EFEFCT OF POTASSIUM CHLORIDE AND SULPHATE NUTRITION OF PEPPER PLANTS YIELD

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Abstract: *The aim of our study was to clarify the effect of two typical potassium fertilizers on pepper. Our plants were grown on sand soil. The two fertilizers were potassium chloride and potassium sulphate. Half doses of the fertilizers were applied in solid condition before the planting, and the other half dose as water solution after flowering. The full doses were: 100, 200, 400, 800 and 1 600 kg K_2O/ha. Pepper fruits were weighted in the chloride and sulphate salinity treatment groups.*

***Key words**: potassium-chloride, potassium-sulphate, pepper, fertilizer, yield*

INTRODUCTION

In Hungary, pepper consumption is over 10 kg per person per year. Its nutritional significance is in its high vitamin C content (50-300 mg/100 g vegetable). Adults need 20 mg vitamin C per day. Pepper contains vitamin P, which enhances the effects of vitamin C. It also contains vitamins B1, B2, B6 and α-carotene and β-carotene (Hodossi, Kovács, Terbe, 2004).

Pepper plants need high amounts of nutritions. Nitrogen is needed for vegetative growth and for increasing fruit production. Phosphorous is mainly important in initial growth and especially in normal development of the roots.

Considering the nutrient need of vegetable plants, potassium is needed in the largest amount from the macro elements that are generally supplemented. This phenomenon is also true for pepper plants. Potassium is the nutrient found in the largest amount in pepper, and it regulates plant physiological processes.

Chloride plays an important role in development of pepper plants, this micro element is needed in small amount for physiological processes. Chloride participates in photosynthesis. Cultivated plants need very small amount of chloride, and even though it is one of the most common anions in them, replacement is generally not needed (Bergmann, 1979). Chloride is an important component in most potassium fertilizers. It is important to note that pepper plants are sensitive to salts, therefore application of chloride containing fertilizers is not recommended, even though potassium chloride is one of the cheapest potassium fertilizers, and as a result it is used in the largest amount.

Our goal was to find out how plant growth is influenced by application of different kinds of potassium forms to fulfill potassium need of the chosen Amy variety pepper plants; and what effect potassium chloride, a chloride ion containing salt that is generally dangerous for vegetable plants has on development of test plants compared to potassium sulphate (K_2SO_4) applied in the same concentration.

The experiment was performed in open field conditions on humus rich sand soil. The experiments were carried out in the Demonstration Garden of Kecskemét College, Faculty of Horticulture, in 42 containers filled with sand soil. Pepper plants were treated with 100 kg K_2O/ha, 200 kg K_2O/ha, 400 kg K_2O/ha, 800 kg K_2O/ha and 1600 kg K_2O/ha doses; half of the respective dose was applied as solid fertilizer into the soil before planting, the other half as solution after flowering. In this experiment, yield as well as nutrition and chloride content of the soil were measured.

MATERIALS AND METHODS

The experiment was carried out in the Demonstration Garden of Kecskemét College, Faculty of Horticulture, in an area with ground containers. Diameter of the plastic containers was 60 cm and height was 90 cm, their two third parts were lowered into the ground, and they were filled with humus rich sand soil (Fig. 1). Soil surface was 0.283 m^2 in each container.

Preliminary examination of the container soil was performed in the Soil and Plant Testing Laboratory at the Faculty of Horticulture in Kecskemét. The most important parameters were: soil plasticity according to Arany (K_A): 32; pH (KCl): 7.42; total soluble salt content: 0.02 m/m%; lime content ($CaCO_3$): 2.98 m/m%; humus content: 2.48 m/m%. According to these results, soil in the containers was a humus rich sand soil with good yield potential, it belonged in type 4 of the soil classification system, and it was considered homogeneous. AL-soluble K_2O concentration was homogeneous in the container soil, and it had an average concentration of 176 mg/kg. According to Buzás (1983), this value corresponds to good nutrient content.

Figure 1. Ground containers used in the experiment

Potassium treatment

The plants were transplanted into the above described containers on May 26, 2015. Before planting, solid fertilizers were applied on the soil on April 22: potassium chloride with 60% K_2O content and potassium sulphate with 45% K_2O content, in the following increasing doses: 50, 100, 200, 400, 800 kg K_2O/ha. Each treatment type was applied in 4 repetitions; one container counted as one repetition, and 4 seedlings were planted into each container.

To increase effect of potassium fertilizers, approximately one month after transplanting (on June 23), potassium solution was applied containing the same kind of fertilizers in the same dose, therefore total treatment was 100, 200, 400, 800 and 1600 kg/ha K_2O in the containers in case of both types of potassium fertilizers. The highest two doses can be considered extremely high, provoking doses of nutrition. “Accompanying” ions administered with the treatments: chloride ion 75.6, 151.2, 302.4, 604.8, 1209.6 kg/ha, and sulphate ion 67.9, 135.8, 271.6, 543.2, 1086.4 kg/ha.

