Journal of Fruit and Ornamental Plant Research Vol. 13, 2005: 25-37

STUDIES ON THE ROOT SYSTEMS OF SWEET CHERRY TREES GRAFTED ON DIFFERENT ROOTSTOCKS – PRELIMINARY RESULTS

Mirosław Sitarek and Lidia Sas-Paszt

Research Institute of Pomology and Floriculture
Pomologiczna 18, 96-100 Skierniewice, POLAND
e-mail: msitarek@insad.pl

(Received October 20, 2005/Accepted December 12, 2005)

A B S T R A C T

Trees of two sweet cherry cultivars grafted on three different rootstocks were planted individually in rhizoboxes. The cultivars tested were 'Lapins' and 'Regina'. The rootstocks used were the dwarfing rootstocks P-HL A and GiSelA 5, and the vigorous rootstock F 12/1. The following data were collected: total root length, mean root diameter, total root surface area, total root volume, total number of root tips, root fresh weight and root dry weight. pH in the rhizosphere was measured with an antimony microelectrode. Roots were analyzed for nitrogen, phosphorus, potassium, magnesium and calcium content using standard laboratory techniques. Generally, root length, root surface area, root volume, and number of root tips were highest in GiSelA 5 and lowest in F 12/1. Root fresh weight and root dry weight were also highest in GiSelA 5. Root calcium concentration was lower in P-HL A and GiSelA 5 than in F 12/1. The rhizosphere pH in all three rootstocks was higher at the root tips than in the root bases or middle portions of the roots, especially in GiSelA 5. This means that the young and actively growing root tips are more actively engaged in ion transport than older root bases. Further experiments will concentrate on how the morphology and physiology of dwarfing rootstocks influence growth and performance in the scion cultivar. Ion transport between the root and the rhizosphere deserves special attention.

Key words: sweet cherry trees, rootstock, growth of root system, rhizosphere pH, mineral nutrients in roots

INTRODUCTION

Cherry rootstocks have been the subject of numerous studies. Dwarfing rootstocks such as P-HL A and GiSelA 5 reduce vegetative growth and increase productivity in comparison to vigorous rootstocks such as Mazzard seedling or F 12/1

(Franken-Bembenek, 1998; Grzyb et al., 1998; Sitarek et al., 1999; 2005; Wertheim, 1998). Trees grafted on dwarfing rootstocks also tend to bear earlier, and develop spurs, blossoms and fruit two or three years after being planted in the orchard (Grzyb et al., 1996; Schmidt and Gruppe, 1988; Sitarek and Grzyb, 2002a). Trees grafted on dwarfing rootstock tend to bear smaller fruit because of the lower leaf surface area to fruit mass ratio (Grzyb et al., 1998; Sitarek et al., 1999; Sitarek and Grzyb, 2002b).

Rootstock choice may affect mineral composition in the leaves of sweet cherry cultivars (Ystaas, 1990; Ystaas and Froynes, 1995). In trees grafted on dwarfing rootstocks, leaf calcium and magnesium content are lower than in trees grafted on vigorous rootstocks (Sitarek et al., 1998).

Little research has been done on the growth and development of the root systems of fruit trees cultivated in the temperate zone. Little is known about the processes which take place in the rhizospheres of horticultural plants, as compared to forest and ornamental plants. Some research has been done on mineral exchange in the rhizosphere in strawberries (Sas et al., 1999; 2002; 2003; Sas-Paszt and Żurawicz, 2004). Even though dwarfing rootstocks have been in use for many years, the mechanisms by which they reduce growth in the scion cultivar are still not well understood (Webster, 2004).

The aim of this study was to assess growth and mineral composition in the root systems of sweet cherry trees grafted on various rootstocks and grown in a controlled greenhouse environment. pH changes in the rhizosphere were also monitored. In this paper, we present the preliminary results we obtained after one measurement cycle.

