Uptake of Phosphorus and Potassium in Roots of Tomato (*Lycopersicon esculentum* Mill., cv. “Sidra F_1”) as Dependent Upon Soil Chemical Properties

MILENA DJURIC[1], PAVLE MAŠKOVIC[1], SRECKO CURCIC[2]*, MILAN PAVLOVIC[3], MILANKO LJUJIC[4]

[1]University of Kragujevac, Faculty of Agronomy, Cara Dušana 34, 32000 Čačak, Serbia

[2] University of Kragujevac, Faculty Technical Science Čačak, Svetog Save 65, 32000 Čačak, Serbia

[3] Univesity of Novi Sad,Technical faculty- Mihailo Pupin-, 23000 Zrenjanin, Serbia

[4] JKP 17 september, 32300 Gornji Milanovac, Serbia

The objective of this study was to evaluate the degree of phosphorus and potassium uptake in roots of tomato (Lycopersicon esculentum Mill., cv. 'Sidra F_1') as dependent upon the chemical properties of the soil. The experiment was conducted during 2010 and 2011 under controlled greenhouse conditions at the Faculty of Agronomy, Čačak.. The material used in the study included tomato seedlings and 9.5 litre pots filled separately with one of the following soil types: chernozem, vertisol, fluvisol and pseudogley, which were collected from four different sites located in the Moravica District region in Serbia. Immediately before the experiment, each soil type was subject to chemical analysis to evaluate pH, cation exchange capacity, humus content, and available phosphorus and potassium levels. pH was determined by a digital pH metre, humus content by the bichromatic method, cation exchange capacity (CEC) by the ammonium acetate method, and phosphorus and potassium content by the AL-method. The objective of this part of the analysis was to assess the chemical properties of the test soils prior to the experiment. The experiment was set up in a randomised block design in four treatments (soil types) in five replications. Each treatment in each replication was presented with ten tomato plants which means that the experiment included a total of 200 plants. The agro-technical measures applied in all experimental plots were identical. The P and K content of tomato roots was determined at both the flowering and full maturity phenostage using the AAS method. The results showed that the uptake of both phosphorus and potassium was highest in the treatment involving tomato cultivation on vertisol and lowest in that on luvisol and pseudogley. As opposed to the other soil types, vertisol had favourable chemical properties: neutral to slightly acid reaction, a high cation exchange capacity and a high humus content, which favoured the uptake of phosphorus and potassium by the plant. Luvisol and pseudogley basically do not have these characteristics; therefore, these soils can be recommended for tomato cultivation only after improvement of chemical properties.

Key words: nutrition, humus, cation exchange capacity, pH, soil

Climate and edaphic factors in the Republic of Serbia offer exceptionally favourable conditions for tomato production, due to which there has been a long tradition of widespread tomato cultivation in Serbia. Notwithstanding this fact, tomato yields per unit area in Serbia are rather low as compared to the European average. Low yields of tomato are not the result of the genetic potential of the cultivars and hybrids used but rather of an inadequate use of cultural practices in tomato growing, notably irrigation and fertilisation [1].

Apart from the above factors, successful tomato production also depends upon the type of soil used for the cultivation of this crop. Only soils that exhibit a stable structure, high biological activity, good aeration and water infiltration and retention capacity, favourable chemical properties and a high level of available nutrients have the potential to become a medium for the cultivation of this and other agricultural crops [2].

The objective of this study was to evaluate the degree of phosphorus and potassium uptake in tomato as (*Lycopersicon esculentum* Mill., cv. 'Sidra F_1') dependent upon the chemical properties of the soil used for tomato cultivation.

Phosphorus (P) and potassium (K) are dealt with in this study due to their vital role for tomato development. Phosphorus forms part of nucleoproteins, phospholipids and a large number of enzymes involved in energy processes, which is directly correlated with the development of the plant as a whole and its root system in particular [3].

Potassium plays an important role at the stage of tomato maturation since it activates or regulates the activity of over 80 enzymes closely associated with nutrient synthesis. Moreover, potassium is important for plant osmoregulation since it directly induces a change in the osmotic potential and cell turgor [4]. This study was conducted on four different soil types, including leached soil (luvisol), pseudogley, alluvial soil (fluvisol) and vertisol, which are widely present in the Republic of Serbia.

