids (Menon & Rao, 2012). It also contains vitamin C, flavonoids, vitamin B, and fiber and is naturally low in fat and sodium. In addition, it has no cholesterol and provides many essential nutrients, especially potassium (Manchali et al., 2021). Furthermore, melons used as vegetables have flavonoids, alkaloids, and bitter elements, which increase health advantages (Gómez-García et al., 2020).

In Malaysia, rock melon is commercially grown to fulfill a demand for the local and export markets. Over the years, rock melon production has increased drastically, up to 45.56% since 2012, with total production recorded at 5,845.71 metric tonnes in 2018 (Department of Agriculture Malaysia and Agro-based Industry Malaysia [DOA], 2018). The increase in production areas is due to high consumers' demand for high fruit quality. According to Lester (2006), fruit quality, such as sweetness, taste, texture, and flavor, is the most important reason for consumers' higher preference for melon productions.

Salt addition as a nutrient solution has high potential, is cost-effective, and is easy to be adapted, which can increase rock melon quality. The success has been proven for a variety of horticultural crop species including cucumber (Huang et al., 2009), tomatoes (Azarmi et al., 2010), and watermelon (Costa et al., 2013). Accumulation of salt may reduce water absorption capacity that could increase dry-matter components. An increase in dry matter components ultimately enhances fruit quality attributes, including total soluble solid, titratable acidity, and sugar-acid ratio (Dias et al., 2018). According to Jawandha et al. (2017), applying KNO_3 salts could increase vegetative growth and enhance yield and fruit quality attributes. Besides, high NaCl salt accumulated in the fertilization system has proven to increase fruit quality parameters, such as total soluble solid, total titratable acidity, and sugar-acid ratio (de L. Pereira et al., 2017). On the other hand, the nutrient solution is an inorganic fertilizer that delivers nutrients in the form of a liquid. It comprises many ionic or salt compositions important for sustaining plant performances in horticultural crop productions (Saliqehdar et al., 2014).

Nevertheless, rock melon's excess and continuous supply could lead to salinity development and deleteriously affect the growth and yield. Under a high saline environment, crop growth and yield are reduced significantly, impairing the physiological process (Munns & Tester, 2008). Pessarakli (2016) stated that the rock melon is moderately sensitive to salt stress among cucurbit species. Supplementation using different salinity sources can improve fruit quality without reducing growth, physiological process, and yield (P. Zhang et al., 2016). The salt-tolerant level in rock melon could be increased using salt-tolerant rootstock (Yarsi et al., 2017). Previously, bottle gourd has been proven to be the promising salt-tolerant rootstock for watermelon (Yetisir & Uygur, 2010), cucumber (Huang et al., 2009), and higher growth performance was recorded under salt stress than self-grafted plants. Thus, applying salinity sources on grafted rock melon/bottle gourd could be justified to improve fruit quality without detrimentally affecting growth, physiological process, and yield.

After considering those factors, the studies are necessary to identify and select the most suitable salinity sources for grafted rock melon/bottle gourd. This research may contribute to a new knowledge of growing rock melon with salt added, improving fruit quality without reducing growth, physiological process, and yield. Furthermore, the knowledge produced in this study may be useful in improving rock melon development practices and exploiting new research pathways for rock melon in the future.

MATERIALS AND METHODS

Location and Experimental Materials

This experiment was conducted in the rain shelter structure at University's Agriculture Park nursery, Universiti Putra Malaysia, from September 2020 to December 2020. The planting materials used in this study were rock melon (*Cucumis melo* L.) var. Glamour as scion and bottle gourd (*Lagenaria siceraria*) var. BG696 as rootstock.

Treatments and Experimental Design

This experiment consisted of four salinity source treatments arranged in a randomized complete block design (RCBD) with four replications. The replications used were represented as a block to reduce the errors and interferences in the rain shelter structure. Each of the replicas consisted of eight plants, totaling 128 plants. The salinity sources treatments used in this study were basic nutrient solution (BNS) as control, NaCl, KNO_3, and high strength nutrient solution (NS), with their respective concentrations shown in Table 1.

The formulation for BNS is based on a standard nutrient solution used in the melon fertigation system, prepared at 2.5 dS m^{-1} (Shahid et al., 2009). This solution contains (mg L^{-1}) of 232 nitrogen (N), 67 phosphorus (P), 239 potassium (K), 120 calcium (Ca), 30 magnesium (Mg), 3 iron (Fe), 80 sulfur (S), 0.62 manganese (Mn), 0.44 boron (B), 0.02 copper (Cu), 0.11 zinc

Table 1

The salinity sources treatments with respective concentrations

Salinity sources and concentrations (dS m^{-1})
Basic nutrient solution (BNS) = 2.50 dS m^{-1}
NaCl (50 mM) + BNS (2.50 dS m^{-1}) = 7.13 dS m^{-1}
KNO_3 (50 mM) + BNS (2.50 dS m^{-1}) = 8.55 dS m^{-1}
High strength nutrient solution (NS) = 7.13 dS m^{-1}

(Zn) and 0.048 molybdenum (Mo). The second treatment was prepared by adding 50 mM NaCl salt with 2.5 dS m^{-1} BNS, while the third treatment used a mixture of 50 mM KNO_3 fertilizer with 2.5 dS m^{-1} BNS. The fourth treatment was done by increasing the concentration of BNS from 2.5 dS m^{-1} to 7.13 dS m^{-1}. Each treatment solution was prepared in 200 L fertilizer containers, which were checked and quantified using electrical conductivity (EC) meter (Model HI-98311, Hanna Instrument, USA).

