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EFFECT OF NUTRIENT SUPPLY ON SOME SELECTED PARAMETERS OF SWEET PEPPER (*CAPSICUM ANNUUM* L. CV. 'HRF') TRANSPLANTS

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Abstract

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In the trial the effect of nitrogen deficiency and potassium surplus on the dry weight, photosynthetic activity (A), transpiration (E), stomatal conductance (gs) and water use efficiency (WUE) were examined. The macroelement content of aboveground parts were analysed, too. The plants were grown in pots filled by pure Sphagnum peat. The top-dressing started in the 3-leave stage of plants, with different solution (every irrigation): control treatment: 0.28 g N, 0.097 g P (0.22 g P_2O_5), 0.42 g K (0.50 g K_2O) per litre; nitrogen-deficiency: 0.097 g P (0.22 g P_2O_5), 0.42 g K (0.50 g K_2O) per litre; potassium surplus: 0.28 g N, 0.097 g P (0.22 g P_2O_5), 0.83 g K (1.0 g K_2O) per litre. The transplants grown in the commercial fertilization technology (control treatment) almost in every evaluated parameters shown average value. The potassium surplus resulted significantly higher transpiration activity (2.58 mmol $H_2O.m^{-2}.s^{-1}$) and photosynthetic activity (11.54 µmol $CO_2.m^{-2}.s^{-1}$) than the nitrogen deficiency (E: 1.91 mmol $H_2O.m^{-2}.s^{-1}$ and A: 9.01 µmol $CO_2.m^{-2}.s^{-1}$), but without significant differences with control treatment. The N, P and K content of aboveground parts was significantly lower in the nitrogen deficiency treatment, than in the case of the potassium surplus, too. The effect of treatments on the dry weight of the plants, the stomatal conductance and the water use efficiency was not proven statistically.

Keywords: nitrogen deficiency, potassium surplus, photosynthetic activity, transpiration, macroelements

INTRODUCTION

Nowadays, increasing number of cases has been proven the importance of the quality of the transplants in the vegetable growing practice. The quality of the seedlings is significantly affected by the nutrient supply.

The nitrogen, phosphorus and potassium are called "critical" elements of the plants (Sihna, 2004).

The **nitrogen** is an essential component of many molecules, like proteins, amino acids, nucleic acids, the chlorophyll, some hormones, etc. It has important role in the photosynthesis, protein synthesis, respiration, and a lot of other growing and metabolic processes (Nátr, 1998; Larcher, 2003; Sihna, 2004). The visible nitrogen deficiency symptoms can be observed at first on the matured leaves, because of the high mobility in the plants. The main characteristic deficiency symptom is the chlorosis, the yellowing of the leaves (Larcher, 2003; Sihna, 2004; Terbe and Orosz, 2011). In case of **nitrogen** deficiency, the growing of the aboveground part of the plants is decreasing (Nátr, 1998), and shoot/root ratio is lower (Nátr, 1998; Ciompi *et al.*, 1996; Doncheva *et al.*, 2001). In case of cotton, Radin and Ackerson (1981) observed the decrease the water potential for stomatal closure at the increasing nitrogen level of the nutrient solution. Ciompi *et al.* (1996) proved the decrease of the photosynthetic activity of the plants in nitrogen deficiency, in young sunflower plants. According to González-Meler *et al.* (1998), in the case of nitrogen limitation, the leaf respiration rates of sweet pepper is reducing. At the trial of Doncheva *et al.* (2001), the decreasing of the chlorophyll content and photosyntetic activity was observed also in case of sweet pepper plants, in the adult plants grown in absence of nitrogen. The high nitrogen level increase the shoot dry weight, but decrease the dry matter content of the vegetable transplants (Masson *et al.*, 1991a). The good nitrogen supply (300 and 400 mg . l^{-1}) in the transplant age can improve the yields on the fields, in case of many vegetable species (Masson *et al.*, 1991b).

