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Effect of potassium fertilization on tomato and cucumber plants under greenhouse conditions

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Tomato and cucumber plants grown in the greenhouses require relatively high levels of potassium (K) regimes for optimum growth, yield and fruit quality. Greenhouse managers and farming industry owners who established their projects under the arid conditions of Saudi Arabia are applying K fertilizers to tomato and cucumber plants without taking into consideration the actual plant requirements of this essential element. Therefore, four levels of K fertilizer as potassium sulphate (100, 150, 200 and 250 ppm) were applied in fertigation method to both tomato and cucumber plants grown the in greenhouses at the Experimental Station of College of Agriculture and Veterinary Medicine, Qassim University, Qassim, Saudi Arabia; to evaluate their agronomic performance in response to various levels of K fertilizer. Results revealed that increasing potassium levels resulted in a significant increase in leaf K concentration and chlorophyll content. Both tomato and cucumber fruits produced from plants received high level of K (250 ppm) showed superiority over those produced from plants received low level of K (100 ppm) regarding percentage of total soluble solids contents and firmness. Moreover, there was a direct proportional relationship between the level of applied K fertilizer and studied fruit quality parameters (percentage of total soluble solids, firmness). In addition, our data in the present study revealed that under the suggested K regimes investigated, the marketable yield increased linearly with increasing K levels. In conclusion, increasing K rate to 250 ppm statistically increased leaf K concentration and chlorophyll contents of tomato and cucumber plants. While increasing K rates did not affect TSS% and firmness of tomato and cucumber fruits.

Keywords: ***Lycopersicon esculentum*****;** ***Cucumis sativus*****; Potassium application; Correlation; Cultivars.**

INTRODUCTION

A wide range of high-value cash crop vegetables are grown in Saudi Arabia by both small scale farmers and large farming industries. The major vegetable crops include tomato, cucumber, eggplant, onion, watermelon, squash and pumpkin. Total vegetable production of what in open fields as well as greenhouses has increased from 0.78 million tons in 1900 to 2.6 million tons in 2009 (MOA, 2010). To safeguard water resources, the Saudi Government encourages and supports the practice of agriculture under greenhouse conditions. Based on recent data, loan volume to finance these types of projects by the agricultural development fund covered 326 projects, with a total capital value of 1.22 Billion Saudi Riyals (0.32 Billion US$); this represents 13% of the total value of loans for all agricultural projects (MOA, 2009). As a result, total greenhouse vegetable production reached 400000 tons, representing 25% of total vegetable production (MOA, 2009; Al-Jaloud et al. 2005; Al-Jaloud et al. 2006)

Tomato (*Lycopersicon esculentum* L.) is the second most important vegetable with a total world production of about 136 million tons in 2008, while cucumber (*Cucumis sativus* L.) is ranked as the fifth, with total world production of 32 million tons (FAO, 2009). Greenhouse tomato and cucumber are very popular in many areas of the world. In Saudi Arabia, tomatoes and cucumbers are considered the most important vegetable crops grown under greenhouse conditions. Tomato production increased from 310401 tons in 2000 to 542589 tons in 2009, about 64% of the production is produced under greenhouse conditions. Cucumber production increased from 135948 tons in 2000 to 326330 tons in 2009, about 96% is produced under greenhouse conditions (MOA, 2010).

Potassium (K) is the nutrient having the strongest influence on quality attributes that determine fruit marketability (Al-Moshileh, 2003; Lester et al. 2007). The role of potassium in plant metabolism, growth, and development and its significance in production of marketable fruit and on fruit firmness, quality and visual appearance are published and well known (Besford and Maw, 1974; Kader, 1992; Johnson and Jones, 1979; Daliparthy et al. 1994; Al-Moshileh et al. 2005).

Recent technological advances in delivering chemical fertilizers with irrigation water (Fertigation) lead to widespread adoption of this method in Saudi Arabia (Al-Jaloud et al. 2006). It is an effective method to increase the productivity of vegetables by increasing use efficiency of water and Fertirrigation improved fertilizer use efficiency by the plants (Phene et al. 1989). It is found that this system is affecting tomato yields (Locascio and Myers, 1974; Dangler & Locascio, 1990). Papadopoulos, 2000 emphasized the advantage of fertigation in supplying crop need using soluble fertilizers with irrigation water, thus optimizing water and nutrient application directly in the area where roots are actively growing. Greenhouse producers in Saudi Arabia are applying approximate rates of K to tomato and cucumber (Al-Jaloud et al. 2005; Al-Jaloud et al. 2006).

