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Supplementary potassium sulfate and potassium chloride fertilizers on yield and quality of Fujisawa Melon (*Cucumis melo* L.)

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Abstract

A completely randomized design was applied to investigate the effects of potassium sulfate and potassium chloride fertilizers on the yield and quality of Fujisawa melon (*Cucumis melo* L.). There were 9 treatments, 3 replicates. The treatments were: no potassium fertilizer (T1), soil-applied potassium sulfate (K_2SO_4) at a rate of 3.6 g/plant (T2), soil-applied potassium chloride (KCl) at 3.0 g/plant (T3), foliar-applied K_2SO_4 at 1.2 g/plant/time (T4), foliar-applied KCl at 1.0 g/plant/time (T5), soil-applied K_2SO_4 at 1.8 g/plant + foliar-applied K_2SO_4 at 0.6 g/plant/time (T6), soil-applied KCl at 1.5 g/plant + foliar-applied KCl at 0.5 g/plant/time (T7), soil-applied K_2SO_4 at 1.8 g/plant + foliar-applied KCl at 0.5 g/plant/time (T8), and soil-applied KCl at1.5 g/plant + foliar-applied K_2SO_4 at 0.6 g/plant/time (T9). The results revealed that T5 and T4 produced the highest skin thickness and weight of melon fruits. The highest content of total soluble solids (TSS) was observed in T2. The potassium content in the plant parts significantly influenced both the yield and quality components of the melon fruits, particularly impacting the quantity of TSS. Furthermore, the sulfur content, derived from K_2SO_4, was positively correlated with the quantity of TSS. The application of KCl as fertilizer increased the potassium levels in both the fruit flesh and peel. Additionally, the chloride content in the melon fruit flesh increased, influencing the flesh thickness and contributing to higher fruit weight.

Keywords: Melon, fertilizer, potassium chloride, potassium sulfate

1. Introduction

Melon (*Cucumis melo* L.) is a fruit-bearing plant renowned for its sweet taste and delightful fragrance. The fruit comes in various shapes, including spherical or elongated, with a smooth, rough, or reticulated pattern on the surface. The skin can display shades of yellow, brown, or greenish-yellow, while the flesh may be orange, green, or white. Farmers often cultivate melons as a primary crop or as an additional source of income. High-quality produce can command premium prices in the market. In Thailand, the total melon production was 9,547.71 tonnes [1]. Given the rising trend in consumer demand, effective fertilizer management in melon cultivation has become crucial to enhance the quality of the melons produced. A notable issue in current melon production is that the quality of the produce often falls short of the required standards. According to the standard of melon that established by National Bureau of Agricultural Commodity and Food Standards, and the Ministry of Agriculture and Cooperatives, the melon must be harvested in the appropriate time and contained the total soluble solids (TSS), the parameter measuring sweetness of fruit, not be less than 12% Brix. [2]. It has been hypothesized that the key factor directly influencing the sweetness of melons is the amount of potassium (K), which plays a crucial role in the growth, yield, and quality of melons [3].

Potassium plays a key role in the formation of high-energy phosphate compounds, essential for the creation and transportation of starch and sugar, which are produced through photosynthetic process occurring in the leaves, serving as a source of production. They are transported internally through plants and accumulate in fruits, becoming a vital source for food storage [4]. Numerous studies have been done for investigating the effects of K on yield quality in various plants species such as Chalermpak [5] found that increasing K fertilizer resulted in TSS increase in pineapple. Similarly, Cannon [6] found that fruit sweetness was increased when increasing K fertilizer rate was applied to longan. Moreover, Lester et al. [7] reported that the quantity of soluble solids in melon fruits was directly correlated with the K intake by the plant. In general, potassium chloride (KCl) or muriate of potash is the most commonly used potassium fertilizer globally. While it provides potassium to plants, it also contains chloride, a micronutrient that plants require in small quantities. Jifon and Lester [8] indicated that foliar sprayed with KCl fertilizer solution,gave the highest K content accumulated in leaves following by foliar spraying with potassium sulfate (K_2SO_4) as 16 and 14.8 mg K/g dry weight, respectively. However, excessive chloride intake from KCl fertilizer may lead to toxicity in plants, potentially affecting the quality of the yield in crops, such as tobacco, potatoes, beans, citrus and etc. [9]. Therefore, application of potassium fertilizer in a chloride-free form is necessary. For example, using K_2SO_4 as a fertilizer not only provides potassium but also supplies sulfur, a secondary nutrient as Efnan et al. [10] reported that applied K_2SO_4 in the higher ratio increased TSS of tomato from 3.67 to 3.97 %Brix. However, the cost of these fertilizers is based on their chemical composition, specifically whether they are sulfate salts or chlorides, with sulfate-based fertilizers being twice as expensive as chloride-based ones. Moreover, Natwat et al. [11] revealed that applied K fertilizer at the ratio of KCl:K_2SO_4 as 25:75 and 0:100 gave the highest TSS in tomato. Hence, the objective of this research was to investigate the effects of K_2SO_4 and KCl fertilizers on yield quality of melons and nutrient concentration in various components of the melon.

