Title

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Impact of reduced potassium nitrate concentrations in nutrient solution on the growth, yield and fruit quality of melon in hydroponics

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ABSTRACT

In general, foods with high K content are restricted to the patient with chronic kidney disease but our daily diets including melons are rich in K. Thus, they can't eat usual diets with other family members, as it is eating normal melon fruits are like a dream to the dialysis patients. As a result of this normal diet restriction, their qualities of life (QOL) decrease greatly. Therefore, melon (*Cucumis melo* L. cv. Panna) were grown in nutrient solution with reduced KNO_3 concentrations from anthesis till harvest to investigate its impact on the fruit K content while maintaining normal growth, yield and other fruit qualities. Three independent melon cultures were verified during the spring seasons from 2009 to 2011. A general trend of decreasing K content in fruit was observed with the decrease of KNO_3 concentration in nutrient solution without significant decline in fruit yield. Plant growth variables were not decreased greatly except root dry weights in nutrient solution with reduced KNO_3. Citric acidity was decreased significantly due to KNO_3 restriction in the first two cultures while soluble solids content was found to be decreased only in spring 2011. In spring 2009, melon plants were grown in nutrient solution with 1/4th KNO_3 decreased fruits K by 39% compared to fruits K in standard nutrient solution whereas, it was decreased by about 35% and 43% when melon plants were grown in nutrient solution with 1/16th and O levels of KNO_3 in the spring 2010 and 2011, respectively. Supplementation of melon fruits containing lower K than usual can be a very useful prevention method for the patient with chronic kidney diseases. It was evident that fruit K content was not decreased expectedly even after limiting the K level to zero. The possible reason behind might be the excessive absorption into the plant parts during vegetative growth and storage before the start of K restriction in turn translocated into the melon fruits. Therefore, consideration of K translocation from leaves and stems to fruits during fruit developmental stage is an important issue for this study. Appropriate quantitative management of K nutrition in culture solution from the early vegetative growth period of melon plants for decreasing fruits K content to a greater extend.

Key words: *Cucumis melo* L., Chronic kidney disease, Potassium nutrition, Fruits potassium, Potassium translocation, Quantitative management of potassium.

1. Introduction

It has been reported that currently about 13.3 million peoples are suffering from chronic kidney disease (CKD) in Japan. This number was obtained from the glomerular filtration rate (GFR) estimation formula by the Japanese Society of Nephrology (CKD practice guide, 2011). The above figure of CKD patients is one in eighth of adults, therefore, it has becoming a major problem as a new national disease in Japan. In addition, since the CKD patient population is increasing year by year, it expected that the total number of patients will continue to increase progressively. Therefore, the preventive measures should be stressed to divert the prevalence of this disease in a decreasing trend. As the symptoms of kidney disease are subtle, and one of the most significant primary disease is diabetes. It is estimated that ten thousands to several million peoples have a preliminary stage of kidney disease (Atkins and Zimmet, 2010), this indicate a further increase in dialysis patients.

K is crucial for the normal functioning of muscles, heart, and nerves in human body. It is one of the main electrolytes, and is concentrated within the body cell. About 90% of body K is normally excreted by the kidneys but patients with kidney dysfunction suffering from CKD can't completely excrete it and thus accumulated. Abnormally elevated level of K in the blood (hyperkalemia) can cause adverse effect on human body. Kes, (2001) reported that a normal kidney has the capacity to excrete in excess of 400 mmol of K per day, and it is unlikely that an individual will become chronically hyperkalemic without some degree of chronic renal impairment. Sometimes hyperkalemia causes arrhythmias, muscle weakness, disturbed consciousness, heart failure, and even leading to sudden death (Putcha and Allon, 2007; Spital and Stems, 1988). Restricted diets are mainly used as means of treatment for chronic kidney disease patients. As a primarily control measure, foods with high K content are restricted but our daily diet such as fruits including melon, fresh vegetables, seaweed, beans and potatoes are rich in K (Weiner and Wingo, 1988). Dialysis patients in kidney disease are suggested not to take raw vegetables, rather boiled or leached them in water to remove excessive K before eating (Burrowes and Ramer, 2008). Although K content is partially reduced by these methods, the degree of reduction is limited. In addition, other important minerals and vitamins are also washed out and disassembled by these methods. In the above condition, dialysis patients can't eat usual diet with other family members. For example, eating melon fruits is like a dream to the dialysis patients. As a result of this normal diet restriction, their qualities of life (QOL) decrease greatly. Therefore, supplementation of fruits and vegetables containing lower K than usual can be a very useful prevention method for the peoples of the above kind.

K on the other hand is one of the major nutrients, essential for normal growth and development of plants (Schachtman and Liu, 1999). Plants absorb more K than any other mineral

element with the exception of N (Tisdale and Nelson 1975, Mäser et al., 2002, Britto and Kronzucker, 2008; Szczerba et al. 2009). It is the only monovalent cation that is essential for all higher plants, and is involved in three major functions: enzyme activation, charge balance and osmoregulation (Mengel, 2007; Szczerba et al., 2009). It is inevitable that reduced K supply will inhibit plant growth and yield. Therefore, investigation on minimal requirements of K in plants maintaining their normal growth and development is necessarily important. In this context, production of melon fruits with low K content will provide supplemental diet to the dialysis patients and would be of great interest of research.

Generally greenhouse cultured raw melon has higher K content of 340 mg/100 g fresh weight (Standard Tables of Food Composition in Japan, 2011). Decrease of this K content in melon fruits to a greater extent would improve the diet of dialysis patients. In general, hydroponic culture provides ample supply of mineral nutrients and thus plants absorb excessive nutrients beyond their requirement. It is possibly the most intensive culture method providing efficient use of water, minerals and space. It enables a more precise control of growth conditions which make easier to study the variables factors or parameters. Since a regular nutritional testing is conducted in the hydroponic growing system, so it can be more easy defined whether the desired amount of nutritional content is present in the plants or not. In addition, undesired nutrient contents, for instance nitrites, heavy metal contamination can be easily kept away from the system. It has also the precise control over concentration and composition of culture solution which can be used for the production of either mineral enriched or deficient fruits or vegetables. Considering the above advantage of hydroponics, simple management of culture solution used for melon by reducing the K at lowest possible level would decrease fruit K content.

Therefore, the objective of the study was to investigate the impact of reduced K concentrations in nutrient solution on the fruit K content of melon while maintaining normal growth, yield and other fruit qualities.

2. Materials and methods

2.1. Melon cultivar

Melon (*Cucumis melo* L. cv. Panna), a netted melon grown in standing culture at the greenhouse with one fruit per plant were used as the planting material in this study. The seeds of this melon cultivar were collected from Takii & Co. Ltd. Kyoto, Japan. The cultivar has excellent sweet taste with green flesh. This cultivar is generally grown as spring culture in the greenhouse. It has tolerance to Fusarium wilt disease and its fruit development is possible even at lower temperature. Fruits can be harvested at 55 days after anthesis.

2.2. Enshi nutrient solution

Melon plants were cultured in hydroponics using 50% □Enshi□ nutrient solution with an electrical conductivity (EC) of 1.32 dS/m and pH of 6.93 (Table 1). In the present study we have reduced the amount of KNO_3 keeping other nutrients constant to produce melon fruits with low K content through hydroponic culture. Although the pH of the nutrient solutions used was not varied, the EC was decreased gradually with the gradual decrease of KNO_3. The EC of 50% nutrient solution with 1/2, 1/4, 1/8, 1/16, and 0 levels of KNO_3 were 1.08, 0.97, 0.91, 0.88, and 0.85 dS/m, respectively. The EC and pH of tap water used for this experiment were 0.22 dS/m and 8.18, respectively.

2.3. Climatic conditions of the experimental site

Three independent studies were conducted to produce low K content melon fruits using hydroponic system at the greenhouse (20 m × 5 m) of Experimental Research Center for Biological Resources Science, Shimane University. The studies were conducted during the spring seasons of 2009, 2010 and 2011. The study area is generally characterized by a moderate weather condition. During the culture period of 2009, 2010 and 2011 the mean temperatures were 24.6, 21.1, and 21.1 °C; relative humidity of 80.4, 80.4, and 79.9%; amount of solar radiation of 343.4, 322.0, and 346.6 W/m^2; and rainfall of 6.0, 6.3, and 3.4 mm, respectively. The above weather parameters were further analyzed in respect of crop growth stages to study their influence in each stage (Fig. 1). Air temperatures were increased about 3 °C in fruit maturation from anthesis in 2009 whereas; it was about 9 °C in 2010 and 2011. Greater rainfalls during fruit development stage were recorded during 2009 and 2010. Although relative humidity of all three years was similar during growth stages of melon, amount of solar radiation found to be lower at early fruit developmental stages compared to other two growth stages in all three years.