MATERIAL AND METHODS

Plant cultivation

In the spring of 2003, trees of two sweet cherry cultivars grafted on three different rootstocks were planted individually in rhizoboxes measuring 75 × 50 × 10 cm. At planting, the trees had two-year-old root systems. The boxes were filled with mineral soil which had been passed through a 2 mm sieve. The cultivars tested were 'Lapins' and 'Regina' (both *Prunus avium* L.). The rootstocks used were the dwarfing rootstocks P-HL A (*P. avium* L. x *P. Pseudocerasus* L.) and GiSelA 5 (*P. cerasus* L. x *P. canescens* L.), as well as the vigorous rootstock F 12/1 (*P. avium* L.). Seven trees of each cultivar on each rootstock were studied, as well as seven ungrafted trees of each rootstock for a total of sixty three trees. The trees were grown in a greenhouse belonging to the Research Institute of Pomology and Floriculture in Skierniewice, central Poland.

In order to ensure good root growth up against the removable Plexiglas lids, the rhizoboxes were kept lid down at a 50º angle in special constructed racks (Fig. 1). The transparent lids were kept covered with black sheet plastic to exclude light. All plants were fertilized, irrigated and otherwise treated in the same way.

Figure 1. View of the experiment – the rhizoboxes in racks

Root morphology and rhizosphere pH

After the front wall of the rhizobox had been carefully removed, root morphology and pH in the rhizosphere were measured using methods which did not damage the roots (Marschner and Röemheld, 1983; Dinkelaker et al., 1993ab).

In the autumn of 2004, two root samples were collected from opposite corners of each rhizobox with a special 0.5 litre cylinder. The resulting holes were filled in with fresh soil. The following data were collected: total root length, mean root diameter, total root surface area, total root volume, total number of root tips, root fresh weight and root dry weight. All data were recorded in units per litre of soil. Measurements were made in accordance with the procedure described by Arsenault, using a Hewlett Packard ScanJet 6100C scanner and Delta-T software (Arsenault et al., 1995).

pH in the rhizosphere was measured by introducing an antimony microelectrode into the rhizosphere through a thin layer of agar (Marschner et al., 1982; Marschner and Römheld, 1983).

Determination of root dry biomass

About 7 g of air-dried plant material was dried at 105ºC for six hours, cooled for half an hour in a desiccator filled with silica gel, and then weighed. The procedure was repeated until the samples reached constant weight (Ostrowska et al., 1991).

Root mineral content

Roots were analyzed for nitrogen, phosphorus, potassium, magnesium and calcium content using standard laboratory techniques.

Wet mineralization of plant material to determine total nitrogen (Polish standard PN-73C-04576/12).

Plant material for the analysis of mineral composition was dried at 60°C

for 48 h, ground to pass through a 1 mm sieve and mixed thoroughly. The ground plant material was then mineralized in Kjeldahl flasks using the wet method H_2SO_4 catalyzed by H_2O_2 and $CuSO_4$ x 5 H_2O (Ostrowska et al., 1991). The mixture was cooled and diluted with deionised water to the specified volume. Total nitrogen was determined using the standard Kjeldahl method based on the steam distillation of ammonia from the alkalised solution, and determining the ammonia content in the distillate by titration.

Wet mineralization of plant material to determine macro-elements

Ground plant material (see above) was mineralized in teflon-coated containers in a microwave oven in a 5:1 mixture of HNO_3 and H_2O_2 under controlled temperature and pressure. Macro-element concentrations in the diluted digests were determined with an inductively coupled plasma emission spectrometer (ICP).

Statistical analysis

Data were elaborated using single factor ANOVA analysis, followed by Duncan's multiple range t-test at $P \leq 0.05$.

RESULTS

The rootstocks studied differed in terms of root growth parameters. Generally, root length, root surface area, root volume, and number of root tips were highest in GiSelA 5 and lowest in F 12/1. This was true for both grafted and ungrafted rootstocks (Fig. 2 – 6). Root fresh weight and root dry weight were also highest in GiSelA 5 (Fig. 7 and 8).

Root calcium concentration also depended on the rootstock, and was lower in the dwarfing rootstocks P-HL A and GiSelA 5 than in the more vigorous rootstock F 12/1. No significant differences in root nitrogen, phosphorus, potassium or magnesium concentrations were observed in this experiment (Tab. 1).