2. Materials and methods

2.1 Experimental design

A completely randomized design was used, comprising 9 experimental treatments, each having 3 replicates (one plant = one replication). The study involved 2 fertilization patterns: 1) soil application of K_2SO_4 and KCl in the pre-harvest period, administered once at 15 days before harvest. and 2) foliar spray application of potassium chloride and potassium sulfate, spraying 3 times at intervals of 2 days, beginning at 10 days prior to harvest. in The rates of applied fertilizers for each application were detailed in Table 1.

Table 1 Experimental treatments for various types of potassium fertilizers.

Treatments	Fertilizer types	Rates of soil application (1 time)	Rates of foliar application (3 times)
T 1	Control	-	-
T 2	K_2SO_4	0-0-50 (3.6 g/plant)	-
T 3	KCl	0-0-60 (3.0 g/plant)	
T 4	Foliar K_2SO_4	-	0-0-50 (1.2 g/plant/time)
T 5	Foliar KCl	-	0-0-60 (1.0 g/plant/time)
T 6	K_2SO_4+Foliar K_2SO_4	0-0-50 (1.8 g/plant)	0-0-50 (0.6 g/plant/time)
T 7	KCl+Foliar KCl	0-0-60 (1.5 g/plant)	0-0-60 (0.5 g/plant/time)
T 8	K_2SO_4+Foliar KCl	0-0-50 (1.8 g/plant)	0-0-60 (0.5 g/plant/time)
T 9	KCl+Foliar K_2SO_4	0-0-60 (1.5 g/plant)	0-0-50 (0.6 g/plant/time)

2.2 Planting and care guidelines

The Fujisawa melons were cultivated in the smart greenhouse at the Faculty of Agriculture, Kamphaeng Saen, Kasetsart University, Thailand. The sphagnum peat-moss was used as the melon seedling. At age 10 days, the seedlings were transplanted into pots containing coco-coir dust, with one plant per pot. The coco- coir dust was prepared by thoroughly washing with tap water until its electrical conductivity (EC) was less than 1.0 dS/m. The cultivation process involved growing melon seedlings in 14-inch plastic pots each with 6 kg of coco-coir dust. The plants were grown in a netted greenhouse (6x15x3.5 m). Insect netting (mesh size 40) was used to protect the plants. The pots were arranged in double rows 30 cm apart and pot space within a row were also 30 cm apart. The double rows were 1.0 m apart. Fertilization was carried out using a drip irrigation system. Cultivation involved the application of Enshi Solution [12], a standard plant nutrient solution consisting of Solutions A ($Ca(NO_2)_3{\cdot}4H_2O$ and Fe-EDTA) and B (KNO_3, $NH_4H_2PO_4$, $MgSO_4{\cdot}7H_2O$), along with micronutrients (H_3BO_3, $MnSO_4{\cdot}4H_2O$, $ZnSO_4{\cdot}7H_2O$, $CuSO_4{\cdot}5H_2O$, $NaMoO_4{\cdot}2H_2O$). for the initial 35 days, a mixture of nutrient solutions A and B with filtered water was used, with a targeted EC value of 1.7–1.8 dS/m. In the second phase (days 36 – 63), a well-blended combination of nutrient solutions A and B was applied, with a targeted EC value of 2.5 dS/m. Finally, during the third phase (day 37 until harvesting), a well-mixed solution of nutrient solutions A and B was applied, with a targeted EC value of 2 dS/m [2]. All melon plants received uniform amounts of water and chemical fertilizer. After transplanting, each plant was supplied with 0.5 liters of water per day, while during the flowering and fruiting stages, the water supply was increased to 2 L/Plant.d. All tops and branches from points 1 to 8 were removed, retaining only branches 9 to 12 for use in pollination. Pollination activity was conducted between 6:00 a.m. and 10:00

a.m. Once a melon had 25 true leaves, the top of the main vine was removed. A single fruit per plant was maintained. The harvest of the Fujisawa melons for each experimental treatment was conducted 75 days after planting the seed (40–45 days after pollination). During the last week, the water supply was gradually reduced until 2 days before harvest when the melon plants began to show signs of wilting during the day.

2.3 Data collection

2.3.1 Nutrient accumulation in plants

Melon leaf, stem and fruit samples were collected at the post-harvest stage. The fruit part was further subdivided into fruit peel and fruit flesh, followed by drying at 70°C for 72 hours. Subsequently, the dried plant samples were finely ground and subjected to wet digestion for decomposition [13]. Next, the potassium content was analyzed using atomic absorption spectrophotometry, while the sulfur content was determined based on the turbidity method [14]. The amount of chloride was assessed using the titration method [14].

2.3.2 Productivity and quality components

Fruit weight and fruit size were determined by diameter along both the transverse and longitudinal sides, peel thickness measured as the distance between the outermost part of the peel and the fruit flesh, flesh thickness measured as the distance between the inner part of the peel and the edge of the space within the fruit. Firmness was measured from two opposite sides of the fruit, with the shell removed, using a firmness tester, featuring an indenter head with a diameter of 0.3 cm. The derived value was calculated in Newton units (N), with the reading value (kg) multiplied by 9.807. Sweetness, quantified as a percentage of °Brix, was ascertained by measuring the TSS in the sampled fruit flesh. Samples were collected from the fruit center, fruit stem-end, and fruit tips; their TSS values were analyzed using a digital refractometer.