2.4. Hydroponic culture of melon in nutrient solutions with 1/1 and 1/4th levels of KNO_3 during spring 2009

Melon seeds were sown in the cell trays (30 cm × 50 cm × 5.5 cm, 51 cells) with vermiculite on 1 May. After the germination, seedlings having similar growth and vigor were selected for hydroponic nursery in plastic container (60 cm × 48 cm × 23 cm) with 60 L of 25% Enshi nutrient solution on 18 May. After three weeks on 10 June, similar vigor seedlings were transplanted in same sized plastic container supported by four urethane blocks (23 mm × 23 mm × 27 mm). Three seedlings were planted in each containers filled with 60 L of 50% standard culture solution aerated continuously. The culture solutions were renewed at every two weeks interval throughout the entire growth period. On 28 June, 8 to 11 lateral branches were marked for female flower. Pollination was done only in first collateral female flower and pinching above second female flower. The lower five leaves were removed and main stem was pinched under 21st node on 1 July. Reduction of KNO_3 in the culture solution were started on 2 July after pollination and continued till harvest. There were two types of nutrient solutions viz. the 50% standard nutrient solution (control) and the standard nutrient solution with 1/4th of KNO_3. On 10 July, fruit thinning were done leaving only one fruit per plant. On 25 August, cultivation of melon was terminated and fruits were harvested. At harvest, number of leaves, dry weight of leaves, stem and root, fresh weight of fruits and fruit qualities such as soluble solids, and citric acidity were measured. Fruit K concentrations were determined following methods described in section 2.8.

2.5. Hydroponic culture of melon in nutrient solutions with 1/1, 1/2, 1/4, 1/8 and 1/16th levels of KNO_3 during spring 2010.

Seeds of melon were sown in cell trays (30 cm × 50 cm × 55 mm, 51 cells) with vermiculite on 6 April. Nursery of seedlings was done as previous study. Three seedlings with similar growth were planted in one plastic container (60 cm × 48 cm × 23 cm) using four urethane blocks (23 mm × 23 mm × 27 mm) as support filled with 50% of 50 L standard nutrient solution aerated continuously on 28 May. Culture solutions were renewed biweekly with 50 L nutrient solution. On 20 June, 8 to 11 lateral branches were marked for female flowers. Pollination was done only in first collateral female flower and pinching above second female flower. The lower five leaves were removed and main stem was pinched under 21st node on 23 June. Low KNO_3 treatments were started on 24 June, after pollination following anthesis till harvest of melon fruits. The nutrient solutions used were 50% standard nutrient solution with 1/1, 1/2, 1/4, 1/8 and 1/16th levels of KNO_3 having four replications. On 16 August, experiment was terminated. Numbers of leaves, length of stem, dry weight of leaves,

stem and root, fresh weight of fruits were measured. Melon fruit qualities such as soluble solid content, titratable citric acidity, ascorbic acid content were also determined. Mineral nutrients content in melon fruits and plant parts were also determined as described in section 2.8 and 2.9.

2.6. Hydroponic culture of melon in nutrient solutions with 1/1, 1/8, 1/16 and 0 levels of KNO_3 during spring 2011

Seeds of melon were sown in cell trays (53.5 cm × 28.5 cm × 3.2 cm, 72 cells) with vermiculite on 7 March. After germination, seedlings with high vigor were transplanted into plastic container (60 cm × 48 cm × 23 cm) with 50 L Enshi nutrient solution for nursery on 29 March. Three seedlings with similar growth were planted in one plastic container using four urethane blocks (23 mm × 23 mm × 27 mm) as support filled with 50% of 50 L nutrient solution aerated continuously on 26 April. The culture solutions were renewed weekly. When the amount of culture solution decreased considerably then fresh standard nutrient solution were added to each container before the weekly change. 11 to 15 lateral branches were marked for female flowers. Female flowers from first node of secondary branches were pollinated and the branches were detopped leaving the second node. The lower five leaves were removed and main stem was pinched under 25th node on 23 June. At the fruit growing stage, melon plants supplied with 50% standard nutrient solution with 1/1, 1/8, 1/16 and 0 levels of KNO_3 having four replications. Cultivation was terminated on 29 May and growth, yield and fruit quality of melon were measured such as stem length, dry weight of leaves, stem and roots, fresh weight of fruit, soluble solid content, titratable citric acidity, and ascorbic acid content. Minerals concentrations including K in fruit juice and plant parts were determined as follows.

2.7. Analysis of melon fruit qualities

After harvest melon fruits were undergone maturation of 4 days storing at room temperature. Then edible parts of melon fruit were sliced, mixed by juicer (Zojirushi BM-RS08-GA, Zojirushi Corporation, China) and prepared juice for the analysis of soluble solids, titratable acidity and ascorbic acid content.

2.7.1. Soluble solid content

About 0.4 ml of the melon juice was placed onto the prism surface of pocket digital refractometer (PAL-1, Atago Ltd., Tokyo, Japan) and soluble solid contents were recorded. Repeated

measures were conducted by washing the prism surface by distilled water and also rinsed with the test juice.

2.7.2. Titratable acidity

Titratable acid contents were determined by diluting each 2 ml aliquot of melon juice to 10 ml with 8 ml distilled water and added 2–3 drops of phenolphthalein then adjusted the pH to 8.2 using 0.1 N (w/v) NaOH. The quantity of NaOH (ml), and the amount for appropriate acidity was converted into citric acidity (%).

2.7.3. Ascorbic acid concentration

Ascorbic acid contents were measured following 2,4-dinitrophenylhydrazine (DNP) colorimetry. Melon fruit juice (0.5 ml) were taken in 50 ml glass test tube then 0.5 ml of 10% meta-phosphoric acid solution, 1 ml of distilled water, 1 ml of 0.03% 2,6-dichlorophenol-indophenol (DCP), 2 ml of thiourea, and 1 ml of DNP was added to the samples sequentially following three hours incubation at 37 ºC in water bath (BW400, Yamato Scientific Co. Ltd. Japan). After incubation 5 ml of 85% H_2SO_4 were added keeping the samples in iced water. After 30 minutes cooling ascorbic acid content were measured at 520 nm by Spectrophotometer (U-2900, Hitachi High Technologies Corporation, Tokyo, Japan).

2.8. Determination of K concentration in melon fruit samples

The concentrations of K including Ca, Mg, Fe and Na in melon fruit were measured following the procedures described below. After maturation, edible parts of melon fruits were cut into small pieces, kept in the 15 ml plastic test tube and iced for subsequent analysis of minerals. On the day of analysis melon samples were kept out of freezer for thawing. Then fresh weight of each fruit sample (8-10g) was measured through (Excellence XS Analytical Balance, XS204DRV, Greifensee, Switzerland) and placed in a 250 ml plastic bottle that contains 200 ml of 1% HCl. Then the samples were shacked in a bio shaker (Bio-Shaker BR-43FL, Japan) for 30 minutes at 150 rpm for complete liquefy of fruits flesh. The dissolved fruit samples were then filtrated (Advantec Grade no. 131, 185 mm thickness) and analyzed the above minerals with polarized Zeeman Atomic Absorption Spectrophotometer (Z-2310, Hitachi High Technologies Corporation, Tokyo, Japan).

In glass test tube 0.5 ml of filtered fruit samples were taken, 1.0 ml of ammonium molybdate stock solution and 3.5 ml of ascorbic acid solution (ascorbic acid 0.5 g/100 ml) was added. The prepared test solutions were shaken (Tube mixture, TRIO TM-1N, AsOne, China) and shipped for measuring PO_4^{-3} at 720 nm by Spectrophotometer. Ammonium molybdate stock solution was

prepared by mixing the following two chemicals. First, 20 g of ammonium molybdate weighed, melted in about 300 ml mild hot water, cooled by putting the beaker in cold water and then measured upto 500 ml volume by volumetric flask. Second, 330 ml of concentrated hydrochloric acid were taken in 500 ml measuring cylinder, added 170 ml distilled water for measured the upto 500 ml and then cooled in the cold water.

2.9. Determination of K concentration in melon plant parts

Melon plant parts were separated into leaves, stem and roots and kept in a constant temperature oven (DKN 812, Yamato Scientific Co., Ltd. Japan) for at least 72 h at 80 °C. When the dry matter reaches constant weight, it was ground into powder with a mixer machine (National MX-X53, Japan). Samples weighing 0.5 g were mixed with 8 ml of HNO_3 and digested by microwave sample preparation system (ETHOS1, Milestone S.r.l, Bergamo, Italy). After digestion samples were measured up to 50 ml of volumetric flask and then filtered with qualitative filter paper (Grade no. 131). The filtered sample solutions were analyzed for K, Ca, Mg, Fe and Na by Zeeman Atomic Absorption Spectrophotometer.

