Running title: Improving fruit quality and physiological process of rockmelon using salinity

**Effects of salinity sources on growth, physiological process, yield, and fruit quality of grafted rockmelon (*Cucumis melo* L*.*)**

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**Novelty statement**

Previously, there such no information and research had been generated on rockmelon on the most suitable sources of salinity that could increase fruit quality. Application of salinity using NaCl (50 mM) and high strength nutrient solution on salt-tolerant grafted rockmelon has beneficially increased the fruit quality aspect without interfering all physiological process. We found that, supplementation of NaCl salt (50 mM) is more feasible, cheaper and it is readily accessible compared to other sources of salinity that can bring about these improvements.

**Abstract**

There is an increase in demand for high fruit quality of rockmelon for local and export market. To improve fruit quality, supplementation of salt into nutrient solution is a viable approach that can be implemented. Therefore, the present study was conducted to determine the best salt treatment that can be utilized to increase fruit quality without causes growth, yield and physiological process reductions. Grafted rockmelon/bottle gourd at 18 days after grafting (DAG) was arranged in a Randomized Complete Block Design (RCBD) and treated with four sources of salinity; basic nutrient solution (BNS) (2.5 dS m-1) as control, NaCl (50 mM) + BNS (7.1 dS m-1), KNO3 (50 mM) + BNS (7.1 dS m-1), and high strength nutrient solution (NS) (7.1 dS m-1). Salinity induced using KNO3 + BNS sustained most of the growth variables, fruit quality, relative water content and leaf gas exchange as compared with control. However, application of NaCl + BNS and high strength NS were capable of sustaining all physiological process and increase fruit quality components such as total soluble solid and sugar acid ratio as compared to control. Fruit weight was significantly reduced regardless of salinity sources as compared to those grown in control with their respective fruit weight reduction of 28.8%, 28.26% and 27.72%. To conclude, incorporation of NaCl at 50 mM is the most feasible approach to be applied on grafted rockmelon/bottle gourd eventhough the fruit weight had reduced. It is due to high fruit quality measured, capable to sustain all physiological process, provides lower cost as well as easily accessible compared to other sources of salinity.

**Keywords:** Graftedrockmelon; Salinity stress; Salinity sources; Salt-tolerant rootstock;

Fruit quality

**Introduction**

Rockmelon which is also known as muskmelon (*Cucumis melo* L.*)* is a short-term horticultural crop and belongs to the *Cucurbitaceae* family. In Malaysia, rockmelon is commercially grown to fulfil a demand for the local and export markets. Over the years, rockmelon productions have increased drastically up to 45.56% since 2012 with total production recorded at 5,845.71 metric tonnes in 2018 (Department of Agriculture, 2018). The increase in production areas is due to high demand from consumers for a high fruit quality of rockmelon. According to Lester (2006), fruit quality characteristics including sweetness, taste, texture and flavour are the most important reason that highly preferred by the consumers in melon productions.

In order to increase fruit quality of rockmelon, salt addition into nutrient solution has a high potential, cost-effective and easily to be adapted. This 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 absorbtion capacity that could increase dry-matter components. Increased in dry matter components ultimately enhances fruit quality attributes including total soluble solid, total titratable acidity and sugar acid ratio (Dias *et al.*, 2018). This is supported by Jawandha *et al.*, (2017) that, application of KNO3 salts could increase vegetative growth performances as well as enhanced yield and fruit quality attributes. Besides, high NaCl salt accumulated in fertilization system has proven to increase fruit quality parameters such as total soluble solid, total titratable acidity and sugar acid ratio (Pereira *et al.*, 2017).

Nevertheless, excess and continuous supply in rockmelon could lead to salinity development and deleteriously affects the growth and yield. Reduction of crop growth and yield are significant consequences under high saline environment by impairing the physiological process (Munns and Tester, 2008). This also being supported by Pessarakli, (2016) that, rockmelon has been classified as moderately sensitive to salt stress among cucurbit species. In order to improve fruit quality without causing growth, physiological process and yield reduction, supplementation using different sources of salinity can be done (Zhang *et al.*, 2016). By using salt-tolerant rootstock in rockmelon, the salt-tolerant level could be increased (Yarsi *et al.*, 2017). Thus, the application of salinity sources could improve fruit quality without detrimentally affecting growth, physiological process and yield.

Considering these factors, the studies are thus necessary to be done to identify and select the most suitable salinity sources used to enhance fruit quality without causing growth, physiological process and yield reductions in salt-tolerant grafted rockmelon. This research may contribute to the new knowledge of growing rockmelon with salt addition, which will improve fruit quality without causing growth, physiological process and yield reduction. Knowledge produced in this study may be useful in improving rockmelon development practices as well as exploiting new research pathways for rockmelon in the future.