The rhizosphere pH in all three rootstocks was higher at the root tips than in the root bases or middle portions of the roots. This was true for both grafted and ungrafted rootstocks. The lowest pH values were measured in the meristematic root zones of GiSelA 5. This indicates that proton-mediated cation uptake was more intense in GiSelA 5 than in the other rootstocks (Fig. 9).

DISCUSSION

The preliminary results obtained in the experiment showed that the choice of rootstock influences root growth, root calcium concentration and rhizosphere pH in sweet cherry trees.

In the orchard, tree size is correlated with the size of the root system. Larger trees usually have larger root systems. When grown under Polish conditions, F 12/1 is the most vigorous of the rootstocks tested, and P-HL A is the most dwarfing (Sitarek et al., 1999; 2004). In this study, root growth was found to be the most active in GiSelA 5, and the least active in F 12/1. However, this may change in future growing seasons.

Earlier studies had shown that the choice of rootstock might also have an effect on nutrient content in leaves of

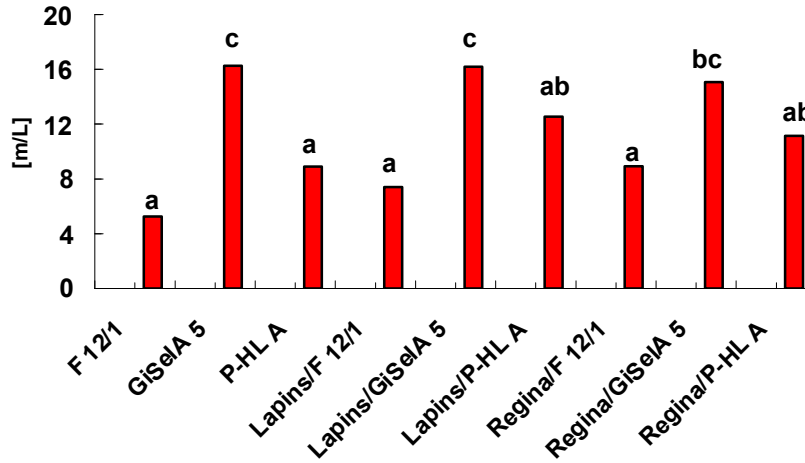

Figure 2. Total root length per litre of soil in different rootstock/scion combinations in the sweet cherry. Bars designated with the same letter are not significantly different

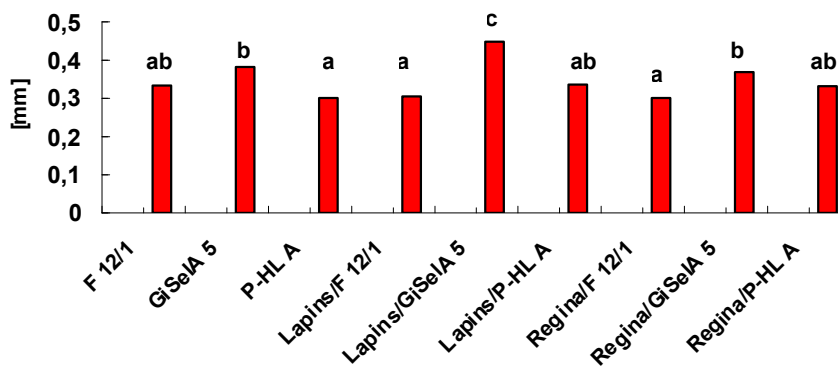

Figure 3. Average root diameter in different rootstock/scion combinations in the sweet cherry