Plant Maintenance and Treatment Applications

Seeds were sown in a germination tray filled with 100% peat moss and placed under 25% shade on a 1.2-meter bench. Eight days after sowing (DAS), the uniform-sized seedlings were selected and transplanted into a 400 ml pot filled with 100% cocopeat for grafting. All the seedlings designated as rootstock were daily watered by manual drench. Rock melon seedlings in germination tray sown as scion were maintained and watered at field capacity daily. At 13 DAS, all the uniformed-sized scion and rootstock were selected and grafted together using the tongue approach grafting (TAG) technique, a procedure described by Lee and Oda (2003). At six and 12 days after grafting (DAG), approximately 0.5 g of N: P: K (15:15:15) compound fertilizer were given to all grafted plants and daily watered up to field capacity. At 18 DAG, uniform sizes grafted plants were transplanted into the 12 liters of white polyethylene bags filled with 100% cocopeat.

As the plant grew, excess water shoots were removed to increase the growth of the main shoot. The growing shoots were attached to a rope to support the plant's structure and facilitate maintenance. During the reproductive stage, assisted pollination was done from 0830 h to 1030 h. Male flowers were attached to female flowers with the ratio of flowers used at 3:1; male: female to initiate the pollination process. Pollinated flowers were labeled with the date and time. Approximately two to three female flowers per plant were pollinated along the flowering stages. At the fruit setting stage, only one fruit per plant was maintained throughout this experiment, whereas the rest was removed. Growing fruits were supported with the rope to prevent abortion. Pest and disease management was done when necessary, depending on the growing stages

of the plants. At 70 days after transplantation (DAT), all the fruits were harvested with careful handling for data collection.

At 18 DAG, the solution of the treatments was manually drenched using plastic cups with the amounts of 1 liter/plant for 70 days. The frequency of the treatment solution given was increased gradually according to the growing stages as once a day (1-5 DAT), twice/day (6-15 DAT), thrice/day (16-35 DAT), fourfold/day (36-55 DAT), and fivefold/day (56–70 DAT). The EC of the growing media was determined using the pour-through method (Cavins et al., 2000) at vegetative (15 DAT) and fruiting (50 DAT) stages from 1300 h to 1400 h. The EC of four treatment solutions recorded were 2.73, 8.62, 9.25, and 9.05 dS m^{-1} for BNS, NaCl + BNS, KNO_3 + BNS, and high strength NS, respectively. During the experiment, average maximum temperature and relative humidity were recorded once a week at 1400 h under natural photoperiod conditions (12 hours light/12 hours dark). The maximum temperature recorded was 35.0 (±5) ºC, with relative humidity (RH) at 62.4 (±10) %. Besides, average carbon dioxide concentrations and light intensity were recorded once a week as 459.9 ppm and 986.17 µmol $m^{-2}s^{-1}$, respectively.

Data Collection

Growth Measurements. Plants were randomly sampled from each treatment to determine plant height, stem diameter, leaf number, total leaf area, and dry weight. Dry weight components, including leaf, stem, and root, were taken at 70 DAT. Plant height was measured from the graft union to the highest shoot tip using a measuring tape. Scion diameter was measured at 1 cm from the growing media surface using an electronic digital caliper (Model CD6''CS Mitutoyo Corp., Japan). At the same time, the leaf number was manually counted based on fully expanded leaves. The whole plants were then harvested and separated into leaf, stem, and root to determine the leaf areas and dry weight matter. Leaf areas were measured and recorded as total leaf area per plant using an automatic leaf area meter (Model LI-3100C, LI-COR Biosciences, USA). All samples were dried to constant weight for at least 72 hours in a forced draught oven at 70 ˚C before being weighed using a digital analytical balance (Model CDS125, Mitutoyo Inc., Japan).

Physiological Process

Relative Water Content (RWC). The water status of the plants was determined by RWC in the leaves using Khare et al.'s (2010) method. RWC was measured at 55 DAT on a fully expanded leaf. Samples of leaves were kept in the icebox and were carried to the laboratory. Ten leaf discs of 5 mm diameter were cut using a single hole puncher, and the fresh weight (FW) was recorded using a digital analytical balance. The leaf discs were then floated in a small dish containing deionized water for four hours to regain turgidity and reweighted to estimate the turgid weight (TW). Later, the leave discs were dried in a drying oven

at 70 °C for 72 hours to determine the dry weight (DW). The RWC was calculated based on the following equation, and the values were expressed in percentage:

$$RWC\ (\%) = (FW - DW / TW - DW) \times 100\%$$

where,
RWC = Relative water content
FW = Fresh weight
DW = Dry weight
TW = Turgid weight

Leaf Gas Exchanges. Leaf gas exchanges were determined by measuring the net photosynthesis, stomatal conductance, and transpiration rate on a selected fully expanded leaf at 55 DAT. The measurements were taken using a portable close photosynthesis machine (infra-red gas analyzer, Li 6400, LI-COR Biosciences, USA) between 9.30 a.m. to 10.30 a.m. with three measurements for each leaf. The measurements used optimal cuvette conditions, at 1000 µmol $m^{-2}s^{-1}$ photosynthetic photon flux density (PPFD), 400 µmol/ mol carbon dioxide (CO_2) at 30 °C cuvette temperature, and 60% relative humidity with the air flow rate set at 500 cm^3/min. Irradiance was provided by a light emitting diode red, green, and blue (LED RGB) light source (LI-6400-02B, LI-COR Biosciences, USA).

Maximum Efficiency of Photosystem II (F_v/F_m). The chlorophyll fluorescence measurements were taken on a selected fully expanded leave at 55 DAT. Chlorophyll fluorescence was measured using a portable fluorescence spectrometer (Mini-PAM, WALZ, Germany). Before the measurements started, the leaves' surface was attached to a light-exclusion clip for 20 minutes. The leaf clip shutter plate was then slid to the open position, and the exposed leaf area was illuminated on the sensor head. As a result, the chlorophyll fluorescence was expressed in F_v/F_m, where F_v is variable fluorescence and F_m is maximal fluorescence (Lambers et al., 2008).