2.10. Determination of K concentration in melon fruits peduncle and collateral leaves

After harvest of melon, the fruit peduncle, first and second collateral leaves were separated. Small pieces of each part were placed in a 15 ml plastic tube and frozen at –30 ºC in the refrigerator. At the day of analysis, the samples were thawed, crushed with a glass rod, and 1 ml of sap were taken in glass test tube. Ten times solutions were prepared by adding 9 ml distilled water in the sap solution. Then filtered samples of these three parts were analyzed for K concentration by polarized Zeeman Atomic Absorption Spectrophotometer.

2.11. Statistical analysis

Analysis of variance was performed to test for significant effects of different KNO_3 levels in the nutrient solution on the plant growth, fruit yield and qualities and minerals in plant parts of melon in all three studies. Mean separations were performed by Tukey-Kramer test (Statcel 2 Software, OMS publication, Tokorozawa, Saitama, Japan) at $P < 0.05$.

3. Results

3.1. Effects of reduced KNO_3 in nutrient solution on the growth, yield and fruit quality of melon during spring 2009

The preliminary study showed that, the reduced KNO_3 concentration in the nutrient solution had significant influence on root dry weight, citric acidity and K concentration of melon grown in hydroponics (Table 2). The other studied growth characters such as number of leaves, dry weight of leaves and stem were not affected significantly when grown in nutrient solution with reduced (1/4th) KNO_3 compared to plants grown in standard nutrient solution. Fruit yield in terms of fresh weight showed no significant difference between nutrient solution with standard and reduced KNO_3 concentration. Fruit qualities such as soluble solid content were not varied in the two nutrient solutions whereas, citric acidity were decreased significantly in plants grown with reduced KNO_3. The K concentration in melon fruits were lowered significantly to about 39% in plants grown in reduced KNO_3 supplied nutrient solution than that of plants grown in standard nutrient solution.

3.2. Effects of reduced KNO_3 in nutrient solution on the growth, fruit yield and quality and mineral concentration of melon during spring 2010

3.2.1. Growth, yield and fruit qualities of melon

The effects of reduced KNO_3 concentration had no significant influence on the growth variables such as number of leaves, stem length, dry weight of leaves, and dry weight of stem but only root dry weights were reduced significantly in nutrient solution with 1/16th levels of KNO_3 (Table 3). Root dry weights were in decreased in all nutrient solution having reduced KNO_3 and it was about 37% in nutrient solution with lowest K nitrate level. Melon fruits fresh weight and qualities except citric acidity were not affected significantly due to the reduced KNO_3 concentration in the culture solution (Table 3). Soluble solid content of melon fruits were not decreased in plants grown with reduced KNO_3 concentration compared with standard nutrient solution. Although ascorbic acid concentrations were decrease gradually with the decrease of KNO_3, there were no significant variations among the nutrient solution studied. Titratable acidity in terms of citric acidity were decreased only in nutrient solution with 1/8 and 1/16th KNO_3 and melon plants harvested from nutrient solution with 1/2 and 1/4th KNO_3 has statistically similar acidity as melon from standard nutrient solution.

3.2.2. K concentration in melon fruit

Reduction of KNO_3 in the culture solution results in melon fruits having significantly decreased K content compared to standard nutrient solution (Fig. 2). It is evident from the figure that K content in melon fruits decreased gradually with the gradual decrease of KNO_3 in the nutrient solution. The fruit K content in melon plants grown in 1/2th or 1/4th KNO_3 of standard nutrient

solution had not decreased significantly but it was decreased significantly in nutrient solution containing 1/8th and 1/16th KNO_3. It was found that, about 35% lowered K content melon fruits were harvested from plants grown in nutrient solution with 1/16th KNO_3 compared to standard nutrient solution. Other mineral nutrient such as Ca, Mg, and Fe were not varied significantly in plants gown in the nutrient solution used. Na content in melon fruits increased linearly with the gradual decrease of KNO_3 in the culture solution (data not shown).

3.2.3. K concentration in different plant parts of melon

Accumulation of K in leaves, stem and root of melon plants were varied significantly due to the reduction of KNO_3 concentration in the culture solution (Fig. 3). Result showed that compared to standard nutrient solution, other nutrient solution containing reduced KNO_3 lead to decreased K accumulation in all plant parts. Leaves K concentrations were decreased about 39, 64, 77 and 82% in plants grown with 1/2, 1/4, 1/8 and 1/16th KNO_3 of standard nutrient solution, respectively compared to plants grown in standard nutrient solution. Stem and root K concentrations were also decreased proportionately as in leaves. The lowest K contents in stem and root (89 and 90%, respectively) were determined from plants grown in nutrient solution with 1/16th KNO_3 of standard nutrient solution. It also evident that K concentration was higher in melon plant stem than its leaves or roots.

Concentration of other mineral nutrients were not varied but accumulation of Na in leaves, stem and root of melon plants were increased significantly when grown in nutrient solution with reduced KNO_3 than standard nutrient solution (data not shown). Na concentration in plant parts were not increase proportionately as K concentration. Leaves Na concentration was increased about 63-79% in plants grown with the reduced KNO_3 levels whereas this figure was about 66-68% in case of root. Na concentration in stem did not increased greatly (10-22%) in the reduced KNO_3 levels of culture solution rather decreased considerably (67%) in 1/16th KNO_3 level, compared to plants grown in standard nutrient solution.

3.2.4. K concentration in fruit peduncle and fruits collateral leaves of melon

K concentration in melon fruit peduncle and collateral leaves were also showed the proportional decrease with the reduced levels of KNO_3 in the culture solution (Fig. 4). In fruits collateral leaves, K concentrations was decreased upto 78% in 1/16th of KNO_3 in the nutrient solution whereas, it was upto 89% in case of fruits peduncle. Comparatively higher K concentration was determined in fruits peduncle than in fruits collateral leaves, however this difference were not evident in 1/8 and 1/16th level of KNO_3 concentration.

3.3. Effects of reduced KNO_3 in nutrient solution on the growth, fruit yield and quality, mineral concentration, and weekly K absorption by melon plants during spring 2011

3.3.1. Growth, yield and fruit qualities of melon

There were no significant effects of reduced KNO_3 in the culture solution on the growth variables, yield and fruit qualities of melon (Table 4). Plant height in terms of stem length, dry weight of leaves at 6-11 nodes and 12-25 nodes, dry weight of stem from 1-11 nodes and 12-25 nodes, and dry weight of root were not affected due to reduced KNO_3. However, dry weights of stems and root tended to insignificantly decrease in 1/16th and 0 KNO_3 in the culture solution. Melon fruit yield and qualities except soluble solids were not influenced significantly by the reduction of KNO_3 in the culture solution. Although fruit yield were not varied significantly among the nutrient solutions used, plant grown in nutrient solution without KNO_3 after anthesis produce about 391 g lesser fresh weight per fruit compared to fruit produced in standard nutrient solution. Soluble solids were significantly decreased in fruits obtained from nutrient solution containing 1/16th or without KNO_3.

3.3.2. K concentration in melon fruit

K concentration in melon fruits were significantly decreased in nutrient solutions with the reduced levels of KNO_3 (Fig. 5). Melon fruit obtained from plants grown in nutrient solution containing 1/8 and 1/16th level of KNO_3 from anthesis to harvest has 20 and 29% lower K content, respectively than plants grown in standard nutrient solution. When melon plants grown in nutrient solution without KNO_3 during anthesis to harvest, the fruits K decreased greatly to about 43% compared to control. Na concentration in melon fruits followed the reverse trend of K concentration (data not shown). Its concentration increased significantly in all the reduced K levels supplied during anthesis to harvest. However, there were no significant increases in fruit Na concentration among the lower KNO_3 treatments. It was found that melon plants grown in nutrient solution without KNO_3 during anthesis to harvest produced fruits with increased Na concentration of about 56%. Other minerals were not showed any significant effect due to reduced KNO_3 in the nutrient solution (data no shown).

3.3.3. K concentration in different plant parts of melon

The reduced supply of KNO_3 during anthesis to harvest has significant effects on the accumulation of K in different plants of melon plants (Fig. 6). The K accumulation capacity in

leaves, stem or root has found to be different in plants grown in standard nutrient solution. Stem K concentration determined as two times higher than that of K concentration in leaves or roots. All the plants such as leaves at 6-11 nodes and 12-25 nodes, stem from 1-11 nodes and 12-25 nodes, and roots has lower K accumulation when KNO_3 were restricted during anthesis to harvesting period. It is evident that, in general lower parts of melon plants (leaves or stem bellow 11 node for fruit setting) have greater K accumulation. Results also showed that K accumulation decreased significantly about 79-88, 77-94, and 75-85% in leaves, stems and roots, respectively compared to plants grown with standard nutrient solution throughout the culture period.