Experimental part

Materials and methods

This study was conducted in 2010 and 2011 under controlled greenhouse conditions at the Faculty of Agronomy in Čačak. The material used in the study included tomato (*Lycopersicon esculentum* Mill., cv. 'Sidra F_1') plants and 9.5 litre pots filled separately with one of the following soil types: luvisol, pseudogley, fluvisol and vertisol. All seedlings of tomato ((*Lycopersicon esculentum* Mill., cv. 'Sidra F_1') used in the study were produced in a certified

* email: srecko.curcic@ftn.kg.ac.rs

Soil chemical properties	Soil type			
	Pseudogley	Fluvisol	Vertisol	Luvisol
pH (KCl)	4.4	6.9	6.9	4.9
Humus content (%)	2.39	3.03	4.56	3.16
Exchange capacity (meqv $100g^{-1}$ soil)	14	22	40	16
Phosphorus content (mg $100g^{-1}$ soil)	13.2	35.0	51.6	3.4
Potassium content (mg $100g^{-1}$ soil)	24	63.2	89.5	17.7

Table 1
CHEMICAL ANALYSIS OF SOIL TYPES

Soil type	Average content of P in tomato roots (% dry matter)			
	Stage of development (flowering)		Stage of development (maturity)	
	2010 year	2011 year	2010 year	2011 year
Pseudogley	0.58±0.04 [1]	0.60±0.01	0.58±0.06	0.52±0.03
Fluvisol	0.75±0.07	0.78±0.08	0.72 ±0.07	0.73 ±0.02
Vertisol	0.79±0.09	0.82±0.04	0.80 ±0.03	0.73 ±0.04
Luvisol	0.52±0.08	0.50±0.05	0.45 ±0.10	0.48 ±0.05
$Lsd_{0.01}$=0.19				

[1]Values of standard error of mean are given after ±.

Table 2
AVERAGE CONTENT OF P IN TOMATO ROOTS (% DRY MATTER)

plantation near the Faculty, and according to form and uniformity of appearance to each other did not significantly differ.

Soil samples were collected from four different sites located in the Moravica District region, i.e. luvisol from Trbušani, pseudogley from Prijevor, fluvisol from Trnava and vertisol from Zablaće. The soil was sampled from different plot zones at a depth of up to 40 cm and mixed thereafter to obtain uniformity of each soil type tested. Immediately upon soil delivery to the greenhouse, the pots were filled with adequate soil types. Before that, each soil type was subject to chemical analysis to evaluate *p*H, cation exchange capacity, humus content, and available phosphorus and potassium levels.

*p*H was determined by a digital pH metre [5], humus content by the bichromatic method [6], cation exchange capacity (CEC) by the ammonium acetate method [7] and phosphorus and potassium content by the AL-method [8]. The objective of this part of the analysis was to assess the chemical properties of the test soils prior to the experiment.

In both years of study the planting of tomato seedlings were performed in May wherein each seedlings planted separately in each pot. The experiment was set up in a randomised block design in four treatments (soil types) in five replications. Each treatment included ten tomato plants, making up a total of 200 plants. The trial design was identical in both years.

Throughout the experiment, all tomato plants received identical care, irrigation, fertilisation, and other cultural operations vital for successful plant growth. Tomato plants were grown under conditions of organic production. The P and K content of tomato roots was determined at both the flowering and full maturity phenostage using the AAS method [9].

The data obtained were subject to standard statistical methods of the analysis of variance (ANOVA) and multiple test ($Lsd_{0,01}$) using Microsoft Excel 2003. The data analysed were used to interpret the results of the study and draw corresponding conclusions.

Results and discussions

The results of the chemical analysis of the test soil types are presented in table 1.

Table 2., 3. and 4. outline the average P content of tomato roots as dependent upon soil type, plant development stage and year of the study.

Tables 5, 6 and 7 show an analysis of the average K content in tomato roots as dependent upon soil type, plant development stage and year of the study

Phosphorus content in tomato roots

The results given in tables 2 and 3 suggest significant dependence of the phosphorus content in tomato roots on the chemical properties of the soil used for tomato cultivation. A statistically significantly higher P content was found in the roots of tomato plants cultivated on vertisol and fluvisol (alluvium) than in those grown on luvisol and pseudogley, regardless of plant phenostage and year of the study. These results are compatible with the findings of many scientists who also reported a lower uptake degree on pseudogley and especially on luvisol as compared to the other soil types [10-12]. Reasons for the lower uptake of phosphorus by plants grown on luvisol and pseudogley include lower P and K contents in these soils, low *p*H and a low humus content, this being very unfavourable in terms of phosphorus uptake [13]. Namely, at low *p*H, aluminium ions are released from the soil adsorption complex to create strong bonds with phosphorus ions and, hence, block the uptake of phosphorus in the plant [14]. Moreover, in soils deficient in organic matter, the degree of phosphorus uptake is lower, due to the lower ability to create bonds between humus components and Al and Fe ions. These results in Al and Fe ions remaining free in the soil solution and bonding to phosphorus ions, making them unavailable for plants.

