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Effects of various kinds of potassium fertilizers on the yield and quality of greenhouse tomatoes

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Abstract

The effects of KCl, K_2SO_4 and KNO_3 on the yields of greenhouse tomatoes variety 'Revermun' cultivated on a peat substrate were examined. On the basis of fruit yield, dry weight content in the fruit and the content of K, Ca, Mg, Cl, S-SO_4 in the soil and of N, P, K, Ca, Mg, Cl, S-SO_4, Fe, Cu, Mn, Zn, Mo in leaf stalks it was found that KCl is the best form for fertilizing greenhouse tomatoes cultivated on peat. No adverse effects of chlorine at concentrations of 1500 mg Cl/liter peat and 6.0% Cl in the dry mass of tomato leaves were observed.

INTRODUCTION

Tomatoes are plants with a high requirement for potassium. Under conditions of intensive greenhouse culture the use of potassium is in the range 1000 to 1200 kg K_2O per hectar of surface. This substance may be given to plants as the nitrate, sulphate or chloride salt.

The results of investigations performed up to the present time were the basis for recommending that salts containing chlorine should not be used for tomatoes (Buchner, 1958; Hösslin et al., 1964; Müller and Preising, 1971; Nowosielski, 1973). However work showing the positive effects of chlorine on the yields of some plants and on the dry mass content in their leaves indicate that this substance is useful for higher plants (Arnold, 1955; Broyer et al., 1954; Broyer, 1966; Johnson et al., 1957; Ulrich and Ohki, 1956).

The reaction of plants to the differentiated forms and doses of particular nutrients also depends on the type of substrate. At present in greenhouses mainly substrates containing peat, brown coal, bark and mixtures of these components are used.

In our earlier investigations concerning tomatoes and other vegetables grown on high peat we have shown that the plants are capable

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of taking up and accumulating in the biomass of high amounts of chlorine (Nurzyński, 1976). Therefore the question arose at what chlorine content in the substrate and in leaf stalks of tomatoes a negative reaction on the plants to this component takes place and also whether chlorine affects the uptake of other nutrients.

The following problems were examined in tomatoes cultivated on a peat substrate in a heated greenhouse using three forms of potassium salts: KCl, K_2SO_4 and KNO_3.

METHODS

The substrate in the tomato cultures was gardening peat from Ludwin (Lublin district) with a pH 4.9 which was treated with $CaCO_3$ to increase the pH to 6.2. Moreover, during vegetation (on March 26) 10 g of $CaCO_3$ were added per pot as symptoms "blossom-end rot" of tomato fruit had been observed. Seeds of tomatoes of variety 'Revermun' were planted on December 11, 1976, the seedlings were transferred to 0.2 l pots on January 13, 1977 and the plants were transferred to 8 liter vinidur cylinders on February 12, 1977. The plants were maintained with six clusters. The first fruits were collected at the end of April and the experiment was finished on June 30, 1977. The period of plant vegetation starting from planting the seeds until the end of the experiment was 27 weeks.

In the experimental scheme three doses of KCl and K_2SO_4 and one dose (intermediate) of KNO_3 were included as the differentiation of KNO_3 doses would have automatically changed the $NH_4 : NO_3$ ratio in the soil. The amounts of potassium used in particular experimental series are included in Table 1. The remaining nutrients were used in g per plant in the following amounts: N — 10, P_2O_5 — 15, MgO — 5, and in mg per plant — Cu — 107, Mo — 29, Mn — 29, B — 19, Zn — 6, Fe — — 64.

The forms of the salts used — N — NH_4NO_3, P — superphosphate 46%, Mg — $MgSO_4$, Mn — Cu — Zn — SO_4, B — H_3BO_3, Mo — NH_4 molybdate, Fe — EDTA.

During the period of plant vegetation the plants were watered with tap water containing about 2 ppm of Cl up to about 70% of the total water capacity of the peat.

The chemical analyses of the leaf stalks taken between the second and third and the third and fourth clusters and the analyses of the substrate were performed at three dates (May 10, June 2, and June 27 1977).

