ACTA AGRICULTURAE SLOVENICA

93 • 2
2009

Biotehniška fakulteta Univerze v Ljubljani
Biotechnical Faculty University of Ljubljana

Acta agriculturae Slovenica • ISSN 1581-9175 • 93 – 2 • Ljubljana, julij 2009

Acta agriculturae Slovenica
Volume / Letnik **93** · Number / Številka **2** · **2009**

VSEBINA / CONTENTS

COBISS Code 1.01

DOI: 10.2478/v10014-009-0010-4

Agrovoc descriptors: Oryza sativa; rice; phosphorus; mineral deficiencies; crop yield; glomus mosseae; glomus intraradices; mycorrhizae; roots; flood irrigation

Agris category code: P34

Phosphorus mobilization and uptake in mycorrhizal rice (*Oryza sativa* L.) plants under flooded and non-flooded conditions

Roghieh HAJIBOLAND[1], Naser ALIASGHARZAD[2] and Robabeh BARZEGHAR[3]*

Received August 14, 2008; accepted June 15, 2009.
Delo je prispelo 14. avgusta 2008, sprejeto 15. junija 2009.

ABSTRACT

Phosphorus (P) deficiency severely limits rice production in the world. Colonization of plant root with arbuscular mycorrhizal fungi (AMF) may have a considerable consequence for P uptake and plant growth. In contrast to other crop species, there is little experimental evidence about the role of mycorrhizal colonization in lowland rice plants. This study was undertaken to examine whether inoculation of rice plants can contribute in the mobilization and uptake of insoluble P form. In addition, an attempt was made to compare flooded plants with non-flooded ones in their mycorrhizal responsiveness. In one experiment, insoluble P was supplied for plants inoculated either with *Glomus mosseae* or *Glomus intraradices,* then growth and P uptake was determined. Results showed that colonization with AMF significantly improved uptake of P derived from insoluble P source. In other experiment, rice plants were inoculated with *Glomus mosseae* or *Glomus intraradices* in non-flooded nurseries and then transplanted either to flooded or non-flooded conditions. Root colonization by AMF was decreased due to flooding conditions from 43% to 27%. Nevertheless, the plant growth responded positively (117% increase) to inoculation when grown at flooded conditions, while dry matter of non-flooded plants was diminished up to 64% by inoculation. Mycorrhizal colonization had also a significant contribution in the uptake of P and K in flooded but not in non-flooded plants.

Key words: *Glomus mosseae, Glomus intraradices,* lowland rice, *Oryza sativa*, flooding

IZVLEČEK

MOBILIZACIJA IN PRIVZEM FOSFORJA V RIŽU (*Oriza sativa* L.) V PRISOTNOSTI MIKORIZNIH GLIV S POPLAVNIM NAMAKANJEM IN BREZ LE-TEGA

Pomanjkanje fosforja (P) omejuje svetovno pridelavo riža. Naselitev rastlinskih korenin z arbuskularnimi mikoriznimi glivami (AMF) bi lahko pomembno vplivala na privzem P in rast rastlin. Poskusni podatki o vlogi mikorizne kolonizacije riževih rastlin so v primerjavi z nekaterimi drugimi vrstami rastlin redki. Ta raziskava je bila zastavljena, da bi proučili, ali inokulacija korenin riža z mikoriznimi glivami vpliva na mobilizacijo in privzem netopne oblike P. Mikorizna odzivnost je bila preizkušena v razmerah z in brez uporabe poplavnega namakanja. Netopna oblika P je bila dodana rastlinam, inokuliranim z *Glomus mosseae* ali *Glomus intraradices*, opazovana je bila rast rastlin in privzem P. Naselitev riževih korenin z AMF je vplivala na povečan privzem P iz netopnega vira tega elementa. V drugem poskusu so bile rastline inokulirane z istima vrstama mikoriznih gliv v nepoplavnih razmerah in nato presajene v poplavne in nepoplavne razmere. Naselitev korenin z AMF se je v poplavnih razmerah znižala s 43% na 27%. Kljub temu je bil odziv rastlin na inokulacijo in izpostavitev poplavnim razmeram pozitiven, rast se je povečala za 117%, medtem ko se je suha snov rastlin iz nepoplavnih razmer zmanjšala za 64%. Inokulacija z mikoriznimi glivami je prav tako pomembno vplivala na privzem P in K v poplavnih razmerah, tega vpliva pa ni bilo mogoče zaznati pri rastlinah v nepoplavnih razmerah.

Ključne besede: *Glomus mosseae*, *Glomus intraradices*, riž, *Oryza sativa*, poplavljanje

[1] Associate Professor of Plant Science Department, University of Tabriz, Iran

[2] Associate Professor of Soil Science Department, University of Tabriz, Iran

[3] M.Sc. of Plant Physiology, University of Tabriz, Iran

* This paper is a part of the M.Sc. thesis of R.B. under supervision of R.H. and N.A.

1 INTRODUCTION

The roots of most plant species are often colonized with arbuscular mycorrhizal fungi (AMF). The greatest beneficial effect of AMF symbiosis for host plant has been related to improved phosphorus (P) nutrition. Root colonization with AMF can enhance the uptake of P by plant roots by providing a larger absorbing surface for uptake of P and by overcoming problems relating to development of depletion zone, via translocation in external hyphae to the host plant root (Peterso and Massicotte, 2004; Shenoy and Kalagudi, 2005). In addition to increased absorption surface in mycorrhizal root systems, mycorrhizal plants have been shown to have increased uptake of P from poorly soluble P sources, such as iron and aluminum phosphates and rock phosphate. Solubilization of soil P is achieved by rhizospheric modifications through the release of organic acids, phosphatase enzymes and some specialized metabolites like siderophores (Shenoy and Kalagudi, 2005). Indirect mechanisms deriving from the effects of AMF on rhizosphere properties have also been suggested. These include changes in pH (Li et al., 2001) and root exudation patterns (Laheurte et al., 1990). Besides the direct effect of AMF on P nutrition, uptake from soil of other mineral elements by the mycorrhizal mycelium and subsequent transfer to the plant have been demonstrated in particular for potassium (George et al., 1992) and nitrogen (George et al., 1995).

Rice is an important food crop particularly in Asia. Phosphorus deficiency is one of the most limiting factors in rice production and annually large amounts of P fertilizers are being used in rice fields in the world (Itao et al., 1999). In contrast to other crop species such as clover (Nadian et al., 1997; Bi et al., 2003), sorghum (Bagayoko et al., 2000) and wheat (Hawkins and George, 1999), there is little experimental evidence about the role of mycorrhizal colonization in rice plants (Solaiman and Harita, 1996; Purakayastha and Chhonkar, 2001; Gao et al., 2007).

Although rice is grown in different ecosystems, 78% of the world's rice is grown under irrigated or rainfed lowland conditions (Itao et al., 1999). It was reported that rice plants readily form mycorrhizal associations under upland conditions, but under submerged conditions infection is rare due to the anoxic environment (Ilag et al., 1987). Barea (1991) reported, however, that AMF can survive in waterlogged conditions, and this is supported by the fact that *Glomus etunicatum*, showed fairly high colonization in rice roots and best survival under submerged conditions (Purakayastha and Chhonkar, 2001). In a work on six aerobic rice genotypes, relatively high colonization of roots (28-57% depending on genotypes) was observed (Gao et al., 2007) and significant effect on Zn uptake was reported. However, there is a paucity of information available on the involvement of AMF in mobilizing and uptake of P in rice particularly under waterlogged conditions.

Therefore, this work was aimed to investigate the effect of AMF colonization on mobilization of insoluble P form and P uptake. The second aim was to evaluate the effect of AMF colonization on growth and P uptake under flooded conditions compared with non-flooded colonized plants.

2 MATERIAL AND METHODS

Preparation of substrate and fungal inoculum

Quartz sand used as growth substrate was washed with tap water and treated with 1% HCl for 24 h. Then it was washed again once with tap water and 2 times with distilled water. After sterilization in autoclave for 2 hours and subsequent drying, quartz sand was weighed and then pots were filled.

The AMF species were *Glomus mosseae* (Nicol and Gerd) Gerdemann and Trappe or *G. intraradices* Schenck and Smith (provided by Soil Biology Laboratory, Faculty of Agricultural, University of Tabriz), that were propagated for 4 months on sorghum plants in greenhouse. Pot contents, including sand, root segments, hyphae and spores were used as inoculum. Number of spores in the inoculum was 33-35 per g for both of mycorrhizae species and root colonization percentages were 74.8 and 78.8 (%) for *G. mosseae* and *G. intraradices* respectively.

Plant material, seed germination, nursery cultivation and transplantation

Rice (*Oryza sativa* L. cv. Shafagh) provided by Rice Research Center, Guilan, Iran, were surface-sterilized and then germinated in the dark on filter paper soaked with saturated $CaSO_4$ solution. Germinated seeds were transferred to nursery culture including three treatments (without AMF inoculation, inoculation with *G. mosseae*, inoculation with *G. intraradices*) with three replicates per treatment. Nursery containers were filled with mixed sterilized sand and inoculum, then 30 young seedlings were transferred to each container and plants were grown for three weeks. Non-inoculated containers received the same amount of sterilized inoculum. Containers were irrigated with distilled water daily to maintain moisture at field capacity and were fed each week with half strength nutrient solution (Yoshida et al., 1972) without P, but $Ca_3(PO_4)_2$ was added at 4 g Kg^{-1} to each container. At the end of nursery culture, colonization of seedling roots was tested by random sampling.

Treatments and experimental design

Colonized plants were transplanted to the 3 L pots and 5 plants were cultivated in each pot. Roots were carefully separated from rhizosphere soils and were washed with distilled water for removing soil particles before transplanting. Two separate experiments were conducted:

Experiment I. Three AMF treatments including without inoculation (–AMF), inoculation with *G. mosseae* or *G. intraradices*, four P treatments including without P, 0.05 mM soluble P (as K_2HPO_4), 0.05 mM insoluble P (as $Ca_3(PO_4)_2$) and both P forms each at 0.05 mM were applied in this experiment. Plants were grown under non-flooded conditions (60% of water holding capacity).

Experiment II. Three AMF treatments similar with Experiment I and two watering regime including flooded (0.5 cm water above the sand) and non-flooded and two P levels (without and with 0.3 mM KH_2PO_4) were applied in this experiment.

Plants were grown for one month under controlled environmental conditions with a temperature regime of 25°/18°C day/night, 14/10 h light/dark period, a relative humidity of 70/80% and at a photon flux density of about 300-400 µmol $m^{-2}s^{-1}$. Plants were daily irrigated by distilled water or nutrient solution (Yoshida et al., 1972), the latter was performed after determination of nutrients depletion by measuring N and P concentrations in the pots.

Harvest and analyses

Harvested plants were first rinsed with tap water and then with distilled water. The mycorrhizal colonization percentage was evaluated by the grid line interest method (Phillips and Hayman, 1970). Shoots and roots were blotted dry on filter papers and dried at 70°C for 2 days to determine plant dry weight. For determination of elements content, oven-dried samples were ashed in a muffle furnace at 550°C for 8 h and then digested in 1:3 HNO_3. The digested samples were dried on a heating plate and subsequently ashed at 550°C for another 3 h. Samples were resuspended in 2 ml 10% HCl and made up to volume by double distilled water. Concentration of P was determined spectrophotometrically by ammonium-vanadate- molybdate method (Gericke and Kurmies, 1952) and of K was determined by flame photometry. Nutrient uptake was calculated for each pot as the sum of nutrient content of shoot and root for 5 plants.

Experiments were conducted in a randomized complete block design using three replications. Statistical analyses of data were carried out by ANOVA test (Tukey test at $p<0.05$).

3 RESULTS

AMF colonization was not observed in the non-inoculated plants. The highest colonization rate occurred in the absence of added P in both experiments. In Experiment I, presence of soluble and insoluble P reduced colonization of root by about 30-31% to 15-16%. Effect of soluble P form in lowering colonization of roots was greater than insoluble P form. The lowest colonization (10%) was observed in the presence of both P forms (Table 1). In Experiment II, application of P lowered colonization from 43% to only 25% in non-flooded and from 27% to 15% in flooded plants inoculated with G. intraradices. Flooding had a significant inhibitory effect on colonization of roots, it resulted in reduction of colonization rate from 35-43% to 25-27% in –P and from 22-25% to 12-15% in +P plants (Table 2).

Effect of inoculation on chlorophyll content and growth of plants

Experiment I: Plants growth and chlorophyll content of leaves was significantly reduced when roots were inoculated with AMF. Growth inhibition of colonized plants was 28-60% compared with non-inoculated ones depending on AMF species and P supply form. Negative effect of AMF colonization was more prominent in plants inoculated with *G. mosseae* compared with plants colonized with *G. intraradices* and was similar for root and shoot. The highest plants growth was achieved at supply of soluble P and application of both P forms under non-inoculation conditions (Table 1).

Experiment II: The growth response of plants to colonization by AMF was greatly depended on flooding treatment. In flooded plants, in contrast to plants grown at non-flooded condition, AMF inoculation stimulated growth significantly (shoot and root dry weight). Plants height and chlorophyll content was also affected positively by AMF inoculation in flooded but not in non-flooded plants. The positive effect of AMF colonization on shoot and root dry weight of flooded plants was clearly depended on AMF species and the level of P. In –P plants, the positive effect of *G. intraradices* was mainly higher than *G. mosseae*, and in +P plants the trend was inverse (Table 2).