2.4 Statistical analysis

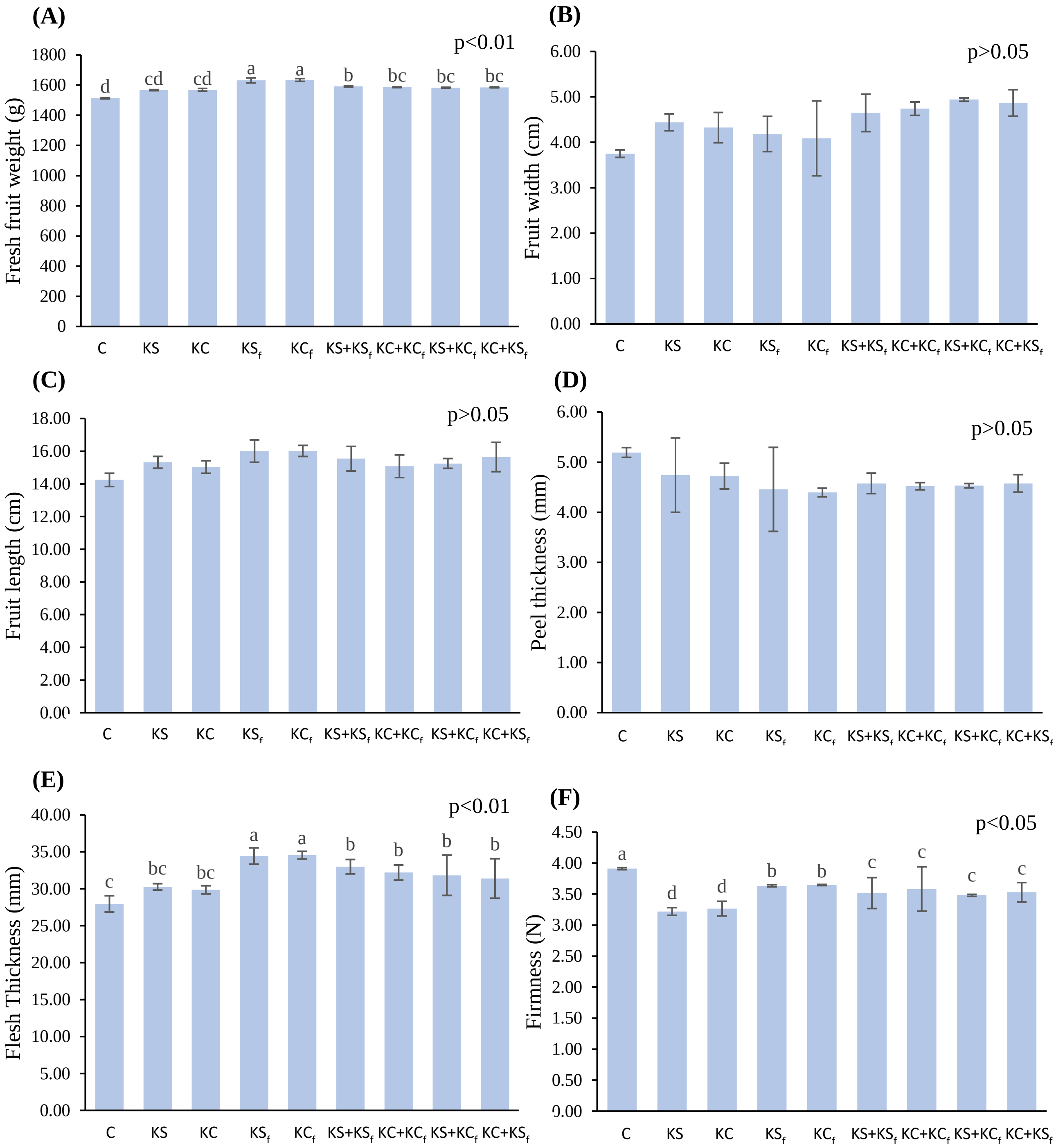
The normality of the data was assessed using the Shapiro-Wilk test before conducting further analysis. Analysis of variance was conducted and mean separation was performed by using Duncan's new multiple range test (P=0.05). Additionally, the relationship between nutrient contents and yield components in the melons was investigated using Pearson's correlation coefficient (r).