The peat was analyzed according to Nowosielski's proposal (1972). In the leaf stalks total N, P, K, Ca, Mg were examined after wet

Table 1

Effect of different forms of K fertilization on total tomato yield and on the content of mineral components in peat substrate in mg/l

Forms of K	KCl	KCl	KCl	K_2SO_4	K_2SO_4	K_2SO_4	KNO_3
Doses of K_2O g/pot	18	24	30	18	24	30	24
Yield kg/pot	3.04 d	2.59 ab	2.67 bc	2.55 ab	2.31 a	2.54 ab	2.98 cd
Dry matter of fruit (%)	5.87 b	6.26 d	6.23 d	5.47 a	6.04 c	6.08 c	5.92 b
				Content of elements in substrate			
K	228 a	436 bc	543 d	202 a	405 b	604 e	488 cd
Ca *	1877	1906	2100	2015	1887	2190	1933
$N\text{-}NO_3$	193 cd	217 d	172 bc	161 ab	180 bc	146 a	207 d
$P\text{-}PO_4$	318 c	359 ab	391 d	242 a	278 b	260 ab	337 c
Cl	1040 c	1330 d	1540 e	162 a	261 b	223 ab	230 ab
$S\text{-}SO_4$	203 a	194 a	203 a	358 b	492 c	606 d	202 a
pH H_2O	5.82 a	5.80 a	5.80 a	5.80 a	5.75 a	5.90 a	6.37 b
Salinity g NaCl/l	2.75 a	3.93 d	5.34 e	3.30 b	3.60 c	4.00 d	2.70 a

Numbers marked with the same letters do not differ significantly at P=0.05.
* not significant at P=0.05.

burning, NO_3, Cl, S-SO_4 in 2% acetic acid extract (Nowosielski, 1972), microelements after burning in a mixture of HNO_3, H_2SO_4, $HClO_4$ by the method of atomic absorption and Mo colorimetrically by the CNS-method.

RESULTS

During the period of vegetation differences in the growth and appearance of plants from particular experimental variants could be observed. The leaf color was a lighter green in the plants supplemented with KCl than in the plants supplemented with K_2SO_4 and KNO_3. When K_2SO_4 was used the plants were taller and the fruit smaller. The first red fruit appeared at the end of April and the highest numbers of fruit were produced by plants supplemented with KCl (Table 1).

The yield of fruit thus confirmed the suitability of the chloride form of potassium for tomatoes. Also the percent dry mass content was the highest when KCl was used. The positive effect of KCl occurred at a high concentration of chlorine in the substrate (1500 mg Cl/liter) and in the leaf stalks (6.2% Cl in dry mass).

Moreover analyses of indicator parts of plants have shown that the plants fed with the chlorine form of potassium contained more Ca, Mg, Fe, Mn, Mo, and less P and NO_3 as compared with plants of the remaining combinations.

A lower amount of molybdenum contained by the plants from the experimental variant with K_2SO_4 may be explained by the possible antagonistic effect of sulphate ions on the uptake of this microelement. This problem has broader aspects, because a poorer supply of plants in molybdenum affects the reduction of nitrate ions as a result of which the accumulation of nitrates in plants takes place.

In the undertaken experiment in culture of plants under conditions of optimal supplementation in macroelements the plants fed with K_2SO_4 contained in their leaf stalks about 60% more nitrates than tomatoes supplemented with KCl (Table 2).

These interrelationships affect the quality of the yield, moreover on the basis of NO_3 content in indicator parts of plants the nitrogen requirements of plants are commonly determined. It seems that an elevated sulphate level may cause the accumulation of nitrates in the plant which is not a result of excess nitrogen fertilization but a decreased ability to reduce nitrates.

In the light of the above results the conclusion may be drawn that a high level of nitrates in the plant is not always a proper indication of the nitrogen requirements of the plant.

Table 2

Effect of different forms of K fertilization on the content of mineral components in dry matter of leaf stalks of tomato

Forms of K	KCl	KCl	KCl	K_2SO_4	K_2SO_4	K_2SO_4	KNO_3
Doses of K_2O g/pot	18	24	30	18	24	30	24
N total (%)	1.86 a	2.14 bc	2.14 bc	2.24 c	2.27 c	2.30 c	2.00 ab
$N\text{-}NO_3$ (%)	0.22 a	0.32 ab	0.41 b	0.79 d	0.67 cd	0.66 cd	0.61 c
P_2O_5 total (%)	1.33 bc	1.23 ab	1.23 d	1.63 cd	1.53 bcd	1.47 bc	0.94 a
$P\text{-}PO_4$ (%)	0.37 b	0.37 b	0.34 ab	0.56 c	0.56 c	0.51 c	0.27 a
K (%)	3.75 a	5.37 b	6.84 c	5.38 b	6.77 c	7.23 d	6.53 c
Ca (%)	3.05 c	2.94 c	3.23 c	5.38 b	1.69 a	1.56 a	1.79 ab
Mg (%)	1.30 b	1.19 ab	1.10 ab	1.13 ab	1.02 ab	0.97 a	1.11 ab
Cl (%)	5.13 b	5.60 c	6.26 d	0.43 a	0.38 a	0.32 a	0.28 a
$S\text{-}SO_4$ (%)	0.56 a	0.53 a	0.51 a	0.72 b	0.77 bc	0.93 d	0.66 b
Fe ppm	78.5 b	77.2 b	74.3 b	65.1 ab	69.8 ab	54.8 a	70.3 b
Cu ppm	3.7 ab	4.0 b	3.5 a	3.7 ab	4.1 b	3.4 b	3.5 a
Mn ppm	236.0 bc	286.1 d	297.0 d	216.9 b	253.1 bc	186.3 a	177.5 a
Zn ppm	46.5 b	51.2 b	50.2 b	45.5 ab	44.7 ab	46.1 b	33.9 a
Mo ppm	6.3 e	4.2 c	4.0 c	4.7 d	3.4 a	2.8 a	7.7 f