Sources of variation	Degrees of freedom	Mean squares	F-exp.	Significance
Soil type(A)	3	0.00116	36.971	**
Development stage (B)	1	0.00120	38.160	**
Year (C)	1	0.000416	13.204	ns
Interaction AB	3	0.0000708	2.244	**
Interaction AC	3	0.000522	16.549	ns
Interaction BC	1	0.0000374	1.187	ns
Interaction ABC	3	0.000181	5.765	ns
Error	75	0.0000315		

** - highly significant ; ns - non significant

Table 3
ANLYSIS OF VARIANCE OF THE AVERAGE CONTENT OF P IN TOMATO ROOTS

Stage of development	Soil type			
	Pseudogley	Fluvisol	Vertisol	Luvisol
Flowering	0.591	0.762	0.804	0.508
Full maturity	0.552	0.725	0.763	0.466
Lsd $_{0.01}$=0.036				

Table 4
INTERACTION AB - SOIL TYPE x DEVELOPMENT STAGE

Soil type	Average content of K in tomato roots (% dry matter)			
	Stage of development (flowering)		Stage of development (maturity)	
	2010 year	2011 year	2010 year	2011 year
Pseudogley	5.34±0.12 [1]	6.05±0.07	6.34±0.13	5.90±0.13
Fluvisol	8.11±0.17	7.91±0.13	7.86±0.06	6.86±0.12
Vertisol	8.73±0.09	8.68±0.11	8.33±0.14	7.61±0.26
Luvisol	3.98±0.12	3.83±0.10	4.00±0.22	2.86±0.24
Lsd $_{0.01}$=0.29				

[1]Values of standard error of mean are given after ±.

Table 5
AVERAGE CONTENT OF K IN TOMATO ROOTS (% DRY MATTER)

The analysis of variance of the average content of P in tomato roots also showed a statistically significantly high effect of plant development stage on phosphorus content in tomato roots, with the differences on year level being random (table 3). The analysis of the relationship between interaction means in the soil type x development stage interaction shows a decrease in the average phosphorus content in the root, from the stage of flowering until full maturity in all soil types (table 4). The decrease in phosphorus content in tomato roots in the maturation stage was as expected, given the plant phosphorus demand during plant development.

Potassium content in tomato roots

In both years, the highest K content in tomato roots was found in the treatment involving cultivation on vertisol (table 5). These results are attributed to the more favourable chemical characteristics of vertisol as compared to the other soil types tested. Vertisol was found to have neutral *p*H, high exchange capacity and good supply with potassium, which favoured potassium uptake by the plant. Similar results were reported by many other authors who also determined a high degree of K uptake by plants grown on vertisol [15, 16].

The lowest K content in tomato roots was found in plants grown on luvisol and pseudogley, regardless of plant phenostage and year of the study. The lower uptake of potassium by plants grown on luvisol and pseudogley was due to low K content, acid *p*H and low cation exchange capacity [17]. The unsuitability of luvisol and pseudogley as media for tomato cultivation was very easily observed, being reflected in the very appearance of the root of tomato plants grown on these soils, which was short, poorly branched, of an untypical colour, showing first symptoms of decay.

The analysis of variance of the average content of K in tomato roots also showed a statistically significant decrease in K content in tomato roots from the stage of flowering to full maturity in all soil types, which was realistically expected, given the plant demands for potassium at the maturation stage (table 6, 7).

The present study also suggest a positive correlation between the degree of phosphorus and potassium uptake by tomato plants, regardless of the soil type used for tomato cultivation. Depending on soil chemical properties, the decrease in potassium uptake corresponded to the decrease in phosphorus uptake by the plant, and vice versa.

Sources of variation	Degrees of freedom	Mean squares	F-exp.	Significance
Soil type(A)	3	0.944	2.716	**
Development stage (B)	1	0.232	667.632	**
Year (C)	1	0.240	690.459	ns
Interaction AB	3	0.00714	20.547	**
Interaction AC	3	0.00585	16.838	ns
Interaction BC	1	0.163	469.944	ns
Interaction ABC	3	0.00358	10.313	ns
Error	75	0.000347		

** - highly significant ; ns - non significant

Table 6.
ANALYSIS OF VARIANCE OF THE AVERAGE CONTENT OF K IN TOMATO ROOTS

Development stage	Soil type			
	Pseudogley	Fluvisol	Vertisol	Luvisol
Flowering	5.70	8.01	8.70	3.90
Full maturity	6.12	7.35	7.87	3.43
$Lsd_{0.01}$=0.294				

Table 7
INTERACTION AB - SOIL TYPE x DEVELOPMENT STAGE

Conclusions

The degree of potassium and phosphorus uptake by tomato plants (*Lycopersicon esculentum* Mill., cv. 'Sidra F_1') is higher in plants cultivated on soils having neutral to slightly acid reaction, increased organic matter content and higher cation exchange capacity. Luvisol and pseudogley basically do not have the reported characteristics; therefore they can be recommended for tomato cultivation only after improvement of their chemical properties, most notably through an increase in *p*H by liming, followed by the use of meliorative fertilisation to increase P and K levels as needed.