3. Results and discussion

3.1 Effect of potassium fertilizer application on yield and quality components

The various fertilizer formulas involving K_2SO_4 and KCl radicals applied to Fujisawa melons produced significant differences in fruit fresh weight, flesh thickness, flesh firmness, and melon sweetness (measured as the amount of total soluble solids: TSS), as shown in Figure 1(A)-1(G). The application of KCl foliar fertilizer at a rate of 1.0 g/plant/time (experimental treatment T5) resulted in the highest fresh fruit weight and flesh thickness,1,634.6 g and 34.56 mm, respectively. This was comparable to the foliar application of K_2SO_4 at a rate of 1.2 g/plant/time (T4), which yielded 1,631.3 g in fresh fruit weight and 34.44 mm in flesh thickness. Next, the soil application of K_2SO_4 at a rate of 1.8 g/plant combined with foliar application at a rate of 0.6 g/plant/time (T6) produced an average fruit weight of 1,591.0 g and an average flesh thickness of 32.99 mm. The melons in the control treatment (T1) had the lowest average fruit weight (1,512.7 g) and the smallest average flesh thickness (27.96 mm). However, the control treatment (T1) had the highest average firmness (3.91 N). The next best firmness was the foliar fertilizations with both KCl (T5) and K_2SO_4 (T4) that resulted in average firmness values of 3.65 and 3.63 N, respectively. In contrast, soil applications of both KCl (T3; 3.0 g/plant) and K_2SO_4 (T2; 3.6 g/plant) produced the lowest average melon firmness values of 3.27 and 3.22 N, respectively. The sweetness of melons (based on the TSS) was highest for the soil application with K_2SO_4 (T2), averaging 17.70 %Brix, followed closely by the soil application of KCl (T3), with a TSS value of 17.60 %Brix. The foliar applications of both K_2SO_4 (T4) and KCl (T5) produced average TSS values of 17.07 and 17.04 %Brix, respectively. Additionally, in the control treatment (T1), melon had the lowest TSS value (16.83 %Brix). Initially, it was observed that soil application with K_2SO_4 resulted in sweeter melons compared to soil application with KCl. However, the various potassium fertilization methods did not impact the fruit size and the thickness of the melon peel. Across all experimental treatments, the fruit width was in the range 13.12–14.42 cm and the fruit length was in the range 14.25–16.02 cm. The thickness of the fruit peel was in the range 4.40–5.19 mm.

Overall, the application of potassium fertilizers, as both K_2SO_4 and KCl, had an impact on the sweetness of melons, whether applied directly to the soil [15] or through foliar spraying [7]. As shown in Figure 1(A)-1(G), potassium played a crucial role in protein synthesis, the conversion of starch to sugar, and the translocation of sugar to the fruit [4]. Furthermore, potassium was reported to be linked to nutrient transportation, water absorption by plants, and the regulation of mineral exchange between inside and outside plant cells, ultimately influencing the quality of agricultural products [16]. In addition, the current study revealed a significant difference in sweetness between the two different forms of soil potassium fertilizer application (T2 and T3). This finding aligned with the results of Natwat et al. [11], who demonstrated that K_2SO_4 applied as soil fertilizer resulted in tomatoes being sweeter compared to KCl applied as soil fertilizer. The observed effect was attributed to the tendency of plants receiving sulfur (S) to accumulate more potassium (K) [17]. Nevertheless, the foliar application of different forms of potassium fertilizer (T4 and T5) did not result in significant differences in sweetness. This finding was consistent with the report by Jifon and Lester [8], who observed that providing different forms of potassium did not influence fresh fruit weight, flesh thickness, and firmness. Notably, differences were identified between soil and foliar fertilizer application, as plants primarily absorb nutrients through their roots [18]. In the current study, both forms of potassium fertilizer that applied through root fertilization and foliar spray resulted in significant differences in fresh fruit weight, flesh thickness, firmness, and sweetness (Figure 1(A), 1(E), 1(F) and 1(G), respectively).