Relative Chlorophyll Content (SPAD) and Photosynthetic Pigments. Relative chlorophyll content was measured on the fully expanded leaves of each plant at 55 DAT using a leaf chlorophyll meter (SPAD-502 Plus Chlorophyll Meter, Konica Minolta, Inc., Japan). The measurements were taken from three different spots on the leaf surface. The measurements of photosynthesis pigments were taken at 55 DAT. Photosynthetic pigments consisted of chlorophyll *a*, *b*, total chlorophyll (*a* + *b*), and chlorophyll *a*/*b* ratio. Three plant samples of fully expanded leaves were selected from each replication. Samples were taken from the leaf samples using a single-hole puncher at a 5 mm diameter. After a modified procedure, pigments were extracted from ten leaf disks using dimethyl sulfoxide (Nikolopoulos et al., 2008). First, samples were pipetted with 10 ml of dimethyl sulfoxide and then incubated at 65 °C in an oven for four hours until all the pigments were extracted and the leaf disks became transparent. Then, a 3 ml aliquot of the green color was pipetted into the cuvette, and 3 ml of dimethyl sulfoxide was pipetted into another cuvette to serve as a blank. Samples were quantified using a

spectrophotometer (OPTIZEN™ POP UV Vis Spectrophotometer, Korea) and were read at 649, 665, 480, and 510 nm under low light conditions. Chlorophylls and total carotenoid content were calculated based on the following equations (Lichtenthaler & Buschmann, 2001):

nmol (Chl *a*) / cm^2 = [(12.47 E_{665} – 3.62 E_{649}) x V x 1.119] / A

nmol (Chl *b*) / cm^2 = [(25.06 E_{649} – 6.45 E_{665}) x V x 1.102] / A

nmol (Chl *a* + *b*) / cm^2 = (Chl *a*) + (Chl *b*)

(Chl *a*/*b*) = Chl *a* / Chl *b*

nmol (Carotenoid) / cm^2 = [(7.60E_{480} - 1.49E_{510}) x V x 1.102] / A

where,
V = Final volume of aliquot
A = Total area in m^2 of the leaf tissue extracted
E = Absorbance of aliquot

Note. Chlorophyll *a*, *b*, total chlorophyll, and total carotenoid content were expressed as nmole/ cm^2 of FW materials, while chlorophyll *a*/*b* is a dimensionless ratio.

Yield Components

Fruit yield components consisted of fruit weight and fruit retention time. At 70 DAT, the fruit was harvested and weighed using a digital analytical balance. The fruit retention time was calculated based on the total days of the fruit retained on the stem that started on the day of assisted pollination until harvesting day.

Fruit Quality Components

Fruit quality is referred to as its chemical characteristics as the measurements consisted of pH, total soluble solid (TSS), total titratable acidity (TTA), sugar acid ratio, vitamin C, and fruit firmness. Harvested fruit was then cut, and the juice was extracted and transferred into a digital refractometer (PR-100SA, Atago CO., LTD., Japan), and the reading was taken in degrees Brix (^oBx). Determination of vitamin C was done using the volumetric methods of titration according to Pisoschi et al. (2009). The pulp was blended, and 10 g of samples were mixed with 20 ml of 3% phosphoric acid (HPO_3) (Sigma-Aldrich, USA) and filtered. Then, 10 ml of the filtrate was pipetted and titrated against dichlorophenol indophenol (DCPIP) (Systerm Chemicals, Malaysia) until the solution turned slightly pink. Another 5 g of the blended samples were mixed with 50 ml of distilled water for pH and TTA determinations. The TTA was quantified as the methods described by Melkamu et al. (2009). Both pH and TTA were read using a titrator instrument (Metrohm 848 Titrino plus, Germany). The value for TTA was expressed by citric acid, which served as a major organic acid. The sugar-acid ratio was calculated by the dimensionless ratio of TSS/TTA. Fruit firmness was measured using a texture analyzer (TA.XT Plus 100, United Kingdom). A cylinder probe of 5 mm diameter size was forced onto the pulp surface, and the reading was expressed in Newton (N).

Organoleptic Assessment

Vallone et al.'s (2013) method did a sensory evaluation for rock melon pulp. The evaluation involved 16 untrained panelists, who were given six pieces of ripe fruits from each treatment. The fruits used were harvested two hours before the beginning of the test. The panelists were requested to assess the fruits' color, sweetness, texture, and flavor, where the scores were based on a scale from zero (unacceptable) to seven points (perfect).

Statistical Analyses

All the data taken was computed using a statistical analysis system (SAS) (version 9.4). All the variables were assessed for normal distribution using a univariate procedure. Variables were not meet the normally distributed curve were transformed using log transformation. The general linear model (GLM) procedure was used for variance (ANOVA) analysis, and mean comparisons at $P \leq 0.05$ were done using Duncan's Multiple Range Test (DMRT). Relationships among the variables for all salinity sources treatments were pooled and determined using Pearson's correlation coefficients (r) at $P \leq 0.05$ by correlation procedure. The data for fruit sensory evaluation taken by 16 panelists was assessed using the GLM procedure and the mean comparison test using orthogonal contrast at $P \leq 0.05$.

RESULTS

Effect of Salinity Sources on Growth

The growth measurements include stem diameter, leaf number, total leaf area, leaf, and stem dry weight of grafted rock melon were significantly affected ($P < 0.05$) by salinity sources (Table 2).