It is important to establish K rates based on research data and not guess-work. Therefore, the objective of this study was to determine the optimum K recommendation rate for tomatoes and cucumber grown in the greenhouses under the arid conditions of Saudi Arabia.

MATERIALS AND METHODS

The present study was conducted during the seasons of 2009 and 2010 at the Experimental farm of the College of Agriculture and Veterinary Medicine, Qassim University, Al-Qassium region (latitude 26-27 N, longitude 44-45 E, altitude 725 m above sea level), Kingdom of Saudi Arabia.. Soil and water samples were collected prior to planting at 0-20 cm depth and their properties are shown in Table 1.

Table 1: Physical and chemical properties of soil and water used for the study.

Properties	Value
Physical properties	
Sand (%)	94. 1
Silt (%)	3.6
Clay (%)	2.3
Soil texture	Sandy
Chemical properties	
pH* soil	7.62
pH water	7.11
ECe (dS/m)** soil	6.57
ECe (dS/m)** water	1.51
Soluble cations (meq/L)	
Na+	30.43
K+	2.47
Ca++	25.0
Mg++	7.40
Soluble anions (meq/L)	
HCO_3^-	2.16
Cl^-	30.6
CO_3^{--}	--
SO_4^{--}	7.20
Nutrient (mg/kg)***	
Total N	149.9
P	16.4
K	135.9

***pH: was measured in the extract of saturated soil paste.**
****ECe (dS/m): was determined using EC meter according to Jackson (1973).**
*****Total N was determined by Kjeldahal method; P was extracted using the method described by Olsen et al. (1954); K by 1 N NH_4OAc at pH 7.**

Plots were arranged in a randomized complete block design, with four potassium rates replicated three times. Each replicate consists of four plant lines that are 33 m long. All plots received basic application of 250 kg P_2O_5 ha^{-1} using di-ammonium phosphate (46% P_2O_5), applied at once before planting. Nitrogen was applied in sufficient amounts to avoid deficiency. K as potassium sulphate treatments consisted of four rates (100, 150, 200 and 250 ppm). Plants were arranged in plots with 50 cm between rows and 30 cm between plants in the row. Hybrid Dutch cultivars of tomato namely JV 15 and cucumber namely Sovana RZ were used in this study. Irrigation water samples used in this study were analyzed for EC and pH (Table 1).

Average day and night temperatures in greenhouses were 25^{o}C and 18^{o}C. This conforms within normal temperature ranges established for greenhouse (Johnson, 1980) Maynard and Hochmuth, 2007 reported that the optimum temperature for cucumber growth lies between 18-24^{o}C.

Data Recorded:

Leaf K concentration: Potassium was determined according to the method described by Page et al. (1982).

Chlorophyll content: Total chlorophyll content was measured using a SPAD-502 chlorophyll meter (Minolta, Japan). For this measurement the average of three leaves per plant per replication per treatment was taken.

Fruit firmness: fruit firmness was measured by a Bishop FT Oil model pressure tester (probe 7.9 mm).

Total soluble solids percentage (TSS %): was measured as Brix^o by using the refractometer. Yields were determined by weighing tomato and cucumber fruits during the various picks and only marketable yield data are reported in this paper. Average fruit yield per plant was determined by the total fruit weights per line divided by the plant population count per line. The total production per hectare was computed by multiplying average fruit weight per plant by planting density per hectare. Each plot consisted of 116 plants in a plant line.

Statistical Analysis

All recorded data were statistically analyzed and the least significant difference (LSD) test was used to compare means at the level of 5% of probability according to Snedecor and Cochran, (1980).