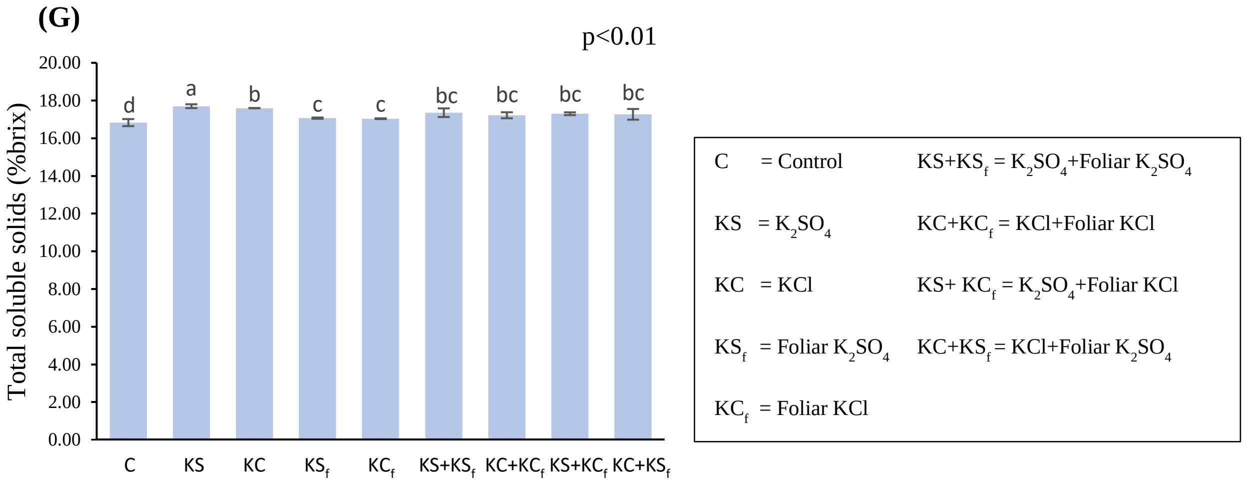


Figure 1 Harvest yield and quality components as fresh fruit weight (A), fruit width (B), fruit length (C), peel thickness (D), flesh thickness (E), firmness (F) and total soluble solids;TSS (G) of melons receiving supplementary potassium sulfate fertilizer and potassium chloride fertilizer by various application methods and rates. Error bar represent SE (n = 27).

3.2 Potassium concentrations in various plant parts s at harvest

The supplementary application of K_2SO_4 and KCl through various formulas resulted in significant differences in the potassium content found in the leaf, stem, fruit peel, and fruit flesh of Fujisawa melons during the harvesting phase (Table 2). The investigation revealed that the highest average potassium concentration in leaves (49.40 g/kg) was achieved through the soil application of K_2SO_4 fertilizer at a rate of 1.8 g/plant, coupled with foliar application of KCl at 0.5 g/plant/time (T8). This was followed closely by the combination of soil KCl fertilizer at 1.5 g/plant with foliar K_2SO_4 at 0.6 g/plant/time (T9) that produced an average potassium concentration in leaves equal to 48.67 g/kg. In the control treatment (T1), the average potassium concentration in leaves was the lowest (37.50 g/kg), while soil fertilization with K_2SO_4 at a rate of 3.6 g/plant (T2) and soil fertilization with KCl at a rate of 3.0 g/plant (T3) resulted in the highest average potassium concentration in plants (60.90 g/kg and 60.73 g/kg, respectively). Foliar fertilization using both K_2SO_4 (T4) and KCl (T5), produced potassium concentrations in the stem of 59.67 and 54.67 g/kg, respectively. Notably, the control treatment (T1) resulted in the lowest average potassium accumulation in the stems (45.70 g/kg). In addition, the soil application of K_2SO_4 at a rate of 1.8 g/plant, combined with foliar application of KCl at a rate of 0.5 g/plant/time (T8), the soil application of KCl at a rate of 1.5 g/plant, combined with foliar application of K_2SO_4 at a rate of 0.6 g/plant/time (T9), the soil application of K_2SO_4 at a rate of 1.8 g/plant, combined with foliar application of K_2SO_4 at a rate of 0.6 g/plant/time (T6), and the soil application of KCl at a rate of 1.5 g/plant, combined with foliar application of KCl at a rate of 0.5 g/plant/time (T7) resulted in potassium concentrations in the fruit peel of 46.56, 46.50, 46.43, and 46.37 g/kg, respectively. The control treatment (T1) had the lowest average potassium accumulation in the fruit peel (39.67 g/kg).

The highest potassium concentration in the fruit flesh was recorded for the soil application of K_2SO_4 at a rate of 1.8 g/plant, combined with foliar application of K_2SO_4 at a rate of 0.6 g/plant/time (T6) and for the soil application of KCl at a rate of 1.5 g/plant, combined with foliar application of KCl at a rate of 0.5 g/plant/time (T7), with values of 45.47 and 45.37 g/kg, respectively. These were followed by the soil application of K_2SO_4 at a rate of 1.8 g/plant, combined with foliar application of KCl at a rate of 0.5 g/plant/time (T8) and the soil application of KCl at a rate of 1.5 g/plant, combined with foliar application of K_2SO_4 at a rate of 0.6 g/plant/time (T9) that resulted in potassium accumulations in the fruit flesh averaging 44.50 and 44.10 g/kg, respectively. In contrast, the control treatment (T1) had the lowest average potassium accumulation in the fruit flesh (38.57 g/kg).

In general, various parts of plant tissue accumulate potassium in differing amounts [3]. The current study revealed that the supplementary application of potassium fertilizer in the form of K_2SO_4 and KCl, both through soil application and foliar spraying, led to varying levels of accumulation of potassium in the leaves, fruit peel, and fruit flesh of melons compared to conditions where no supplementary potassium fertilizer was added [3,7]. Furthermore, Gratieri et al. [19] discovered that the accumulation of potassium in leaves increased proportionally with the quantity of potassium fertilizer applied. Potassium plays a crucial role in the mechanism governing the opening and closing of stomata. As the concentration of potassium ions is elevated, water from adjacent cells diffuses into the cell, transforming it into a hypotonic cell, which resulted in the stomata opening. The quantity of potassium accumulated in the fruit flesh was reported to be linked to the overall quality of melon yield [3].

Table 2 Potassium contents (g/kg) in leaves, stems, peel, and flesh at harvest of melons receiving supplemental potassium sulfate fertilizer and potassium chloride fertilizer by various application methods.