Table 2

Effects of salinity sources on growth as plant height, stem diameter, leaf number, total leaf area, leaf, stem, and root dry weight of grafted rock melon (Mean ± SD; n=4)

Factor	Levels	Plant height (cm)	Stem diameter (mm)	Leaf number	Total leaf area (cm^2)	Leaf DW (g)	Stem DW (g)	Root DW (g)
Salinity sources	BNS	224.7 ± 7.8^{a}	10.39 ± 0.42^{b}	35.2 ± 2.56^{ab}	12810.9 ± 296.63^{a}	83.652 ± 15.21^{a}	37.015 ± 5.58^{a}	6.99 ± 2.69^{a}
	NaCl + BNS	223.6 ± 6.39^{a}	10.07 ± 0.30^{bc}	35.6 ± 1.45^{ab}	9909.0 ± 779.29^{b}	52.264 ± 8.27^{b}	29.956 ± 5.55^{b}	6.028 ± 1.68^{a}
	KNO_3 + BNS	226.5 ± 5.54^{a}	11.39 ± 0.38^{a}	32.9 ± 0.88^{b}	12284.7 ± 1121.88^{a}	59.699 ± 10.8^{b}	42.044 ± 7.26^{a}	7.208 ± 3.13^{a}
	High strength NS	230.8 ± 4.04^{a}	9.74 ± 0.19^{c}	37.7 ± 1.92^{a}	9517.2 ± 657.94^{b}	51.859 ± 5.85^{b}	25.995 ± 3.30^{b}	6.834 ± 5.08^{a}

Note. Means in each column with different letters within each level indicate significant differences at a 5% level of significance according to Duncan's Multiple Range Test (DMRT). BNS = Basic nutrient solution; NS = Nutrient solution; DW = Dry weight

Salinity induced by KNO_3 + BNS significantly increased stem diameter compared to BNS, NaCl + BNS, and high-strength NS with the respective increments of 8.78%, 11.59%, and 14.49%. However, this treatment application significantly reduced leaf number compared to high-strength NS, resulting in 12.73% reductions. In total leaf area measurements, salinity induced by KNO_3 + BNS was similar to control, while significantly higher than NaCl + BNS and high strength NS applications with their respective increments of 19.34% and 22.53%. Leaf dry weight was significantly reduced by NaCl + BNS, KNO_3 + BNS, and high strength NS applications compared to control with their respective reductions of 37.52%, 28.63%, and 38.01%. In addition, dry stem weight was significantly reduced by NaCl + BNS and high strength NS applications compared to BNS with their respective reductions of 19.07% and 29.77%.

Effect of Salinity Sources on Physiological Process

The relative water content of grafted rock melon was not significantly affected ($P > 0.05$) by salinity sources (Table 3). Therefore, it is indicated that saline treatments have shown comparable water status with BNS.

Table 3

Effects of salinity sources on the relative water content of grafted rock melon (Mean ± SD; n=4)

Factor	Levels	Relative water content (%)
Salinity sources	BNS	80.77 ± 3.04[a]
	NaCl + BNS	74.61 ± 4.22[a]
	KNO_3 + BNS	76.47 ± 2.75[a]
	High strength NS	76.15 ± 2.39[a]

Note. Means in each column with different letters within each level indicate significant differences at a 5% level of significance according to Duncan's Multiple Range Test (DMRT). BNS = Basic nutrient solution; NS = Nutrient solution

Chlorophyll fluorescence and all leaf gas exchange parameters taken, such as net photosynthesis, stomatal conductance, and transpiration rate in grafted rock melon, were not significantly affected ($P > 0.05$) by salinity sources (Table 4).

Table 4

Effects of salinity sources on leaf physiology as net photosynthesis, stomatal conductance, transpiration rate, and chlorophyll fluorescence of grafted rock melon (Mean ± SD; n=4)

Factor	Levels	Net photosynthesis (mol CO_2 $m^{-2}s^{-1}$)	Stomatal conductance (mol H_2O $m^{-2}s^{-1}$)	Transpiration rate (mmol H_2O $m^{-2}s^{-1}$)	Chlorophyll fluorescence (F_v/F_m)
Salinity sources	BNS	12.103 ± 2.64[a]	0.263 ±0.10[a]	3.817 ± 0.91[a]	0.783 ± 0.02[a]

Table 4 *(Continue)*

Factor	Levels	Net photosynthesis (mol CO_2 $m^{-2}s^{-1}$)	Stomatal conductance (mol H_2O $m^{-2}s^{-1}$)	Transpiration rate (mmol H_2O $m^{-2}s^{-1}$)	Chlorophyll fluorescence (F_v/F_m)
Salinity sources	NaCl + BNS	10.627 ± 0.54[a]	0.166 ± 0.04[a]	2.807 ± 0.40[a]	0.788 ± 0.02[a]
	KNO_3 + BNS	10.723 ± 1.13[a]	0.189 ± 0.03[a]	3.069 ± 0.39[a]	0.771 ± 0.03[a]
	High strength NS	12.635 ± 2.24[a]	0.242 ± 0.10[a]	3.609 ± 1.07[a]	0.777 ± 0.05[a]

Note. Means in each column with different letters within each level indicate significant differences at a 5% level of significance according to Duncan's Multiple Range Test (DMRT). BNS = Basic nutrient solution; NS = Nutrient solution

Moreover, all photosynthetic pigments measured in grafted rock melon were significantly affected ($P < 0.05$) by salinity sources, while no significant effect ($P > 0.05$) was observed in relative chlorophyll content in the SPAD unit (Table 5).