The **potassium** has also role in many metabolic processes (photosynthesis, respiration, translocation, etc.), and it is an activator more than 40 enzymes. Very important role in the control of osmotic potential of the plants and the permeability of the biological membranes (Nátr, 1998; Larcher, 2003; Sihna, 2004). The first visual symptoms of the potassium is the yellowing of the leaves, in the intervenal regions (Terbe, 2011). Similarly to the nitrogen, the potassium also highly mobile element, it can be observed the highest concentration of it in the young plant tissues (Sihna, 2004). The deficiency of potassium causes disturbance in the water balance of the plants, also (Egilla *et al.*, 2005; Terbe and Orosz, 2011). According to experience of Wen Xu *et al.* (2011), both the deficiency and high surplus of potassium can lead to water loss through high transpiration rate and low water absorption. At their experiment in test plants (*Houttuynia cordata* Thunb) the optimal potassium supply resulted the highest chlorophyll concentration. Lei Ma *et al.* (2011) also observed that the optimal potassium fertilizing can increase the chlorophyll content. At their trial (test plant: *Stevia rebaudiana* Bertoni), the favourable potassium supply improved photosynthesis rate and decreased the chlorophyll a/b ratio. As the observation of Kanai *et al.* (2011), the potassium deficiency stress decreased photosynthesis, expansion and transport of ^{14}C assimilates of the source leaf in case of greenhouse tomato plants. The potassium overdose resulted salt-damage symptoms, or the deficiency of some antagonist element (Ma, Ca, B, Zn, Mn) (Terbe, 2011).

The good **phosphorus** supply is important for the energy balance of the plants; it is a main constituent of the ATP molecules (Nátr, 1998). Next to this, the phosphorus is needed for nucleic acids, phospholipids, sugar phosphates, etc (Sihna, 2004). The deficiency of this element can be observed by the undeveloped of the root system (less side-roots), and the greenish grey or purple colour of the leaves (Terbe, 2011).

According to Kappel (2008), the recommended macroelement concentration in the nutrient-solutions in the transplant-growing period is: 250–260 mg . l^{-1} N, 40–60 mg . l^{-1} P, 250–260 mg . l^{-1} K. As the observation of Bar-Tal *et al.* (1990), the optimal N content for the sweet pepper transplants (in peat-vermiculite 1:1 v/v substrate) is 5 mM, while the optimal phosphorus concentration was 0.5 mM. In case of sweet pepper transplants, at the trial of Aloni *et al.* (1991) nitrogen levels below 100 mg . l^{-1} inhibited shoot growth and leaf chlorophyll content. The optimal potassium content in the vegetable transplant production is not clear, in case of tomato Melton and Dufault (1991) did not found deficiency effect on the transplant growing parameters also at 25 mg . l^{-1} potassium level – which is only 10% of the recommendation of Kappel (2008).

According to Bar-Tal *et al.* (1990), the optimal sweet pepper seedling can be characterized by the 39 g . kg^{-1} N, 5.5 g . kg^{-1} P and 67 g . kg^{-1} K in dry matter.

The aim of our trial was to find that physiological parameters, which can show the effect of nutrient supply of the sweet pepper transplants in that case, when the deficiency (N) and surplus (K) does not results perceptible symptoms. In addition, the critical macroelement content of the green parts was examined to study the effect of treatments on nutrient-uptake.

MATERIALS AND METHODS

The trial was conducted in 2011 in Lednice at the Faculty of Horticulture of Mendel University in Brno. As a model plant was selected *Capsicum annuum* L. 'HRF F1' (indeterminate growth, conical white fruits, Hungary origin).

The seeds were sown into the polystyrene trays filled with white-peat based substrate ('POT 20') on August 19th 2011. On the 28th day after sowing (September 16th), the plants were transplanted to the polyethylene pots (size: 70×70×65 mm). Before planting, the pots were filled with wetted, pure Shagnum peat substrate. The average pot contained 26.5 g mass of dry substrate.

After the pricking, the plants were irrigated with phosphorus-overdosed fertilizer solution (Yara Ferticare Starter, N:P:K = 15:30:15, concentration: 0.2%). After this, during a week, every plant was irrigated with solution of Yara Ferticare I. (N:P:K = 14:11:25, concentration: 0.2%), independently of the final treatments.

The treatments of different nutrient solutions were started on the 40 days after sowing (September 28th). The plants were separated to three groups. Every group contained 25 plants, and the groups were placed next to each other, on a transplant growing table. The applied nutrient solutions were mixed from deionized water and "mono" fertilizers (ammonium nitrate, potassium sulphate and monopotassium phosphate). The macroelements concentration of the control solution was determined based on the nutrient content of Ferticare I. fertilizer. The nutrient content of solutions is shown in the Tab. I. The nutrient solutions were used in every irrigation.