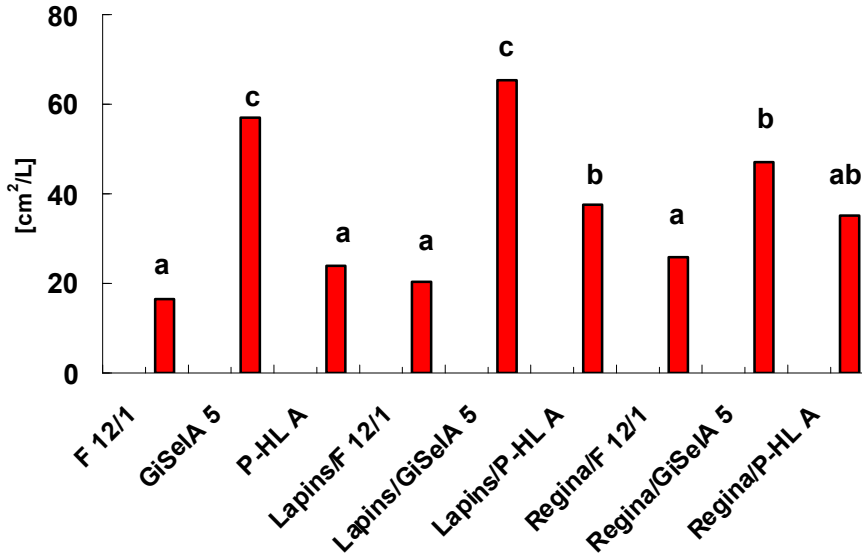

Figure 4. Total root surface area per litre of soil in different rootstock/scion combinations in the sweet cherry

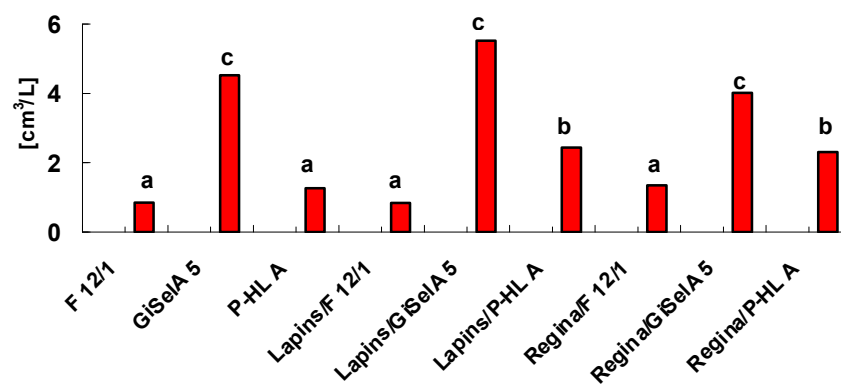

Figure 5. Total root volume per litre of soil in different rootstock/scion combinations in the sweet cherry

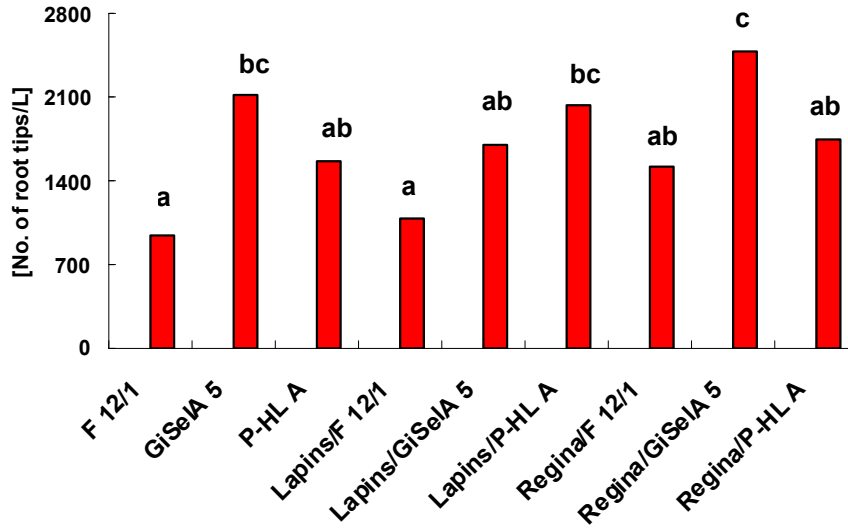

Figure 6. Total number of root tips per litre of soil in different rootstock/scion combinations in the sweet cherry