**Materials and Methods**

**Plant materials and maintenance:** This experiment was conducted in the rainshelter structure at University’s Agriculture Park nursery, University Putra Malaysia from September 2020 till December 2020. The planting materials used in this study were rockmelon (*Cucumis melo* L.) var, Glamour as scion and bottle gourd (*Lagenaria siceraria*) var. BG696 as salt-tolerant rootstock. Previous studies have shown that, bottle gourd has been proven to be the promising salt-tolerant rootstock for watermelon (Yetisir and Uygur, 2010) and cucumber (Huang *et al.*, 2009). The procedure to raise planting materials of rockmelon was followed by Mahamud *et al.*, (2009). Seeds were sown in a germination tray filled with 100% peat moss and placed under 25% shade on a 1.2 meter bench. At eight days after sowing (DAS), the uniform sized seedlings were selected and transplanted into 400 ml pot filled with 100% cocopeat for grafting. All the seedlings designated as rootstock were daily watered by manually drench. Rockmelon seedling in germination tray which was sown as scion were maintained and watered at field capacity every day. At 13 DAS, all the uniformed sized scion and rootstock were selected and grafted together using tongue approach grafting (TAG) technique as procedure described by Lee and Oda (2003). At 6 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 litres white polyethylene bags filled with 100% cocopeat.

Grafted plants were maintained using standard operating procedure of rockmelon as recommended by Malaysia Agriculture Research and Development Institute (Mahamud *et al.*, 2009). This comprises of proper agronomic planning includes pest and disease management. 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 structure of the plant as well as to facilitate the maintenance procedure. During reproductive stage, assisted pollination procedure was done from 0830 to 1030 h. To initiate the pollination process, male flowers was attached to female flowers with the ratio of flowers used at 3:1; male: female. Pollinated flowers were labelled with the date and time. Approximately 2 to 3 female flowers per plant were pollinated along the flowering stages. At 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 transplanted (DAT), all the fruits were harvested with careful handling for data collection.

**Treatments and experimental design:** This experiment consisted of four treatments of salinity sources which were arranged in the Randomized Complete Block Design (RCBD) with four replications. The replications used were represented as block to reduce the errors and interferences in the rainshelter structure. Each of the replicate consisted eight plants that were totalling to 128 plants. The salinity sources treatments used in this study were basic nutrient solution (BNS) as control, NaCl, KNO3 and high strength nutrient solution (NS). The formulation used for BNS in this study is in accordance to Mahamud *et al.*, (2009). While, the commercial NaCl salt from groceries and commercial soluble fertilizer as KNO3 (13-0-46) were used in this study. Besides, the preparation of high strength NS was followed accordingly with the formulation described in BNS (Control). Based on the previous studies on the effects of NaCl concentration on melon done by Colla *et al.* (2006), salinity concentration at 75 mM was classified as threshold level in melon crop. Therefore, salinity concentration at 50 mM was selected to be used in for each saline treatment as shown in Table 1.

Each of the treatment solution was prepared in 200L fertilizer containers which were checked and quantified using electrical conductivity (EC) meter (Hanna Instruments, model HI-98311). At 18 DAG, the solution of the treatments was manually drenched every day for 70 days in a sufficient volume with drainage. The frequency of the treatment solution given was increased gradually according to the growing stages (Mahamud *et al.*, 2009). The EC of the growing media was determined using pour-through method (Cavins *et al.*, 2000) at vegetative (15 DAT) and fruiting (50 DAT) stages from 1300 to 1400 h. The EC of four treatments solutions recorded were 2.73, 8.62, 9.25 and 9.05 dS m-1 for BNS, NaCl + BNS, KNO3 + BNS and high strength NS respectively. During the experiment, average maximum temperature and relative humidity was recorded once a week at 1400 h under natural photoperiod conditions (12 hours light/ 12 hours dark). The maximum temperature recorded as 35.0 (±5)ºC with relative humidity (RH) at 62.4 (±10)%. Besides, average carbon dioxide concentrations and light intensity were also recorded once a week as 459.9 ppm and 986.17 μmol m-2s-1 respectively.

**Data collection**

**Growth measurements:** Plants were sampled at random from each treatment for determination of plant height, stem diameter, leaf number, total leaf area and dry weight determinations. Dry weight components include leaf, stem, and root were taken at 70 DAT according to the classical approach (Hunt, 2003). Measurement of plant height was taken from the graft union to the highest shoot tip using a measuring tape. Scion diameter was measured at 1 cm marking from growing media surface using Electronic Digital Caliper (Model CD6’’CS Mitutoyo Corp., Japan) while 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 automatic leaf area meter (Model LI-3100C, LI-COR, Nebraska, USA). All samples were dried to constant weight for at least 72 hours in a forced draught oven at 70ºC (Ismail and Muhammad, 1995) before weighed using digital analytical balance (Model CDS125, Mitutoyo Inc, Japan).