I: *Macroelement content of fertilizing solutions [g . l⁻¹]*

Treatment	Nitrogen	Phosphorus (P_2O_5)	Potassium (K_2O)
Control	28	22	50
Nitrogen deficiency	0	22	50
Potassium surplus	28	22	100

The transplant growing was conducted in heated greenhouse (20–24 °C by day, 16–18 °C by night; natural lighting). 7 days before the measuring of the plant physiology processes, the plants were transported to the laboratory. During this period, the plants were grown under controlled conditions (8 hours lighting, 24 °C; 16 hours dark, 16 °C). At the day period, the light conditions were similar to the measuring conditions.

The measuring of the plant physiology processes were carried out on November 7th (the 81st days after sowing, 40 days after the first applying of the special nutrient solutions), at the 9–11 leaves stage of the plants. From every treatments, 12 average plants were selected for the measuring.

The portable photosynthetic system LCpro+ with an infrared gas analyzer and leaf chamber was used to measure the rate of photosynthesis. The conditions of chamber: 25 °C, light irradiance 650 µmol $m^{-2}s^{-1}$. It was registered the photosynthetic rate (A [µmol $CO_2 . m^{-2} . s^{-1}$]), transpiration rate (E [mmol $H_2O . m^{-2} . s^{-1}$]) and stomatal conductance (gs [mol $CO_2 . m^{-2} . s^{-1}$]) of the leaves. The water use efficiency was calculated based on the following formula: WUE = A / E [µmol CO_2 . mmol H_2O^{-1}]. For the observation of the physiological parameters, the youngest fully-developed leaves were measured.

For the fast and orientational measuring of the chlorophyll content was used the Yara N-tester. The instrument operates by measuring the chlorophyll content of the leaves. (The showed data is a relative index.). The same leaf was measured like in case of the measuring of the A, E and gs value, in 30 micro-sampling place on the leaves.

After the measuring of the plant physiology processes, the aboveground parts of the plants (shoot and leaves) were dried at 40 °C. The dry weight of plants was measured individually. From the dry samples [g per plants], the N, P and K [mg . g^{-1}] content was analyzed at the Plant Analytical Laboratory of the Department of Vegetable and Mushroom Growing, Corvinus University of Budapest. After the digestion by sulphuric acid, the nitrogen content was analysed by the Kjeldahl-method. The phosphorus content was measured by spectrophotometer, while the potassium content was analyzed by flame photometer.

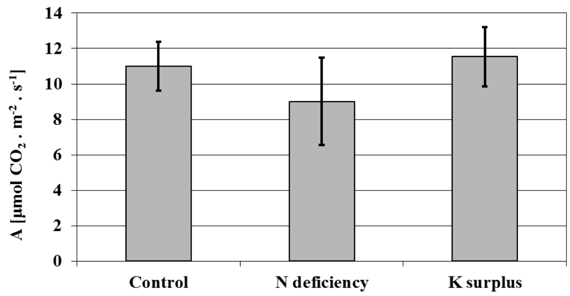
The results were processed in 'RobStat' using method Anova and Tukey-Kramer pairwise comparison or Games-Howell pairwise comparison of means, at level of 90–95–99% probability. The values of standard deviation are presented in all figures.

RESULTS

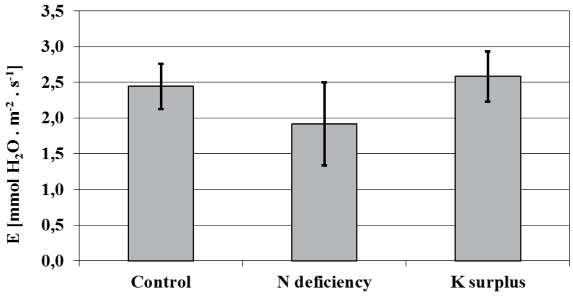
Photosynthetic rate (A). The potassium surplus treatment resulted the most intensive photosynthesis (11.54 µmol $CO_2 . m^{-2} . s^{-1}$) (Fig. 1). However, the photosynthetic rate of the control plants was very similar (11.00 µmol $CO_2 . m^{-2} . s^{-1}$) to them. The plants treated with nitrogen deficient solution were characterized by the lowest average value (9.01 µmol $CO_2 . m^{-2} . s^{-1}$). The nitrogen deficiency resulted statistically ($p < 0.05$) lower photosynthetic rate than the potassium surplus.