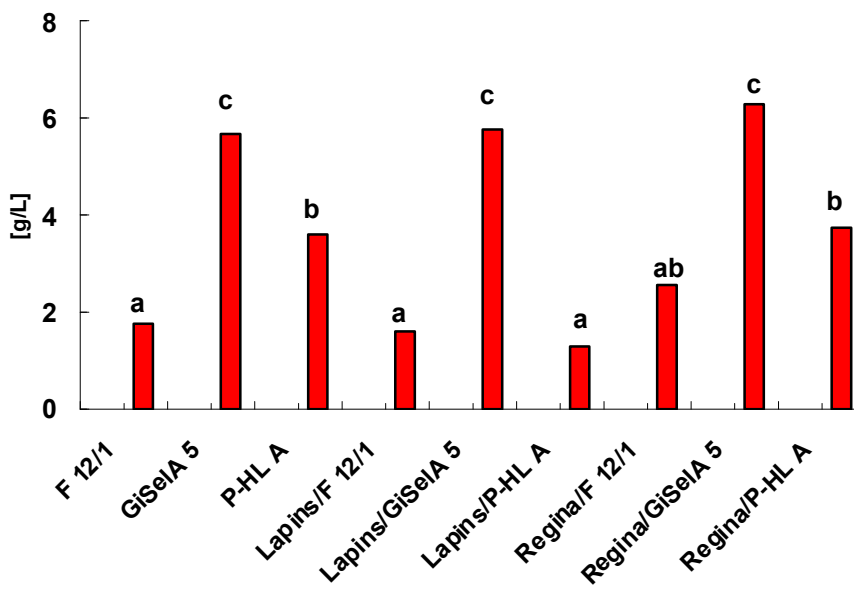

Figure 7. Weight of fresh roots per litre of soil in different rootstock/scion combinations in the sweet cherry

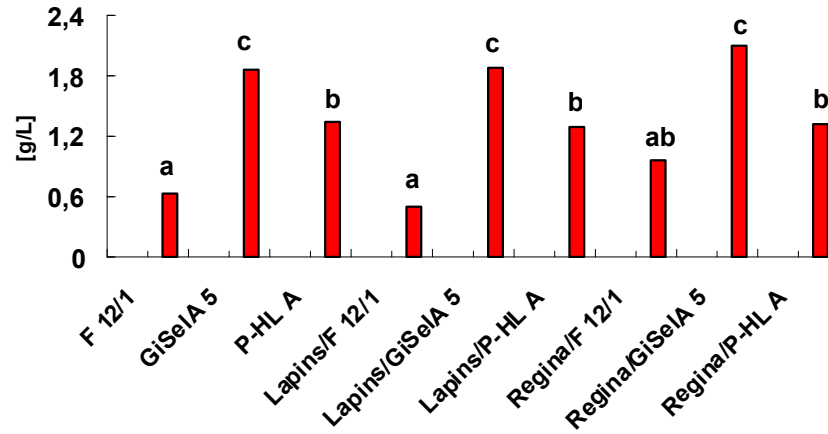

Figure 8. Weight of dry roots per litre of soil in different rootstock/scion combinations in the sweet cherry

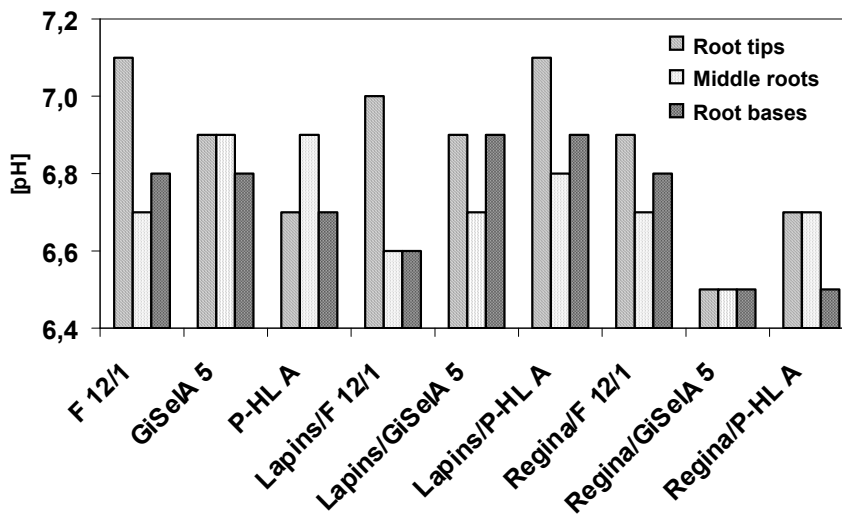

Figure 9. Rhizosphere pH in different parts of the root systems in different rootstock/scion combinations in the sweet cherry