Applied potassium fertilizers

Red potassium chloride fertilizer with 60% active ingredient content and powder form of potassium sulphate fertilizer with 50% active ingredient content were used. During production of potassium chloride, KCl is separated from NaCl. Production of potassium sulphate (K_2SO_4) is performed with double decomposition reaction of concentrated forms of KCl and $MgSO_4$. The latter is especially recommended in case of chloride sensitive crops (Schmidt, 2011).

Fertilizer solution

Use of fertilizer solution refers to use of dissolved fertilizers during the vegetation period of the plants. Its goal is to cease nutrient deficiency and increase growth that is slow normally (Balázs, 2000).

Pepper was fertilized with "Pétisó" (27% N) on June 2, 2015, and again one week later, on June 9. 3.2 g fertilizer was applied on each container, which corresponds to 30 kg/ha N active substance. The main active ingredient of Pétisó is NH_4NO_3 (ammonium nitrate), and it contains 27% nitrogen (N). Pepper plants were fertilized with calcium nitrate (16% N) on July 7, 2015. Active substance content also was 30 kg/ha N in this case.

Sampling and yield measurement

Fruit harvesting was performed continuously, several times during crop season. Harvested fruits were collected into plastic bags, and they were weighted noting treatment and repetition. In 2015, after weighing the fruits, those were classified according to size. 3 groups were differentiated: fruits lower than 60 g, which were below average, 60–100 g, which were typical to this variety, and higher than 100 g, which were extra large fruits.

After terminating the experiment, soil samples were taken from the containers for laboratory evaluation, and pH, electric conductivity (EC), chloride ion content and nutrient content of each soil sample were determined (in 1:5 watery extract: P_2O_5, K_2O, CaO, MgO, Na^+).

RESEARCH RESULTS

After terminating the experiment, chloride ion concentration of the soil extract was determined with argentometry. Chloride ion values are presented in the Table 1.

Table 1

Chloride ion content in the soil solution after terminating the field experiment, mg/L

Code of sample (Type of K)	Dose of treatment	Chloride content (mg/L)	Correlation coefficient
Control	0 kg K_2O/ha	7.11	
KCl 1	100 kg K_2O/ha	14.9	
KCl 2	200 kg K_2O/ha	24.1	
KCl 3	400 kg K_2O/ha	23.4	
KCl 4	800 kg K_2O/ha	24.1	
KCl 5	1600 kg K_2O/ha	37.6	$r_{/P=5\%/}$ = 0.92
K_2SO_4 1	100 kg K_2O/ha	5.32	
K_2SO_4 2	200 kg K_2O/ha	11.7	
K_2SO_4 3	400 kg K_2O/ha	7.81	
K_2SO_4 4	800 kg K_2O/ha	8.52	
K_2SO_4 5	1600 kg K_2O/ha	8.52	$r_{/P=5\%/}$ = 0.09

7.11 mg/L chloride content of the control treatment is normal value in arable fields. According to literature, chloride ion content in 1:5 watery solutions can be considered optimal, if it is under 30 mg/L (Terbe, Hodossi, Kovács, 2005).

With the increasing doses of potassium chloride fertilizers, chloride ion content of the soil increased. Regression analysis revealed strong correlation between fertilizer doses and chloride ion concentration of the soil, correlation coefficient was 0.92. Coefficient value is 0.811 in the table; the calculated value is higher than that, which means the treatment had a significant effect. Chloride ion content was the highest (37.6 mg/L) in case of the highest dose of potassium chloride treatment, and this concentration exceeded the above mentioned literature data on optimal concentration limit. No significant increase in chloride ion concentration was seen in case of potassium sulphate treatment.

After terminating the experiment, nutrition content of the soil was determined. Potassium content was determined in AL (ammonium lactate) extract with a ICP-OES spectrometer. The results are presented in the following Table 2.

Table 2

AL-soluble potassium content of the soil in the field experiment, mg/kg

Code of sample (Type of K)	AL-soluble nutrient content	
	Dose of treatment	AL-K_2O mg/kg
Control	0 kg K_2O/ha	63.1
KCl 1	100 kg K_2O/ha	60.9
KCl 2	200 kg K_2O/ha	78.4
KCl 3	400 kg K_2O/ha	84.4
KCl 4	800 kg K_2O/ha	170
KCl 5	1600 kg K_2O/ha	334
K_2SO_4 1	100 kg K_2O/ha	85.3
K_2SO_4 2	200 kg K_2O/ha	83.7
K_2SO_4 3	400 kg K_2O/ha	117
K_2SO_4 4	800 kg K_2O/ha	141
K_2SO_4 5	1600 kg K_2O/ha	374

The table shows that potassium content of the soil increased to about the same extent in case of both potassium chloride and potassium sulphate fertilizers; the reason is that both contained almost the same amount of potassium nutrient.