Transpiration rate (E). The average values and the standard deviation of the treatments are presented in the Fig. 2. The tendency among the treatments was the similar to the photosynthetic activity. The plants grown in nitrogen deficient nutrient solution shown the lowest transpiration activity (1.92 mmol $H_2O . m^{-2} . s^{-1}$). The highest average value was observed in the case of potassium surplus treatment (2.58 mmol $H_2O . m^{-2} . s^{-1}$). The statistical analysis confirmed the significant difference between the nitrogen deficiency and potassium surplus treatments, on $p < 0.05$ level. The control nutrient solution resulted average value. (The ANOVA proved differences between the control and nitrogen deficiency treatment on $p < 0.1$ level.)

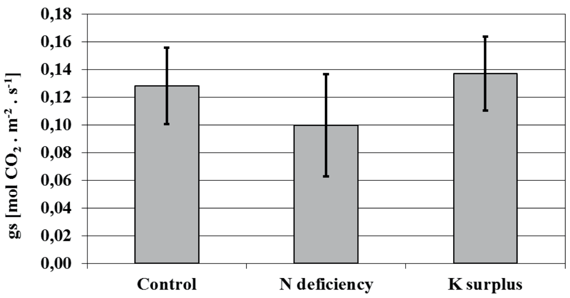
The **stomatal conductance (gs)** of the leaves showed the same tendency, like the transpiration rate and photosynthetic rate, however the statistical analysis did not prove the differences between the treatments, because of the variability of the data in the groups (Fig. 3).



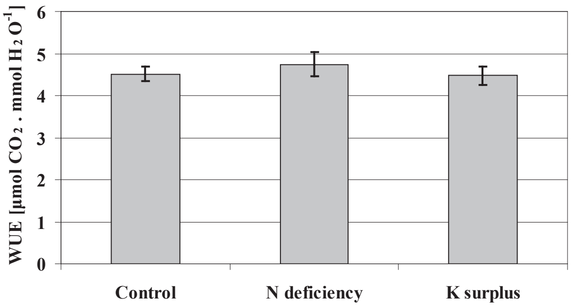
1: *Photosynthetic rate (A) of sweet pepper transplants grown in different nutrient solutions*



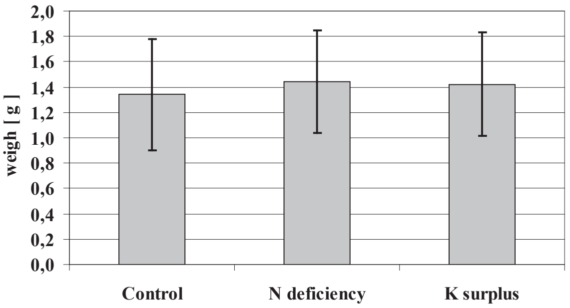
2: *Transpiration rate (E) of sweet pepper transplants grown in different nutrient solutions*



3: *Stomatal conductance (gs) of sweet pepper transplants grown in different nutrient solutions*



4: *Water use efficiency (WUE) of sweet pepper transplants grown in different nutrient solutions*



5: *Dry weight of the sweet pepper transplants grown in different nutrient solutions*

As the effect of treatments, the **water use efficiency (WUE)** of the leaves was not significantly different. The nitrogen deficiency resulted the highest efficiency, the average value of the plants in this treatment was 4.75 µmol CO_2 . mmol H_2O^{-1} (Fig. 4).

The treatments were of not significant effect to the **dry weight of plants**, the average values of the treatments were between 1.34 g and 1.44 g (Fig. 5).

The average values and the standard deviation of the main macroelement (N, P, K) content in the top parts of the plants are presented in the Tab. II.

The **nitrogen content** was measured by two way. The fast analysis method, which is non-destructing method of the showing the relative chlorophyll status of the plants (N-tester), between the higher potassium supply and nitrogen deficiency observed significant differences ($p < 0.05$) (650.38 and 610.69 relative values). The laboratory analysis (after the drying) showed the differences also between the control and nitrogen deficiency treatment. The 40 days using of the nitrogen deficient nutrient solution resulted significant ($p < 0.05$) lower nitrogen content in the green parts than the solutions contained 28 g nitrogen per liter.