Table 1. The concentration of major nutrients in different rootstock/scion combinations in the sweet cherry after one year of growth in rhizoboxes

Cultivar/rootstock combination	Constituent as percent of root dry matter				
	N	P	K	Mg	Ca
Ungrafted F 12/1	1.90*	0.10*	1.13*	0.23*	1.55 c**
Ungrafted P-HL A	2.02	0.13	1.00	0.21	1.26 b
Ungrafted GiSelA 5	1.84	0.13	1.02	0.20	1.00 a
Regina/F 12/1	1.86	0.13	1.05	0.21	1.23 b
Regina/P-HL A	1.92	0.11	1.05	0.22	1.03 a
Regina/GiSelA 5	2.12	0.15	1.11	0.25	1.08 a
Lapins/F 12/1	2.08	0.15	1.05	0.21	1.32 b
Lapins/P-HL A	2.22	0.13	1.15	0.21	1.13 a
Lapins/GiSelA 5	2.14	0.17	1.05	0.20	1.00 a
Mean for rootstock					
F 12/1	1.95	0.13	1.07	0.22	1.37
P-HL A	2.05	0.12	1.07	0.21	1.14
GiSelA 5	2.06	0.15	1.06	0.22	1.03

* No significant differences were observed in the concentrations of N, P, K and Mg in roots
** Means followed by the same letters are not significantly different

sweet cherry cultivars (Ystaas, 1990; Ystaas and Froynes, 1995). In another experiment conducted in Poland, leaves of trees grafted on P-HL A had lower levels of calcium and magnesium than leaves of trees grafted on F 12/1 (Sitarek et al., 1998).

In the present study, root calcium concentration was the only root mineral concentration to differ among the rootstocks tested. Root calcium concentration was higher in the vigorous rootstock F 12/1 than in the dwarfing rootstocks P-HL A and GiSelA 5. However, macro-element concentrations were generally much lower in the roots than in the leaves except for phosphorus.

Roots cause changes in rhizosphere pH due to proton-mediated ion transport. Protons are released during the uptake of cations such as NH_4^+, or during the release of anions such as HCO_3^- and organic acids (Marschner, 1995; Sas et al., 2001; 2002; 2003; 2004).

In all three rootstocks studied in this experiment, the lowest rhizosphere pH values were measured at the root tips, and the highest pH

values were measured at the root bases. This means that the young and actively growing root tips are more actively engaged in ion transport than older root base tissue. This agrees with an earlier study on strawberries, in which anion uptake was highest in the root tips and lowest in the root bases (Sas et al., 2002; 2003).

In this experiment, the lowest pH values were measured in the meristematic root zone of GiSelA 5. This means that ion transport was more intense in the roots of GiSelA 5 than in the roots of the other two rootstocks. These results are consistent with the results of a previous study, in which different strawberry cultivars showed had different capacities to bring about changes in the pH of the rhizosphere (Sas-Paszt and Żurawicz, 2004).

The mechanism by which dwarfing rootstocks reduce scion vigour in temperate zone fruit trees has not yet been elucidated. Early studies suggested that the graft union between the scion and the dwarfing rootstock somehow limits the flow of water or solutes. Anatomical and other evidence had been gathered to support this hypothesis. However, recent studies suggest that this is not likely to be the primary cause of dwarfing. Plant hormones may play an important role (Webster, 2004). In any case, one thing is sure: dwarfing is a complicated phenomenon influenced by many factors, including the anatomy and physiology of the root system.

Our experiments on sweet cherries have shed some light on how dwarfing rootstocks influence growth and performance in the scion cultivar. Future experiments will further elucidate the role of root anatomy and physiology. Special attention will be paid to ion transport, which at this point seems to play a key role in the dwarfing mechanism.