In general, Na concentration in stems was several times greater than in leaves and roots (data not shown). Na concentration in leaves and root was determined as less than 1.5 ppm in plants grown in all the types of nutrient solution. In case of leaves obtained from plants grown with reduced KNO_3 levels, Na accumulation rate showed an increasing trend in leaves at 6-11 nodes (16-33%) and 12-25 nodes (43-52%) than control. Na concentration increased significantly (upto 67 and 49% in stem under and above 11 node, respectively) in stem until 1/16th level of KNO_3 in culture solution during anthesis to harvest however, it did not increased in nutrient solution without KNO_3. Moreover, compared to upper stem (12-25 nodes) the lower stem (1-11 nodes) had higher Na concentration in all types of nutrient solution. There were no significant differences in other minerals accumulation in melon plant parts due to reduced KNO_3 levels in nutrient solution.

3.3.4. K concentration in fruit peduncle and fruits collateral leaves of melon

K concentration in fruits peduncle, it collateral leaves were determined to realize the source route of K to melon fruit (Fig. 7). Compared to collateral leaves fruits peduncle has higher concentration of K. It is evident from the figure that concentration of K decreased gradually with the increase of distance of plant parts i.e., fruit peduncle, first collateral leaf and second collateral leaf. The concentrations of K in these parts decreased greatly (about 88-94, 95-97, and 97% in fruit peduncle, first and second collateral leaf, respectively) after restrict the KNO_3 or without supply from anthesis to harvest.

3.3.5. Weekly K absorption per plant

The amount of K absorption per plant grown in hydroponics using 50% standard nutrient solution was measured before the start of KNO_3 restriction (Fig. 8). K requirements increased until fourth week and then declined. The weekly absorption of K per plant were 11, 20, 33, 76 and 69 ppm in first, second, third, fourth, and fifth week, respectively. K absorption per plant was also measured after start of restricted KNO_3 in the nutrient solution (Fig. 9). Plants grown in standard nutrient

409 solution absorbed a great amount of K where as the plants grown in nutrient solution with reduced
410 KNO_3 levels absorbed proportional to supplied amount in the nutrient solution. It is evident from the
411 figure that melon plants requirement of K decrease gradually after anthesis and during fruit
412 development absorption turns to minimum. Plants grown in nutrient solution without KNO_3 also
413 absorbed K at minimum levels throughout the growing period, which comes possibly from tap water.
414
415 **4. Discussion**
416 In this present study melon plants were cultured through hydroponics in plastic containers.
417 We used this managed culture technique as fertilizer management is easy, simple and accurate in this
418 managed compared to soil cultivation. Changes in nutrient concentrations in the culture medium can
419 be possible from any growing stage only by dissolving the required fertilizers. We found that simple
420 management of nutrient solution concentration can reduce melon fruit K upto 43% compared to
421 control group without significant decline in growth, fruit yield and qualities (Fig. 5). These results
422 were verified through three independent cultures during the spring seasons from 2009 to 2011. A
423 general trend of decreasing K content in fruit was observed with the decrease of KNO_3 concentration
424 in nutrient solution. In spring 2009, melon plants were grown in nutrient solution with 1/4th KNO_3
425 decreased fruits K by 39% compared to fruits K in standard nutrient solution whereas, it was
426 decreased by about 35% and 43% when melon plants were grown in nutrient solution with 1/16th
427 and O levels of KNO_3 in the spring 2010 and 2011, respectively. Compared to melon fruit K of 340
428 mg/100g FW (Standard Tables of Food Composition in Japan, 2011), about 39% (207 mg/100g FW)
429 decreased K was found in melon fruits grown in nutrient solution without KNO_3 from fruit formation
430 to final harvest during spring 2011. Fruit K content was not decreased expectedly even after limiting
431 the K level to zero. The possible reason behind might be the excessive absorption into the plant
432 foliage during vegetative growth and storage before the start of K restriction. Most of the researchers
433 suggested that adequate K nutrition increased yields, fruit size, increased soluble solids and ascorbic
434 acid concentrations, improved fruit color, increased shelf life, and shipping quality of many
435 horticultural crops (Geraldson, 1985; Lester et al., 2005, 2006, 2007; Kanai et al., 2007). However, K
436 accumulation in plant parts and storage organ may not only depend on K absorption efficiency but
437 also its use efficiency. Recently it was found that K absorption efficiency increased but K use
438 efficiency decreased significantly with increasing K^+ concentration in the medium in two halophytes,
439 *Catapodium rigidum* and *Hordeum maritimum* (Hafsi et al., 2011). K uptake also depends on plant
440 factors, including genetics and developmental stage such as vegetative versus reproductive stages
441 (Rengel et al., 2008). It was also revealed that if we reduced the KNO_3 levels in the nutrient solution,

the concentration of K in the edible parts of melon increased greatly compared to K absorption form the root. Under such condition the translocation of K to fruits become greater than any other organ.

The concentration of Ca, Mg and Fe in edible part of melon fruits were not varied considerably in the nutrient solution with different K levels (data not shown) except Na (Fig. 2 and 7). Na concentration in fruits increased progressively with the decrease of K in the nutrient solution. It showed clear antagonistic relation with fruit K concentration due to the reduced levels of KNO_3. Compared to control plants about 83% (spring 2010) and 51% (spring 2011) increased Na were found in fruit harvested from plants grown in nutrient solution with 1/6th or without K, respectively. Ogawa et al., (2012) found that Na and Mg contents in leafy vegetables and tomato were increased significantly when K content restricted in the culture solution. This is suggested that the increment of these ions compensated for the reduction of K. The presence of Na in the environment and its uptake by plants can reduce the amount of K required to meet the plants basic metabolic requirements. Thus, in the presence of Na, the critical level of K can be reduced for example, the lowest tissue K level at which 95% of the maximum yield of field vegetables crops can be achieved (Greenwood and Stone, 1998). For crops that have a capacity to substitute Na for K, the critical level for K is reduced as a function of the Na supply. Research results also suggested that the increase in Na and Mg concentrations in tomato fruits resulted in response to the decrease in K levels (Diem and Godbold, 1993; Pujos and Morard, 1997). Therefore, presence of Na and Mg ions would be an important factor in alleviating the effects of K deficiency in plants.

It has been reported that K deficiency is related to reduced stomatal conductance, thereby impairing CO_2 fixation, disrupting the conversion of light energy to chemical energy, and the phloem export of photosynthates from the source to sink (Cakmak, 2005). However, we found that fruit yield of melon was not decreased significantly due to reduced K supply in all three cultures (Table 2, 3 and 4). This indicated that the reduced K levels still maintain K sufficiency in the hydroponic culture solution used for melon. In case of without supply of K from anthesis to harvesting period revealed that luxurious absorption of K by melon plants during vegetative growth (transplanting to anthesis) was sufficient for higher fruit yield. All the growth variables of melon plants except root dry weight were not inhibited significantly in the reduced KNO_3 nutrient solution (Table 2 and 3). This inhibited root activity/growth might be due to the passive effect of competition for photoassimilates between developing fruits and vegetative organs during reproductive growth stages (Lester et al. 2010a).

Fruit qualities in terms of soluble solids, citric acidity and ascorbic acid were determined to whether there were any influences of reduced K in the nutrient solution on them. Soluble solids and citric acidity were found to be decreased significantly in nutrient solution with reduced K although ascorbic acid concentration was not affected. The decreased soluble solids content in melon fruits in

476 spring 2011 culture might be due to the variation in metabolism and respiration rate in reduced
477 KNO_3 in the culture solution. Lester et al. (2010b) reviewed many examples of the positive effects of
478 K fertilization improving fruit disease control, yield, weight, firmness, sugars, sensory attributes,
479 shelf-life, and human bioactive compound concentrations. They also mentioned that finding in these
480 studies are limited to the mode of fertilization (e.g., soil vs. foliar, fertigation or hydroponic applied),
481 and differences in sources of K fertilizer (e.g. KCl, K_2SO_4, KNO_3, Glycine-complexed K). At the
482 same time some particular studies also concluded that there is little or no change in fruit quality due
483 to K fertilization in apple (Hassanloui et al., 2004), cucumber (Umamaheswarappa and Krishnappa,
484 2004), mango (Rebolledo-Martinez et al., 2008), pear (Johnson et al., 1998), bell pepper (Hochmuth
485 et al., 1994), strawberry (Albregts et al., 1996) and watermelon, (Locascio and Hochmuth, 2002;
486 Perkins-Veazie et al., 2003). On the other hand, soil applications K generally had little or no effects
487 on fruit qualities (Demiral and Koseoglu, 2005; Lester et al., 2005, 2006; Jifon and Lester, 2009).
488 Several studies also suggested that fruit quality improvements appeared to depend on K source and
489 growing season. For instance, Jifon and Lester (2009) showed that when mid to late season soil or
490 foliar K applications were made using KNO_3 there were little or no improvements in fruit marketable
491 or human-nutritional quality attributes in muskmelon and in some instances, these attributes were
492 actually inferior compared to fruit from control plots.
493 Reduced supply of K in nutrient solution leads to drastic reduction of its accumulation in the
494 melon plant parts. It was found that against to control K concentration decreased over 80% in leaves,
495 stems or roots when K restricted to 1/16th levels of standard concentration during spring 2010 (Fig.
496 3). On the other hand Na content increased over 60% in leaves and root while slightly increased
497 (upto 22%) in stem and greatly decreased in 1/16th levels of K (data not shown). In spring 2011,
498 compared to control more than 75% decreased K accumulation was found in K restricted melon plant
499 parts (leaves, stem and root) whilst increased Na accumulation was observed (Fig. 6). These results
500 indicated that melon plant grown in standard nutrient solution has higher K concentration in plant
501 parts at the harvest, as we restrict or stop the K supply from anthesis stage, therefore, the decreased
502 amount of K from plant parts translocated to fruit during maturation stage. The above results also
503 indicated that Na ions could replaced K ion in non-specific physiological and biochemical functions
504 (Flowers and Läuchli, 1983). It has reported that substituting 20% NaCl for 20% KCl showed no
505 significant effects on growth in spinach grown in sand culture (Tomemori et al., 2002). The
506 underlying mechanism of K substitution by Na reviewed by Rengel et al., (2008) that accumulation
507 of K in vacuoles creates the necessary osmotic potential for cell extension and rapid cell extension
508 requires high mobility of the osmoticum, so only few other ions (e.g. Na^+) can replace K in this role.
509 Osmotic maintenance can also be carried out by less mobile molecules such as sugars, and amino