Table 5

Effects of salinity sources on relative chlorophyll content (SPAD), chlorophyll a, b, *total chlorophyll, chlorophyll* a/b *ratio, and carotenoid content of grafted rock melon (Mean ± SD; n=4)*

Factor	Levels	SPAD	Chl *a* (mg g^{-1})	Chl *b* (mg g^{-1})	Chl *a* + *b* (mg g^{-1})	Chl *a*/*b* (mg g^{-1})	Carotenoid (mg g^{-1})
Salinity sources	BNS	63.7 ± 2.89[a]	65.27 ± 1.70[a]	18.29 ± 0.18[b]	83.56 ± 2.12[a]	3.57 ± 0.34[a]	29.25 ± 0.52[a]
	NaCl + BNS	62.2 ± 2.27[a]	58.50 ± 3.67[a]	16.98 ± 0.19[b]	75.48 ± 2.50[a]	3.45 ± 0.23[a]	27.08 ± 1.37[a]
	KNO_3 + BNS	58.1 ± 1.57[a]	13.52 ± 3.64[b]	43.39 ± 0.17[a]	56.86 ± 3.82[b]	0.32 ± 0.58[b]	20.86 ± 0.51[b]
	High strength NS	65.2 ± 1.46[a]	64.02 ± 5.87[a]	18.71 ± 0.16[b]	82.72 ± 3.05[a]	3.42 ± 0.15[a]	29.12 ± 1.03[a]

Note. Means in each column with different letters within each level indicate significant differences at a 5% level of significance according to Duncan's Multiple Range Test (DMRT). BNS = Basic nutrient solution; NS = Nutrient solution; Chl = Chlorophyll

Salinity induced by KNO_3 + BNS application significantly decreased chlorophyll *a* compared to BNS, NaCl + BNS, and high strength NS with the respective reductions of 79.29%, 76.89%, and 78.89%. In contrast, chlorophyll *b* was significantly increased by KNO_3 + BNS application compared to BNS, NaCl + BNS,

and high strength NS with the respective increments of 57.85%, 60.87%, and 56.88%. Total chlorophyll was significantly decreased by KNO_3 + BNS application compared to control, NaCl + BNS, and high strength NS with the respective reductions of 31.95%, 24.67%, and 31.26%. The chlorophyll *a*/*b* ratio was significantly decreased by KNO_3 + BNS application compared to BNS, NaCl + BNS, and high strength NS with the respective reductions of 91.04%, 90.72%, and 90.64%. Carotenoid was significantly decreased by KNO_3 + BNS application than BNS, NaCl + BNS, and high strength NS with the respective reductions of 29.70%, 22.97%, and 28.37%.

Effect of Salinity Sources on Yield Components

Salinity source applications significantly affected ($P < 0.05$) both yield components in fruit retention time and fruit weight for grafted rock melon (Table 6).

Table 6

Effects of salinity sources on yield components such as fruit retention time and fruit weight of grafted rock melon (Mean ± SD; n=4)

Factor	Levels	Fruit retention time (Day)	Fruit weight (kg)
Salinity sources	BNS	51.5 ± 0.78^{a}	1.84 ± 2.66^{a}
	NaCl + BNS	46.2 ± 1.78^{c}	1.31 ± 1.90^{b}
	KNO_3 + BNS	43.1 ± 1.04^{d}	1.32 ± 1.64^{b}
	High strength NS	48.1 ± 1.53^{b}	1.33 ± 3.92^{b}

Note. Means in each column with different letters within each level indicate significant differences at a 5% level of significance according to Duncan's Multiple Range Test (DMRT). BNS = Basic nutrient solution; NS = Nutrient solution

Salinity induced by NaCl + BNS, KNO_3 + BNS, and high strength NS applications significantly decreased fruit retention time than those grown in control, with their respective reductions of 10.29%, 16.31%, and 6.6%. Similarly, fruit weight was significantly decreased by NaCl + BNS, KNO_3 + BNS, and high strength NS applications than those grown in control with their respective reductions of 28.80%, 28.26%, and 27.72%.

Effect of Salinity Sources on Fruit Quality Components

Salinity source applications significantly affected ($P < 0.05$) fruit quality components of grafted rock melon as total soluble solid, sugar acid ratio, and firmness (Table 7).

Table 7

Effects of salinity sources on fruit quality such as pH, total soluble solid, total titratable acidity, sugar acid ratio, vitamin C, and firmness of grafted rock melon (Mean ± SD; n=4)

Factor	Levels	pH	Total soluble solid (ºBx)	Total titratable acidity (%)	Sugar acid ratio (TSS/TTA)	Vitamin C (mg/100g FW)	Firmness (N)
Salinity sources	BNS	6.56 ± 0.48^{a}	13.9 ± 3.16^{b}	0.155 ± 0.12^{a}	89.61 ± 3.64^{c}	0.35 ± 0.03^{a}	7.742 ± 1.57^{b}
	NaCl + BNS	6.72 ± 0.42^{a}	15.4 ± 2.95^{a}	0.136 ± 0.15^{a}	114.10 ± 2.36^{a}	0.39 ± 0.05^{a}	10.919 ± 1.14^{a}
	KNO_3 + BNS	6.62 ± 0.30^{a}	14.0 ± 3.02^{b}	0.155 ± 0.15^{a}	93.05 ± 5.73^{bc}	0.38 ± 0.03^{a}	12.201 ± 0.75^{a}
	High strength NS	6.72 ± 0.47^{a}	15.6 ± 3.27^{a}	0.141 ± 0.18^{a}	111.78 ± 2.89^{ab}	0.38 ± 0.04^{a}	10.104 ± 1.01^{ab}

Note. Means in each column with different letters within each level indicate significant differences at a 5% level of significance according to Duncan's Multiple Range Test (DMRT). BNS = Basic nutrient solution; NS = Nutrient solution; FW = Fresh weight

Total soluble solid was significantly increased by NaCl + BNS and high strength NS applications compared to BNS with their respective increment of 9.74% and 9.09%. In addition, the sugar-acid ratio was significantly increased by NaCl + BNS compared to BNS and KNO_3 + BNS, respectively, with 21.91% and 18.45%. At the same time, firmness was significantly increased by NaCl + BNS and KNO_3 + BNS compared to BNS with their respective increment of 29.1% and 36.55%.