CONCLUSIONS

Preliminary results indicate that the rootstocks tested differed in terms of the anatomical structure and physiological activity of their root systems. Root length, root surface area, root volume, and number of root tips were highest in GiSelA 5 and lowest in F 12/1. Root calcium concentration was lower in the dwarfing rootstocks P-HL A and GiSelA 5 than in the more vigorous rootstock F 12/1. The rhizosphere pH in all three rootstocks was higher at the root tips than in the root bases or middle portions of the roots. This means that the young and actively growing root tips are more actively engaged in ion transport than the older root bases. Further experiments will concentrate on how morphology and physiology of dwarfing rootstocks influence growth and performance in the scion cultivar. Ion transport between the root and the rhizosphere deserves special attention.

REFERENCES

Arsenault J.L., Poulcur S., Messier C., Guay R. 1995. WinRHIZO a root-measuring system with a unique overlap correction method. HORTSCIENCE 30: 906.

Dinkelaker B., Hahn G., Römheld V., Wolf G.A., Marschner H. 1993a. Non-destructive methods for demon-

strating chemical changes in the rhizosphere I. Description of methods. PLANT SOIL 155/156: 67-70.

Dinkelaker B., Hahn G., Marschner H. 1993b. Non-destructive methods for demons-trading chemical changes in the rhizosphere II. Application of methods. PLANT SOIL 155/156: 71-74.

Franken-Bembenek S. 1998. Gisela 5 (148/2) – dwarfing rootstock for sweet cherries. ACTA HORT. 468: 279-283.

Grzyb Z.S., Sitarek M., Omiecińska B. 1996. The influence of dwarf root-stocks on the growth and yield of sweet cherry cultivars in the first two years after planting. ACTA HORT. 410: 265-268.

Grzyb Z.S., Sitarek M., Omiecińska B. 1998. Growth and fruiting of five sweet cherry cultivars on dwarfing and vigorous rootstocks. ACTA HORT. 468: 333-338.

Marschner H., Römheld V., Ossenberg-Neuhaus H. 1982. Rapid method for measuring changes in pH and reducing processes along roots of intact plants. Z. PFLANZEN-PHYSIOL. 105: 407-416.

Marschner H., Römheld V. 1983. *In vivo* measurement of root-induced pH changes at the soil-root interface: Effect of plant species and nitrogen source. Z. PFLANZENPHYSIOL. 111: 241-251.

Marschner H. 1995. The soil-root interface (rhizosphere) in relation to mineral nutrition. Mineral Nutrition of Higher Plants, Second edition. Academic Press, London, UK, pp. 537-595.

Ostrowska A., Gawliński S., Szczubiołka Z. 1991. Metody analizy i ocena właściwości gleb i roślin. Warszawa: Instytut Ochrony Środowiska.

Sas L., Mercik S., Matysiak B. 1999. Rola rizosfery w mineralnym odżywianiu się roślin. POST. NAUK ROL. 6: 27-36.

Sas L., Rengel Z., Tang C. 2001. Excess cation uptake and extrusion of proton and organic acid anions by *Lupinus albus* under P deficiency. PLANT SCI. 160: 1191-1198.

Sas L., Marschner H., Römheld V., Mercik S. 2002. The influence of aluminium on rhizosphere and bulk soil pH and growth of strawberry plants. ZESZ. PROB. POST. NAUK ROL. 482: 467-474.

Sas L., Marschner H., Römheld V., Mercik S. 2003. Effect of nitrogen forms on growth and chemical changes in the rhizosphere of strawberry plants. ACTA PHYSIOL. PLANT. 25/3: 241-247.

Sas-Paszt L., Żurawicz E. 2004. The influence of nitrogen forms on root growth and pH changes in the rhizosphere of strawberry plants. ACTA HORT. 649: 217-221.

Schmidt H., Gruppe W. 1988. Breeding dwarfing rootstocks for sweet cherries. HORT. SCI. 23(1): 112-114.

Sitarek M., Grzyb Z.S. 2002a. Wpływ podkładek o różnej sile wzrostu na termin i intensywność kwitnienia czereśni. ANNALES UNIVERSI-TATIS MARIAE CURIE-SKŁO-DOWSKA. LUBLIN-POLONIA, VOL. X: 195-199.