Treatments	Potassium concentration in leaves (g/kg)	Potassium concentration in stem (g/kg)	Potassium concentration in Peel (g/kg)	Potassium concentration in Flesh (g/kg)
Control (T1)	37.50^{g}	45.70^{d}	39.67^{f}	38.57^{e}
T 2	44.40^{d}	60.90^{a}	43.23^{e}	41.80^{d}
T 3	43.23^{de}	60.73^{a}	43.73^{d}	42.87^{d}
T 4	41.83^{f}	59.67^{ab}	44.40^{c}	43.23^{c}
T 5	40.87^{f}	54.67^{ab}	45.23^{b}	43.83^{c}
T 6	46.57^{c}	46.30^{cd}	46.43^{a}	45.47^{a}
T 7	47.40^{bc}	49.73^{b-d}	46.37^{a}	45.37^{a}
T 8	49.40^{a}	54.20^{a-d}	46.56^{a}	44.50^{b}
T 9	48.67^{ab}	55.20^{a-c}	46.50^{a}	44.10^{b}
F-test	**	**	**	**

Means followed by different letters were significantly different by DMRT, ** = significant at $p \leq 0.01$

3.3 Sulfur concentrations in various plant parts at the harvest

Fertilizing with K_2SO_4 and KCl in various methods has affected the amount of sulfur in the stem, peel, and flesh of Fujisawa melon at harvesting time, with statistically significant difference (Table 3). Soil application of K_2SO_4 (3.6 g/plant) (T2) gave the highest average sulfur concentration in the stem, peel, and flesh, equal to 9.33, 2.40 and 3.03 g/kg, respectively followed by foliar application of K_2SO_4 (T4) (1.2 g/plant/time), the average sulfur concentrations in the stem, peel, and flesh were 8.47, 2.20 and 2.73 g/kg, respectively. However, sulfur concentration in leaves was not statistically difference (Table 3). Fertilizing with K_2SO_4 and KCl in various methods had no effect on the sulfur concentration in the leaves. At the harvest, the sulfur concentration in the leaves was in the range of 2.60 - 2.96 g/kg [4]. It was found that normal plants contain 0.1 - 0.5 % sulfur by weight. However, plants in each family have different amount needs for this element.

Moreover, soil application of K_2SO_4 fertilizer (T2) resulted in different sulfur accumulation in various parts of the melon plant, except the leaves. Sulfur is necessary for the synthesis of amino acids (cysteine and methionine) and proteins. It plays multiple roles in the regulation of plant growth, such as in photosynthesis, low-temperature tolerance, the nitrate reductase process where NO_3^-N is converted into amino acids, creating the characteristic odors of plants [20]. Sulfur is an essential element for plants in the synthesis of chlorophyll, proteins, amino acids, vitamins, and plant-derived enzymes, especially in fruit trees, because it helps increase the utilization of nitrate-nitrogen in plants. Generally, plants absorb sulfur in the form of sulfate. When the soil has low sulfur levels, it directly affects the quality of produce to be decreased [8]. The interactions between potassium and sulfur could enhance the absorption of zinc from nutrient solutions. When there is an adequate level of both sulfur and potassium, it promotes zinc uptake that was found for barley [21].

Table 3 Sulfur concentrations (g/kg) in leaves, stems, peel, and flesh at harvest of melon receiving supplementary potassium sulfate fertilizer and potassium chloride fertilizer using various application methods.

Treatments	sulfur concentration in leaves (g/kg)	sulfur concentration in stem (g/kg)	sulfur concentration in Peel (g/kg)	sulfur concentration in Flesh (g/kg)
Control (T1)	2.77	3.50^{c}	2.03^{c}	2.20^{f}
T2	2.96	9.33^{a}	2.40^{a}	3.03^{a}
T3	2.60	3.37^{c}	2.03^{c}	2.33^{e}
T4	2.90	8.47^{b}	2.20^{b}	2.73^{b}
T5	2.88	3.37^{c}	2.07^{c}	2.50^{c}
T6	2.88	8.33^{b}	2.13^{c}	2.67^{b}
T7	2.67	3.30^{c}	2.07^{c}	2.40^{d}
T8	2.68	3.50^{c}	2.10^{c}	2.63^{b}
T9	2.65	3.07^{c}	2.10^{c}	2.67^{b}
F-test	ns	**	**	**

Means followed by different letters were significantly different by DMRT, ** = significant at $p \leq 0.01$; ns = Not significant at $p > 0.05$

3.4 Chloride concentrations in various plant parts at the harvest

Fertilizing with K_2SO_4 and KCl using various methods had a significant effect on the chloride (Cl) contents in the leaves, peel, and flesh of Fujisawa melons at harvest but had no effect on the chloride concentration in the stems (Table 4). It was found that the soil application of KCl (3.0 g/plant; T3) produced the highest average chloride concentrations in the leaves and flesh, 3.80 and 3.90 g/kg, respectively, followed by the foliar application of KCl (1.0 g/plant/time; T5) and soil application of KCl (1.5 g/plant) together with foliar application (0.5 g/plant/time; T7),with chloride concentrations in the leaves and flesh of 3.63 and 3.47 g/kg, respectively.