The **phosphorus content** of the green part show the same tendency, like was observed in the most parameters: the nitrogen deficiency resulted significant lower value than the potassium surplus, and in the control treatment was observed average value.

According to the results of **the potassium content** analysis, it can be said, that the positive effect of the higher potassium supply was detected, and the effect was very strong (statistically proved effect on $p < 0.01$). The significant difference was found between the potassium surplus and nitrogen deficiency, and also between the potassium surplus and control treatment.

DISCUSSION

At the experiment the nitrogen deficiency and the applied potassium surplus level did not results perceptible symptoms, both groups of plants were characterized by the same colour and size according to the visual observations.

Compared to the optimal nutrient supply control treatment, the examined plant physiology processes did not changed significantly affected by the nutrient supply treatments. However, in the most parameters was significant favourable effect of the extra potassium supply, compared with the effect of fertilizing with nitrogen-absent solution.

Based on the stomatal conductance and water use efficiency value, it was not observed high differences between the treatments in the water balance of plants. However, the transpiration rate and the photosynthetic activity showed the positive effect of the potassium supply and also the negative effect of nitrogen deficiency. The results confirmed and

II: *Nitrogen, phosphorus and potassium content of the green parts*

Treatments	Nitrogen [mg . g^{-1}]		Phosphorus [mg . g^{-1}]		Potassium [mg . g^{-1}]	
	Average	SD	Average	SD	Average	SD
Control	48.05	3.30	8.91	0.71	74.00	5.18
N deficiency	38.45	2.92	8.61	0.62	76.75	5.72
K surplus	48.65	2.68	9.40	0.76	85.00	4.68

supplemented the observations of Kanai *et al.* (2011) and Lei Ma *et al.* (2011) (effect of potassium supply), and Ciompi *et al.* (1996) and Doncheva *et al.* (2001) (nitrogen deficiency).

Examined the nutrient content of the transplants, although in the previous 40 days before measuring the nutrient solution in the nitrogen deficiency treatment did not contain any nitrogen, the plants could use the storage nitrogen from the substrate and some from the older plant parts.

According to Bar-Tal *et al.* (1990), it can be concluded, that in our experiment the transplants grown in the control treatment, contained more nitrogen, phosphorus and potassium, than their recommendation. We observed in the nitrogen deficiency treatment the similar amount of nitrogen, which was recommended based on the optimal treatment in their experiments. The ratio of the N:P:K content of the plants in our experiment was 1:0.18:1.54, while in their observation was 1:0.14:1.7. However, it can be caused by the differences of the climatic conditions from the transplant growing, and also from the different cultivars used like test plants. 39 g . kg^{-1} N, 5.5 g . kg^{-1} P and 67 g . kg^{-1} K in dry matter.

According to the experience of Del Amor (2006), in our experiment was also observable the effect of the fertilizing by the non-destructive measuring way of the chlorophyll content (Yara N-tester). However, it was found a sensitivity of the sampling: the fast test showed only the high differences in case of young fully-developed leaves in the nitrogen content. In the laboratory, when the whole plant (green part) was analyzed, the minor differences also were observable. Probably, testing the older leaves shows more significant differences analyzed by the fast N-test, because of the translocation of the element inside of the plants (Sihna, 2004; Terbe and Orosz, 2011).

CONCLUSION

The potassium surplus resulted significantly higher transpiration activity (2.58 mmol H_2O. m^{-2} . s^{-1}) and photosynthetic activity (11.54 µmol CO_2. m^{-2} . s^{-1}) than the nitrogen deficiency (E: 1.91 mmol H_2O. m^{-2} . s^{-1} and A: 9.01 µmol CO_2. m^{-2} . s^{-1}), but without significant differences with control treatment The N, P and K content of green parts was significantly lower in the nitrogen deficiency treatment, than in the case of the potassium surplus, too. The effect of treatments on the dry weight of the plants, the stomatal conductance and the water use efficiency was not proven statistically. The transplants grown in the traditional fertilization technology (control treatment) almost in every measured parameters shown average value.

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