Chapter 1

Introductory Chapter: Potassium in Quality Improvement of Fruits and Vegetables

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1. Introduction

Potassium is one of the essential plant nutrients that play a crucial role in the quality improvement of fruits and vegetables. It has also a great requirement and impact on the postharvest qualities of fruits and vegetables. In this regard, hydroponic technology is a managed culture system where proper management of potassium nutrition is possible for producing quality horticultural crops. Management of chemical composition including potassium content of hydroponic culture solution and physical modification of growing environments can enhance the performance of agricultural produce. Therefore, development of cultivation methods leads to production and supplementation of specialty fruits and vegetables providing several human health benefits beyond basic nutrition.

2. Potassium as major plant nutrition

Potassium is the most abundant ion in the plant cell and regulates a range of cell functions and activates numerous enzyme reactions [1]. It is necessary for normal growth and development of plants [2] and absorbed by roots than any other mineral element except nitrogen [1, 3–5]. It has major function in the process of enzyme activation, ionic charge balance, and osmoregulation of cell [5, 6].

In terms of water and nutrient balance in plants, potassium has two major functions. It plays biochemical role in activation of enzymes for production of proteins and sugars, while it also plays biophysical function in maintaining turgor of cell and thus protecting water content in plant. A turgid cell keeps the vitality of plant leaves and efficient photosynthesis.

Most of the researchers suggested that adequate potassium nutrition increased yields and yield attributes especially size and shape, improved qualities such as soluble solids contents, ascorbic acid concentrations, fruit color, shelf life, and also shipping quality of many horticultural crops [7–11].

3. Interaction of potassium with other nutrients

Potassium concentration affects the sodium levels in the growing medium of plants. In general, antagonistic interaction exists in between potassium and sodium uptake by plants. However, the synergistic or antagonistic effect between them depends on the amount of each element present in the soil and on the plant type [12]. Under saline condition, plants preferably uptake sodium instead of potassium. While in sodium salinity condition, plant uses more selective high-affinity system for potassium uptake in order to maintain adequate potassium nutrition. Several studies showed the antagonistic effects of potassium and sodium in corn [13], rice [14], faba bean [15], and tomato [14]. It is also reported that adverse effect of sodium on plant growth is attributed to its antagonistic relationship with calcium, potassium, and zinc in plants [13].

It is inevitable that reduced potassium supply will inhibit plant growth and yield. Therefore, investigation on minimal requirements of potassium in plants maintaining their normal growth and development is necessarily important. Recent research reported that low potassium concentration in the nutrient solution significantly decreased the fruit potassium content in netted melon [16]. In leafy vegetables and tomato, sodium and magnesium content found to be increased significantly when potassium content was restricted to the culture solution [17].

Research results also showed that decrease in potassium levels increase the concentration of sodium and magnesium in tomato fruits [18, 19]. Sodium concentration in melon fruit increased with the decrease of potassium concentration in the nutrient solution and its concentration increase to 56% compared to standard concentration when plants were cultured without potassium fertilizer from anthesis to harvest [16].

4. Hydroponic nutrient management for improving quality of fruits and vegetables

Hydroponic nutrient solution contains mainly inorganic soluble salts of essential elements for higher plants. Each essential element has a clear physiological role, and its absence prevents the plant from normal growth and development [20]. Mineral composition in nutrient solution determines different chemical properties such as pH, electrical conductivity, and osmotic potential that affect uptake by plants. In general, hydroponic nutrient solution contains sufficient amount of essential nutrient for luxurious uptake by plant roots. If it is applied continuously, plants can uptake essential ions at very low concentrations. Therefore, researchers

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reported that higher concentrations of mineral nutrients are not used by plants or their uptake does not impact the higher production. It has been shown that the concentration of nutrient solution can be reduced by 50% without any adverse effect on biomass and quality in gerbera [21] and geranium [22].

In another study, no adverse effect on growth, fruit yield, and fruit quality in tomato was reported when there is reduction of macronutrient concentrations to 50% of the control level [23]. High levels of potassium in the nutrient solution increased fruit dry matter, total soluble solid content, and lycopene concentration of tomato [24]. Recent studies showed that reduced KNO_3 concentration in standard hydroponic nutrient solution produced melon fruits with lower potassium content [16].