Table 1. *Leaf chlorophyll content and growth of rice (Oryza sativa L. cv. Shafagh) without (–AMF) and with inoculation by Glomus mosseae or Glomus intraradices supplied by different phosphorus form and grown under non-flooded conditions. Data in each column followed by the same letter are not different significantly (P<0.05).*

P	AMF	Root colonization(%)	Chlorophyll (Relative)	Plant Height (cm)	Shoot Yield (mg pot^{-1})	Root Yield (mg pot^{-1})
–P	–AMF	0 ^{f}	100±3 ^{a}	73±1 ^{b}	2073±18 ^{b}	890±12 ^{c}
	G. m	31±3 ^{a}	42±3 ^{f}	38±3 ^{g}	834±135 ^{f}	410±37 ^{f}
	G. in	30±1 ^{a}	63±8 ^{d}	50±1 ^{e}	1374±17 ^{d}	480±15 ^{ef}
+P (soluble)	–AMF	0 ^{f}	88±5 ^{b}	77±2 ^{a}	2454±59 ^{a}	1749±211 ^{a}
	G. m	16±1 ^{c}	49±5 ^{ef}	45±3 ^{f}	1328±72 ^{d}	595±15 ^{de}
	G. in	15±1 ^{c}	74±10 ^{c}	66±4 ^{c}	1754±159 ^{c}	863±14 ^{c}
–P (insoluble)	–AMF	0 ^{f}	94±4 ^{ab}	72±1 ^{b}	1817±70 ^{c}	877±10 ^{c}
	G. m	18±1 ^{b}	42±3 ^{f}	36±2 ^{h}	1001±17 ^{e}	436±10 ^{f}
	G. in	18±0 ^{b}	57±3 ^{de}	51±2 ^{e}	1309±56 ^{d}	503±26 ^{ef}
+P (Soluble+ insoluble)	–AMF	0 ^{f}	91±3 ^{b}	77±2 ^{a}	2321±83 ^{a}	1614±59 ^{b}
	G. m	12±1 ^{d}	42±3 ^{f}	37±1 ^{gh}	1270±54 ^{d}	597±12 ^{de}
	G. in	10±1 ^{e}	72±3 ^{c}	56±2 ^{d}	1405±107 ^{d}	704±112 ^{d}

Table 2. *Leaf chlorophyll content and growth of rice (Oryza sativa L. Cv. Shafagh) without (–AMF) and with inoculation by Glomus mosseae or Glomus intraradices supplied by different phosphorus level and grown under flooded or non-flooded conditions. Data in each column followed by the same letter are not different significantly (P<0.05).*

P	Flooded/ Non-flooded	AMF	Root colonization(%)	Chlorophyll (Relative)	Plant Height (cm)	Shoot Yield (mg pot^{-1})	Root Yield (mg pot^{-1})
–P	Flooded	–AMF	0 ^{g}	131±25 ^{ab}	26±4.1 ^{bc}	677±153 ^{c}	269±84 ^{d}
		G. m	25±1 ^{c}	152±18 ^{ab}	34±0.9 ^{ab}	1297±101 ^{b}	1006±134 ^{b}
		G. in	27±1 ^{c}	175±12 ^{a}	34±1.8 ^{ab}	1473±109 ^{b}	1472±275 ^{a}
+P	Flooded	–AMF	0 ^{g}	100±2 ^{b}	24±9.0 ^{bc}	1171±231 ^{b}	497±120 ^{cd}
		G. m	12±2 ^{f}	128±7 ^{ab}	40±7.2 ^{a}	2580±319 ^{a}	1538±249 ^{a}
		G. in	15±1 ^{e}	126±18 ^{ab}	34±0.6 ^{ab}	2209±311 ^{a}	1262±95 ^{ab}
–P	Non-Flooded	–AMF	0 ^{g}	192±27 ^{a}	37±5.5 ^{a}	1333±157 ^{bc}	823±126 ^{c}
		G. m	35±2 ^{b}	185±39 ^{a}	26±1.3 ^{bc}	699±48 ^{cd}	521±98 ^{cd}
		G. in	43±2 ^{a}	188±12 ^{a}	25±1.3 ^{bc}	481±82 ^{d}	367±96 ^{d}
+P	Non-Flooded	–AMF	0 ^{g}	196±13 ^{a}	40±0.3 ^{a}	2066±177 ^{a}	1384±142 ^{ab}
		G. m	22±1 ^{d}	187±5 ^{a}	31±3.4 ^{ab}	1140±189 ^{b}	1048±213 ^{bc}
		G. in	25±1 ^{c}	142±42 ^{ab}	29±1.3 ^{bc}	856±153 ^{cd}	554±49 ^{cd}

Flooding had an obvious effect on plants growth depending on mycorrhizal status. In non-mycorrhizal plants, flooding conditions reduced dry weight of shoot and root by about 43-48% and 64-67% respectively. Inoculation with AMF changed the plants growth response to flooding. Flooding improved shoot and root dry weight of mycorrhizal plants up to 86-206% in –P and 56-156% in +P treatments when inoculated with *G. mosseae* and *G. intraradices* respectively.

Nutrients uptake under inoculation and non-inoculation conditions

Experiment I: P uptake was lower significantly or in tendency in mycorrhizal plants with the exception of plants supplied with insoluble P as the sole P source. In the latter treatment, a significant effect of mycorrhization was observed for P uptake only in plants colonized with *G. mosseae*. Potassium uptake was significantly lower in mycorrhizal plants under all P supply form and inoculation with both AMF species (Fig. 1).

Experiment II: A significant positive response of P uptake to inoculation was observed only in flooded plants inoculated with *G. mosseae* in both P treatments. In contrast, in plants at non-flooded conditions, P uptake was decreased slightly or significantly by AMF inoculation in both P treatments. Potassium uptake was slightly higher in flooded plants at both P treatments (Fig. 2).

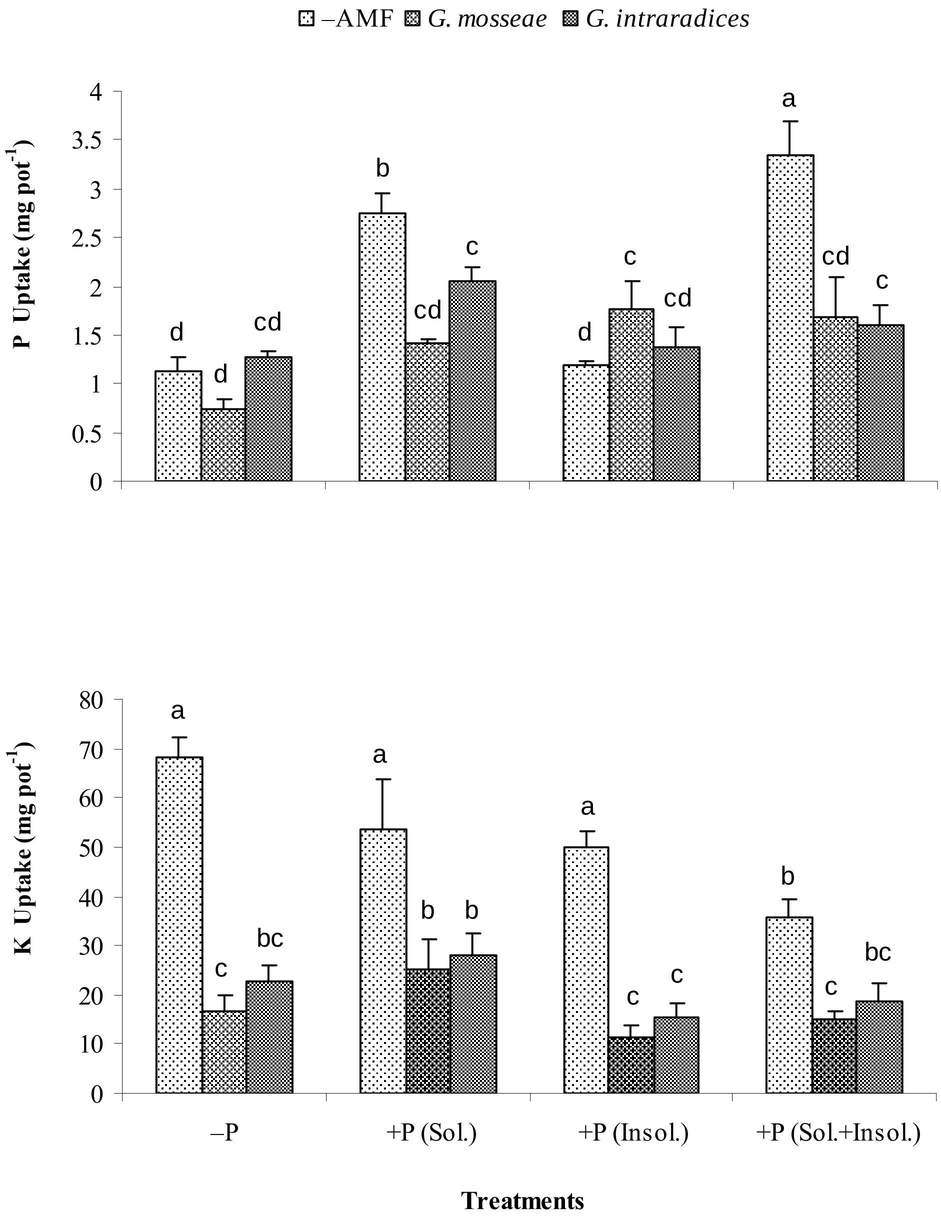


Fig. 1. *Uptake of P and K by rice (Oryza sativa L. cv. Shafagh) without (–AMF) and with inoculation by Glomus mosseae or Glomus intraradices supplied by different phosphorus form and grown under non-flooded conditions. Columns indicated by the same letter are not different significantly (P<0.05)*

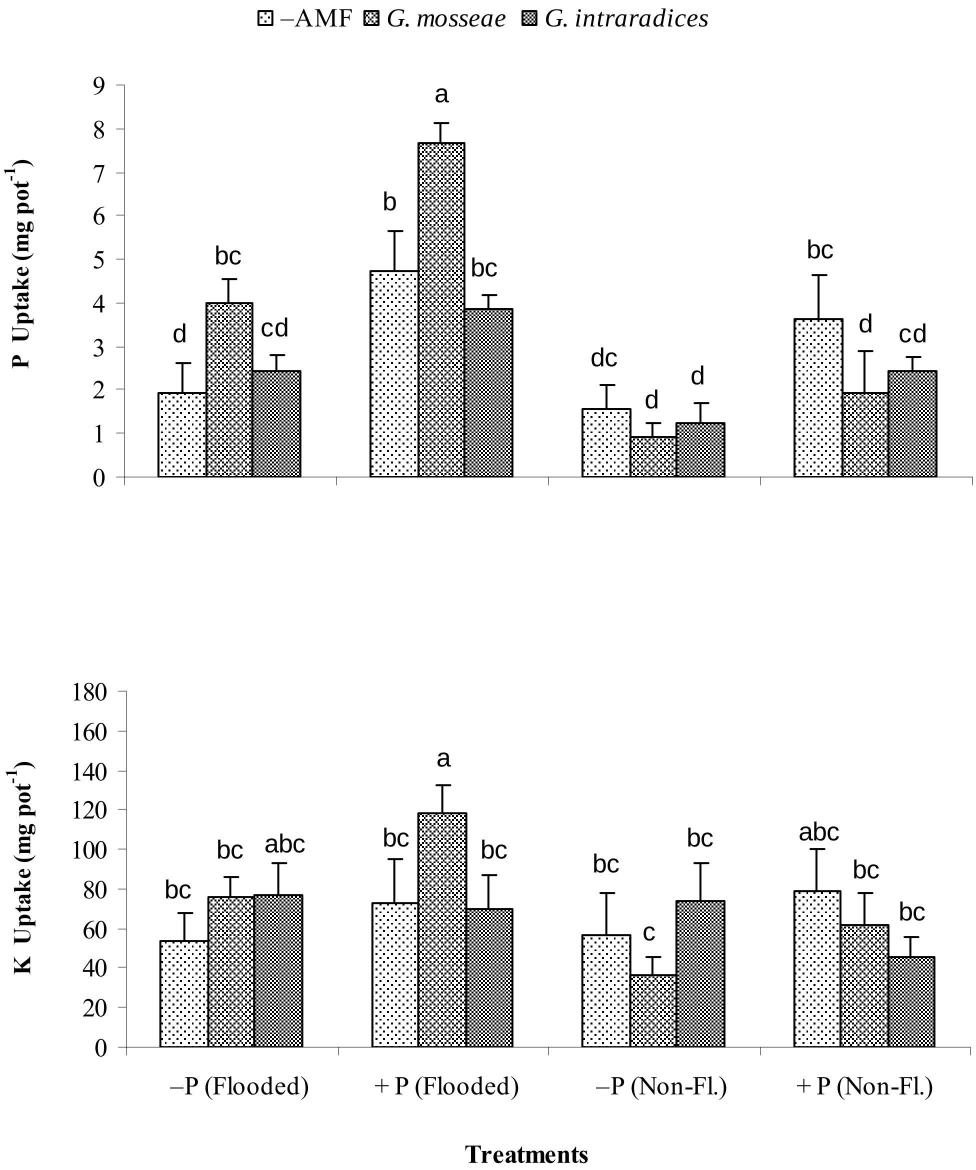


Fig. 2. *Uptake of P and K by rice (Oryza sativa L. cv. Shafagh) without (–AMF) and with inoculation by Glomus mosseae or Glomus intraradices supplied by different phosphorus level and grown under flooded or non-flooded conditions. Columns indicated by the same letter are not different significantly (P<0.05).*