**Relative water content (RWC):** The water status of the plants was determined by RWC in the leaves using the method of Barrs and Weatherly (1962). RWC was measured at 55 DAT on a fully expanded leaf. Samples of leaves were kept in icebox and were carried to the laboratory. Ten leaf discs of 5 mm diameter were cut using single hole puncher, and the fresh weight (FW) was recorded using digital analytical balance. The leaves discs were then floated in a small dish containing deionized water for 4 hours to regain turgidity and reweighed (TW). Later, the leave discs were dried in a drying oven at 70ºC 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) X 100

**Leaf gas exchanges:** Leaf gas exchanges was 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, Licor, Lincoln, Nebraska, USA) between 9.30 to 10.30 am with three measurements for each leaf. The measurements used optimal cuvette conditions, at 1000 µmol m-2s-1 photosynthetic photon flux density (PPFD), 400 µmol/ mol CO2 at 30 ºC cuvette temperature and at 60% relative humidity with air flow rate set at 500 cm3/min. Irradiance was provided by an LED RGB (Light Emitting Diode Red Green Blue) light source (LI-6400-02B, Li-Cor Inc.).

**Maximum efficiency of Photosystem II (fv/fm):** The chlorophyll fluorescence measurements were taken on a selected fully expanded leave at 55 DAT. Chlorophyll fluorescence was measured using portable fluorescence spectrometer (Mini-PAM, Walz, Germany). Before the measurements started, surface of the leaves 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. The chlorophyll fluorescence was expressed in fv/fm which fv as variable fluorescence and fm as 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 leaf chlorophyll meter (SPAD-502 plus, Konica Minolta Optic, Inc, Japan). The measurements were taken from three different spot 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 by using a single hole puncher at 5 mm diameter size. Pigments were extracted from ten leaf disks using dimethyl sulfoxide following a modified procedure (Shinano *et al.*, 1996). Samples were pipetted with 10 ml of dimethyl sulfoxide and then incubated at 65ºC in an oven for 4 hours until all the pigments were extracted and the leaf disks became transparent. Then, 3 ml aliquot of the green colour 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 Spectrophotometer (UV Vis Spectrophotometer Optizen Pop, Republic of Korea) and were read at 649, 665, 480 and 510 nm under low light condition. Chlorophylls and total carotenoid content were calculated based on the following equations (Wellburn, 1994).

nmol (Chl a) / cm2 = [(12.47 E665 – 3.62 E649) x V x 1.119] / A

nmol (Chl b) / cm2 = [(25.06 E649 – 6.45 E665) x V x 1.102] / A

nmol (Chl a+b) / cm2 = (Chl a) + (Chl b)

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

nmol (Carotenoid) / cm2 = [(7.60E480 - 1.49E510) x V x 1.102] / A

Chlorophyll a, b, total chlorophyll and total carotenoid content were expressed as nmole/cm2 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 were harvested and weighed using digital analytical balance. Fruit retention time was calculated based on the total days of the fruit retained on the stem which started on the day of assisted pollination until harvesting day.

**Fruit quality components**: Fruit quality is referred to 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-100, palette, Atago Co. LTD., Japan) and the reading was taken in degrees Brix (Bxo). Determination of vitamin C was done by using the volumetric methods titration according to Pisoschi *et al.* (2009). The pulp was blended and 10 g of samples were mixed with 20 ml of 3% HPO3 and filtered. Then, 10 ml of the filtrate was pipetted and titrated against dichlorophenol indophenol (DCPIP) until the solution turned to a slight pink colour. 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 reading using a titrator instrument (Metrohm, Tiamo 848 Titrino plus, Germany). The value for TTA was expressed by citric acid that served as a major organic acid. Sugar acid ratio was calculated by dimensionless ratio of TSS/TTA. Fruit firmness was measured by using texture analyser ([XT Plus 100C](https://www.stablemicrosystems.com/TAXTplus100.html), UK). A cylinder probe at 5 mm diameter size was forced onto the surface of the pulp and the reading was expressed in Newton (N).

**Organo-leptic assessment:** The evaluation involved 16 untrained panellists, who were given 6 pieces of ripe fruits from each treatment. The fruits used were harvested two hours before the beginning of the test. The panellists were requested to assess the colour, sweetness, texture and flavour of the fruits where the scores were based on a scale from zero (unacceptable) to seven points (perfect).