Sitarek M., Grzyb Z.S. 2002b. Leaf area to fruit yield ratio in sweet cherry trees budded on vigorous and dwarf rootstocks. SODININKYSTE IR DARZININKYSTE 21(4): 58-64.

Sitarek M., Grzyb Z.S., Czynczyk A., Omiecińska B. 1999. Growth and fruiting of sweet cherry trees grafted on various rootstocks or treated with Cultar. J. FRUIT ORNAM. PLANT RES. 7/1: 11-17.

Sitarek M., Grzyb Z.S., Omiecińska B. 2005: Performance of sweet cherry trees on Gisela® 5 rootstock. ACTA HORT. 667: 389-391.

Sitarek M., Grzyb Z.S., Olszewski T. 1998: The mineral elements concentration in leaves of two sweet cherry cultivars grafted on different rootstocks. ACTA HORT. 468: 373-376.

Webster A.D. 2004. Vigor mechanisms in dwarfing rootstocks for temperate fruit trees. ACTA HORT. 658: 29-41.

Wertheim S.J. 1998. Rootstock guide. Publication of Fruit Research Station Wilhelminadorp, The Netherlands.

Ystaas J. 1990. The influence of cherry rootstocks on the content of major nutrients in the leaves of sweet cherry cultivars. ACTA HORT. 274: 517-519.

Ystaas J., Froynes O. 1995. The influence of Colt and F 12/1 rootstocks on sweet cherry nutrition as demonstrated by the leaf content of major nutrients. ACTA AGRIC. SCAND. SECT. B. SOIL PLANT SCI. 45: 292-296.

BADANIA SYSTEMU KORZENIOWEGO CZEREŚNI SZCZEPIONYCH NA RÓŻNYCH PODKŁADKACH

Mirosław Sitarek i Lidia Sas-Paszt

S T R E S Z C Z E N I E

Doświadczenie założono wiosną 2003 roku w szklarni Instytutu Sadownictwa i Kwiaciarstwa w Skierniewicach. Przedmiotem badań były czereśnie odmian 'Lapins' i 'Regina' szczepione na podkładkach 'F 12/1', 'P-HL A' i 'GiSelA 5'oraz same podkładki rosnące na własnych korzeniach stanowiące kombinację kontrolną. Rośliny posadzono pojedynczo do skrzyń z PCV o wymiarach 75 x 50 x 10 cm napełnionych ziemią mineralną, u których jedna ze ścian jest przezroczysta, co umożliwia obserwację wzrostu korzeni. Wszystkie drzewka były standardowo nawożone i pielęgnowane. Po jednym roku wzrostu roślin w skrzyniach mierzono pH rizosfery oraz w próbce pobranej z każdej skrzyni określano świeżą i suchą masę korzeni, ich długość, średnicę, powierzchnię i objętość, a także liczbę wierzchołków oraz zawartość składników mineralnych w korzeniach.

Najniższą wartość pH rizosfery stwierdzono w części merystematycznej korzeni podkładki 'GiSelA 5'. Świadczy to o tym, że podkładka ta w większym stopniu niż inne wydziela jony wodorowe i intensywniej pobiera kationy. Odczyn gleby rizosfery zmierzony w strefie wierzchołkowej korzeni był w przypadku wszystkich badanych podkładek i niezależnie od zaszczepionej odmiany wyższy niż u ich podstawy i w części środkowej. W ciągu pierwszego roku badań najintensywniej rosły korzenie podkładki 'GiSelA 5', a najsłabiej – 'F 12/1'. Fakt zaszczepienia odmian czereśni na podkładkach nie modyfikował w sposób istotny wzrostu ich systemu korzeniowego.

Rodzaj zastosowanej podkładki miał wpływ na zawartość wapnia w korzeniach. Korzenie podkładki 'F 12/1' zawierały go więcej niż korzenie podkładek 'P-HL A' i 'GiSelA 5'. Natomiast nie stwierdzono istotnych różnic pomiędzy korzeniami poszczególnych podkładek w poziomie azotu, fosforu, potasu i magnezu.

Słowa kluczowe: czereśnia, podkładka, wzrost korzeni, pH rizosfery, zawartość makroelementów w korzeniach