Based on the fruit preferences score, the sweetness and flavor of the fruit were significantly affected ($P < 0.01$) by the comparisons between BNS and KNO_3 + BNS, NaCl + BNS, and KNO_3 + BNS as well as KNO_3 + BNS and high strength NS (Table 8).

Table 8

Sensory evaluation of rock melon grown at different salinity sources

Salinity sources	Fruit preferences score		
	Sweetness	Texture	Flavor
BNS	6.07	5.71	6.29
NaCl + BNS	6.43	5.79	6.14
KNO_3 + BNS	3.93	5.14	4.79
High strength NS	6.00	5.71	5.93

Table 8 *(Continue)*

Salinity sources	Fruit preferences score		
	Sweetness	Texture	Flavor
Paired orthogonal contrast			
BNS vs. NaCl + BNS	ns	ns	ns
BNS vs. KNO_3 + BNS	**	ns	**
BNS vs. High strength NS	ns	ns	ns
NaCl + BNS vs. KNO_3 + BNS	**	ns	**
NaCl + BNS vs. High strength NS	ns	ns	ns
KNO_3 + BNS vs. High strength NS	**	ns	**

Note. **Significant at 1% probability level, ns = Not significant
The number of panelists = 16. The maximum possible score is 7
BNS = Basic nutrient solution; NS = Nutrient solution

On the other hand, the sweetness and flavor of the fruit were not significantly affected ($P > 0.05$) by the comparisons between BNS and NaCl + BNS, BNS, and high strength NS and NaCl + BNS and high strength NS.

Correlation Analysis on Growth, Yield, and Fruit Quality of Grafted Rock Melon

Table 9 shows the relationships among the selected significant parameters, including growth, yield components, and fruit quality. All the relationships were elaborated based on significant relationships observed towards fruit yield and quality elements.

Table 9

Pearson's linear correlation coefficients (r) between growth parameters, yield components, and fruit quality of grafted rock melon

	SD	LN	TLA	LDW	SDW	FW	FRT	TSS	SAR	FN
SD	1	-0.50*	0.64**	0.32ns	0.79**	0.01ns	-0.55*	-0.66**	-0.52*	0.46ns
LN		1	-0.40ns	0.02ns	-0.27ns	-0.01ns	0.32ns	0.59*	0.18ns	-0.14ns
TLA			1	0.79**	0.86**	0.28ns	0.11ns	-0.72**	-0.81**	-0.04ns
LDW				1	0.64**	0.38ns	0.49ns	-0.46ns	-0.68**	-0.32ns
SDW					1	-0.04ns	-0.23ns	-0.54*	-0.68**	0.24ns
FW						1	0.58*	-0.47ns	-0.14ns	-0.56*
FRT							1	0.01ns	-0.09ns	-0.86**
TSS								1	0.61*	0.14ns
SAR									1	-0.01ns
FN										1

Note. SD = Stem diameter (mm); LN = Leaf number; TLA = Total leaf area (cm^2); LDW = Leaf dry weight (g); SDW = Stem dry weight (g); FW = Fruit weight (kg); FR = Fruit retention time (Day); TSS = Total soluble solid; SAR = Sugar acid ratio; FN = Firmness (N)
**Significant at 1% level of significance; *Significant at 5% level of significance; ns = Not significant

In terms of relationships between growth parameters and yield components, stem diameter was negatively correlated with fruit retention time. There was significant medium negative correlation (r = -0.55; $P \leq 0.05$) between stem diameter and fruit retention time.

Most growth parameters, such as stem diameter, leaf area meter, and stem dry weight, were negatively correlated with fruit quality components, such as total soluble solid and sugar-acid ratio. Among the relationships, the strongest correlation was observed between total leaf area with both fruit quality components, such as total soluble solid (r = -0.72; $P \leq 0.01$) and sugar-acid ratio (r = -0.81; $P \leq 0.01$).

Other than that, relationships between fruit yield and fruit quality components showed that fruit weight and fruit retention time were negatively correlated with fruit firmness. Among the relationships, the strongest negative correlation was observed between fruit retention time and fruit firmness (r = -0.86; $P \leq 0.01$).

DISCUSSION

Effect of Salinity Sources on Growth

At the fruit development stage (70 DAT), the growth performance of plants treated under KNO_3 + BNS application improved by exhibiting higher stem diameter comparable with total leaf area and dry weight compared to BNS. An increase in growth elements might be attributed to an increase in cell division and cell elongation, which is related to the mineral ion compositions of the plants. Generally, nitrogen and potassium exist in KNO_3 and play an important role in plant growth and development. Nitrate is an important ingredient in KNO_3 that plays a role in stimulating the development of the plant by synthesizing amino acids and protein (Liu et al., 2014). Besides, potassium is known to improve protein and carbohydrate synthesis, with photosynthates translocated from the leaves (source) to the place where they may be used or stored (sink) (Haddad et al., 2016). Thus, both salt types, like nitrate and potassium, promoted the grafted rock melon to attain high dry matter components.