**Statistical analyses**

All the data taken was computed using statistical analysis software (SAS) version 9.4 (SAS Institute Inc., Cary, NC). All the variables were assessed for normal distribution using univariate procedure. Variables were not meet normally distributed curve were transformed using log transformation. GLM procedure was used to do analysis of variance (ANOVA) and mean comparisons were done using Duncan Multiple Range Test (DMRT) at P ≤ 0.05. Relationships among the variables for all salinity sources treatments were pooled and determined using Pearson correlation coefficients (r) at P ≤ 0.05 by CORR procedure. The data for fruit sensory evaluation taken by 16 panellists was assessed using GLM procedure and the test of mean comparison using orthogonal contrast at P≤0.05.

**Results**

**Effect of salinity sources on growth**

Stem diameter, total leaf area, leaf and stem dry weight of grafted rockmelon were significantly affected by salinity sources at P ≤ 0.01, whereas leaf number was significantly affected by salinity sources at P ≤ 0.05 (Table 2). On the other hand, plant height and root dry weight were not significantly affected (P ≤ 0.05) by salinity sources. Salinity induced by KNO3 + BNS significantly increased stem diameter as 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 as compared to high strength NS resulted in 12.73% reductions. In terms of total leaf area measurements, salinity induced by KNO3 + BNS was similar with control while significantly higher as compared to 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, KNO3 + BNS and high strength NS applications as compared to control with their respective reductions of 37.52%, 28.63% and 38.01%. Stem dry weight was significantly reduced by NaCl + BNS and high strength NS applications as compared to BNS with their respective reductions of 19.07% and 29.77%.

**Effect of salinity sources on physiological process**

Relative water content of grafted rockmelon was not significantly affected (P ≤ 0.05) by salinity sources (Table 3). It is clearly indicated that saline treatments have shown comparable water status with BNS. Chlorophyll fluorescence and all leaf gas exchange parameters taken such as net photosynthesis, stomatal conductance and transpiration rate in grafted rockmelon were not significantly affected (P ≤ 0.05) by salinity sources (Table 4).

Moreover, all photosynthetic pigments measured in grafted rockmelon were significantly affected (P ≤ 0.01) by salinity sources while no significant effect (P ≤ 0.05) was observed in relative chlorophyll content in SPAD unit (Table 5). Salinity induced by KNO3 + BNS application significantly decreased chl a as 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 KNO3 + BNS application as 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 KNO3 + BNS application as compared to control, NaCl + BNS and high strength NS with the respective reductions of 31.95%, 24.67% and 31.26%. Chlorophyll a/b ratio was significantly decreased by KNO3 + BNS application as 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 KNO3 + BNS application as compared to 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 sources applications significantly affected both yield components in grafted rockmelon specifically the fruit retention time (P ≤ 0.01) and fruit weight (P ≤ 0.05) (Table 6). Salinity induced by NaCl + BNS, KNO3 + BNS and high strength NS applications significantly decreased fruit retention time as compared to 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, KNO3 + BNS and high strength NS applications as compared to 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 sources applications significantly affected fruit quality components of the grafted rockmelon such as total soluble solid (P ≤ 0.01), sugar acid ratio (P ≤ 0.05) and firmness (P ≤ 0.05) (Table 7). Total soluble solid was significantly increased by NaCl + BNS and high strength NS applications as compared to BNS with their respective increment of 9.74% and 9.09%. Sugar acid ratio was significantly increased by NaCl + BNS as compared to BNS and KNO3 + BNS with the respective increments of 21.91% and 18.45%. Based on fruit preferences score, sweetness and flavour of the fruit were significantly affected (P≤0.01) by the comparisons between BNS and KNO3+BNS, NaCl+BNS and KNO3+BNS as well as KNO3+BNS and high strength NS (Table 8). On the other hand, colour and texture of the fruit were not significantly affected (P≤0.05) among treatment comparisons. In addition, sweetness and flavour of the fruit was not significantly affected (P≤0.05) by the comparisons between BNS and NaCl+BNS, BNS and high strength NS as well as NaCl+BNS and high strength NS.

**Correlation analysis on growth, yield and fruit quality of grafted rockmelon**

Result in table 9 showed 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.

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 ≤ 0.05) between stem diameter and fruit retention time.

Most of the growth parameters such as stem diameter, leaf area meter and stem dry weight were negatively correlated with both 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 ≤ 0.01) and sugar acid ratio (r= -0.81; P ≤ 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 ≤ 0.01).

**Discussion**

**Effect of salinity sources on growth**

At fruit development stage (70 DAT), the growth performance of plants treated under KNO3 + BNS application was improved by exhibiting higher stem diameter as comparable with total leaf area and stem dry weight compared to BNS. Increase in growth elements might be attributed to increase of cell division and cell elongation which is related to mineral ion compositions of the plants. Generally, nitrogen and potassium existed in KNO3 play an important role in plant growth and development. Nitrate is an important ingredient in KNO3 that plays a role in stimulating the development of the plant by synthesizing amino acid 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 salts types like nitrate and potassium promoted the grafted rockmelon to attain high dry matter components.