RESULTS AND DISCUSSION

Effect of different levels of potassium application on tomato plants:

Effect on K and chlorophyll content:

Leaf K concentration data showed that there was no significant difference among the 100, 150, and 200 ppm K (Table 2). However, increasing K rate up to 250 ppm statistically increased leaf K concentration. With the exception of 100 ppm K, the chlorophyll content was increased significantly when K rates were increased, but 250 ppm K gave the highest leaf K concentration and chlorophyll percentage (Table 2). Our data are in agreement with those reported by Al-Jaloud et al. (2005) for research conducted under similar environmental conditions. Concentrations of K are also within the optimum ranges for tomatoes grown under greenhouse conditions (Hochmuth, 1994). Hebbarb et al. (2004) reported that leaf chlorophyll content of tomato plants was significantly higher in fertigation treatments over K applied using traditional methods. This could be due to enhanced photosynthesis which in turn led to the development marketable size fruit, and thus producing more fruits per plant.

Effect on total soluble solids, firmness, and marketable yield:

A slight increment but non-significant effect in total soluble solids of tomatoes was recorded by increasing K rates (Table 3). Tomato firmness was increased significantly by increasing K levels. On the other hand, marketable yield at the 250 ppm rate was the highest compared to all the other rates. This finding is in line with results reported by Besford and Maw (1974), who found that K content in tomato fruits was closely correlated with the dry matter content. Similarly, Almeselmani et al. (2010) reported that there was significant improvement in protein, ascorbic acid, lycopene, total soluble solids, reducing sugar levels, and titratable acidity in fruit as leaf K concentration increased. In Brazil, Fontes et al. (2000) mentioned that total, marketable and weighted yields of tomato increased as K rates increased. Johnson and Jones, (1979) as well as Taber et al. (2008) reported that tomato fruit quality was increased significantly by increasing potassium application.

Effect of different levels of potassium application on cucumber plants:

Effect on leaf K and chlorophyll content:

Leaf K concentration data (Table 4) showed

Table 2: Effect of different levels of potassium on K concentration and chlorophyll content of tomato plants.

K treatment (ppm)	Leaf K concentration (mg/kg)	Chlorophyll content (SPAD unit)
100	3.35[b]	38.39 [b]
150	3.45[b]	36.15 [b]
200	3.43[b]	43.29[a]
250	4.19 [a]	46.03[a]
LSD (0.05)	0.66	3.13

Means followed by different letter are significantly different at 5% level of significance

Table 3: Effect of different levels of potassium on tomato total soluble solids, firmness and marketable yield of tomato plants.

K treatment (ppm)	TSS (%)	Firmness (Lbs/inch^2)	Marketable yield (Ton ha^{-1})
100	4.32[b]	7.28[b]	77.06[c]
150	4.49[ab]	8.05[ab]	76.59[d]
200	4.56[ab]	8.89[a]	77.74[b]
250	4.80[a]	9.19[a]	78.89[a]
LSD (0.05)	0.45	1.33	0.69

Means followed by different letter are significantly different at 5% level of significance

Table 4: Effect of different levels of potassium on leaf K and chlorophyll content of cucumber plants.

K treatment (ppm)	Leaf K concentration (mg/kg)	Chlorophyll content (SPAD unit)
100	3.88[b]	35.59[b]
150	3.59[b]	36.54[b]
200	4.03[ab]	46.63[a]
250	4.43[a]	49.14[a]
LSD (0.05)	0.46	3.46

Means followed by different letter are significantly different at 5% level of significance

Table 5: Effect of different levels of potassium on total soluble solids, firmness and marketable yield of cucumber plants.

K treatment (ppm)	TSS (%)	Firmness (Lbs/inch^2)	Marketable yield (Ton ha^{-1})
100	3.44[b]	14.01[c]	26.02[c]
150	3.68[a]	14.45[bc]	28.40[bc]
200	3.78[a]	15.31[bc]	30.04[b]
250	4.14[a]	17.42[a]	34.19[a]
LSD (0.05)	0.46	0.89	2.52

Means followed by different letter are significantly different at 5% level of significance

that there was no significant difference among the 100, 150, and 200 ppm K. However, increasing K rate to 250 ppm statistically increased leaf K concentration. This finding is in agreement with those obtained by Al-Jaloud et al. (2006). Chlorophyll content was increased as K rates were increased (Table 4). However, the best statistical result was obtained with applying 250 ppm K rate. Huett (1993) found that a combination of the lowest N and K levels produced the softest fruit while the highest N and K combination produced the firmest fruit. This finding is in agreement with the results obtained by Lamrani et al. (1996), who reported that K treatment acted positively on the chlorophyll and carotene content in cucumber.