Numbers marked with the same letters do not differ significantly at $P=0.05$.

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DISCUSSION

Optimal conditions for the growth and development of plants should be determined not only from the point of view of crop yields but also crop quality should be considered (Fritz and Venter, 1974). In the culture of tomatoes in greenhouses this is not always analyzed. Taking into consideration the quality of the crop and thus its nutritive value it is not enough to estimate the dose of the pure component but is also necessary to consider the forms of the component used.

Our investigations concerning the effects of three types of potassium salts KCl, K_2SO_4 and KNO_3 have shown that potassium uptake was not the same in the case of the three salts. Plants grown on the lowest amount of KCl contained less potassium which did not have an averse effect on the fruit yield. It should be stressed that the chlorine concentration in plants grown with KCl is high, often higher than that of potassium.

The K : Cl ratio in plants grown with the chlorine from of potassium was from 0.7 — 1.1, with the sulphate 12.5-22.6, with the nitrate 23.3. The K : SO_4 ratio varied only slightly and was 6.7-13.4, 7.5-8.8 and 9.9 respectively.

As a result of the use of potassium in the three above-mentioned forms the amounts of other components in the indicator parts of plants change. The use of KCl as compared with K_2SO_4 had positive effects on the uptake of magnesium, molybdenum and specially calcium. The accumulation of calcium in the plant appears to be favorable as it provents "blossom-end rot". The fruit collected from plants fertilized with KCl were stricken with "blossom-end rot" in about 2%, while those from plants grown on K_2SO_4 in about 30%.

Thus the presented results are not in agreement with the common view of the harmfulness of chlorine for tomatoes (Buchner, 1958; Hösslin et al., 1964; Müller and Preising, 1971). There are few elaborations concerning the physiological functions of chlorine, especially in cultivated plants. This problem requires more investigation. It seems that the possible adverse effects of chlorine on plants should be considered with the physical aspects of the substrate and the content of organic substances in it.

Taking into consideration the specific properties of greenhouse cultures where the plants do not have access to mineral components, including chlorine which come with the precipitation the question arises whether it would not be useful to add chlorine to the substrate on which the plants are grown. The amounts of chlorine which are added mainly with the water may not be sufficient.

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Wpływ różnych form nawozów potasowych na plon i jakość owoców pomidorów szklarniowych

Streszczenie

Badano wpływ trzech form nawozów potasowych (KCl, K_2SO_4, KNO_3) na plon całkowity i zawartość składników pokarmowych w podłożu i w częściach wskaźnikowych (ogonki liściowe) pomidorów odmiany 'Revermun' uprawianych w szklarni na torfie wysokim. W wyniku przeprowadzonych badań stwierdzono, że chlorkowa forma potasu (KCl) jest odpowiednią formą żywienia potasowego dla tych roślin. Zawartość chloru w podłożu torfowym w granicach 1000-1500 mg Cl/litr oraz w ogonkach ilościowych 5,1-6,2% Cl w s.m. nie miała ujemnego wpływu na przebieg wegetacji i plonowanie pomidorów. Rośliny żywione siarczanową formą potasu zawierały więcej azotanów oraz mniej Ca, Mg, Mn, Mo, w porównaniu z pomidorami zasilanymi KCl. Na podstawie zawartości NO_3 w częściach wskaźnikowych roślin określa się powszechnie potrzeby żywienia azotowego roślin. Wydaje się, że zbyt wysoki poziom siarczanów może spowodować nagromadzenie się azotanów w roślinie, co nie jest wynikiem przenawożenia azotowego, ale osłabioną zdolnością ich redukcji i dalszego przetwarzania. Nieuwzględnienie tego zjawiska może prowadzić do błędnych wniosków przy interpretacji wyników analiz części wskaźnikowych roślin.