Al-Hamzawi (2010) has reported that, application of 15 mM KNO3 considerably improved growth parameters by increased plant height, leaves number and total leaf area of cucumber. Khoshbakt *et al.* (2018) also found that, supplementary of KNO3 under NaCl salt-stressed treatments increased leaf number, leaf area, stem elongation, and dry matter of stem in grafted citrus (cv. Valencia). Despite the positive effects mention in most of the growth parameters (Table 1), salinity induced by KNO3 + BNS that is prolonged until fruiting stage have resulted in lower leaf number. This is probably due to the excess nitrates accumulated in the leaves. Increase in nitrate at 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 in colour. Therefore, the percentage of the leaves to abort 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). This is similar with previous study by Chen *et al.* (2004), where the growth response of leafy vegetables tested under various concentrations was strongly decreases after nitrates were accumulated higher in the plant.

**Effects of salinity sources on photosynthetic pigments**

Our results clearly showed that salinity induced using KNO3 + BNS in prolonged periods until the fruiting stage decreased the photosynthetic pigments components. Excessive KNO3 accumulated in the leaves had increased the salinity levels which negatively affected the chlorophyll contents. Chlorophyll reduction under saline stress is a common phenomenon that attributes to a variety of factors, including inhibition of chlorophyll biosynthesis caused by the activation of the chlorophyllase enzyme (Noreen and Ashraf, 2009) and membrane deterioration caused by salinity-mediated chlorophyll degradation (Ashraf and Bhatti, 2000). It is also showed that reduction in salt stressed plant chlorophyll has also been regarded as a common indication of oxidative stress (Elsheery and Cao, 2008). This is also corroborated with Noreen and Ashraf (2009) that reduction of chlorophyll content in pumpkin genotypes might have been due to salt-induced increase in the activity of the chlorophyll degrading enzyme such as chlorophylase. Cucumber treated plants under salt stress at 75 mM had decreased the total chlorophyll, Chl b, Chl total and Chl a/Chl b ratios (Shu *et al.*, 2012) Reduction of carotenoid content in the leaves also due to the long exposure of KNO3 salt. More salt is also known to impact photosynthesis through non-stomatal restrictions, including changes in carotenoid content (Zhang *et al.*, 2012). According to Duarte *et al.* (2013), long-term exposure to salt stress in young leaves cause a decrease in the level of carotenoid even in halophyte plants. This result concurred in research conducted in tomato (Gong *et al.*, 2013) and maize (Singh *et al.*, 2008). In contrast, plants treated under KNO3 + 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 functions to collect sunlight before transported into chlorophyll a that is commonly known as principal pigment which captures light for photosynthesis. Therefore, more chlorophyll b was necessitated and synthesized in order to sustain the growth of the plant 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 when compared to BNS. Among the saline treatments tested, KNO3 + BNS application had the lowest fruit retention time followed by NaCl + BNS and lastly high strength NS. Shorter fruit retention time under saline treatments is due to the adverse effect of salinity that strongly impaired reproductive growth of grafted rockmelon. Salinity imposed during flower anthesis or pollination time had delayed the fruit setting due to flower abortion incidence. Therefore, shorter fruit retention time was obtained in these treatments. This condition had delayed the time of fruit setting which further caused higher fruit bearing as shown under saline treatments in Figure 1 (B, C and D). According to Sheoran and Saini (1996), reduction in fruit set under salinity was associated with low pollen fertility, by decreases in starch concentration through invertase inhibition and low carbon fluxes to the anthers, leading to flower abortion. A similar finding was obtained by Ghanem *et al.* (2009), where flowers aborting percentage were significantly higher and fruit setting process was delayed in tomato under NaCl salinity treatment. They concluded that accumulation of toxic ions such as Na+ ion in the female parts caused high abortion rate by hampering the germination of pollen and its subsequent growth. Previous research on mango shows that, KNO3 application particularly at 4% level, was mildly phytotoxic to leaves and inflorescences and resulted in necrotic leaves and extremities of the inflorescence branches (Oosthuyse, 1996).