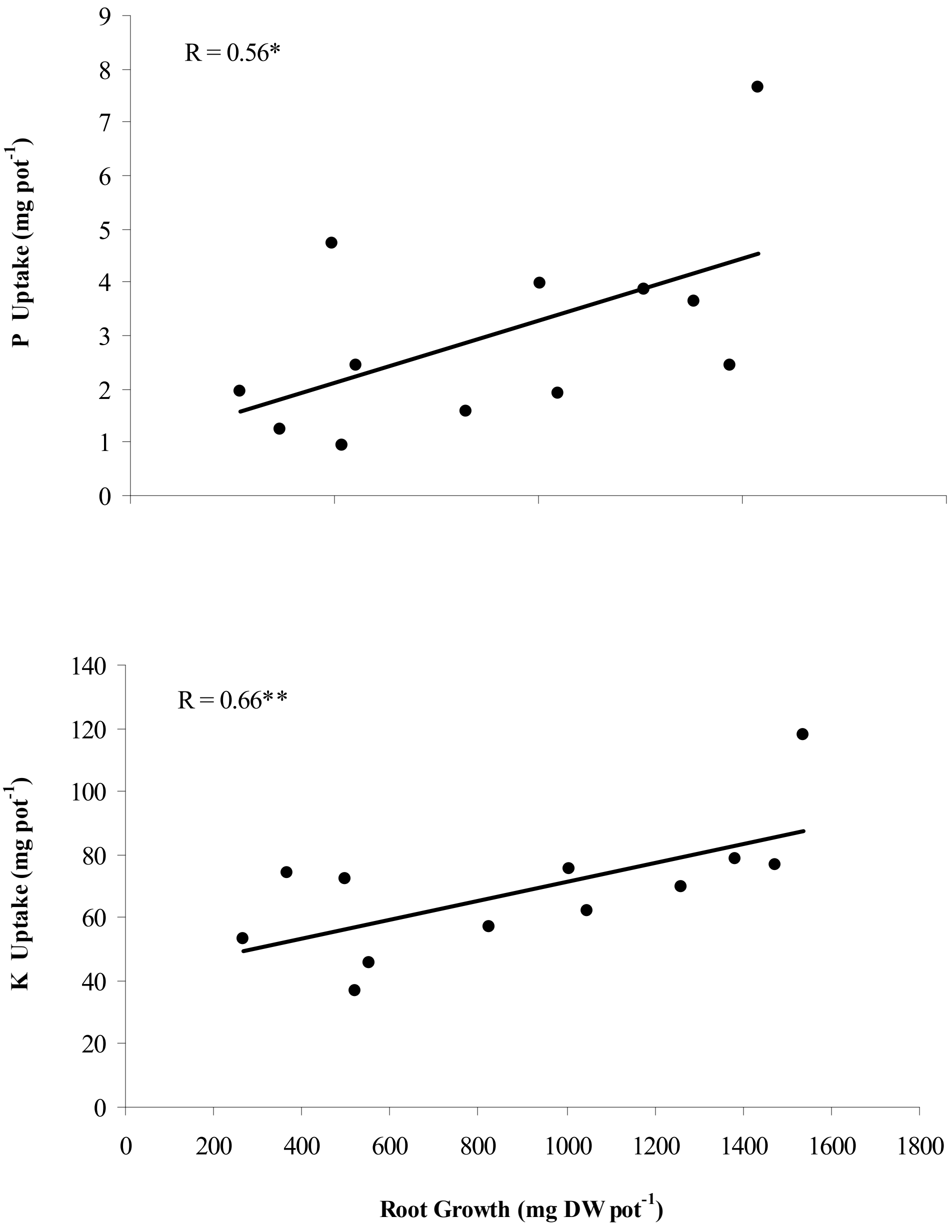


Fig. 3. *The correlation between root growth (mg DW pot^{-1}) and uptake of P and K (mg pot^{-1}) in rice (Oryza sativa L. cv. Shafagh) without or with inoculation by AMF. R values followed by * or ** are significant at the 0.05 or 0.01 probability levels, respectively.*

4 DISCUSSION

Mycorrhizal colonization and plant growth

Colonization of roots with AMF in plants grown non-flooded, reduced distinctly plants growth at all P treatments. It suggests that, AMF colonization reduces plant performance under non-flooded conditions independent from their P nutritional status. It is well known that the establishment and maintenance of mycorrhizal symbiosis is linked to a flow of carbon from the host plant to the fungus. Accordingly, a substantial proportion of photosynthates allocated to the roots, is required for symbiosis. Environmental conditions such as shading and defoliation, which limit photosynthates supply to plants also depress colonized plants growth (Marschner, 1995). Therefore, depression of plant yield in response to AMF colonization in this work, could be well explained by competition of fungus with plants for photosynthates, because of a low photosynthesis rate of plants, which is most likely due to a low light intensity in growth chamber (300-400 µmol $m^{-2}s^{-1}$) compared with open field conditions (1700-2000 µmol $m^{-2}s^{-1}$). However, this explanation could not be applied for mycorrhizal plants under flooded conditions. The cause of different mycorrhizal responsiveness of flooded and non-flooded plants could not be interpreted by their flooding response when nonmycorrhizal. It is likely the result of a specific interaction between AMF and plants which is likely established only under flooded conditions. Whether the greater P and K uptake observed in flooded compared with non-flooded mycorrhizal plants is the cause or result of positive mycorrhizal responsiveness of flooded plants is not known and should be further investigated in detail.

The colonization rate of flooded plants at harvest was significantly lower than non-flooded plants. Because the colonization rate of roots was similar for plants before transplanting, the effect of different colonization rate of seedlings at the start of transplanting stage could be ruled out. Therefore, differential colonization of roots was most likely developed after transplantation and throughout the experiment due to submergence. AMF fungi are obligate aerobes, accordingly, a low colonization rate of roots under flooded conditions could be the result of lower oxygen availability to fungi. Nevertheless, it was reported that, the colonization of roots of rice with *G. etunicatum* in aerobic nursery conditions persisted under waterlogged conditions when the rice was transplanted (Purakayastha and Chhonkar, 2001). Difference among AMF species and plants genotype in their response to oxygen availability is one explanation of this discrepancy. However, in this work a significant benefit of host plants from AMF inoculation under flooded conditions was achieved though a low colonization.

Effect of AMF inoculation on P uptake

Mycorrhization of plants with *G. mosseae* caused a significant mobilization of insoluble P in the substrate and uptake by plants. Effect of *G. intraradices* was not significant. Mycorrhizal plants have increased uptake of P from poorly soluble P sources through either direct or indirect mechanisms deriving from the effects of AMF on rhizosphere properties including changes in pH (Li et al., 2001) and root exudate patterns (Laheurte et al., 1990). We observed a significant acidification of rhizophere in mycorrhizal rice plants under low P supply that reached up to 1.7 pH units (Hajiboland et al., 2007).

AMF colonization had also a significant effect on uptake of soluble P in flooded plants. In P deficient soils, root colonization by AMF, improved significantly P uptake per unit root length due to the enhancement of the total root surface by hyphal growth (Smith and Read, 1996). In addition of improvement of P uptake per unit root length as the consequence of increased total root surface, one of the main causes of increased P uptake by inoculation and genotypic differences is the response of root growth to AMF. Increased P uptake was clearly associated with increased root growth e.g. root weight. Root dry weight was increased up to 274 and 209% in –P and +P flooded plants respectively inoculated with *G. mosseae* which was associated with 105 and 61% increase in P uptake of –P and +P plants respectively. The corresponding values for K uptake was 42 and 63% for –P and +P plants respectively. Conversely, root growth was inhibited by inoculation up to 24 and 37% in non-flooded –P and +P plants respectively, which results in reduction of P uptake up to 40-47% and K uptake by about 35-21% in –P and +P plants respectively. The contribution of root growth in increased nutrient uptake was reflected in the correlation coefficient (R) between root dry weight and P and K uptake (Fig. 3). Therefore, root growth response to AMF was a determining factor in the response of P and K uptake to AMF inoculation.

Reduction of K uptake due to AMF colonization observed in the Experiment I and in the non-flooded plants in the Experiment II could be also the result of an overall growth reduction particularly root growth and surface area in AMF inoculated plants. Root length and spatial availability are particularly important for nutrients such as P and K (Marschner, 1995), accordingly, K uptake responded similar with P to the changes in the root growth in this work. Uptake of K was reported to increase by AMF inoculation in some tropical plant species, cowpea and sorghum (Bagayoko et al., 2000), decrease in millet (Bagayoko et al., 2000) or remained unchanged in barley (Mohammad et al., 2003).

Effect of AM colonization in dependence of AMF species

Mycorrhizal species were different in their effect on growth and nutrient uptake. Although negative effect of AMF colonization on plant growth under non-flooded conditions (Experiment I) was more prominent in plants inoculated with *G. mosseae* compared with *G. intraradices*, effect of colonization with the former AMF species in mobilization and uptake of insoluble P form was higher than that with the latter species. Similarly, inoculation by *G. mosseae,* had a beneficial effect on P uptake under flooded but not non-flooded conditions. A poor effectivity of *G. intraradices* cannot be explained by lower root colonization. It might be related to poor development and activity of the external hyphae, low hyphal transport rates, and poor solute interchange at the arbuscule-host root cell interface (Marschner, 1995).

5 REFERENCES

Bagayoko M., George E., Römheld V., Buerkert A. 2000. Effects of mycorrhizae and phosphorus on growth and nutrient uptake of millet, cowpea and sorghum on a West African soil. J. Agricultural Science, 135: 399-407.

Barea J.M. 1991. Vesicular-Arbuscular Mycorrhizae as Modifiers of Soil Fertility. Advances in Soil Science, 15: 1-40.

Bi Y.L., Li X.L., Christie P. 2003. Influence of early stages of arbuscular mycorrhiza on uptake of zinc and phosphorus by red clover from a low-phosphorus soil amended with zinc and phosphorus. Chemosphere, 50: 831-837.

Gao X., Kuyper T.W., Zou C., Zhang F., Hoffland E. 2007. Mycorrhizal responsiveness of aerobic rice genotypes is negatively correlated with their zinc uptake when nonmycorrhizal. Plant and Soil, 290: 283-291.

George E., Häussler K.U., Vetterlein D., Gorgus E., Marschner H. 1992. Water and nutrient translocation by hyphae of *Glomus mosseae*. Canadian Journal of Botany, 70: 2130-2137.

George E., Marschner H., Jakobson I. 1995. Role of arbuscular-mycorrhizal fungi in uptake of phosphorus and nitrogen from soil. Critical Reviews in Biotechnology, 15: 257-270.

Gericke S., Kurmies B. 1952. Die kolorimetrische Phosphorsäure-bestimmung mit Ammonium-Vanadat-Molybdat und ihre Anwendung in der Pflanzenanalyse. Zeitschrift für Pflanzenernährung , Düngung und Bodenkunde, 59: 235-247.

Hajiboland R., Alisasgharzad N., Barzeghar R. 2007. Impacts of inoculation with two species of arbuscular mycorrhizae on rice (*Oryza sativa* L.) growth, P and K uptake and rhizosphere pH. Iranian Journal of Soil and Water Sciences, 21: 111-121.

Hawkins H.J., George E. 1999. Effect of plant nitrogen status on the contribution of arbuscular mycorrhizal hyphae to plant nitrogen uptake. Physiologia Plantarum, 105: 694-700.

Ilag L.L., Rosales A.M., Elazegvi F.V., Mew T.W. 1987. Changes in the population of infective endomycorrhizal fungi in a rice based cropping system. Plant and Soil, 103: 67-73.

Itao E., Ella E., Kawanto N. 1999. Physiological basis of submergence tolerance in rainfed lowland rice ecosystem. Field Crops Research, 64: 75-90.

Laheurte F., Leyval I., Berthelin J. 1990. Root exudates of maize, pine and beech seedlings influenced by mycorrhizal and bacterial inoculation. Symbiosis, 9: 111-116.

Li X.L., Christie P. 2001. Changes in soil solution Zn and pH and uptake of Zn by arbuscular mycorrhizal red clover in Zn-contaminated soil. Chemosphere, 42: 201-207.

Marschner H. 1995. Mineral Nutrition of Higher Plants. 2nd ed. Academic Press, London, UK.

Mohammad M.J., Malkawi H.I., Shibli R. 2003. Effects of arbuscular mycorrhizal fungi and phosphorus fertilization on growth and nutrient uptake of barley grown on soils with different levels of salts. Journal of Plant Nutrition, 26: 125-137.

Nadian H., Smith S.E., Alston A.M., Murray R.S. 1997. Effects of soil compaction on plant growth, phosphorus uptake and morphological characteristics of vesicular-arbuscular mycorrhizal colonization of *Trifoliun subterraneum*. New Phytologists, 135: 303-311.

Peterso R.L., Massicotte H.B. 2004. Exploring structural definitions of mycorrhizas, with emphasis on nutrient-exchange interfaces. Canadian Journal of Botany, 82: 1074-1088.

Phillips J.M., Hayman D.S. 1970. Improved procedure for clearing roots and staining parasitic and VAM fungi for rapid assessment of infection. Transactions of the British Mycological Society., 55: 158-161.

Purakayastha T.J., Chhonkar P.K. 2001. Influence of vesicular-arbuscular mycorrhizal fungi (*Glomus etunicatum* L.) on mobilization of Zn in wetland rice (*Oryza sativa* L.). Biology and Fertility of Soils, 33: 323-327.

Shenoy V.V., Kalagudi G.M. 2005. Enhancing plant phosphorus use efficiency for sustainable cropping. Biotechnological Advances, 23: 501-513.

Smith S.E., Read D.J. 1996. Mycorrhizal Symbiosis. 2nd ed., Academic Press, London.

Solaiman M.Z., Harita H. 1996. Effectiveness of arbuscular mycorrhizal colonization at nursery stage on growth and nutrition in wetland rice (*Oryza sativa* L.) after transplanting under different soil fertility and water regimes. Soil Science & Plant Nutrition, 42: 561-571.

Yoshida S., Forno D.A., Cock J.H., Gomez K. 1972. Routine methods of solution culture for rice. In: Laboratory Manual for Physiological Studies of Rice. 2nd ed. The International Rice Research Institute, Philippines.