In addition, adding K_2SO_4 and KCl by using various methods had an effect on the chloride concentration in the peel. In other words, foliar application of KCl (1.0 g/plant/time; T5) resulted in the highest average chloride concentration in the peel (5.53 g/kg), followed by the soil application of KCl (3.0 g/plant; T3), with a chloride concentration in the peel of 5.40 g/kg.

However, adding K_2SO_4 and KCl in various methods had no effect on the amount of chloride accumulation in the stems. The chloride concentration at harvest was in the range 7.47–8.67 g/kg. Osotsapa [4] reported that plants in nature accumulate 0.2–2.0 % chloride by weight, which is common concentration of micronutrient elements found in plants.

The chloride content in peel and flesh was highest when applying KCl as soil fertilizer at a rate of 3.0 g/plant and KCl as foliar fertilizer at a rate of 1.0 g/plant/time. Chloride is classified as a micronutrient that plants need only in small quantities [4]. However, it plays a crucial role in photosynthesis, especially in the Hill reaction of chloroplasts and thus, it is directly involved in water splitting in Photosystem II, accelerating the non-cyclic photophosphorylation process and promoting ATP synthesis [22]. In addition, the chloride anion has an essential indirect role in stomatal control. Potassium (K) is essential for the opening and closing of stomata; anions, especially chloride, are needed in this process. If there is a deficiency in chloride, it can lead to abnormal stomatal closure. Additionally, chloride deficiency has been associated with a slowdown in protein synthesis [4].

Table 4 Chloride contents at harvest in leaves, stems, peel, and flesh (g/kg) of melons receiving supplementary potassiumsulfate fertilizer and potassium chloride fertilizer using various application methods.

Treatments	chloride concentration in leaves (g/kg)	chloride concentration in stem (g/kg)	chloride concentration in Peel (g/kg)	chloride concentration in Flesh (g/kg)
Control (T1)	2.63^{c}	7.60	4.37^{c}	1.73^{d}
T2	2.60^{c}	7.47	4.53^{c}	1.70^{d}
T3	3.80^{a}	8.67	5.40^{b}	3.90^{a}
T4	2.60^{c}	7.80	4.67^{c}	1.80^{d}
T5	3.63^{ab}	8.20	5.53^{a}	3.93^{a}
T6	2.67^{c}	7.50	4.73^{c}	1.67^{d}
T7	3.47^{ab}	8.13	5.10^{c}	3.53^{ab}
T8	3.27^{b}	7.67	4.57^{c}	2.87^{c}
T9	3.33^{b}	7.63	5.33^{c}	3.17^{bc}
F-test	**	ns	**	**

Different letters were significantly different by DMRT, ** = significant at $p \leq 0.01$; ns = Not significant at $p > 0.05$

3.5 Correlation between nutrient contents and quality components in melon

Analysis of the correlation between the nutrient contents and quality components in melon at harvest (Table 5) revealed that potassium contents in melon leaves were positively correlated with the potassium content in the flesh and peel, (r = 0.49 and 0.59, respectively). In other words, the higher the potassium content in the leaves, the greater the potassium contents in the flesh and peel. Potassium content in leaves also correlated with the sweetness and firmness of melon, with r values of 0.65 and -0.59, respectively. This indicated that when K content in leaves increases, there are high potential to have high K content in flesh and high TSS in fruit. Williams and Kafkafi [23] mentioned that melon has one of the highest potassium concentration in the flesh. Therefore, the growth of melon requires a good supply of potassium to facilitate the movement of starch and sugar in the plant tissues. According to Lin et al. [3], potassium accumulation in tissue was associated with the quality of melon, namely, an increase in total sugar and TSS. Similarly, in the current study, there was a positive correlation between the potassium content in melon leaves and flesh (r = 0.67), indicating that experimental conditions with increased K_2SO_4 fertilizer application led to higher sulfur accumulation in the melon. Cook [17] reported that plants receiving S promoted increased K uptake, which was consistent with Reich et al. [24], who reported a positive relationship between K and S because when plants received S, there would be more K accumulation in the roots.

The potassium contents in the flesh had a significant positive correlation with the potassium contents in the peel and the chloride content in the flesh (r = 0.96 and 0.48, respectively). When melons accumulate a higher potassium content in the flesh, leading to increased levels of chloride content in the flesh. In addition, this affected the weight and fresh skin thickness of the melon, with correlation coefficients of 0.64 and 0.53, respectively, suggesting that a higher potassium content in the flesh promoted increased weight and fresh skin thickness of the melon. Similarly, the potassium content in the peel had a positive correlation with the chloride content in the flesh, fresh fruit weight, and flesh thickness, with correlation coefficients of 0.40, 0.64, and 0.52, respectively. In other words, the experimental conditions with increased KCl fertilizer application led to increased potassium and chloride accumulation in various parts of the plant tissue, resulting in a higher weight and thickness of the fresh skin. This aligned with the findings of Sukyankij et al. [25], who investigated KCl foliar application fertilizer in yard-long beans. They reported a significant linear relationship between potassium uptake and the dry yield of yard-long beans ($p \leq 0.01$) with a coefficient of 0.82.