Al-Hamzawi (2010) has reported that the application of 15 mM KNO_3 considerably improved growth parameters by increasing plant height, leaves number, and total leaf area of cucumber. Supplementary KNO_3 under NaCl salt-stressed treatments had increased leaf number, leaf area, stem elongation, and dry matter in grafted citrus (Khoshbakht et al., 2014). Despite the positive effects mentioned in most growth parameters (Table 2), salinity induced by KNO_3 + BNS that is prolonged until the fruiting stage has resulted in a lower leaf number. It is probably due to the excess nitrates accumulated in the leaves. An increase in nitrate at a certain level will increase the osmotic concentration, thus leaving the salts behind. As a result, the leaves were dehydrated and appeared to be burnt. It was suddenly wilting and becoming yellow or brown. Therefore, the percentage of the leaves aborting increases, consequently reducing the leaf number. Excess nitrate accumulated in plants if

double the amount of fertilization resulted in deleterious effects on plant growth and yield (Sharifi et al., 2011). Similarly, the growth response of leafy vegetables tested under various concentrations of nitrates was strongly decreased after it accumulated higher in the plant (Chen et al., 2004).

Effects of Salinity Sources on Photosynthetic Pigments

The results showed that salinity induced using KNO_3 + BNS for prolonged periods until the fruiting stage decreased the components of photosynthetic pigments. Excessive KNO_3 accumulated in the leaves had increased the salinity levels, negatively affecting the chlorophyll contents. Chlorophyll reduction under saline stress is a common phenomenon attributed to various factors, including inhibition of chlorophyll biosynthesis caused by the activation of the chlorophyllase enzyme (Noreen & Ashraf, 2009) and membrane deterioration caused by salinity-mediated chlorophyll degradation (Ashraf & Bhatti, 2000). It is also shown that the reduction of salt in the stressed plant chlorophyll has also been regarded as a common indication of oxidative stress (Elsheery & Cao, 2008). It is also corroborated by Noreen and Ashraf (2009), who stated that the reduction of chlorophyll content in pumpkin genotypes might have been due to a salt-induced increase in the activity of the chlorophyll degrading enzyme such as chlorophyllase. Cucumber-treated plants under salt stress at 75 mM had decreased the total chlorophyll, chlorophyll *b*, and chlorophyll *a*/*b* ratio (Shu et al., 2012). The reduction of carotenoid content in the leaves is also due to the long exposure to KNO_3 salt. More salt is also known to impact photosynthesis through non-stomatal restrictions, including changes in carotenoid content (L. Zhang et al., 2012).

Long-term exposure to salt stress in young leaves causes a decrease in carotenoid levels, even in halophyte plants (Duarte et al., 2013). This result concurred with research conducted on tomatoes (Gong et al., 2013) and maize (Singh et al., 2008). In contrast, plants treated under KNO_3 + BNS had the highest chlorophyll b content. Higher chlorophyll b pigment observed is due to the chlorophyll *a* degradation after salt stress exposure. Chlorophyll *b* is the accessory pigment that collects sunlight before being transported into chlorophyll *a,* commonly known as the principal pigment that captures light for photosynthesis. Therefore, more chlorophyll *b* was necessitated and synthesized to sustain the plant's growth by transmitting the light sources into chlorophyll *a* pigment for photosynthesis.

Effects of Salinity Sources on Yield

In terms of yield components, fruit retention time was considerably reduced under all saline treatments compared to BNS. Among the saline treatments tested, KNO_3 + BNS application had the lowest fruit retention time, followed by NaCl + BNS and high strength NS. Shorter fruit retention time under saline treatments is due to salinity's adverse effect that strongly impaired grafted rock melon's reproductive growth. In

addition, salinity imposed during flower anthesis, or pollination time, had delayed the fruit set due to flower abortion incidence. Therefore, a shorter fruit retention time was obtained in these treatments. This condition had delayed the time of fruit setting, causing higher fruit bearing shown under saline treatments in Figure 1 (B, C, and D).

Reduction in fruit set under salinity was associated with low pollen fertility by decreasing starch concentration through invertase inhibition and lowing carbon fluxes to the anthers, leading to flower abortion (Sheoran & Saini, 1996). In addition, a decrease in fruit set under a saline environment has also been attributed to stigma receptivity reduction (Khan & Abdullah, 2003). A similar finding was obtained by Ghanem et al. (2009), where flowers aborting percentage were significantly higher, and the fruit setting process was delayed in tomatoes under NaCl salinity treatment. They concluded that the accumulation of toxic ions such as sodium ion (Na^+) in the female parts caused a high abortion rate by hampering the pollen germination and its subsequent growth. Previous research on mango shows that the KNO_3 application, particularly at a 4% level, was mildly phytotoxic to leaves and inflorescences and resulted in necrotic leaves and extremities of the inflorescence branches (Oosthuyse, 1996).

In addition, the reduction in fruit weight under all saline treatment applications in this study suggested the interference of salinity stress towards fruit development. It is noted that the salinity stress limits the

Figure 1. Effect of salinity sources as BNS (A), NaCl + BNS (B), KNO_3 + BNS (C), and high strength NS (D) on fruit yield of grafted rock melon at 60 DAT, respectively

[*Note*. BNS = Basic nutrient solution; NS = Nutrient solution]

productivity of crops, with adverse effects on crop yield (Munns & Tester, 2008). These might be explained by the fact that high salt levels diminish water potential in plants, resulting in less water flowing into fruit and reducing the fruit expansion rate (Al-Ismaily et al., 2014). Enlargement rate reduction during the exponential phase of fruit growth is particularly vulnerable to ionic and osmotic damages induced by ion accumulation in the plants (Helaly et al., 2017). On the other hand, yield reduction in melon is due to nutritional imbalances produced by the disrupted absorption or distribution of essential mineral elements caused by salinity stress (Del-Amor et al., 1999). De L. Pereira et al. (2017) reported

that the average weight of marketable melon decreased when the solution salinity increased. Freitas et al. (2014) found losses of 11% per dS m^{-1} in melon yield irrigated with high-saline water (EC = 4.5 dS m^{-1}). Dias et al. (2018) also found that the melon weight (cv. Néctar) was reduced when solution salinity increased above 3.5 dS m^{-1}. This finding was supported by a significant medium-positive correlation (Table 9) observed between fruit weight and fruit retention time, indicating that the fruit weight increased when fruit retention time increased.