In addition, reduction in fruit weight under all saline treatment applications in this study suggested the interference of salinity stress towards fruit development process. It is notably that, salinity stress limits the productivity of agricultural crops, with adverse effects in crop yield (Munns and 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 reduce the rate of fruit expansion (Al-Ismaily *et al.*, 2014). Reduction of enlargement rate during the exponential phase of fruit growth has been found to be 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). Perreira *et al.* (2017) reported that the average weight of marketable fruit in melon decreased when the solution salinity increased. Freitas *et al.* (2014) found losses of 11% per dS m-1 in the fruit yield of melon irrigated with high-saline water (EC = 4.5 dS m-1). Dias et al., (2018) also found that, the fruit weight of melon (cv. Nectar) was reduced as solution salinity increased above 3.5 dS m-1. Our finding was supported by significant medium positive correlation (Table 8) observed between fruit weight and fruit retention time indicating the fruit weight increased as fruit retention time increases.

**Effects of salinity sources on fruit quality**

Despite those saline treatments negatively affected fruit yield component, fruit quality characteristics such as total soluble solid, sugar acid ratio and fruit firmness were considerably improved. In comparison to BNS, salinity induced by NaCl + BNS and high strength NS applications had better total soluble solid and sugar acid ratio. This indicated the fruit produced under the saline treatments is sweeter with better flavour preferences for fruit consumption. Higher TSS content of the fruit under high salinity water is presumably caused by a lower mean fruit weight that promoted an increase in the photoassimilate concentration (Pereira *et al.*, 2017). Awang *et al.* (1993) have concluded that fruit quality enhancement by salinity would relate significantly with fruit water depression, which raises the relative amount of dry matter and sugars. Our 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, highest sugar acid ratio recorded in both saline treatments is associated with total soluble solid. Larger differences between total soluble solid and acid content in the fruit pulp treated under saline treatments resulted in higher sugar acid ratio. This is supported by significant medium positive correlation observed between total soluble solid and sugar acid ratio (r = 0.61; P ≤ 0.05) (Table 8) indicating direct relationships was established in this study. Saline environments generally raise TSS and fruit juice acid concentrations. This has been proven by previous studies demonstrated on melon, tomato, sweet pepper, and cucumber. Previous studies on melon (cv. Galia) revealed that, increased concentrations in nutrient solution and duration of application resulted in an increase the TSS and sugar acid ratio in the fruit (Del-Amor *et al.*, 1999). High TSS and sugar acid ratio was exhibited in both the saline treatments that was attributed to smaller growth characteristics as correlation was established in this study. Total soluble sugar was negatively correlated with total leaf area (r= -0.72; P ≤ 0.01) (Table 8) and stem dry weight (r= -0.54; P ≤ 0.05) (Table 8). While, sugar acid ratio was negatively correlated with total leaf area (r= -0.81; P ≤ 0.01) (Table 8), and stem dry weight (r= -0.68; P ≤ 0.01) (Table 8).

Salinity induced by NaCl + BNS and KNO3 + BNS applications resulted in an increase of fruit firmness. Improvements of fruit firmness could be due to the presence of smaller cells with thicker wall in the mesocarp of the fruit under saline conditions (Peterson *et al.*, 1998). According to Abdelgawad *et al.* (2019), increase in fruit firmness is probably due to the chemical compositions in the fruit such as TSS, ascorbic acid and lycopene contents. This is proven by the study observed in tomato (Del-Amor *et al.*, 1999). We could also suggest that, increase of fruit firmness by NaCl and KNO3 + BNS application is due to low fruit retention time. Lower fruit retention time compared to BNS, leads to varying levels of fruit maturity. Thus, shorter fruit retention time obtained in these treatments had reduced the conversion time of dry matter content into starch resulting in a higher fruit firmness. Our result was corroborated with significant negative relationship established between fruit firmness and fruit retention time (r= −0.86; P ≤ 0.01) (Table 8), indicating the fruit firmness increased as fruit retention time decreased.

Fruit preferences for sweetness, texture and flavour were represented as total soluble solid, firmness and sugar acid ratio respectively from instrumental results. Panellists failed to distinguish the texture of the fruits well as greater fruit firmness achieved by NaCl+BNS and KNO3+BNS applications compared to BNS from the instrumental results. In terms of sweetness and flavour characteristics, fruits produced by plants under BNS, NaCl+BNS and high strength NS treatments perceived as tastier compared to KNO3+BNStreatments. Panellists failed to determine the similarity of the sweetness and flavour between BNS and KNO3+BNSas no significant difference in total soluble solid and sugar acid ratio observed from the instrumental results. Comparable sweetness and flavour characteristics on fruits grown under BNS, NaCl+BNS and high strength NS applications, exhibited similar taste levels. This indicated that the panellists 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 flavour preferences between NaCl+BNS and high strength NS applications by panellists are consistent with the instrumental results.

Based on overall variables taken, grafted rockmelon exhibited different characteristics depending on the saline treatments given. Salinity induced using KNO3 + BNS application was capable of sustaining most of the growth parameters. It was also able to 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 also reduced 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 rockmelon. Both saline treatments had reduced most of 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**

Supplemention of KNO3 salt (50 mM) into nutrient solution showed 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 high strength nutrient solution had high fruit quality without interfering all physiological process. 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 all physiological process as well as it being inexpensive and easily available.