5. Production of specialty vegetables through hydroponic nutrient management

Potassium plays an important role in our body through several vital electrolytic activities. Chronic kidney disease (CKD) patients can't excrete unnecessary potassium through their impaired kidneys and thus get accumulated in the blood. This abnormally elevated level of potassium in the blood causing hyperkalemia disease to them. Hyperkalemic or dialysis patients are suggested to avoid potassium-rich food, but our daily diets including fruits and vegetables are rich in potassium. Therefore, production of low potassium content fruits and vegetables would benefit this type of people greatly.

In general, the greenhouse cultured raw melon has higher potassium content of 340 mg/100 g fresh weight [25]. Significant decreases in potassium content in melon fruits would improve the diet of dialysis patients. Therefore, quantitative management of hydroponic culture solution yielded melon fruits having sufficiently low potassium content (**Figure 1**) [16]. A simple management of

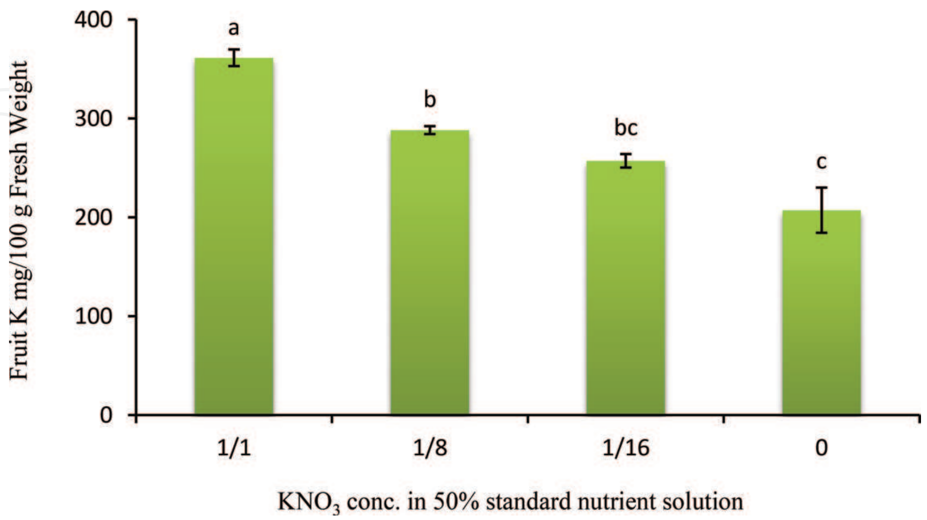

Figure 1. Reduced potassium nitrates levels decrease the fruit potassium content of netted melon grown in hydroponics [16].

culture solution was used for melon by reducing the potassium at lowest possible level. Therefore, melon plants were grown in nutrient solution with reduced KNO_3 concentrations from anthesis till harvest to investigate its impact on the fruit potassium content while maintaining normal growth, yield, and other fruit qualities. On the other hand, sodium concentration in melon fruits followed the reverse trend of potassium concentration. Its concentration increased significantly in all the reduced potassium levels of KNO_3 supplied during anthesis to harvest. It was found that melon plants grown in nutrient solution without potassium nitrate during anthesis to harvest produced fruits with an increased sodium concentration of about 56% (**Figure 2**).

Strawberry is the most popular fruit in the world. This sweet-sour taste fruit rich in potassium attracts all aged people. However, elderly people suffering from chronic kidney disease are restricted to eat this fruit. In general, greenhouse-cultured fresh strawberries have a high potassium content of 170 mg/100 g FW of fruit [25]. In this regard, reducing this potassium level in strawberry fruit would remove the dietary restriction to CKD patients. Therefore, our research team also tried to produce low-potassium strawberries through the management of a KNO_3 fertilizer in nutrient solution from anthesis to the harvest period. In strawberry plants that were grown in 1/32 level of KNO_3 of the standard nutrient solution, fruit potassium was decreased about 23.5% compared to the typical level of potassium in strawberry fruit of 170 mg/100 g FW [25, 26].