Effects of Salinity Sources on Fruit Quality

Despite those saline treatments negatively affecting the fruit yield component, the fruit quality characteristics, such as total soluble solid, sugar acid ratio, and fruit firmness, were considerably improved. Compared to BNS, salinity induced by NaCl + BNS and high strength NS applications had better total soluble solid and sugar-acid ratio. It indicates that the fruit produced under the saline treatments is sweeter, with better flavor preferences for fruit consumption. Higher TSS fruit content under high salinity water is presumably caused by a lower mean fruit weight that promotes an increase in the photoassimilate concentration (de L. Pereira et al., 2017). Awang et al. (1993) have concluded that fruit quality enhancement by salinity would relate significantly to fruit water depression, raising the relative amount of dry matter and sugars. The results are consistent with previous studies on melon, which found that the total soluble solids content of melon cultivars rose as irrigation water salinity increased (Zulkarami et al., 2010). Moreover, the highest sugar acid ratio recorded in both saline treatments is associated with total soluble solids. Larger differences between total soluble solid and acid content in the fruit pulp treated under saline treatments resulted in a higher sugar-acid ratio.

A significant medium positive correlation supports it is observed between total soluble solid and sugar-acid ratio (r = 0.61; $P \leq 0.05$) (Table 9), indicating direct relationships were established in this study. Saline environments generally raise TSS and fruit juice acid concentrations. It has been proven by previous studies demonstrated on melon, tomato, sweet pepper, and cucumber. Previous studies on melon (cv. *galia*) revealed that the increased concentrations in nutrient solution and duration of application resulted in increased fruit's TSS and sugar-acid ratio (Del-Amor et al., 1999). A high TSS and sugar-acid ratio was exhibited in both saline treatments that was attributed to smaller growth characteristics as a correlation was established in this study. Total soluble sugar was negatively correlated with total leaf area (r = -0.72; $P \leq 0.01$) and stem dry weight (r = -0.54; $P \leq 0.05$), while the sugar-acid ratio was negatively correlated with total leaf area (r = -0.81; $P \leq 0.01$) and stem dry weight (r = -0.68; $P \leq 0.01$) (Table 9).

Salinity induced by NaCl + BNS and KNO_3 + BNS applications increased fruit firmness. Improvements in fruit firmness

could be due to smaller cells with thicker walls in the fruit mesocarp under saline conditions (Ruiz et al., 2015). An increase in fruit firmness is probably due to the chemical compositions, such as TSS, ascorbic acid, and lycopene contents (Abdelgawad et al., 2019). It is proven by the study observed in tomatoes (Del-Amor et al., 1999). It could also suggest that the increase in fruit firmness by NaCl and KNO_3 + BNS application is due to low fruit retention time. Lower fruit retention time compared to BNS leads to varying levels of fruit maturity. Thus, the shorter fruit retention time obtained in these treatments reduced the conversion time of dry matter content into starch, resulting in higher fruit firmness. The result was corroborated by a significant negative relationship established between fruit firmness and fruit retention time (r = −0.86; $P \leq 0.01$) (Table 9), indicating that fruit firmness increased as fruit retention time decreased.

Fruit preferences for sweetness, texture, and flavor were represented as total soluble solid, firmness, and sugar-acid ratio from instrumental results. Panelists failed to distinguish the fruits' texture well as greater fruit firmness achieved by NaCl + BNS and KNO_3 + BNS applications compared to BNS from the instrumental results. In terms of sweetness and flavor characteristics, fruits produced by plants under BNS, NaCl + BNS, and high-strength NS treatments are perceived as tastier than KNO_3 + BNS treatments. Panelists failed to determine the similarity of the sweetness and flavor between BNS and KNO_3 + BNS as no significant difference in the total soluble solid and sugar-acid ratio was observed from the instrumental results. Comparable sweetness and flavor characteristics on fruits grown under BNS, NaCl + BNS, and high-strength NS applications, exhibited similar taste levels. It indicated that the panelists failed to appreciate the increase in total soluble solid and sugar-acid ratio content from both treatments (NaCl + BNS and high strength NS) as presented in the instrumental results. Comparable sweetness and flavor preferences between NaCl + BNS and high-strength NS applications by panelists are consistent with the instrumental results.

Based on the overall variables taken, the grafted rock melon exhibited different characteristics depending on the saline treatments. Salinity induced using KNO_3 + BNS application could sustain most growth parameters. It can sustain the leaf gas exchange components and relative water content. However, the chlorophyll and carotenoid content were significantly impaired. On the other hand, this treatment reduced the yield component, but the fruit quality has been sustained. Application of NaCl + BNS and high strength NS had similar trends based on overall variables taken in grafted rock melon. Both saline treatments reduced most growth parameters, but all the physiological process was sustained. On the other hand, the yield component was reduced, but the fruit quality was improved better than BNS.

CONCLUSION

Supplementation of KNO_3 salt (50 mM) into nutrient solution showed a higher tendency to increase growth while sustaining fruit quality. However, the physiological process and fruit yield had reduced. Salinity induced by NaCl salt (50 mM) and the high-strength nutrient solution had high fruit quality without interfering with all physiological processes. However, the growth and yield were reduced. Based on overall characteristics evaluated among all saline treatments, incorporation of NaCl (50 mM) + BNS is recommended to be adopted due to its ability to increase fruit quality without interfering with all physiological processes, and it is inexpensive and easily available.

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