COBISS Code 1.01

DOI: 10.2478/v10014-009-0011-3

Agrovoc descriptors: Aphidius ervi; parasitoids; identification; classification; geographical distribution; biological control; pest control; hosts

Agris category code: H10

The first record of *Aphidius ervi* Haliday in Slovenia

Katarina KOS[1], Željko TOMANOVIĆ[2], Helena ROJHT[3], Stanislav TRDAN[4]

Received April 10, 2009, accepted July 16, 2009
Delo je prispelo 10. aprila 2009, sprejeto 16. julija 2009

ABSTRACT

In 2008, a lucerne aphid parasitoid *Aphidius ervi* Haliday was first recorded in Slovenia. This oligophagous parasitoid is used as biological control agent against bigger aphid species. By sampling aphid mummies on different locations in Slovenia in 2008, we found parasitoid *Aphidius ervi* on nine host plants (corn, pea, alfalfa, red clover, winter wheat, oat, onion, potato and winter barley). Among 1812 primary parasitoids found in Slovenia in 2008, there were 46 individuals of *Aphidius ervi*; 21 male and 25 female parasitoids. In the present paper description of the species, its geographic distribution and host plant-aphid-parasitoid associations are given.

Keywords: *Aphidius ervi*, parasitoid, first record, biological control, Slovenia

IZVLEČEK

PRVA NAJDBA PARAZITOIDA *Aphidius ervi* Haliday V SLOVENIJI

V letu 2008 smo v Sloveniji prvič ugotovili zastopanost parazitoida *Aphidius ervi* Haliday, ki parazitira zlasti listne uši na metuljnicah (Fabaceae). Ta oligofagni parazitoid se uporablja kot biotični agens večjih vrst listnih uši. Parazitoida *Aphidius ervi* smo v letu 2008 našli na 9 gostiteljskih rastlinah (koruza, grah, lucerna, črna detelja, ozimna pšenica, oves, čebula, krompir in ozimni ječmen) v Sloveniji, in sicer med vzorčenjem ušjih mumij. V letu 2008 smo nabrali 1812 primarnih parazitoidov, med njimi je bilo 46 osebkov vrste *Aphidius ervi*; 21 je bilo samcev in 25 samic. V prispevku je opisana vrsta, njena geografska razširjenost in povezava med gostiteljsko rastlino, ušjo ter parazitoidom.

Ključne besede: *Aphidius ervi*, parazitoid, prva najdba, biotično varstvo rastlin, Slovenija

1 INTRODUCTION

Aphidius ervi Haliday is a Palaearctic oligophagous parasitoid species associated in its region of origin mainly with Macrosiphinae aphids, such as *Acyrthosiphon pisum* Harris on legumes and to a lower degree with *Macrosiphum euphorbiae* Thomas and *Aulacorthum solanii* (Kaltenbach) on other food plants (Takada & Tada, 2000; Takada, 2002). Although *Sitobion avenae* (Fabricious) on cereals in a suitable host for *Aphidius ervi*, this parasitoid has a minor relevance as an aphid biological control agent on the cereal agro-ecosystems in Europe (Cameron, 1984).

Aphidius ervi was already found in Australia, East Palaearctic, Nearctic region and in North Africa (Fauna europaea, 2007). In Europe *Aphidius ervi* is present in some areas of former Yugoslavia (Serbia, Kosovo,

[1] Teach. Assist., B. Sc., University of Ljubljana, Biotechnical Faculty, Department of Agronomy, Jamnikarjeva 101, SI-1111 Ljubljana, Slovenia, e-mail: katarina.kos@bf.uni-lj.si

[2] Assoc. Prof., Ph. D., University of Belgrade, Faculty of Biology, Studentski trg 16, SER-11000 Belgrade, Serbia

[3] Teach. Assist., young reseacher, University of Ljubljana, Biotechnical Faculty, Department of Agronomy, Jamnikarjeva 101, SI-1111 Ljubljana

[4] Assoc. Prof., Ph. D., ibid,

Montenegro), in the Netherlands, Spain, Slovakia, Republic of Moldova, Italy, Ireland, Hungary, Greece, Germany, France, Finland, Czech Republic, Bulgaria, Great Britain and in Andorra (Fauna europaea, 2007).

Females of the *Aphidius ervi* are from 2.8 to 4.1 mm long. It has clypeus with 10-18 long hairs and antennae 18-19 (17,20)-segmented, reaching to the middle of abdomen. Antennal F1 is equal to F2, 3 times as long as wide, with apical portion not thickened. Central areola on propodeum is relatively narrow, upper areola has 5-10 and lower 3-6 hairs. Pterostigma on wing is 4-5 times as long as wide, with metacarpus about 1/3 shorter than pterostigma. Radial abscissa 2 is usually only somewhat shorter than abscissa 1. Tergite 1 is 3.5 times as long as wide at spiracles. *Aphidius ervi* is easily distinguishable from the other congeners by the rugose anterolateral area of tergit 1. The coloration of female head is black brown, with lower part of genae, clypeus and mouthparts yellowish and apices of mandibles dark. Antennae apex of pedicellus and the basal part of F1 is yellowish and the remaining antennomeres from dark-brown to black. Legs are yellow with apices of tarsi and coxae dark brown. Male of *Aphidius ervi* has antennae 20-21(22)-segmented and tergite 1 clearly stouter than in female. The coloration in male is much darker than in female. Head is entirely black brown with clypeus and lower portion of genae more of less yellowish. Antennae are black brown with basal ring of F1 yellowish. Thorax is entirely brown, legs are more or less brown yellowish and abdomen is dark brown (Starý, 1973; Pennacchio, 1989).

Aphidius ervi is the most common on legume aphids, such as *Acyrthosiphon pisum* and *Acyrthosiphon* Mordvilko sp. on different host plants: *Medicago sativa* Linnaeus, *Lathyrus clymenum* Linnaeus, *Lens culinaris* Medikus, *Melilotus alba* Medikus, *Pisum sativum* Linnaeus, *Trifolium nigrescens* Viviani, *Trifolium pretense* Linnaeus, *Vicia faba* Linnaeus, *Vicia sativa* Linnaeus and other. *Aphidius ervi* is also parasitoid of other aphids: *Aulacorthum solani* on *Malva neglecta* Wallr. and *Pedicularis brachyodonta* Schloss. et Vukotin.; *Diuraphis noxia* (Kurdjumov) on *Hordeum vulgare* Linnaeus; *Hyperomyzus lactucae* Linnaeus on *Sonchus* Linnaeus sp.; *Macrosiphum cholodkovskyi* (Mordvilko) on *Filipendula ulmaria* (Linnaeus) Maximowicz; *Macrosiphum euphorbiae* on *Galega officinalis* Linnaeus and *Solanum tuberosum* Linnaeus; *Metopolophium dirhodum* (Walker) on *Avena sativa* Linnaeus, *Avena sterilis* Linnaeus, *Avena* Linnaeus sp., *Hordeum vulgare* and *Triticum aestivum* Linnaeus; *Myzus persicae* (Sulzer) on *Gossypium herbaceum* Linnaeus and *Nicotiana tabacum* Linnaeus; *Rhopalosiphum padi* Linnaeus on *Hordeum vulgare*; *Schizaphis graminum* (Rondani) on *Triticum aestivum*; *Sitobion avenae* on *Dactylis glomerata* Linnaeus, *Festuca* Linnaeus sp., *Hordeum murinum* Linnaeus, *Hordeum vulgare, Secale* Linnaeus sp., *Setaria verticilata* (Linnaeus), *Triticum durum* Desf. and *Triticum aestivum*; and *Sitobion fragariae* (Walker) on *Festuca sp.* (Starý, 1973; Pennacchio, 1989).

***Figure 1**: Female of parasitoid Aphidius ervi (Photo: K. Kos).*

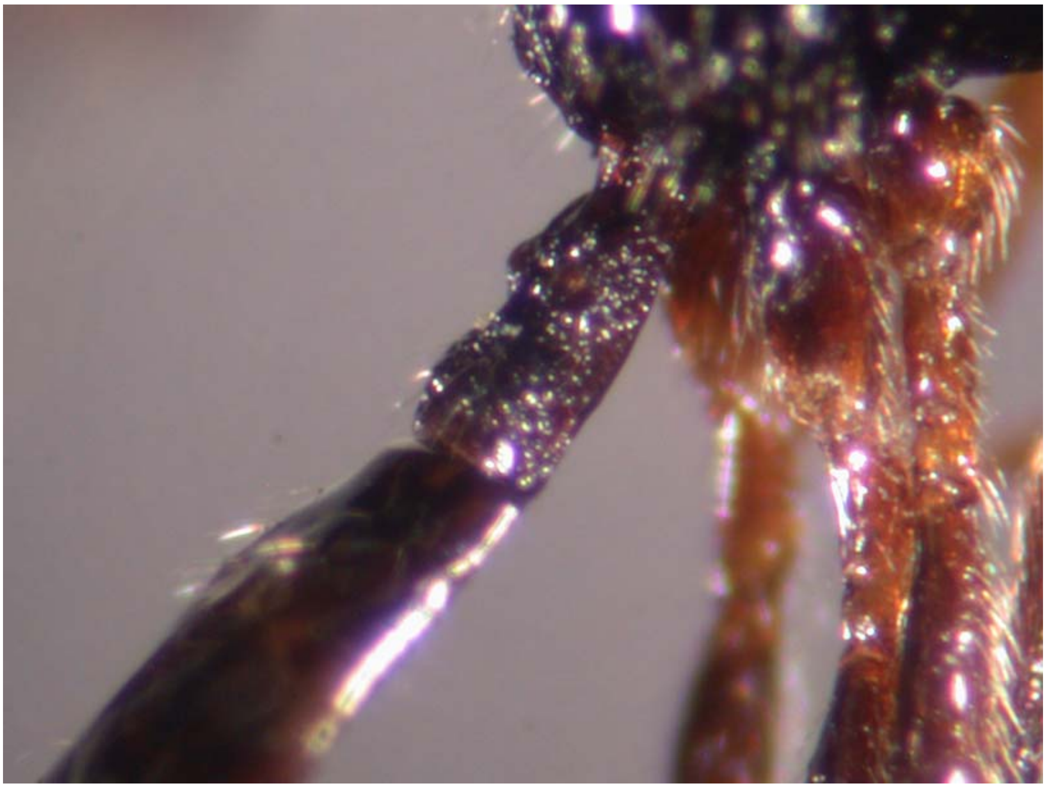


Figure 2*: Rugose petiole of Aphidius ervi female in lateral view (Photo: K. Kos).*

Figure 3*: Forewings of Aphidius ervi female (Photo: K. Kos).*

***Figure 4**: Empty mummy of an aphid, parasitised by parasitoid Aphidius ervi (Photo: K. Kos).*

Parasitoid *Aphidius ervi* is used for biological control of bigger aphid species like *Macrosiphum euphorbiae* and *Acyrthosiphon pisum* since 1996. The total development of wasp takes 26 days at 14 °C, 13.5 days at 20 °C and 12 days at 23.6 °C. A female lays about 350 eggs in a life time of which most are laid during the first 5 to 7 days at a rate of about 55 eggs per day. The recommended release rate to control *Macrosiphum euphorbiae* ranges from 0.15 m^2 to 1 m^2. *Aphidius ervi* has a very good searching ability. Developmental stage at which *Aphidius ervi* is released to control aphids is pupae in form of aphid mummies (van Lenteren, 2003). The parasitic wasp is applied in crops such as tomato, sweet pepper, eggplant, gerbera, rose, cucumber, bean, etc. Biological control of aphids by aphid parasitoids presents a long lasting form of control on several crops, it can be introduced preventatively and it has fast results (Biobest Biological Systems, 2009).

The purpose of this research is to find the indigenous species of aphid parasitoids in Slovenia and to offer environmentally friendly systems of plant production with reduced use of chemical insecticides. Our aim is to explore the possibilities of introduction of biological control agents, their vitality and longevity under certain circumstances of plant production and the efficacy of artificial habitat, which offers food, shelter and alternative hosts/prey to natural enemies.

2 MATERIAL AND METHODS

The sampling took place from 25 April till 30 August 2008 in agro-ecosystems in different regions in Slovenia; in Ljubljana (central Slovenia), Lower Styria (Štajerska), Prekmurje, Upper Carniola (Gorenjska), Lower Carniola (Dolenjska), Goriška and in Slovenian Istria. Aphids, their parasitoids and host plants were collected on cultivated and wild-growing plants.

While sampling parasitoids, we modified the method according to the life cycle of parasitoids in their hosts (after Brajković in Tomanović, 2005). Parasitoids develop in yet living aphids, this way we collected living aphids and their mummies in plastic pots, together with their host plants. The pots were covered with nylon patch, which enabled air flow and at the same time prevented the escape of aphids and later flown out parasitoids. The samples were marked with the successive number of sample, date of sampling and location (place of collection). Additionally, we annotated also species of host plants, on which the samples were collected.

The samples of aphids for identification were kept in an Eppendorf tube (1.5 ml) together with 70 % solution of ethanol. Each tube was marked with the number of sample according to the number on the pot. Because of the easier identification we gathered only bigger specimens of winged and non-winged aphids.

We left pots closed for 2 to 3 weeks, in some cases even longer, so that the wasps flew out from the mummies and died. Afterwards we put the content of the pot on the white surface and separated the parasitoids with the brush from the rest of the content. The parasitoids were kept in the vessels, which were marked with the corresponding number of the sample. Identification of aphids was performed on the Faculty of Agriculture in Zemun (Serbia) and identification of parasitoids was done on the Faculty of Biology in Belgrade (Serbia) (Kos, 2007; Kos *et. al*., 2008).

3 RESULTS WITH DISCUSSION

Parasitoid *Aphidius ervi* was found on nine different host plants; corn, pea, alfalfa, red clover, oat, wheat, onion, potato and barley (Table 1), while aphids are still in process of identification.