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**D**

**C**

**A**

**B**

**Figure 1.**Effect of salinity sources as BNS (A), NaCl+BNS (B), KNO3+BNS (C) and high strength NS (D) on fruit yield of grafted rockmelon at 60 DAT

BNS: Basic nutrient solution, NS: Nutrient solution

**Table 1.** The salinity sources treatments with respective concentrations

|  |
| --- |
| **Salinity sources** |
| Basic nutrient solution (BNS) = 2.50 dS m-1 |
| NaCl (50 mM) + BNS (2.50 dS m-1)= 7.13 dS m-1 |
| KNO3 (50 mM) + BNS (2.50 dS m-1)= 8.55 dS m-1 |
| High strength nutrient solution (NS) = 7.13 dS m-1 |

**Table 2.**Effects of salinity sources on plant height and stem diameter of grafted rockmelon

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Factor | Variables | Plant height (cm) | Stem diameter (mm) | Leaf number | Total leaf area (cm²) | Leaf  DW  (g) | Stem DW  (g) | Root DW (g) |
| Salinity sources  Salinity sources | BNS | 224.7a | 10.39b | 35.2ab | 12810.9a | 83.65a | 37.02a | 6.99a |
| NaCl + BNS | 223.6a | 10.07bc | 35.6ab | 9909.0b | 52.26b | 29.96b | 6.03a |
| KNO3 + BNS | 226.5a | 11.39a | 32.9b | 12284.7a | 59.70b | 42.04a | 7.21a |
| High strength NS | 230.8a | 9.74c | 37.7a | 9517.2b | 51.86b | 25.99b | 6.83a |
|  |  |  |  |  |  |  |  |
|  | F-test (Significant level) | | | | | | |
|  | ns | \*\* | \* | \*\* | \*\* | \*\* | ns |

\*\*Significant at 1% probability level, \*Significant at 5% probability level, ns: Not significant

Means in each column with the different letters within each factor indicate significant differences at P ≤ 0.05 level according to Duncan Multiple Range Test (DMRT)

BNS: Basic nutrient solution NS: Nutrient solution DW: Dry weight

**Table 3.** Effects of salinity sources on relative water content of grafted rockmelon

|  |  |  |
| --- | --- | --- |
| Factor | Variables | Relative water content (%) |
| Salinity sources  Salinity sources | BNS | 80.77a |
| NaCl + BNS | 74.61a |
| KNO3 + BNS | 76.47a |
| High strength NS | 76.15a |
|  | F-test (Significant level) |
|  | ns |

\*\*Significant at 1% probability level, \*Significant at 5% probability level, ns: Not significant

Means in each column with the different letters within each factor indicate significant differences at P ≤ 0.05 level according to Duncan Multiple Range Test (DMRT)

BNS: Basic nutrient solution NS: Nutrient solution

**Table 4.** Effects of salinity sources on net photosynthesis, stomatal conductance, transpiration rate and chlorophyll fluorescence of grafted rockmelon

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Factor | Variables | Net  photosynthesis  (mol CO2m-2s-1) | | Stomatal conductance  (mol H2Om-2s-1) | Transpiration  rate  (mmol H2Om-2s-1) | Chlorophyll fluorescence (Fv/Fm) |
| Salinity sources  Salinity sources | BNS | 12.103a | 0.263a | | 3.817a | 0.783a |
| NaCl + BNS | 10.627a | 0.166a | | 2.807a | 0.788a |
| KNO3 + BNS | 10.723a | 0.189a | | 3.069a | 0.771a |
| High strength NS | 12.635a | 0.242a | | 3.609a | 0.777a |
|  |  |  | |  |  |
|  | F-test (Significant level) | | | | |
|  | ns | ns | | ns | ns |

\*\*Significant at 1% probability level, \*Significant at 5% probability level, ns: Not significant

Means in each column with the different letters within each factor indicate significant differences at P ≤ 0.05 level according to Duncan Multiple Range Test (DMRT)

BNS: Basic nutrient solution NS: Nutrient solution

**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 rockmelon

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Factor | Variables | SPAD | Chl a | Chl b | Chl  a+b | Chl a:b | Carotenoid |
| Salinity sources  Salinity sources | BNS | 63.7a | 65.27a | 18.29b | 83.56a | 3.57a | 29.25a |
| NaCl + BNS | 62.2a | 58.50a | 16.98b | 75.48a | 3.45a | 27.08a |
| KNO3 + BNS | 58.1a | 13.52b | 43.39a | 56.86b | 0.32b | 20.86b |
| High strength NS | 65.2a | 64.02a | 18.71b | 82.72a | 3.42a | 29.12a |
|  |  |  |  |  |  |  |
|  | F-test (Significant level) | | | | | |
|  | ns | \*\* | \*\* | \*\* | \*\* | \*\* |