acids and K ions by partially replacing and recovering from vacuoles (Amtmann et al., 2005; Ogawa and Yamauchi, 2006). K is known to be the highly mobile mineral in plants. Under K^+ deficiency, cytosolic K^+ activity is maintained at the expense of vacuolar K^+ activity (Leigh, 2001; Memon et al., 1985), even though vacuolar K^+ activity is regulated differently in the root and leaf cells (Cuin et al., 2003). On the other hand genotypic efficiency in utilizing K can be an important tool for maximization yield in economic plants. Yang et al., (2004) elucidated that two K-efficient rice genotypes had two-fold higher K concentration in lower leaves, but only 30% higher K concentration in the upper leaves compared with K inefficient rice genotype at the booting stage. By maintaining a higher K concentration in the lower leaves, the K-efficient genotype was able to maintain a larger photosynthetic capacity during grain filling.

We also determined the K concentration in fruit petiole and collateral leaves that play the role in partitioning of K into fruit. It was found that K concentration in fruit peduncle and collateral leaves were decreased upto 89 and 78%, respectively in 1/16th level of K in standard nutrient solution during spring 2010 while it was decreased drastically upto 94, 97 and 97% in fruit peduncle, first and second collateral leaves, respectively (Fig. 4 and 7). Therefore, K translocation capacity between organs may also be an important mechanism for efficient utilization of K within the plant. Capacity to translocations of K from non-photosynthetic organs such as stems and petioles to upper leaves and harvested organs can influence the genotypic capacity to produce a high economic yield per unit of K taken up.

In addition, we measured the amount of K absorbed per plant every week throughout the culture period in spring 2011 (Fig. 8 and 9). These data indicated the weekly K requirements per melon plant. Therefore, the additional K can be removed from the nutritional composition that will restrict the plant from luxurious absorption leading to production of melon with considerably low K content. Results showed that majority of uptake occurred during pollination to early fruit developmental stage (20 May ~ 20 June, 2011). The absorption rate decreased considerably during the fruit maturation stage which indicated that K uptake also depends on plant factors, including genetics and developmental stage like vegetative versus reproductive stages (Rengel et al., 2008). In many fruiting species, K uptake occurs mainly during vegetative stages, when ample carbohydrate supply is available for root growth and uptake processes. Competition for photoassimilates between developing fruits and vegetative organs during reproductive growth stages can limit root growth/activity and K uptake (Lester et al., 2010a). Under such conditions, increasing soil K fertilization may not be enough to alleviate this developmentally-induced deficiency partly because of reduced root growth/activity during reproductive development and also because of competition from other cations for binding sites on roots (Marschner, 1995).

Low K content melon fruit can provide human health benefits to dialysis patients but the higher Na content would cause hyperpiesia and edema. Therefore, it is necessary to evaluate the benefits of the reduction of K against the risks of the increased Na intake by the dialysis patients, whose K intake should be restricted to 1500-2000 mg per day (Agondi et al., 2011) and Na chloride (equivalent to 2000-3200 mg Na) intake should be restricted to 5000-8000 mg per day. Therefore, Na intake must be limited to 1.3-1.6 times of K intake. Limiting the amount of salt used could be an effective way of reducing Na intake than concentrating only on eating foods with low Na content. It can be noted that the benefits of reducing the intake of K are greater than the risks of increasing the intake of Na.

4. Conclusion

In spring 2009, melon plants were grown in nutrient solution with 1/4th KNO_3 decreased fruits K by 39% compared to fruits K in standard nutrient solution whereas, it was decreased by about 35% and 43% when melon plants were grown in nutrient solution with 1/16th and O levels of KNO_3 in the spring 2010 and 2011, respectively. Compared to Standard Tables of Food Composition in Japan (2011), about 39% (207 mg/100g FW) decreased K was found in melon fruits grown in nutrient solution without KNO_3 from fruit formation to final harvest during spring 2011. Fruit K content was not decreased expectedly even after limiting the K level to zero. The possible reason behind was the excessive absorption into the plant foliage during vegetative growth and storage before the start of K restriction which in turn translocated into the melon fruits. Analysis of K concentration in plant parts near the fruits indicated that fruits peduncle is the dominant source of commuting the K from leaves and stem to fruits. Determination of weekly requirement of K per plant can help in removing the additional K from the nutritional composition which will restrict the plant from luxurious absorption leading to production of melon with considerably low K content. Moreover, consideration of K translocation from leaves and stems to fruits during fruit developmental stage is an important issue in stabilizing the low K content melon production technology. Therefore, appropriate quantitative management of culture solutions from the early vegetative growth period of melon plant is our future research thrust. In this present study, we demonstrated that simple management of nutrient solution can reduce the melon fruits K upto 43% compared to control. A general trend of decreasing K content in fruit was observed with the decrease of KNO_3 concentration in nutrient solution without significant decline in growth except root dry weight, fruit yield and qualities except citric acidity. Soluble solids content was also found to be decreased due to higher temperature during fruit maturation in spring 2011 melon culture.

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Table 1.
Full strength □Enshi□ nutrient solution (Hori, 1966).

Chemical compositions	Amounts of salt in tap water	
	(g 1000 L^{-1})	(m mol L^{-1})
$Ca(NO_3)_2$ $4H_2O$	950	4.03
KNO_3	810	8.02
$MgSO_4$ $7H_2O$	500	2.03
$NH_4H_2PO_4$	155	1.35
H_3BO_3	3	0.05
$ZnSO_4$ $7H_2O$	0.22	7.64×10^{-4}
$MnSO_4$ $5H_2O$	2	8.30×10^{-3}
$CuSO_4$ $5H_2O$	0.05	2.00×10^{-4}
Na_2MoO_4	0.02	9.71×10^{-5}
NaFe-EDTA	25	0.06

Table 2.
Effect of reduced potassium nitrate concentrations in nutrient solution on the growth, yield and fruit quality of melon grown in hydroponics during spring 2009.

KNO_3[a]	No. of leaves	Dry weight (g)			Fresh weight/ fruit (g)	Soluble solids (%)	Citric acidity (%)	K conc. in fruit (× 100 ppm)
		leaves	stem	root				
1/1	11.8 a[b]	63.2 a	14.2 a	33.4 a	1792.1 a	16.2 a	0.27 a	28.7 a
1/4	11.3 a	60.1 a	13.4 a	28.3 b	1741.5 a	16.1 a	0.21 b	17.5 b
	ns	ns	ns	*	ns	ns	*	**

ns: non-significant.
[a] KNO_3 concentration in 50% standard □Enshi□ nutrient solution.
[b] Means within column followed by same letters are non-significant according to the Tukey's multiple range test at $P < 0.05$.
* Significant at $P < 0.05$.
** Significant at $P < 0.01$.

Table. 3.
Effects of reduced potassium nitrate concentrations in nutrient solution on the growth, yield and fruit quality of melon grown in hydroponics during spring 2010.