***Table 1**: Number of females and males of A. ervi in different regions of Slovenia on 9 different host plants (f=female, m=male; CS=central Slovenia, LS=Lower Styria (Štajerska), P=Prekmurje, UC=Upper Carniola (Gorenjska), LC=Lower Carniola (Dolenjska), G=Goriška and SI=Slovenian Istria).*

	CS		LS		P		UC		LC		G		SI		
Host plant/sex	f	m	f	m	f	m	f	m	f	m	f	m	f	m	Total
Pisum sativum				1			1			2		1	1	1	7
Trifolium pratense		1													1
Medicago sativa	1	5					1		4	2	4		6	3	26
Solanum tuberosum													1	2	3
Allium cepa											1				1
Hordeum vulgare											2				2
Zea mays		2								1					3
Triticum aestivum											1				1
Avena sativa	1										1				2
Total	2	8	0	1	0	0	2	0	4	5	9	1	8	6	46

Among 2173 primary parasitoids found in Slovenia, there were 46 individuals of *Aphidius ervi*, 21 males and 25 females. 26 members of *A. ervi* were found on alfalfa and 7 on pea. In Prekmurje we did not find any members of *A. ervi*, while in other regions we found 14 individuals in Slovenian Istra, 10 in Goriška and Central Slovenia and 9 in Lower Carniola.

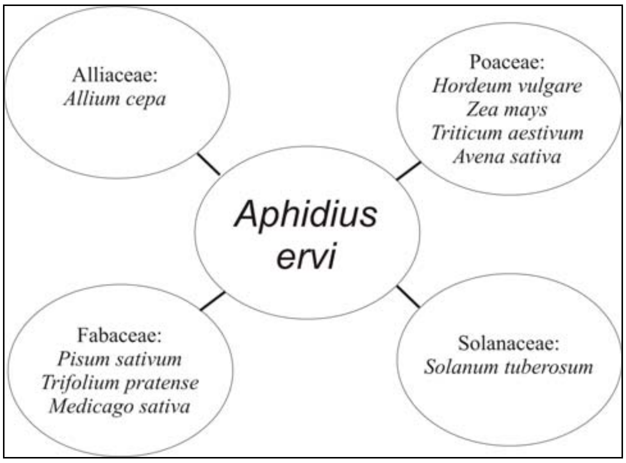


***Figure 5**: Host plants of Aphidius ervi, found in Slovenia in 2008.*

Nine different host plants, where we found *A. ervi*, belong to 4 botanical families: Alliaceae, Poaceae, Fabaceae and Solanaceae (Fig. 5).

4 CONCLUSIONS

The results of the present study indicate that *Aphidius ervi* uses different host plants and is widely distributed in Slovenia, while we found it in almost all Slovenian regions. Data of He *et. al*. (2006) research suggests that this parasitoid has high potential to suppress aphid population, when the latter increases. *Aphidius ervi* is an effective biological control agent for many aphid species. It has proven high efficiency in controlling greenhouse aphid pests. It is effective in controlling *Acyrthosiphon pisum*, *Macrosiphum euphorbiae* and *Myzus persicae*.

Results of our two year research exhibit species diversity and wide circulation of parasitoids in different agricultural ecosystems on selected locations in Slovenia (Kos *et. al*., 2007; 2008; 2009). In 2006 and 2008 we found and identified 2173 primary parasitoids, belonging to 30 species from 8 genera: *Aphidius, Binodoxys, Diaeretiella, Ephedrus, Lipolexis, Lysiphlebus, Monoctonus* and *Praon*. In the future we must pay attention on the conservation of the natural enemies, the conservation of their natural habitats that represents alternative food, hosts and shelter, or even to increase the number of natural enemies in Slovenia with the aim to reduce application of insecticides.

5 ACKNOWLEDGEMENT

This work was done within Horticulture No P4-0013-0481, a program funded by the Slovenian Research Agency, and within the project CRP V4-0524 granted by Slovenian Research Agency and Ministry of Agriculture, Food and Forestry of R Slovenia. Part of the research was funded within Professional tasks from the field of plant protection, the program funded by the Ministry of Agriculture, Forestry and Food of R Slovenia Phytosanitary Administration of the Republic of Slovenia.

5 REFERENCES

Biobest Biological Systems. Ervi-M-System. 2009. http://207.5.17.151/biobest/en/producten/nuttig/aphidius_ervi.htm (23.2.2009)

Brajković, M., Tomanović, Ž. (2005): Entomological practicum. Methods of sampling and preparation of insects. Beogr., Fac. Biol., Univ. Beogr.: 106 p.

Cameron, P.J., Powell W., Loxdale H.D. (1984): Reservoirs for *Aphidius ervi* Haliday (Hymenoptera: Aphidiidae), a polyphagous parasitoid of cereal aphids (Homoptera: Aphididae). Bull. of Entomol. Res., 74: 647-656.

Fauna Europaea. 2007. *Aphidius ervi* (Haliday).

http://www.faunaeur.org/distribution_table.php

He, X.Z., Teulon, D.A.J., Wang, Q. (2006): Oviposition strategy of *Aphidius ervi* (Hymenoptera: Aphidiidae) in response to host density. NZ Plant Prot. 59: 190-194.

Kos, K. 2007. Aphids (Aphididae) and their parasitoids in a vegetable ecosystem. Grad. Thes., Univ. Ljubl., Biotech. Fac., Dept. Agronomy: 69 p. [Slovenian]

Kos, K. Tomanović, Ž., Petrović-Obradović, O., Laznik, Ž., Vidrih, M., Trdan, S. (2008): Aphids (Aphididae) and their parasitoids in selected vegetable ecosystems in Slovenia. Acta Agric. Slov., 91: 15-22.

Kos, K., Tomanović, Ž., Rojht, H., Trdan, S. (2009): Aphid parasitoids in Slovenia and their significance in biological control. Acta entomol. Slov. (in press) [Slovenian]

Noyes, J. Fauna europaea. (2004) http://www.faunaeur.org/ (29.9.2008)

Pennacchio, F. (1989): The Italian species of the genus *Aphidius* Nees (Hymenoptera: Braconidae: Aphidiinae). Boll. Lab. Ent. Agr. Filippo Silvestri, 46: 75-106.

Starý P. (1973): A review of the *Aphidius*-species (Hymenoptera, Aphidiidae) of Europe. Annot. Zool. Bot., 84: 1-85.

Takada H. (2002): Parasitoids (Hymenoptera: Braconidae, Aphidiinae; Aphelinidae) of four principal pest aphids (Homoptera: Aphididae) on greenhouse vegetable crops in Japan. Appl. Entomol. Zool., 37: 237-249.

Takada, H., Tada E. (2000): A comparison between two strains from Japan and Europe of *Aphidius ervi*. Entomol. Exp. Appl., 97: 1-20.

van Lenteren, J.C. (2003): Quality control and production of biological control agents: theory and testing procedures. Wallingford, CABI Publ: 327 pp.

COBISS Code 1.01

DOI: 10.2478/v10014-009-0012-2

Agrovoc descriptors: green manures; triticum; winter crops; perennials; legumes; leguminosae; disease resistance; crop yield

Agris category code: H20

Effect of preceding crops on the winter cereal productivity and diseases incidence

Regina SKUODIENĖ[1], Rita NEKROŠIENĖ[2]

Received August 12, 2008; accepted April 8, 2009.
Delo je prispelo 12. avgusta 2008, sprejeto 8. aprila 2009.

ABSTRACT

Experiments were carried out in the Vėžaičiai Branch of the Lithuanian Institute of Agriculture (West Lithuania region) in 2002–2005. The aim of this research was to estimate the ecological significance of perennial legumes used as green manure for the biological properties of triticale and rye and for diseases resistance. Residues of the perennial grasses tested and ploughed-in aftermath contributed different contents of nitrogen to the soil. The highest content of nitrogen was contributed to the soil with red clover residues and aftermath. Residues of white clover and aftermath ploughed in as green manure determined more favourable soil properties. This had a positive effect on the formation of biological parameters of cereals grown after white clover, which made it possible without mineral and organic fertilisers to produce on average 3.88 t ha^{-1} of triticale grain and 3.82 t ha^{-1} of rye grain, or by 1.09 and 0.28 t ha^{-1} more compared with their growing after red clover managed in the same way as white clover. Different growing conditions of winter cereals, i.e. different preceding crops, had a significant effect on the occurrence of scald and septoriosis.

Key words: preceding crops, winter cereal, productivity, yield forming indicators, diseases

IZVLEČEK

VPLIV PREDHODNIH POSEVKOV NA PRIDELEK TER POJAVNOST BOLEZNI PRI OZIMNIH ŽITIH

Poskusi so bili opravljeni v Vėžaičiai Branch na Lithuanian Institute of Agriculture v obdobju od leta 2002 do 2005. Namen raziskave je bil oceniti ekološki pomen trajnih metuljnic, uporabljenih za zeleno gnojenje, na odpornost proti boleznim ter na biološke lastnosti tritikale in rži. Zaorani ostanki zelenih delov preizkušanih metuljnic so imeli različne vplive na vsebnost dušika v tleh. K najvišji vsebnosti dušika so prispevali ostanki rdeče detelje, zaorani ostanki bele detelje pa so imeli ugodnejše učinke na lastnosti tal. Izboljšane talne lastnosti so pozitivno vplivale na parametre rasti, ki so omogočili pridelek 3,88 t ha^{-1} zrnja tritikale in 3,82 t ha^{-1} zrnja rži brez uporabe mineralnih ali drugih organskih gnojil. Ko je bil predhodni posevek rdeča detelja, je bil pridelek tritikale manjši za 1,09 t ha^{-1}, pridelek rži pa za 0,28 t ha^{-1} manjši v primerjavi s pridelkom po zelenem gnojenju z belo deteljo. Različni predhodni posevki so imeli pomemben vpliv na pojavnost ožiga in listne pegavosti.

Ključne besede: predhodni posevki, ozimna žita, pridelek, bolezni

1 INTRODUCTION

Winter rye (*Secale cereale* L.) is a very important bread cereal. Rye grain dry matter contains 9 – 19 % of protein, 49 – 66 % of starch, 1.6 – 1.9 % of fat, 2.0 – 2.5 % of fibre, various trace elements and vitamins. Winter rye can tolerate acidic soil, is less demanding in terms of nutrient content and can better utilise soil moisture in spring.

Winter triticale (×*Triticosecale* Wittm.), compared with wheat performs better on poorer or even acidic soils (Magyla et al., 2001). In good conditions the grain yield can be as high as 8-10 t ha^{-1} and can exhibit valuable biochemical, physiological and agronomical characteristics. Triticale grain contains 12 – 19% of protein with an appropriate composition of amino acids.

[1] Lithuanian Institute of Agriculture, Vėžaičiai Branch, Gargždų 29, LT 96216 Klaipėda distr., Lithuania, e-mail: rskuod@vezaiciai.lzi.lt, Ph.D.

[2] Botanical Garden of Klaipeda University, Kretingos 92, LT 92327 Klaipeda, Lithuania, e-mail: rita_nekrosiene@mail.ru, Ph.D.

Winter triticale and rye are a promising alternative feed crop in Estonia, Latvia and Poland (Alaru et al., 2003). Winter cereal should be an acceptable alternative crop possessing considerable potential as a source of energy and protein in Lithuania too. There were sown about 56 thousand ha by this crop in our country in 2002.

The productivity of winter cereals depends on soil properties, meteorological factors, fertilisation, and especially humus content in the soil. The residues and ploughed in green material of perennial grasses, as preceding crops, have a positive effect on the formation of productivity elements of cereal crops not only in the first year but also in the second year, which determines the productivity of cereal link (Arlauskienė, 2000). The largest amount of organic matter is left in the soil with the residues of perennial grasses, less with annual grasses, winter cereals, maize, spring cereals, grain legumes and others (Arlauskienė, 2000; Janušienė, 1992; Magyla et al., 1997). In the crop rotations with perennial grasses with plant residues the soil receives much more C, N and ashy elements P_2O_5 and K_2O (Шпаков, 1999).

Winter cereals are annually heavily damaged by the diseases such as scald, leaf spots, various rusts, root rot diseases. Many authors indicate that the incidence of fungal diseases of winter cereals is determined by the weather conditions, imbalanced mineral fertilisation, crop species and variety, soil preparation, sowing time, preceding crop, weed infestation, abundance of pests, and luxuriance of the crop stand. More abundant mineral fertilisation of winter cereals in some cases slows down the spread of Septoria, but sometimes has virtually no effect. Some researchers' data suggest that more abundant fertilisation promotes the spread of Septoria (Bailey et al., 1996; Conway, 1996; Eyal, 1999; Gaurilčikienė et al., 1999; Hutcheon et al., 1996; Lisova et al., 1996). However, experimental results often vary considerably between years. It is maintained that preceding crops of winter cereals have quite a weighty effect on the occurrence of root rots, however, there is little experimental evidence on the effects of this factor on the spread of foliar diseases (Loiveke et al., 2003).

Research on the use of various herbaceous species for green manure in contemporary agriculture has gained new relevance. Cheap and high quality green manure is an important element in crop alternation in specialised cereal crop rotations. The use of green manure tends to reduce weed, disease and pest incidence, and less nutrients are leached from the plough layer into deeper soil layers (Romanovskaja et al., 2003).

The aim of this research was to determine effect of preceding crops (perennial legumes as green manure) on the productivity of winter cereals and occurrence of their diseases.

2 MATERIAL AND METHODS

Experimental layout

Two analogous experiments were set up in 2002 and 2003, each experiment lasted for three years. The field experiments were done following multi-factorial method. The experimental treatments were replicated four times and were arranged randomly. The soil of the experimental site is albi – edohypogleyic luvisol, light loam on medium heavy loam.