The sulfur contents in the flesh had a negative correlation with the chloride content in the flesh and flesh thickness, with correlation coefficients of -0.42 and -0.44, respectively. If the sulfur content in the flesh increased, the chloride content in the flesh and the firmness of the melon decreased. This negative correlation between sulfur and chloride in the flesh was expected to cause by the competitive interaction between the negative charges of both sulfur and chloride ions. Therefore, when plants receive excessive amount of either sulfur or chloride, this leads to a displacement effect on the uptake of the other nutrient, resulting in reduced availability for the plant. However, notably, the sulfur content in the flesh was positively correlated with the sweetness of the melon (TSS), with a correlation coefficient of 0.51. When K_2SO_4 fertilizer was applied, the melon absorbed sulfur in the form of sulfate, resulting in the melons accumulating higher levels of both potassium and sulfur in their flesh, as well as increasing the sweetness of the melon. Osotsapa [4] reported that sulfur played a crucial role in the synthesis of chlorophyll, amino acids, proteins, and vitamins. Additionally, it was involved in plant-derived enzymes, which are essential for the transfer of methyl groups for lignin biosynthesis in plants. Furthermore, sulfur is a component of glutathione, which, in the chloroplasts of leaves, acts as an antioxidant, working together with ascorbate to break down superoxide free radicals. This process occurs when plants are exposed to high light intensity, serving as an efficient defense mechanism to prevent damage to cellular tissues caused by free radicals [4].

The fresh fruit weight of the melon had a significant positive correlation with flesh thickness (correlation coefficient of 0.75). The flesh thickness of the melon increased along with a significant increase in the fresh fruit weight. This was consistent with Boman [26], who reported that Valencia orange trees treated with KNO_3 produced higher yields per tree and larger fruit sizes compared to the control tree. El-otmani et al. [27] found that spraying 5% KNO_3 during the June drop stage increased the fruit size from Mandarin orange trees. Similarly, Vijay et al. [28] found that spraying 4% KNO_3 three times increased sweet orange fruit weight, size, and yield. Furthermore, Abd El-Fatah [29] discovered that spraying 2% KNO_3 on persimmon trees when the fruit was 2–3 cm in diameter increased the fruit weight. These findings indicated that potassium was important in plant nutrition, influencing both the quantity and quality of fruit production.

Fruit firmness was negatively correlated with the sweetness; specifically, as the sweetness of the melon increased, the firmness decreased, with a correlation coefficient of -0.86. Toivonen and Brummell [30] indicated that the natural ripening process occurred through the degradation of pectin compounds by enzymes responsible for cell wall degradation. Typically, the fruit ripening resulted in a reduction in hardness or an increase in softness. The heightened softness was associated with alterations in the cell wall structure, leading to changes in tissue structure or a decrease in strength. It was also determined that the firmness of the fruit was contingent upon the quantity of accumulated starch. The breakdown of starch into sugar was observed to contribute to a reduction in firmness, which was consistent with Jansanthea et al. [31], who reported an increase in the TSS and sugar content influenced the sweeter taste of durian flesh, leading to a softening of the texture. This was also in accordance with Paull et al. [32], who noted that during the ripening of papaya fruits, the increase in soluble pectin and changes in hemicellulose resulted in a softer texture for the papaya fruit.

Table 5 Correlation coefficient (r) between nutrient contents in plant parts and quality components in melon.

	%K in leaf	%K in stem	%K in flesh	%K in peel	%S in flesh	%Cl in flesh	Fresh fruit weight	Flesh thickness	Firmness	TSS
%K in leaf	1	ns	0.49**	0.59**	0.67**	ns	ns	ns	-0.59**	0.65**
%K in stem		1	ns	ns	ns	ns	ns	ns	ns	ns
%K in flesh			1	0.96**	ns	0.48*	0.64**	0.53**	ns	ns
%K in peel				1	ns	0.40*	0.63**	0.52**	ns	ns
%S in flesh					1	-0.42*	ns	ns	-0.44*	0.51**
%Cl in flesh						1	ns	ns	ns	ns
Fresh fruit weight							1	0.75**	ns	ns
Flesh thickness								1	ns	ns
Firmness									1	-0.86**
TSS										1

*= significantly different at p < 0.05 level, ** = significantly different at p < 0.01, ns= not significantly different (p > 0.05)

4. Conclusion

It was concluded that supplementary soil application with potassium sulfate at a rate of 3.6 g/plant resulted in the increase of the melon sweetness as compared to control Foliar spray with K_2SO_4 and KCl at rates of 1.2 and 1.0 g/plant/time, respectively, resulted in the highest fresh fruit weight and flesh thickness. Additionally, it was found that the potassium concentration in leaves and sulfur concentration in flesh had a positive correlation with TSS in fruits (R^2= 0.65 and 0.51, respectively) and potassium concentrations in flesh and peel had a positive correlation with fruit weight (R^2 = 0.64 and 0.63, respectively) and flesh thickness (R^2= 0.53 and 0.52, respectively).

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