KNO_3[a]	No. of leaves	Stem length (cm)	Dry weight (g)			Fresh weight/fruit (g)	Soluble solids (%)	Citric acidity (%)	Ascorbic acid (ppm)
			leaves	stem	root				
1/1	14.9 a[b]	148 a	76.6 a	15.2 a	13.7 a	1588.0 a	13.8 a	0.35 ab	28.6 a
1/2	15.0 a	147 a	82.9 a	15.0 a	13.4 a	1622.3 a	13.5 a	0.35 ab	25.2 a
1/4	15.0 a	158 a	71.5 a	13.2 a	10.0 ab	1500.9 a	13.9 a	0.38 a	22.6 a
1/8	15.4 a	170 a	74.3 a	12.5 a	10.5 ab	1620.4 a	13.4 a	0.32 b	24.4 a
1/16	15.0 a	140 a	69.2 a	11.9 a	8.7 b	1432.5 a	12.9 a	0.29 b	22.0 a
	ns	ns	ns	ns	*	ns	ns	*	ns

ns: non-significant.

[a] KNO_3 concentration in 50% standard □Enshi□ nutrient solution.

[b] Means within column followed by same letters are non-significant according to the Tukey's multiple range test at $P < 0.05$.

[*] Significant at $P < 0.05$.

Table. 4.
Effects of reduced potassium nitrate concentrations in nutrient solution on the growth, yield and fruit quality of melon grown in hydroponics during spring 2011.

KNO_3[a]	Stem length (cm)	Dry weight (g)					Fresh weight/fruit (g)	Soluble solids (%)	Citric acidity (%)	Ascorbic acid (ppm)
		leaves (6-11st node)	leaves (12-25th node)	stem (1-11st node)	stem (12-25th node)	root				
1/1	154.8 a[b]	17.0 a	66.7 a	5.9 a	11.3 a	16.9 a	1818.5 a	13.1 a	0.45 a	214.5 a
1/8	157.5 a	18.1 a	66.5 a	5.3 a	10.3 a	16.1 a	1589.6 a	11.9 ab	0.45 a	213.2 a
1/16	158.8 a	15.5 a	69.7 a	5.3 a	10.3 a	13.4 a	1703.8 a	11.6 b	0.42 a	214.2 a
0	154.9 a	16.8 a	63.2 a	5.0 a	9.5 a	13.1 a	1427.7 a	11.5 b	0.48 a	235.8 a
	ns	ns	ns	ns	ns	ns	ns	*	ns	ns

ns: non-significant.
[a] KNO_3 concentration in 50% standard □Enshi□ nutrient solution.
[b] Means within column followed by same letters are non-significant according to the Tukey's multiple range test at $P < 0.05$.
[*] Significant at $P < 0.05$.

Figure captions:

Fig. 1. Seasonal variation in mean air temperature and rainfall (A), relative humidity and solar radiation (B) for the spring cultures of 2009, 2010 and 2011 at the Experimental Research Center for Biological Resources Science, Shimane University. Weather variables were calculated from daily data from transplanting to anthesis stage (5 ~ 28 June, 2009; 28 May ~ 19 July, 2010; 26 April ~ 19 May, 2011), pollination to early fruit developmental stage (29 June ~ 28 July, 2009; 20 June ~ 18 July, 2010; 20 May ~ 20 June, 2011) and later stage of fruit maturation (29 July ~ 25 August, 2009; 19 July ~ 16 August, 2010; 21 June ~ 22 July, 2011).

Fig. 2. Effects of reduced potassium nitrate levels in culture solution on the fruit potassium content of melon grown in hydroponics during spring 2010. Edible parts of four days maturing melon fruits were used for determining K concentration.

Fig. 3. Accumulation of potassium in the different plant parts of melon grown with reduced potassium nitrate in hydroponics during spring 2010. Leaf samples include 16 leaves from 6-21st nodes, stem samples include total stems, and root samples were taken from total root per plant.

Fig. 4. Accumulation of potassium in the fruit peduncle and fruits collateral leaves of melon grown with reduced potassium nitrate in hydroponics during spring 2010. Sap collected from frozen samples of fruit peduncle and collateral leaves were used for K determination.

Fig. 5. Effects of reduced potassium nitrates in culture solution on the fruit potassium content of melon grown in hydroponics during spring 2011. Edible parts of four days maturing melon fruits were used for determining K concentration.

Fig. 6. Accumulation of potassium in the different plant parts of melon grown with reduced potassium nitrate in hydroponics during spring 2011. L1: leaves from 6-11 nodes, L: leaves from 12-25 nodes, S1: stem from 1-11 nodes, S2: stem from 12-25 nodes, and R: roots.

Fig. 7. Accumulation of potassium in the fruit peduncle and fruits collateral leaves of melon grown with reduced potassium nitrate in hydroponics during spring 2011. Sap collected from frozen samples of fruit peduncle, first and second collateral leaves were used for K determination.

Fig. 8. Amount of potassium absorbed by the melon plants (plant/week) before start of lower potassium nitrate concentration treatment in the culture solution in hydroponics during spring 2011.

Fig. 9. Amount of potassium absorbed by the melon plants (plant/week) after start of lower potassium nitrate concentration in the culture solution in hydroponics during spring 2011.

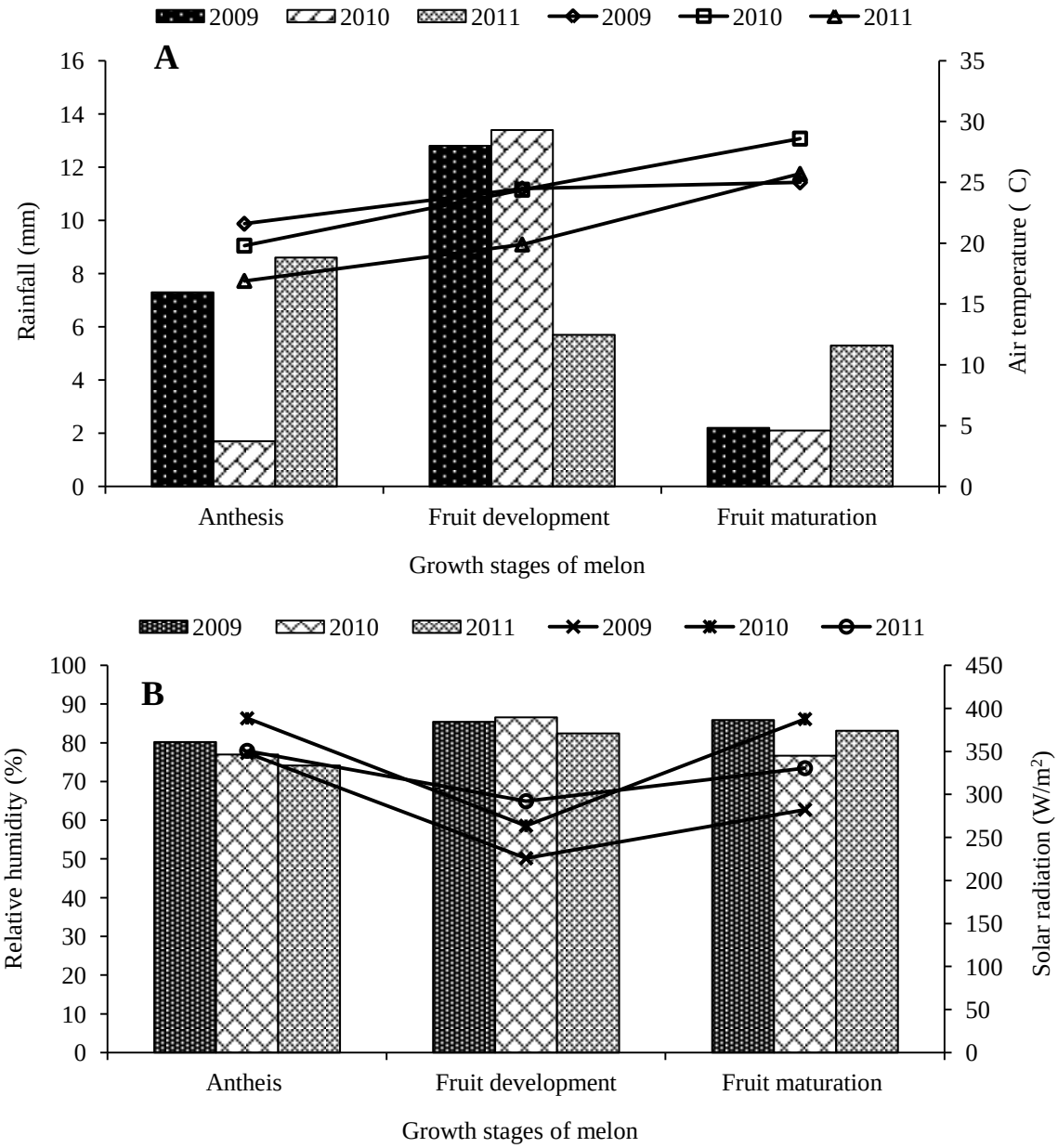

Fig. 1. Seasonal variation in mean air temperature and rainfall (A), relative humidity and solar radiation (B) for the spring cultures of 2009, 2010 and 2011 at the Experimental Research Center for Biological Resources Science, Shimane University. Weather variables were calculated from daily data from transplanting to anthesis stage (5 ~ 28 June, 2009; 28 May ~ 19 July, 2010; 26 April ~ 19 May, 2011), pollination to early fruit developmental stage (29 June ~ 28 July, 2009; 20 June ~ 18 July, 2010; 20 May ~ 20 June, 2011) and later stage of fruit maturation (29 July ~ 25 August, 2009; 19 July ~ 16 August, 2010; 21 June ~ 22 July, 2011).