A factor – preceding crops of winter cereals:

1. Red clover – cut twice (R).
2. Red clover – 1st crop for forage, aftermath ploughed in (R+A).
3. White clover – cut twice (R).
4. White clover – 1st crop for forage, aftermath ploughed in (R+A).
5. Timothy – cut twice 2 (R).

B factor – cereals:

1. Triticale.
2. Rye.

The triticale variety 'Tevo' and rye variety 'Rūkai' were grown observing ecological cultivation recommendations. The cereals were grown after differently managed preceding crops: red clover 'Vyliai', white clover 'Sūduviai' and timothy 'Gintaras II'.

Plant green material was chopped and shallowly incorporated during phytocenosis flourishing period, and after two weeks deeply ploughed in (25 cm). In 2003 cereals were sown on September 8 and in 2004 on September 6. Seeking to determine the ecological value of different preceding crops no mineral fertilisers and plant protection products were used.

Soil samples were collected before trial establishment and after perennial grasses ploughing in from the 0 – 20 cm depth. Available P_2O_5 and K_2O were determined by the A-L method, total nitrogen by Kjeldahl, organic carbon by a mineraliser 'Heraeus'.

Plant residue mass was determined by the Katchinski monolith washing method. We considered the following as plant residues: stubble, undecomposed plant parts present on the soil surface and roots situated at the 25 cm depth. The mass of all plant residues and overground mass were re-calculated into dry matter. Having determined the concentration of major nutrients we calculated the content of nutrients (kg ha^{-1}) incorporated into the soil. The content of phosphorus in the green material of preceding crops, their plant residues and cereal grain and straw was determined by colorimetry and potassium by flame photometry methods. The share of nitrogen fixed from the atmosphere by legume bacteria in the plant mass was calculated by multiplying nitrogen content by the Chopkins – Piters coefficient 0.63 (Trepačev, 1979).

Grain samples for analyses were taken from each plot after pre-cleaning. One thousand grain weight was determined according to ISO 580-77. The data on 1000 grain weight and yield were adjusted to 15% moisture content.

Diseases assessment
Foliar disease assessments on rye and winter triticale were carried out in 2004-2005 in the third ten-day period of June at late milk maturity stage (BBCH 77-80). In each area under assessment 10 places were randomly chosen and three normally developed stems were taken per place. Three top green leaves were assessed per stem (Šurkus et al., 2002).

The following methods were used for the diagnostics of fungal diseases: visual, according to external symptoms and microscopy.

Disease incidence, i.e. per cent of disease-affected leaves (P) was calculated according to the formula:

$$P = \frac{n}{N} \cdot 100,$$

where n – number of affected leaves, N – number of assessed leaves.

The disease-affected leaf area was estimated in per cent according to the scale recommended by the European Plant Protection Organisation (EPPO). This scale is included in the EPPO Standards (1997) .

Disease severity (R) was calculated according to the formula, having added per cent of affected leaf area of each leaf and having divided the sum by the number of assessed leaves:

$$R = \frac{\sum(n \cdot b)}{N},$$

where $\sum(n \cdot b)$ – sum of product of the number of leaves with the same percent of severity and value of severity, N – number of assessed leaves.

Meteorological conditions
In the spring of 2002 warm and dry weather prevailed. At the beginning of summer there was sufficient warmth and moisture for the development of perennial grasses, and in August with prevailing dry weather and declining moisture reserves, the conditions for grass growth were only satisfactory (Table 1). The drought lasted until the second ten-day period of September. In the spring and summer of 2003, except for July, hydrothermal conditions were favourable for the development of perennial grasses. The autumn conditions were also conducive to the emergence, establishment and growth of cereals. During the spring-summer period of 2004 agrometeorological conditions for the development of cereals and perennial grasses were satisfactory. The autumn was warm and wet, which might have intensified biochemical processes in the soil and leaching of some part of released nitrogen. In 2005 the spring and beginning of summer were drier (rainfall only 80 %) compared with the long-term mean. Rainy second half of spring hindered cereal harvesting.

Table 1. *Meteorological conditions of the vegetation period*

Month	Air temperature (°C)					Rainfall (mm)				
	decade			per month	+/– of the long-term mean	decade			per month	+/– of the long-term mean
	I	II	III			I	II	III		
Year 2002										
April	3.1	8.8	9.5	7.1	+ 1.5	0.4	3.8	9.9	14.1	– 29.9
May	17.0	12.4	16.4	15.3	+ 4.1	0.3	11.6	8.4	20.3	– 23.8
June	16.5	16.3	14.5	15.8	+ 1.0	1.0	41.2	21.3	63.5	– 0.3
July	17.1	20.6	18.2	18.6	+ 1.8	32.7	56.8	42.9	132.4	+ 45.8
August	20.3	20.8	18.8	20.0	+ 3.6	0	0	0.3	0.3	– 88.7
Year 2003										
April	0.0	6.1	8.5	4.9	– 0.7	19.2	9.5	18.5	47.2	+ 3.1
May	9.5	10.9	14.3	11.6	+ 0.4	14.9	23.5	4.1	42.5	+ 1.6
June	15.5	13.3	14.9	14.6	– 0.2	2.5	19.6	50.6	72.7	+ 8.8
July	17.0	19.7	21.4	19.4	+ 2.6	22.8	13.5	11.6	47.9	– 38.0
August	18.7	17.1	14.4	16.7	+ 0.3	10.0	35.2	71.6	116.8	+ 27.3
Year 2004										
April	5.1	8.2	8.4	7.2	+ 1.6	6.4	5.7	3.7	15.8	– 27.8
May	15.0	8.5	8.7	10.7	– 0.5	4.6	16.2	16.0	36.8	– 7.1
June	13.7	12.5	14.1	13.4	– 1.3	3.5	41.7	23.7	68.9	+ 4.9
July	15.1	15.4	17.0	15.8	– 1.0	31.7	12.9	7.9	52.5	– 32.8
August	20.5	17.9	16.0	18.1	+ 1.7	4.2	30.3	29.9	64.4	– 24.7
Year 2005										
April	5.0	8.2	5.5	6.2	+ 0.6	10.0	2.0	3.0	15.0	– 28.1
May	8.6	8.9	15.8	11.1	– 0.1	5.0	27.0	6.0	37.0	– 6.8
June	12.0	15.5	15.6	14.4	– 0.3	6.0	30.0	9.0	45.0	– 18.7
July	18.6	19.8	17.4	18.6	+ 1.8	36.0	98.0	59.0	193.0	+ 105.8
August	16.2	15.6	16.6	16.1	– 0.3	171.0	81.0	15.0	267.0	+ 174.9

The experimental data were processed by ANOVA and correlation-regression analysis methods (Tarakanovas et al., 2003).
The symbols used in the paper: * and ** significant at 95 and 99% probability level; R – ploughed in residues, R+A – ploughed in residues and aftermath.

3 RESULTS AND DISCUSSION

Amount of nutrients, soil agrochemical properties

In the sowing year conditions were favourable for the growth of perennial grasses, however, legumes and grasses differed in phytomass and productivity coefficients. Overground phytomass of legumes was by 2.5 – 2.9 times higher than underground, and that of timothy by 0.9 times lower, whereas biological productivity coefficients amounted to 0.32 – 0.40 and 1.26, respectively. A similar trend was identified also in the years of grass use. Underground phytomass of legumes significantly correlated with overground phytomass (white clover r = 0.635** and red clover r = 0.582*), that is with increasing overground phytomass, underground phytomass increased, too. Having ploughed in aftermath, legumes left in the soil 70 – 71% of the total phytomass in the form of roots and plant residues: red clover 8.8, and white clover 5.8 t ha^{-1} dry matter.

Analyses of chemical composition of green manure showed that the highest concentrations of nitrogen, phosphorus and potassium were found in white clover overground phytomass, (2.80, 0.76 ir 2.95% respectively). In the aboveground phytomass of red clover the contents of the above-mentioned biogenic elements were lower by 14, 25, 21%, respectively. Plant overground part was richer in nutrients than underground part: nitrogen content by 1.4 – 1.6, phosphorus by 2.2 – 4.0 and potassium by 2.1 – 3.6 times. The lowest nutrient concentration was identified in the residues of timothy (0.74% N, 0.15% P_2O_5, 0.57% K_2O respectively). The largest amount of all nutrients was contributed to the soil after ploughing in of red clover aftermath (Table 2).

***Table 2**. Amount of nutrients incorporated into the soil with plant residues of preceding crops and with aftermath*

Preceding crops of winter cereals	DM of plant residues and green manure	Nutrients kg ha^{-1}				N: P_2O_5: K_2O
		N		P_2O_5	K_2O	
		total	fixed			
1. Red clover (R)	8.19	144.8	91.2	37.4	85.9	1 : 0.3 : 0.6
2. Red clover (R+A)	10.1	185.8	117.0	50.1	138.0	1 : 0.3 : 0.7
3. White clover (R)	5.58	68.9	43.4	15.6	38.5	1 : 0.2 : 0.6
4. White clover (R+A)	7.18	125.9	79.3	33.4	94.9	1 : 0.3 : 0.8
5. Timothy (R)	8.59	60.2	-	18.4	40.9	1 : 0.3 : 0.7

With incorporation of lower dry matter contents of green manure, which was determined by the yield of plant species and weather conditions, the soil received less nutrients than with plant residues. After red clover, with overground phytomass and residues the soil received 185.8 kg ha^{-1} nitrogen, of which nitrogen fixed by legume bacteria from the atmosphere accounted for the larger (117.0 kg ha^{-1}) part. Here the content of nitrogen was by 1.5 times higher than after identically managed white clover.

The largest amounts of phosphorus and potassium, like those of nitrogen, were contributed to the soil with red clover overground phytomass and residues. With red and white clover aftermath incorporated (2.22 and 2.07 t ha^{-1} dry matter), the soil received more nutrients than with ploughed in root and plant residues of the above mentioned clovers: nitrogen by 1.3 – 1.8, phosphorus by 1.3 – 2.1 and potassium by 1.6 – 2.5 times more. Although with lower mass the soil received less nutrients, the ratio N: P_2O_5: K_2O remained similar, i.e. 1 kg : 0.2 –0.3 kg : 0.6 – 0.7 kg.

The value and effect of preceding crops depend not only on the amount and chemical composition of phytomass but also on soil and climate conditions (Granstedt, 2000, Magyla et al., 2004). It was found that in sandy loam luvisol (East Lithuania) with red clover aftermath yield the soil received on average 94.9 kg ha^{-1} of nitrogen, 8.64 kg ha^{-1} of phosphorus and 88.3 kg ha^{-1} of potassium (Romanovskaja et al., 2003). Under North Lithuania's conditions where sod calcareous heavy loam soils prevail the greatest amounts of nutrients are left in the soil after bastard lucerne and red clover, while the lowest contents are left after vetch and oats mixture.

Perennial grasses with different biological characteristics determined a diverse accumulation of total nitrogen, humus and available P_2O_5 and K_2O in the soil (Table 3). Experimental evidence indicates that in the plough layer (0 – 20 cm depth) after all preceding crops the content of total nitrogen was similar (0.105 – 0.120%), however, compared with its content before the trial the content of total nitrogen after red clover was by 14 – 28% higher, after white clover by 31 – 33% higher. The highest increase in humus content (0.25 percentage units) occurred with ploughing in red clover aftermath, slightly less (0.21 percentage units) with variously managed white clover. The largest amount of available phosphorus in the plough layer was identified after red clover, whose aftermath was ploughed in, and that of available potassium after identically managed white clover.

***Table 3**. The effect of different legumes on soil agrochemical properties*

Preceding crops of winter cereals	N %		Humus %		P_2O_5 mg kg^{-1}		K_2O mg kg^{-1}	
	1	2	1	2	1	2	1	2
1. Red clover (R)	0.105	0.120	1.56	1.66	179	147	163	131
2. Red clover (R+A)	0.090	0.115	1.63	1.88	207	200	148	164
3. White clover (R)	0.090	0.120	1.59	1.80	194	196	163	135
4. White clover (R+A)	0.080	0.105	1.55	1.76	170	185	154	168
5. Timothy (R)	0.095	0.120	1.64	1.78	161	163	174	130

Note: 1– before trial establishment, 2 – after ploughing in of perennial grasses

During mineralization of nitrogen-rich residues of legumes, the gradually released nitrogen has a positive effect on the formation of yield biological parameters during all cereal growth stages, unlike mineral fertilisers of which a large part is leached (McGuire et al., 1999). The productivity of cereals is determined by a lot of characteristics and traits: growing period, overwinter survival, ear productivity, grain size, photosynthetic efficiency, disease resistance and others (Chlebnikov et al., 1997; Plyčevaitienė, 2002).

Yield forming indicators, grain yield and grain protein content

Crop stand density data show that triticale had a significantly higher number of plants, which made up by 11.0% more compared with rye (Fig. 1).

Preceding crops did not have any effect on crop stand density. Similar data were obtained while analysing biological value of legumes in agrocenoses on heavy loam soils (Arlauskienė et al., 2001). Insignificant differences in the number of plants per area unit might have occurred due to different seed placement depth, different seed vigour and other factors. The most important factor for high yield is the number of productive stems per area unit. It shows biological stability of the variety, its persistence or resistance to variable environmental conditions (Chlebnikov et al., 1997; Plyčevaitienė, 2002).

The intensity of productive tillering of all crops was also dependent on the weather conditions. In 2004, when there was a shortage of moisture during the growing season, i.e. the rainfall constituted only 72% of the long-term rate, the mean tillering coefficient of triticale was 1.17, and of rye 1.08. In 2005 when during the growing season the amount of rainfall was 169% of the long-term rate, the mean tillering coefficient of triticale was lower (1.08), and of rye higher (1.13). Cereal species had a significant effect on the formation of productive stems. The number of productive stems in triticale crops was on average 322.6 per m^2 or by 21.8 % more than that of rye. The highest number of productive stems formed in the cultivation sites where red clover aftermath had been ploughed in.