\*\*Significant at 1% probability level, \*Significant at 5% probability level, ns: Not significant

Means in each column with the different letters within each factor indicate significant differences at P ≤ 0.05 level according to Duncan Multiple Range Test (DMRT)

BNS: Basic nutrient solution NS: Nutrient solution Chl: Chlorophyll

**Table 6.** Effects of salinity sources on yield components such as fruit retention time and fruit weight of grafted rockmelon

|  |  |  |  |
| --- | --- | --- | --- |
| Factor | Variables | Fruit retention time | Fruit weight (kg) |
| Salinity sources  Salinity sources | BNS | 51.5a | 1.84a |
| NaCl + BNS | 46.2c | 1.31b |
| KNO3 + BNS | 43.1d | 1.32b |
| High strength NS | 48.1b | 1.33b |
|  | F-test (Significant level) | |
|  | \*\* | \* |

\*\*Significant at 1% probability level, \*Significant at 5% probability level, ns: Not significant

Means in each column with the different letters within each factor indicate significant differences at P ≤ 0.05 level according to Duncan Multiple Range Test (DMRT)

BNS: Basic nutrient solution NS: Nutrient solution

**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 rockmelon

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Factor | Variables | pH | Total soluble solid  (ºBrix) | Total titratable acidity  (%) | Sugar acid  ratio | Vitamin C (mg/100g FW) | Firmness (N) |
| Salinity sources  Salinity sources | BNS | 6.56a | 13.9b | 0.155a | 89.61c | 0.35a | 7.742b |
| NaCl + BNS | 6.72a | 15.4a | 0.136a | 114.10a | 0.39a | 10.919a |
| KNO3 + BNS | 6.62a | 14.0b | 0.155a | 93.05bc | 0.38a | 12.201a |
| High strength NS | 6.72a | 15.6a | 0.141a | 111.78ab | 0.38a | 10.104ab |
|  |  |  |  |  |  |  |
|  |  | | | | | |
|  | F-test (Significant level) | | | | | |
|  | ns | \*\* | ns | \* | ns | \* |

\*\*Significant at 1% probability level, \*Significant at 5% probability level, ns: Not significant

Means in each column with the different letters within each factor indicate significant differences at P ≤ 0.05 level according to Duncan Multiple Range Test (DMRT)

BNS: Basic nutrient solution NS: Nutrient solution FW: Fresh weight

**Table 8.** Sensory evaluation of rockmelon grown at different salinity sources (Number of panellists = 16). The maximum possible score is 7

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variables | Fruit preferences score | | | |
| Sweetness | | Texture | Flavour |
| BNS | 6.07 | | 5.71 | 6.29 |
| NaCl+BNS | 6.43 | | 5.79 | 6.14 |
| KNO3+BNS | 3.93 | | 5.14 | 4.79 |
| High strength NS | 6.00 | | 5.71 | 5.93 |
|  |  |  |  |  |
| *Paired orthogonal contrast* |  |  |  |  |
| BNS vs NaCl+BNS | ns | | ns | ns |
| BNS vs KNO3+BNS | \*\* | | ns | \*\* |
| BNS vs High strength NS | ns | | ns | ns |
| NaCl+BNS vs KNO3+BNS | \*\* | | ns | \*\* |
| NaCl+BNS vs High strength NS | ns | | ns | ns |
| KNO3+BNS vs High strength NS | \*\* | | ns | \*\* |

\*\*Significant at 1% probability level, ns: Not significant

BNS: Basic nutrient solution, NS: Nutrient solution

**Table 9.** Pearson’s linear correlation coefficients (r) between growth parameters, yield components and fruit quality of grafted rockmelon

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **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 |

**SD**: Stem diameter, **LN**: Leaf number, **TLA**: Total leaf area, **LDW**: Leaf dry weight, **SDW**: Stem dry weight, **FW:** Fruit weight, **FR**: Fruit retention time **TSS**: Total soluble solid, **SAR:** Sugar acid ratio, **FN**: Firmness

\*\*Significant at P ≤ 0.01, \*Significant at P ≤ 0.05, ns: not significant

**Standard measurement units and their abbreviations**

**Full name, Symbol**

Area, A

Centimeter, cm

Centimeter square, cm²

Decisiemens per metre, dS m-1

Electrical conductivity, EC

Gram, g

Kilogram, kg

Metric tonnes, mt

Milligram, mg

Milliliter, ml

Millimeter, mm

Millimole, mM

Nanomole, nmole

Newton, N