Effect on total soluble solids, firmness, and marketable yield:

There was no significant effect of various K rates on cucumber total soluble solids. Similarly, cucumber firmness was not statistically affected by increasing K levels (Table 5). Our data deviates from earlier reported by Wang et al. (2005), who found that when proper potassium fertilizer were used, the nutritional level and the flavor or taste quality of cucumber fruits could be increased obviously. On the other hand, marketable yield at the 250 ppm rate was the highest compared to all the other rates. Altunlu and Gül (1995) reported data for cucumber dry matter content, total soluble solids, pH, titratable acidity, fruit firmness, chilling injury, and general appearance; they concluded that 200–300 ppm K and a maximum of 200 ppm N may be responsible for increasing shelf life of cucumber fruits. Application of potassium fertilizer to cucumber grown in greenhouses under arid conditions, and at the 250 ppm level led to the highest marketable yield, although not significantly higher than that the yield obtained at the 200 ppm K (Table 5). Similar results were reported by Al-Jaloud et al. (2005) for research conducted under similar environmental conditions, in which they used 200 ppm as their highest K rate for cucumber.

Relationship between leaf K and chlorophyll content in tomato and cucumber:

With the limited number of point data (n = 4), it was possible to draw a positive correlation (Figure 1) between chlorophyll content and K concentration in tomato ($y = 8.78\ x + 9.11$, $R^2 = 0.56$). A better relationship with higher correlation coefficient between these two variables (Fig. 2) was found for cucumber ($y = 16.65\ x – 24.61$, $R^2 = 0.70$). Using these equations, it is possible to predict one of the variables, if the other is known. Therefore, growers can save time and money by analyzing on these two factors, usually the fastest and least expensive. The second factor can easily be computed using the derived equation. However, we recommend the use of these equations when they are generated based on high data points.

CONCLUSION AND RECOMMENDATIONS

Based on the data of this experiment conducted during two consecutive seasons, It can be concluded that potassium fertilizer applied to tomato and cucumber plants at the 250 ppm level gave the highest leaf K, chlorophyll contents, and total marketable yield.

Figure 1: The correlation between leaf K concentration and chlorophyll content in tomato.

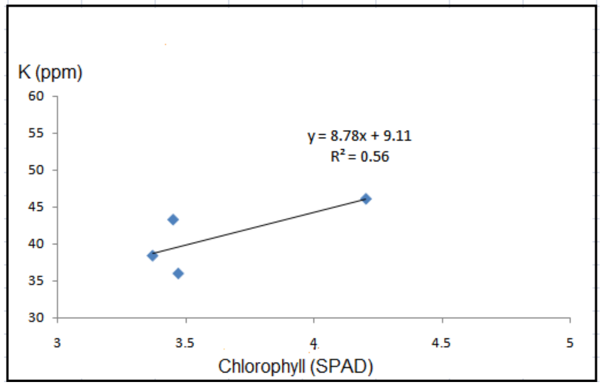
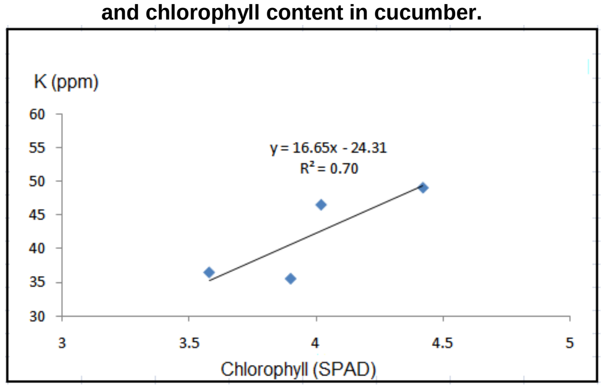


Figure 2: The correlation between leaf K concentration and chlorophyll content in cucumber.



However, increasing K rates did not affect TSS % and firmness of tomato and cucumber fruits. In an attempt to predict one variable if the other is known, and thus saving farmers time and money, two linear equations were developed to calculate chlorophyll content or K concentration for tomato and cucumber.

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