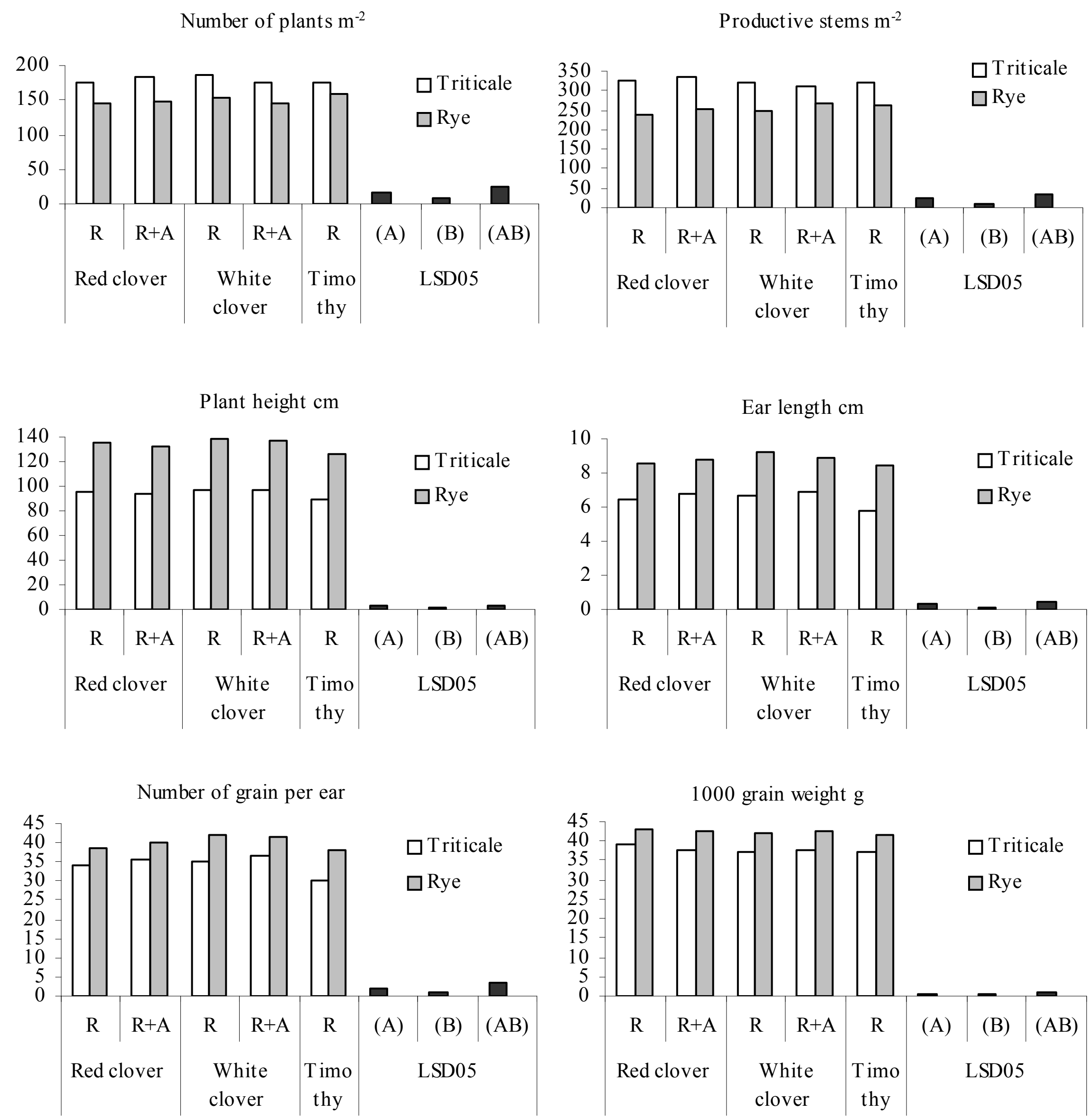


***Figure 1**: The effect of preceding crops on the triticale and rye yield forming indicators*

Plant height is a very variable trait that depends on the characteristics of a variety, weather conditions and geographical terrain (Plyčevaitienė, 2002). Diverse nitrogen contents in clover residues and aftermath determined different plant height of cereals. The greatest plant height of both cereal species was recorded in the treatments fertilised with white clover. Having compared white clover treatments no significant differences were revealed, but different management of red clover did have some significant effect. Having ploughed in red clover residues cereals grew taller. Cereals grown after timothy were the shortest.

Similar data were obtained while analysing ear length. The ears of cereals grown after timothy were significantly shorter (8 – 10 %), compared with clover preceding crops. Different clover green manures did not have any significant effect on ear length; inappreciably longer eras were recorded only after white clover.

Averaged data show that winter rye matured 17.5 % more grain (or 6 grains more) per ear compared with winter triticale. The higher number of grain per era for the varieties of both cereals was obtained in the treatments fertilised with white clover residues and aftermath.

1000 grain weight varies due to different weather conditions during grain formation and ripening stage and is affected by fertilisation and number of plants per area unit (Plyčevaitienė, 2002). 1000 grain weight of winter rye was significantly higher (4.6 g) than that of triticale. 1000 grain weight was less affected by preceding crops than the number of grain per ear. The lowest 1000 grain weight was recorded after timothy and white clover of which only residues were ploughed in. However, having incorporated a larger amount of green manure, i.e. red clover residues and aftermath and white clover aftermath the soil received more nutrients. This leads to the conclusion that a higher content of biological nitrogen incorporated had a significant effect on 1000 grain weight of cereals.

Cereal species had the greatest effect on both 1000 grain weight and grain yield, the effect of the preceding crop was lower. Averaged data show that rye grain yield, irrespective of different preceding crops, was by 0.38 t ha^{-1} higher than that of triticale. Comparison of the preceding crops indicates that having ploughed in white clover aftermath the highest cereal grain yield was obtained. Ploughing in of white clover aftermath increased triticale grain yield by 0.94 t ha^{-1} and that of rye by 0.41 t ha^{-1}, whereas ploughing in of red clover aftermath exerted some effect only on rye grain yield (Fig. 2).

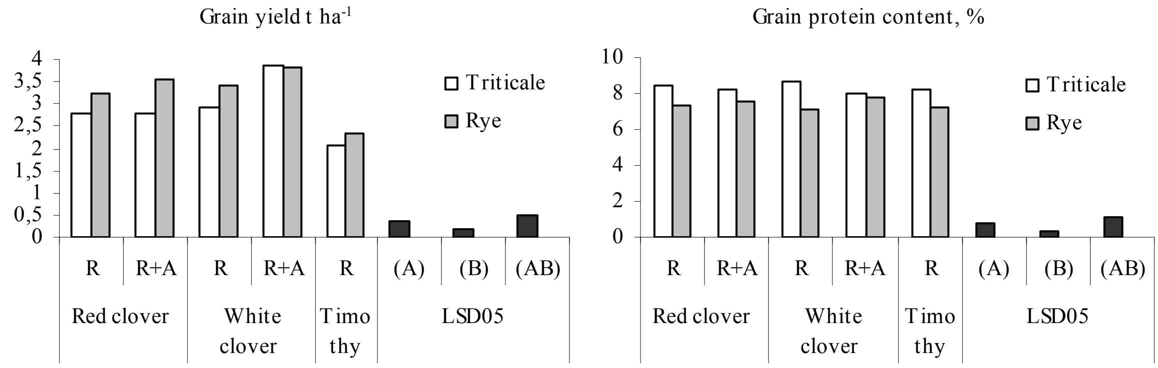


***Figure 2**: The effect of preceding crops on triticale and rye grain yield and grain protein content*

Different enrichment of soil with nutrients did not have any significant effect on protein content in cereal grain (Fig. 2). In all cases nitrogen content in triticale grain was by 5 – 35% higher than that of rye. Only in rye grain nitrogen content was positively influenced by nitrogen-rich plant residues. Comparison of the preceding crops shows that the highest nitrogen increase (18%) was obtained having ploughed in aftermath of white clover.

Different preceding crops and diverse amounts of nutrients contributed to the soil determined different formation of yield biological parameters of winter rye and triticale. Analysis of variance of the data suggests that crop stand density and the number of productive stems were significantly affected only by the species of cereals ($F_{fact.} = 19.49 > F_{theor.0.1} = 7.06$ and $F_{fact.} = 32.82 > F_{theor.0.1} = 7.06$), and plant height, ear length, number of grain per ear, 1000 grain weight and grain yield were affected by both factors investigated, i.e. by preceding crops of winter cereals and cereal species (Table 4).

***Table 4**. Results of Fisher-test of productivity parameters*

Productivity parameters	Variance			
	Treatment	Factor A	Factor B	Interaction AB
Number of emerged plants	1.66	0.21	13.49**	0.16
Number of productive stems	3.92**	0.12	32.82**	0.50
Plant height	129.98**	9.67**	1129.22**	0.48
Ear length	23.98**	3.86**	197.17**	0.80
Number of grain per ear	4.72**	2.87*	29.65**	0.34
1000 grain weight masė	29.82**	3.1*	252.71**	0.81
Grain yield	5.02**	9.46**	4.89**	0.61

Similar regularities of green manure effect were identified while comparing lucerne, red clover and vetch-oats mixture on heavy-textured soils (Arlauskienė et al., 2002; Janušienė et al., 2004; Makštėnienė et al., 2001). The efficiency of green manure in sandy loam soil increases when using this management means together with mineral fertilisation (Romanovskaja et al., 2003; Vaišvila et al., 1997).

Diseases incidence and severity

Grain yield in cereals depends not only on such yield components: number of ears per unit area, number of grains per ear, grain weight per ear and 1000 grain weight, but also on plant resistance to diseases. A strong mutual compensation is usually found between all productivity components and plant resistance to disease. However, a limitation of one component can not be completely compensated for by the others. Grain weight predominantly depends on how much the plant assimilates during the stage of grain-filling, and this is closely related to the area of long-lived green leaves. The favourable results of effective disease control on grain yield are largely based on a higher long-lived green leaves (Darwinkel, 1978).

The spread of the following foliar diseases during the experimental period was more intensive: in rye – scald and brown rust, in winter triticale – scald, brown rust and septoriosis. Experimental findings suggest that in 2004 scald affected from 29.2 to 47.5% of rye leaves and severity of this disease was from 7.0 to 9.75%. In 2005 scald was extremely severe and affected from 50.8 to 69.2% of rye leaves, severity was from 8.75 to 18.32%. Significant differences were determined between treatments, i.e. the incidence of scald in rye grown after variously-managed preceding crops was different.. According to the average research data, rye that grew after white clover whose aftermath was ploughed in (R + A) was by 1.4 times more affected by this disease causal agent and rye that grew after white clover whose only residues were ploughed in (R) was affected by 1.3 times more compared with the rye preceded by timothy (Fig. 3). The severity of scald was also higher in rye grown after white clover by 1.1 and 1.2 times, respectively. Rye stand density (different number of productive stems) did not have any effect on scald severity and incidence (r = 0.171 and 0.215) in 2004. But the lowest incidence of this disease was recorded in rye grown after variously managed red clover in 2005. The incidence and severity of scald depended also on rye stand density. A medium strong positive correlation was identified between scald incidence and severity and the number of rye productive stems: incidence: $y = 21.976 + 0.132\ x$, $r = 0.638^{**}$ ($P < 0.05$); severity: $y = 0.097 + 0.062\ x$, $r = 0.598^{**}$ ($P < 0.05$).

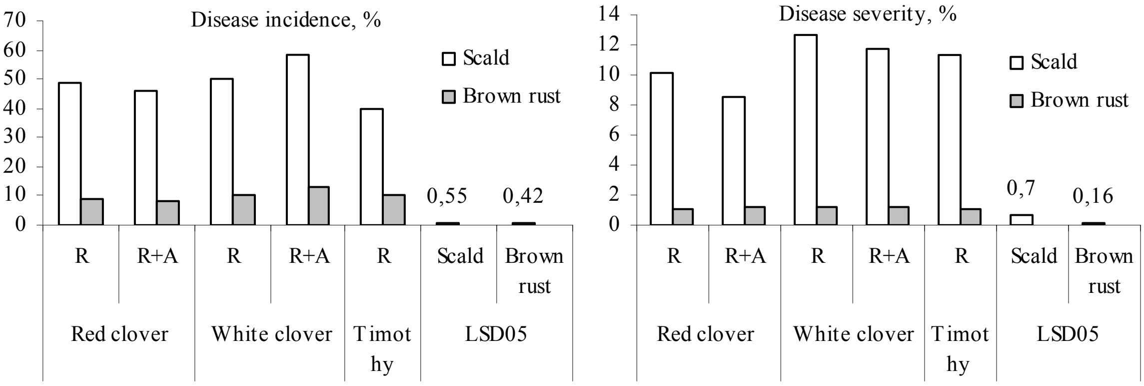


***Figure 3**: The effect of preceding crops on rye foliar fungal diseases incidence and severity. Average data of 2004 – 2005.*

In 2004 and 2005 the incidence of brown rust in rye agrocenose was similar, however, the disease severity was different. In 2004 the higher amount of rainfall in June promoted a more intensive occurrence of brown rust in rye, whereas warmer and drier weather during the same period in 2005 resulted in 2.2 – 3.0 times lower severity of the disease. So, incidence of brown rust was from 5.8 to 16.6% in 2004 and from 9.2 to 12.5% in 2005, and severity – from 1.51 to 1.83 and from 0.52 to 0.85 respectively. The greatest number of brown rust-affected rye (10.8 – 16.6%) in 2004 was identified in the treatments where rye was grown after variously-managed white clover, and the rye preceded by red clover and timothy were the least-affected. In 2005, conversely, the rye grown after red clover and timothy was by 1.1-1.4 times more affected by brown rust, compared with the rye grown after white clover. Average research data suggests that rye growing in different conditions, i.e. after different preceding crops does not have any consistent effect on brown rust incidence and severity (Fig. 3). However, a medium strong correlation was identified between rye stand density and brown rust incidence in 2005: $y = 16.047 – 0.019\ x$, $r = – 0.606^{**}$ ($P < 0.05$).