According to Buzás (1983), optimal AL-K_2O content of sand soils is 161-420 mg/kg, therefore even the provoking treatment doses did not result in extremely high potassium levels.

During the experiment, harvesting took place several times, total yield was calculated by summing up fruit weights of all harvesting events, and yield was referred to t/ha. Table 3 presents the yield values of this experiment.

Table 3

Yields in the open field experiment in 2015.

Code of sample (Type of K)	Dose of treatment	Yield (t/ha)	Correlation coefficient
Control	0 kg K_2O/ha	63.8	
KCl 1	100 kg K_2O/ha	71.3	
KCl 2	200 kg K_2O/ha	79.1	$r_{/P=5\%/} = 0.999$
KCl 3	400 kg K_2O/ha	81.9	
KCl 4	800 kg K_2O/ha	73.5	
KCl 5	1600 kg K_2O/ha	56.8	$r_{/P=5\%/} = -0.999$
K_2SO_4 1	100 kg K_2O/ha	74.7	
K_2SO_4 2	200 kg K_2O/ha	98.3	
K_2SO_4 3	400 kg K_2O/ha	70.6	
K_2SO_4 4	800 kg K_2O/ha	84.3	
K_2SO_4 5	1600 kg K_2O/ha	87.8	$r_{/P=5\%/} = 0.905$

There was significant correlation between pepper yield and the increasing potassium concentration in this experiment (Table 3).

In case of treatment with potassium chloride, yield increased linearly until the moderate 400 kg/ha dose, where maximum peak was reached, and the further increased fertilizer doses resulted in lowering yield tendency. Up to 400 kg/ha potassium chloride treatment, correlation coefficient was 0.999 (P=5%), which represents strong positive correlation between yield and fertilizer doses.

According to statistical results, in the 400 kg/ha to 1600 kg/ha dose range there was very strong negative correlation between yield and potassium chloride concentrations. Correlation coefficient was -0.999, while r value in the table is 0.811 with error level of 5%.

Decreasing yield, the effect of salt stress was seen in case of the higher doses.

Increase in yield was observes in case of potassium sulphate, but an outlier value at 200 kg/ha dose (98.3 t/ha) prevents from proper regression analysis, therefore doses only in the 400 kg/ha to 1600 kg/ha range were evaluated and presented here; correlation coefficient was 0.905. This latter value did not reveal significant difference in the results, but trends were suggested.

Highest yields were 81.9 t/ha and 98.3 t/ha in case of chloride treatment and and sulphate treatment, respectively. Fertilization with potassium chloride resulted in 20% increase in yield in the experiment.

The highest yield of pepper was achieved with the 400 kg/ha dose level in case of potassium chloride, while in case of potassium sulphate, highest yield was achieved with 200 kg/ha dose.

CONCLUSIONS

Potassium nutrient replacement has great significance in humus rich sand soil with low Arany's soil plasticity. Our result show that significant increase in yield can be achieved with both sulphate and chloride containing potassium fertilizers compared to control, however, chloride sensitivity of pepper plants was also seen in case of chloride containing fertilizer treatments.

Trends shown in this experiment were consistent with the results of Navarro, Garrido, Carvaial, Martinez (2002), Terbe (1977) and Slezák, Mihály, Nagy, Kis (2010). Higher yield can be achieved using the sulphate form of potassium fertilizers. The highest yield can be achieved with half the dose of potassium (200 kg K_2O/ha) in case of potassium sulphate compared to potassium chloride (400 kg K_2O/ha).

Our results are consistent with the relevant literature data: according to examinations of Sonnaveld, Beusekom (1974), Haraszty (1975), Terbe (1977), Tadesse, Nichols, Fischer (1999), Wuzhong (2002) and Slezák, Mihály, Nagy, Kis (2010), cultivation of pepper plants is negatively affected by high salt and chloride ion concentrations.

Our results are, however, in contradiction with the results of Somos (1981), who wrote that chloride containing fertilizers did not have a negative effect on pepper plant development. Based on our soil examination results, chloride wash-out is more intensive than potassium was-out, as the optimal 30 mg/l chloride soil concentration was only exceeded in case of the highest applied potassium chloride dose.

Both types of fertilizers are suitable for increasing potassium content of the soil and are suitable for the pepper plants, but since chloride sensitivity develops to higher chloride concentration, potassium sulphate fertilizer is recommended instead of potassium chloride in open field cultivation of pepper.

If no fertilizer solution is used in pepper cultivation, 200 to 400 kg/ha potassium fertilizer doses are recommended following soil examination. It is recommended to apply potassium fertilizers multiple times: in a solid form before planting and in solution after flowering. Our recommendation is that the chloride containing form should not be used as fertilizer solution.

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