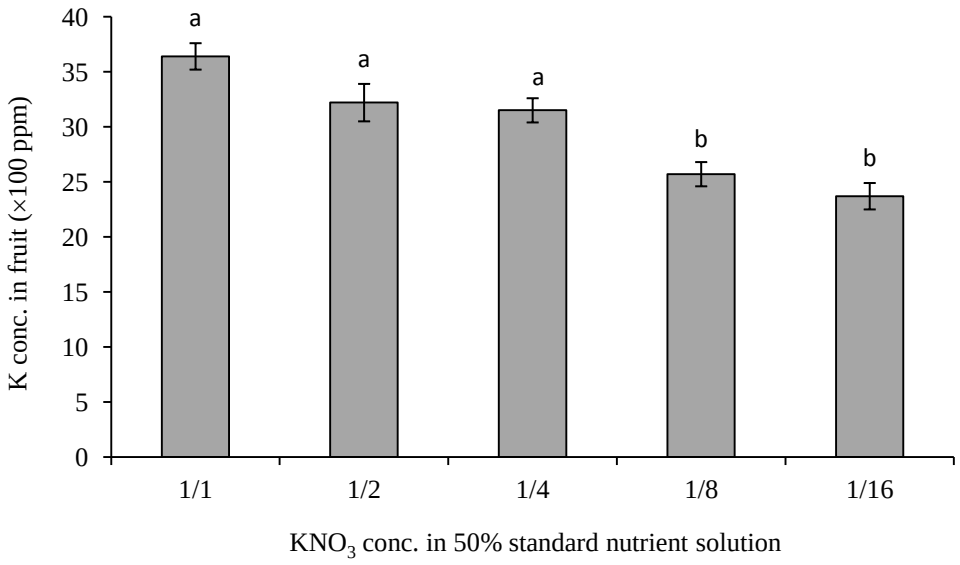

Fig. 2. Effects of reduced potassium nitrate levels in culture solution on the fruit potassium content of melon grown in hydroponics during spring 2010. Edible parts of four days maturing melon fruits were used for determining K concentration.

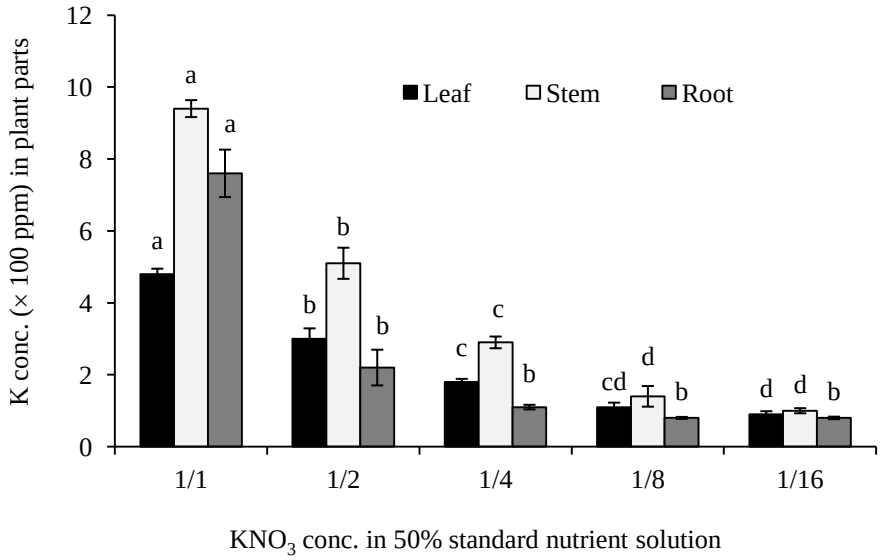

Fig. 3. Accumulation of potassium in the different plant parts of melon grown with reduced potassium nitrate in hydroponics during spring 2010. Leaf samples include 16 leaves from 6-21st nodes, stem samples include total stems, and root samples were taken from total root per plant.

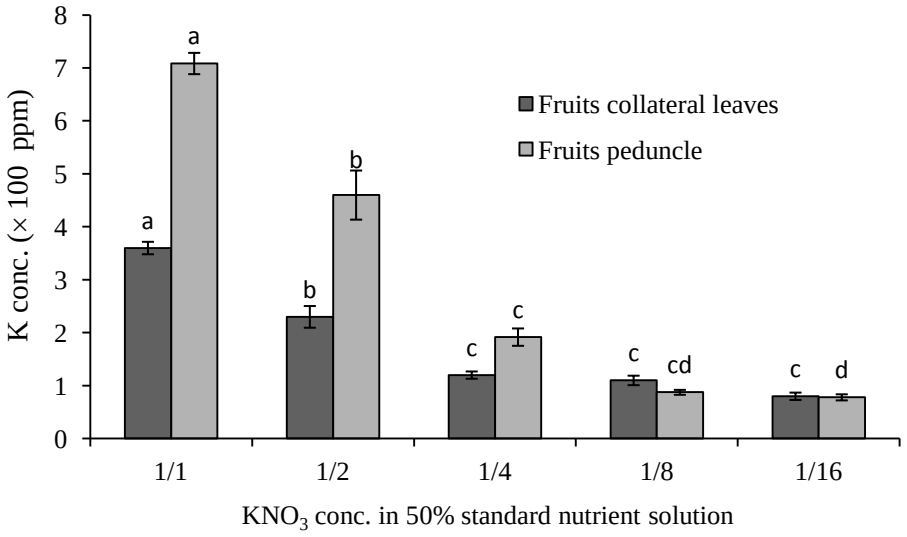

Fig. 4. Accumulation of potassium in the fruit peduncle and fruits collateral leaves of melon grown with reduced potassium nitrate in hydroponics during spring 2010. Sap collected from frozen samples of fruit peduncle and collateral leaves were used for K determination.

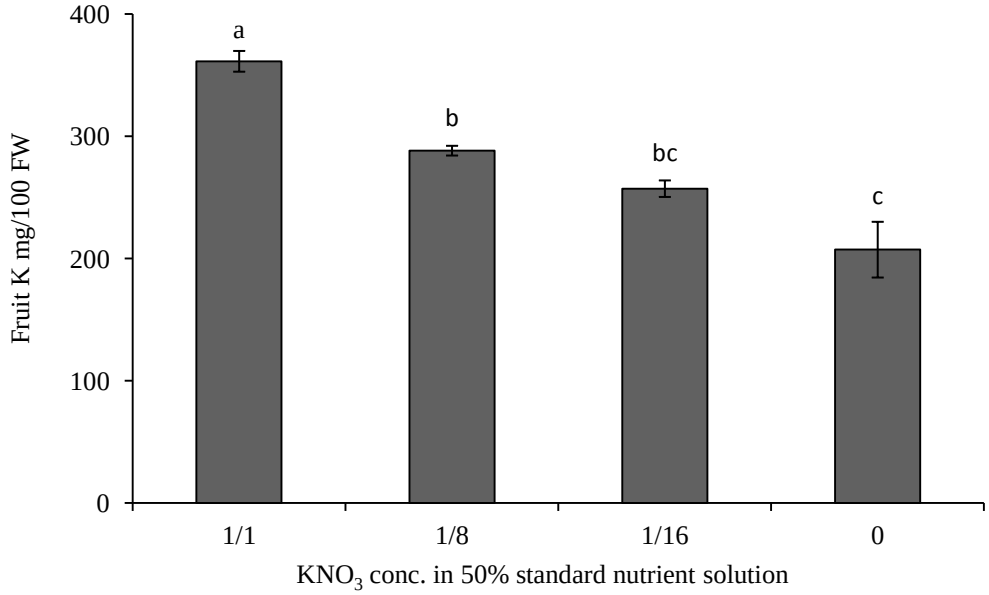

Fig. 5. Effects of reduced potassium nitrates in culture solution on the fruit potassium content of melon grown in hydroponics during spring 2011. Edible parts of four days maturing melon fruits were used for determining K concentration.