Phosphorus and potassium uptake is also substantially affected by soil physical characteristics, available P and K levels in the soil, and plant requirements for these nutrients at certain stages of development. Any fertilisation recommendation that is not based on these parameters but on subjective visual estimation results in a drastic reduction in both yield and quality of the crop and potential harmful leaching of nutrients from the soil into groundwaters.

References

1 GVOZDANOVIC-VARGA, J., LAZIC, B., GVOZDENOVIC, DJ., VASIC, M., BUGARSKI, D., TAKAC, A., JOVICEVIC, D., CERVENSKI, J. 2006. Development of vegetable production over the last 40 years. Zbornik radova Instituta za ratarstvo i povrtarstvo **42**: 191-206.

2.RESULOVC, H., ČUSTOVIC, H., ČENGIC, I. 2008. Sistematika tla/ zemljišta. Sarajevo: Faculty of Agriculture and Food Sciences. p. 171

3 SCHACHTMAN, D.P., REID, R.J., AYLING, S.M. 1998. Phosphorus Uptake By Plants: From Soil to Cell. Plant Physiology **116**(2): 447-453.

4. PETTIGREW, W.T. 2008. Potassium influences on yield and quality production for maize, wheat, soybean and cotton. Physiologia Plantarum **133**(4): 670-681.

5. *** ISO, 10390 standard. 1994. Soil Quality - Determination of pH. International Organization for Standardization. Geneve, Switzerland. 5 p.

6. ALLISON, L.E. 1965. Organic carbon. In Methods of Soil Analysis. Part 2. Madison, Wisconsin. p. 1367-1378.

7. CHAPMAN, H.D. 1965. Cation exchange capacity. In Methods of Soil Analysis. Part 2. Madison, Wisconsin. p. 891-901.

8. EGNER, H., RIEHM, H., DOMINGO, W.R. 1960. Untersuchungen uber die chemische Bodenanalyseals Grundlage fur die Beurteilung de Nahrstoffzustandes der Boden. II. K. LantbrHogsk **26**: 199-215.

9. HANLON, E.A. 1998. Elemental determination by Atomic Absorption Spectrophotometry. Handbook of Reference Methods for Plant Analysis. CRC Press. p 157-165.

10. ARAUJO M.S.B., SCHAEFER, C.E.R., SAMPAIO, E.V.S.B. 2003. Plant Phosphorus Availability in Latosols and Luvisols from Northeastern Semi-arid Brazil. Communications in Soil Science and Plant Analysis **34**(3-4): 407-425.

11. MARKOVIC, M., D. SUPIC, 2003. Charactistics of pseudogley of Gradiska area with recommnedations for agromeliorative treatments. Agroznanje **4**(1): 142-154.

12. PETOSIC, D., V. KOVACEVIC, M. JOSIPOVIC, 2003. Phosphorus availability in hydromorphic soils oh Eastern Croatia. Plant, Soil and Environment **49**(9): 394-401.

13. EFIMOV V.N., SUVOROV, A.K., BUBUKAR D. 2001. The role of acidic soil components in phosphorus sorption. Eurasian Soil Science **34**: 598-607.

14. BOŠKOVIC-RAKOČEVIC, LJ., UBAVIC, M., JAKOVLJEVIC, M., MILIVOJEVIC, J. 2004. Effects of pseudogley chemical amelioration on the changes in soil and plant phosphorus and potassium contents. Journal of Agricultural Sciences **49**(2): 149-158.

15. ROSHANI, G.A., NARAYANASAMY, G., DATTA, S.C. 2005. Effect of potassium on root length density of wheat at different stages of growth. Journal of the Indian Society of Soil Science **53**(2): 217-221.

16. SRINIVASARAO, C., VITTAL, K.P.R., TIWARI, K.N., GAJBHIYE, P.N., SUMANTA K. 2008. Categorisation of soils based on potassium reserves and production systems: implications in K management. Soil Research **45**(6): 438-447.

17. JAKOVLJEVIC, M., KOSTIC, N., ANTIC-MLADENOVIC, S. 2003. The availability of base elements (Ca, Mg, Na, K) in some important soil types in Serbia. Proceedings for Natural Sciences **104**: 11-21

Manuscript received: 5.11.2013