Similar to melon and strawberry, tomato is a potassium-rich fruit vegetable. If low-potassium tomato fruit can be produced, it can improve the dietary options of dialysis patients and their quality of life. A method of producing low potassium content tomato fruit was investigated [27].

Hydroponic culture methods for spinach have been investigated with lower levels of potassium in the culture solution [28]. Spinach plants were grown hydroponically either with reduced potassium application throughout the growth period or without potassium applications during the last half of the growth period. No significant differences in fresh weight that were observed in plants cultured with either of the solution. However, the potassium content in plants was reduced as much as 32% by reduced potassium application throughout growth period and

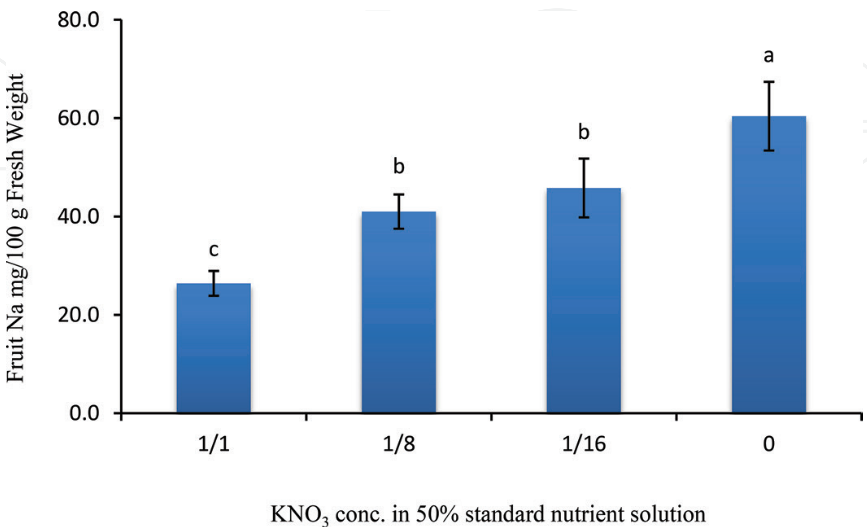

Figure 2. Reduced potassium nitrates levels increases the fruit sodium content of netted melon grown in hydroponics (data not published).

79% by without potassium application during the latter half of growth period compared to control. These results suggest that it is possible to produce low-potassium spinach maintaining the normal plant growth. Other minerals like sodium and magnesium content increased with the decrease of potassium content, showing antagonistic role in osmotic pressure balance.

Lettuce is a popular potassium-rich vegetable usually eaten raw in the salad. CKD patients with hyperkalemia cannot intake large quantities of raw vegetables like lettuce, tomato, strawberry, etc. Therefore, producing low potassium vegetables would be highly appreciable from the viewpoint of dietary restriction. In this case, hydroponic culture systems have wide acceptability as it allows greater control over the root zone environment than soil culture, which makes nutrient management easy based on the plant requirements. Recently, low-potassium-content lettuce has been established by potassium fertilizer management [27]. Hydroponic culture systems have become widely used because they allow greater control over the root zone environment than soil culture, which makes nutrient management easy based on the plant requirements.

6. Conclusion

Potassium is the crucial macronutrient and main electrolytes in plants. Its requirement is higher than other mineral nutrients except for nitrogen, but some crops at their specific stages demand more potassium than nitrogen. Therefore, adequate potassium fertilization is necessary for enhanced and improved yield and qualities of agricultural produce. This monovalent cation interacts both antagonistically and synergistically with other nutrients. In hydroponic nutrient solution, it shows clear antagonism with sodium at its reduced levels. In this regard, management of potassium nutrient based on crop growth stage and following other culture techniques can produce specialty horticultural crops providing human health benefits. For example, low potassium content melon, strawberry, tomato, lettuce, and other leafy vegetables can improve quality of life (QOL) of CKD patients.

This book aims to enumerate available resources on potassium, its importance to plants yield and quality, management in the hydroponic culture solution, and cultivation techniques of production specialty horticultural crops. The content also discusses news ways of managing and developing sustainable production techniques and software for quality horticultural crops through potassium nutrition.

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