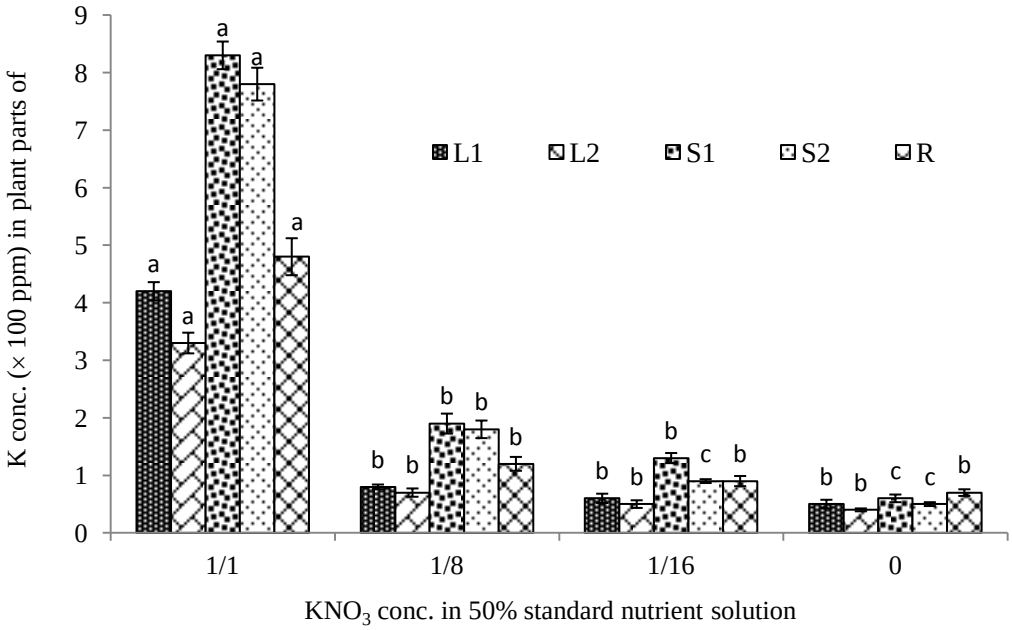

Fig. 6. Accumulation of potassium in the different plant parts of melon grown with reduced potassium nitrate in hydroponics during spring 2011. L1: leaves from 6-11 nodes, L: leaves from 12-25 nodes, S1: stem from 1-11 nodes, S2: stem from 12-25 nodes, and R: roots.

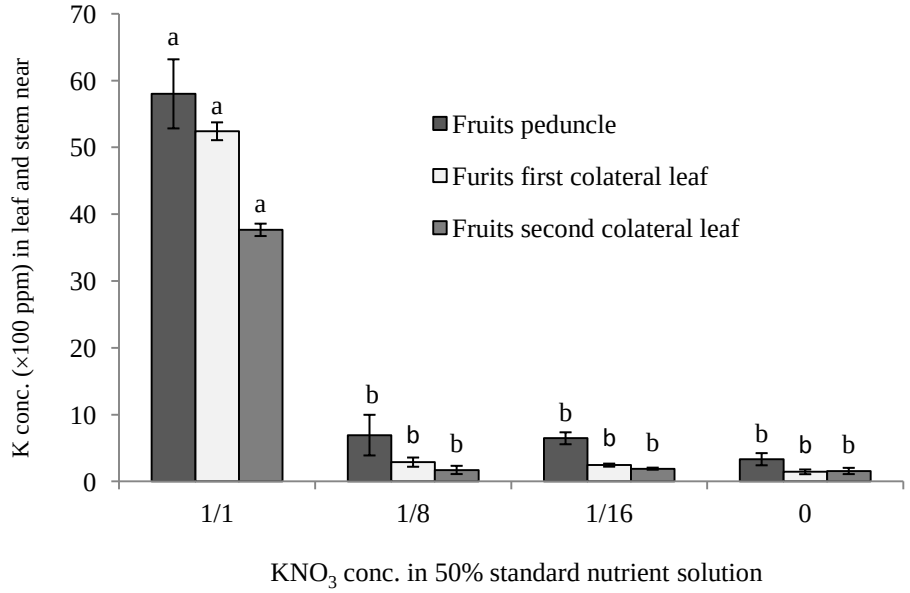

Fig. 7. Accumulation of potassium in the fruit peduncle and fruits collateral leaves of melon grown with reduced potassium nitrate in hydroponics during spring 2011. Sap collected from frozen samples of fruit peduncle, first and second collateral leaves were used for K determination.

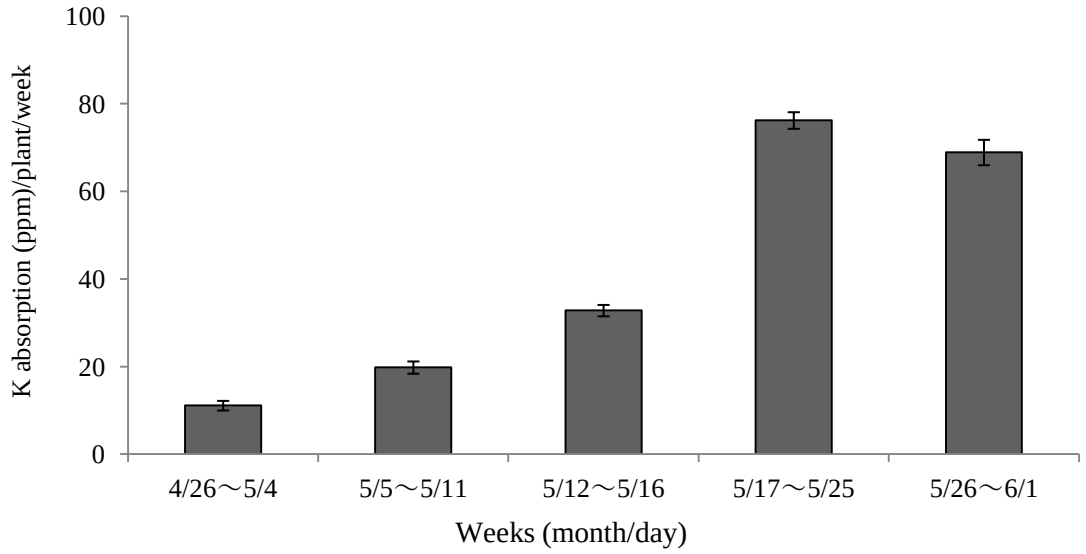

Fig. 8. Amount of potassium absorbed by the melon plants (plant/week) before start of lower potassium nitrate concentration treatment in the culture solution in hydroponics during spring 2011.

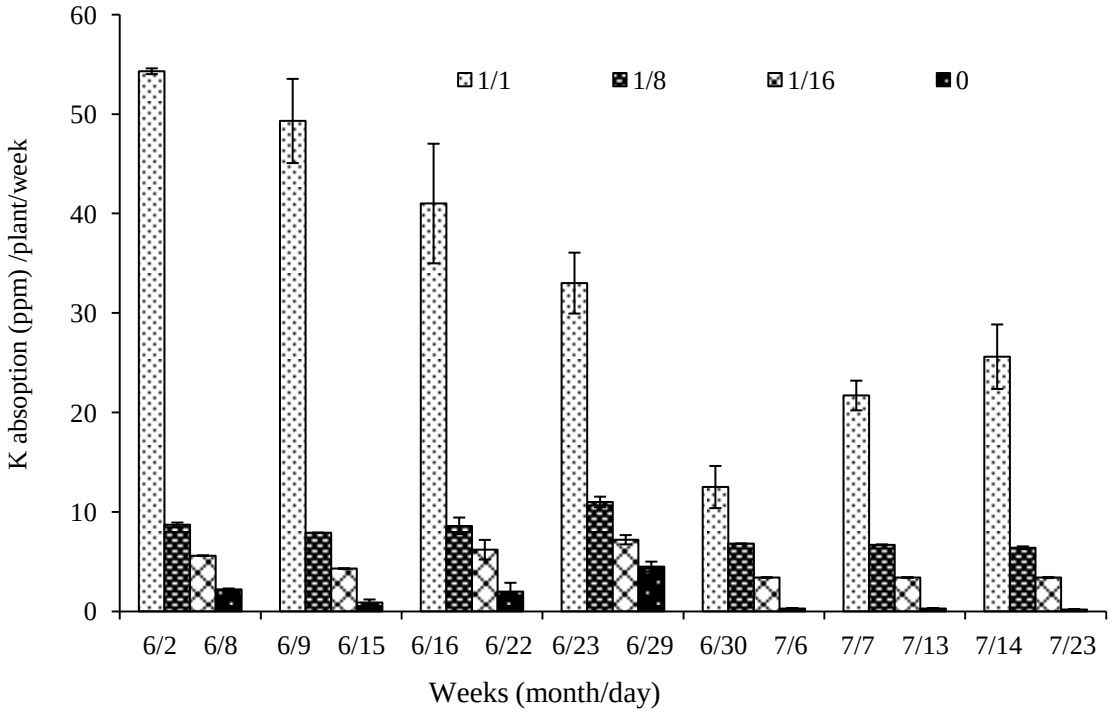

Fig. 9. Amount of potassium absorbed by the melon plants (plant/week) after start of lower potassium nitrate concentration in the culture solution in hydroponics during spring 2011.