In the experimental years the incidence of scald was rather high not only on rye but also on winter triticale. In 2004 after different preceding crops from 31.3 to

52.5% of winter triticale plants were scald affected and in 2005 from 18.8 to 21.3%. According to the average research data significant differences in the incidence of scald were determined between all treatments, however the highest incidence and severity of scald were identified in winter triticale grown after legumes (red and white clovers), compared with the triticale preceded by spiked plants (Fig. 4). Winter triticale stand density had a great effect on the incidence of scald, there was identified a correlation between scald incidence and the total number of winter triticale stems (y = 38.085 – 0.049, r = – 0.565*; P < 0.05) and between scald incidence and the number of triticale productive stems (y = 37.179 – 0.056x, r = – 0.778**; P < 0.05). Different triticale stand densities did not have any effect on the severity of scald (r = – 0.267* and – 0.166*, respectively).

During the experimental period in all agrocenose winter triticale was affected by brown rust causal agent *Puccinia recondita* Roberge ex Desmaz., however the disease severity was very low and in most cases did not reach 1%. In some cases only the traces of the disease were identified. The relationship between the incidence of brown rust and ecological conditions of cereal cultivation site was identified: in 2004 by 5.0 – 7.5 percentage units higher disease incidence was recorded in winter triticale which was preceded by variously-managed white clover. However in 2005 an opposite trend of brown rust incidence was observed, the disease incidence was by 1.4 – 1.6 times higher in the cultivation sites where timothy residues were ploughed in for the preceding crop of the cereal, compared with winter triticale grown after white clover.

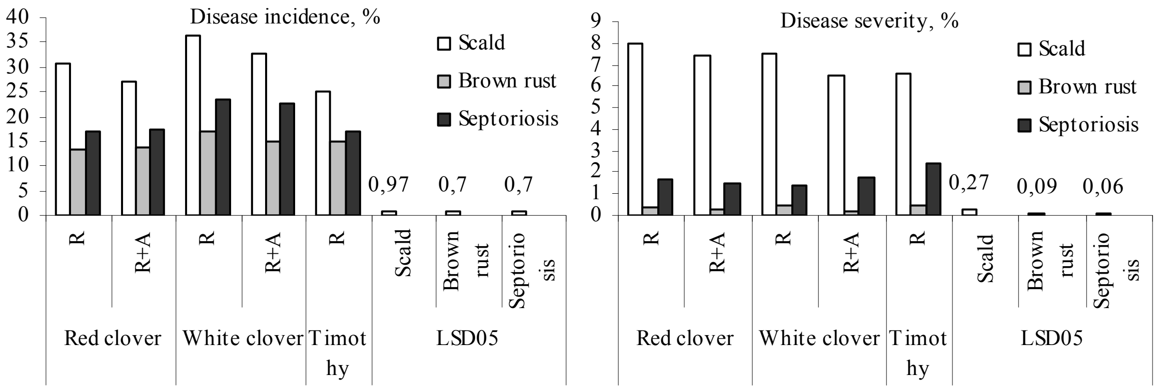


***Figure 4**. The effect of preceding crops on triticale foliar diseases incidence and severity. Average data of 2004 – 2005.*

Moderately strong infection of septoriosis was identified in winter triticale (Fig. 4). The incidence of septoriosis, and in many cases severity, was significantly affected by different winter triticale growing conditions, especially in 2004 the infection level on winter triticale grown after differently-managed white clover was twice as high as in triticale preceded by timothy. As the average data show, the highest disease pressure was identified in triticale grown after white clover whose residues (R) and aftermath were ploughed in (R + A): the triticale grown under such conditions were septoriosis affected by 1.4 – 1.6 times more than triticale grown after the other preceding crops (Fig. 4). Slightly fewer leaf spot-affected winter triticale leaves were identified in the stands with a lower plant density r = – 0.395*.

Disease resistance are very highly dependent on the weather conditions of the year of cultivation and genotype. It is noteworthy that winter rye varieties are characterized by yield stability between years, whereas triticale productivity varies more markedly. When weather contitions are unfavorable or, when there is a shortage of nutrients, the varieties are incapable of actualizing their genetic potential and resistance to diseases too (Sliesaravicius et al., 2006).

4 CONCLUSIONS

Various preceding crops largely determined chemical properties of light loamy soils. The highest humus contents accumulated in the soil after red clover aftermath, while the highest contents of nitrogen, phosphorus and potassium accumulated after white clover aftermath.

Nitrogen and potassium-rich red clover aftermaths used as green manure increased the number of productive stems and 1000 grain weight. Variously -used white clover preceding crop had a positive effect on plant height, ear length and grain number per ear.

Ploughing in of white clover aftermath increased triticale grain yield by 0.94 t ha^{-1} and that of rye by 0.41 t ha-1, whereas ploughing in of red clover aftermath exerted some effect only on rye grain yield.

Host-plants growing conditions influenced the incidence of some diseases. In winter triticale preceded by white clover we identified a more intensive occurrence of diseases, such as septoriosis, compared with other preceding crops. It was identified a more intensive occurrence of diseases, such as scald in rye preceded by white clover compared with the other preceding crops too.

5 REFERENCES

Alaru M., Laur Ű., Jaama E. 2003. Influence of nitrogen and weather comditions on the grain quality of winter triticale. Agron. Research 1: 3–10.

Arlauskienė A. 2000. Ankštinių žolių, kaip priešsėlių, bei jų žaliosios masės užarimo trąšai įtaka dirvožemio savybėms ir javų grandies produktyvumo formavimuisi. Žemdirbystė 70: 48–65.

Arlauskienė A., Maikštėnienė S. 2001. Ankštinių augalų biologinė vertė agrocenozėse. Žemės ūkio mokslai 1: 22–30.

Bailey K.L., Duczek L.J. 1996. Managing cereal diseases under reduced tillage. Canadian J. of Plant Path. 18: 159–167.

Conway K.E. 1996. An overview of the influence of sustainable agricultural systems on plant diseases. Crop Protection 15: 223–228.

Darwinkel A. 1978. Patterns of tillering and grain production of winter wheat at a wide range of plant densities. Neth. J. Agricultural Science 26: 383–398.

EPPO Standarts. 1997. Guidelines for the efficacy evaluation of plant protection products. Fungicide 2: 5-105.

Eyal Z. 1999. Septoria and Stagonospora diseases of cereal: a comparative perspective. Proceedings of the 15th Long Ashton International Symposium – Understanding Pathosystems: a Focus of Septoria, 1–25.

Gaurilčikienė I., Lisova R. 1999. Grybinių ligų paplitimas skirtingai tręštuose tetraploidiniuose rugiuose. Žemdirbystės instituto užbaigtų tiriamųjų darbų konferencijos pranešimai 31: 22-25.

Granstedt A. 2000. Ecological grassland management in the Nordic Countries. In: proceedings of the International Symposium: Conventional and ecological grassland management, Tartu., 45-62.

Hutcheon J.A., Jordan V.W.L. 1996. Influence of cultural practice and rotation on the incidence of stem-base disease in systems comparisons 1989–1994. Aspects of Applied Biology 47: 343–350.

Lisova R., Greimas G., Tripolskaja L. 1996. Tręšimo sistemų įtaka grybinių ligų išplitimui javuose, esant skirtingai sėjomainai ir priešsėliams. Žemdirbystė 52: 72–87.

Loivěke H., Laitamm H., Sarand R.J. 2003. *Fusarium* fungi as potential toxicants on cereal and grain feed grown in Estonia during 1973–2001. Agron. Research 1-2: 185–196.

Janušienė V. 1992. Biologinė medžiagų apykaita natūraliose ir kultūrinėse biogeocenozėse. Dirvotyra 40: 98–108.

Janušienė V., Žekonienė V. 2004. Žaliosios trąšos poveikis humuso bei mineralinio azoto pokyčiams priesmėlio dirvožemyje. Žemės ūkio mokslai 4: 1–6.

Magyla A., Šateikienė D., Šlepetienė A. 1997. Augalinių liekanų kiekis, jų cheminė sudėtis ir dirvožemio humusas įvairios specializacijos sėjomainose. Žemdirbystė 58: 56–75.

Magyla A., Endriukaitis A., Žemaitis V., Kaunas J., Simanavičienė O., Rainys K., Jovaišienė E., Vizgirda M. 2001. Svarbesnių pasėlių išsidėstymas Lietuvoje ir jų koncentracijos arealai. Akademija, 65 p.

Magyla A., Svirskienė A., Šlepetienė A. 2004. Dirvožemio agronominių savybių pokyčiai auginant žirnius po skirtingų priešsėlių ir stebint jų poveikį žieminiams kviečiams. Žemdirbystė 85: 102–119.

Maikštėnienė S., Arlauskienė A. 2001. Ankštinių augalų reikšmė agrosistemos produktyvumo didinimui sunkaus priemolio dirvožemyje. Ekologija 1: 23–30.

McGuire A.M., Byrant D.C., Denison R.F. 1999. Wheat yields, nitrogen uptake, and soil moisture followingwinter legume cover crop vs. fallow. Agron. J. 90: 404–410.

Plyčevaitienė V. 2002. Žieminių rugių linija LŽI 347. Žemdirbystė 77: 162–169.

Romanovskaja D., Tripolskaja L. 2003. Įvairių organinių trąšų naudojimo priesmėlio dirvožemyje agroekologinis įvertinimas. Žemdirbystė 84: 3–22.

Sliesaravicius A., Pekarskas J., Rutkoviene V., Baranauskis K. 2006. Grain yield and disease resistance of winter cereal varieties and application of biological agent in organic agriculture. Agron. Research, 4: 371–378.

Šurkus J., Gaurilčikienė I. 2002. Žemės ūkio augalų kenkėjai, ligos ir jų apskaita. Akademija, 345 p.

Tarakanovas P., Raudonius S. 2003. Agronominių tyrimų duomenų statistinė analizė taikant kompiuterines programas ANOVA, STAT, SPLIT-PLOT iš paketo SELEKCIJA ir IRRISTAT. Akademija, 55 p.

Vaišvila Z., Mažvila J., Ryliškienė E., Arbačiauskas J. 1997. Mineralinių trąšų įtaka žemės ūkio augalų derliui, jo kokybei, maisto medžiagų balansui ir ekologinei būklei vidutinio sunkumo limnoglacialiniame priemolio dirvožemyje. Žemdirbystė 60: 24–37.

Трепащев Е.П. 1979. О понятий вынос азота для бобовых культур. Агрохимия 11: 21–23.

Хлебников Н.Г., Макаров В.И., Маслова Н.Ф. 1997. Сравнительная оценка сортов озимой ржию. Зерновые културы 3: 13–14.

Шпаков А.С. 1999. Роль полевых и естественных кормовых растений в агроландшафтах. Кормопроизводство 12: 12–17.

COBISS Code 1.01

DOI: 10.2478/v10014-009-0013-1

Agrovoc descriptors: heterorhabditis bacteriophora; identification; classification; indigenous organisms; insect nematodes; geographical distribution; biological control; pest control

Agris category code: H10

Heterorhabditis bacteriophora (Poinar) – the first member from Heterorhabditidae family in Slovenia

Žiga LAZNIK[1], Tímea TÓTH[2], Tamás LAKATOS[3], Stanislav TRDAN[4]

Received: December 16, 2008; accepted: June 23, 2009.
Delo je prispelo 16. decembra 2008; sprejeto 23. junija 2009.

ABSTRACT

In August 2008, we examined 95 soil samples for the occurrence of entomopathogenic nematodes in eastern part of Slovenia. 11 samples from 9 different locations were positive to entomopathogenic nematodes, but to this time only sample D54 was analysed. This soil sample was collected in Dravograd. Genetic studies proved that the nematode species in this sample was *Heterorhabditis bacteriophora*. This is the first record of *Heterorhabditis* nematode in Slovenia. Until now we confirmed the presence of four entomopathogenic nematode species in Slovenia; *Steinernema affine, Steinernema carpocapsae, Steinernema feltiae* and *Steinernema kraussei*. We expect that in Slovenia the use of these biological agents against insect pests will become important alternative to insecticides as it is known in many other countries of the world.

Key words: biological control, entomopathogenic nematodes, indigenous species, Slovenia, *Heterorhabditis bacteriophora,* Heterorhabditidae, first record

IZVLEČEK

ENTOMOPATOGENA OGORČICA *Heterorhabditis bacteriophora* (Poinar) – PRVI PREDSTAVNIK IZ DRUŽINE HETERORHABDITIDAE, NAJDEN V SLOVENIJI

V avgustu 2008 smo preučili 95 talnih vzorcev, da bi ugotovili zastopanost entomopatogenih ogorčic v vzhodnem delu Slovenije. 11 vzorcev z devetih različnih lokacij je bilo pozitivnih na zastopanost entomopatogenih ogorčic. Doslej smo analizirali le vzorec D54, ki je bil odvzet blizu Dravograda. Genetska analiza je potrdila, da gre za vrsto *Heterorhabditis bacteriophora*. Gre za prvo najdbo ogorčice iz rodu *Heterorhabditis* v Sloveniji. Doslej smo v Sloveniji potrdili zastopanost 4 vrst entomopatogenih ogorčic, in sicer: *Steinernema affine, Steinernema carpocapsae, Steinernema feltiae* in *Steinernema kraussei*. Pričakujemo, da bo v Sloveniji uporaba omenjenih naravnih sovražnikov škodljivih žuželk postala pomembna alternativa insekticidom, kar je sicer že znano v številnih drugih državah sveta.

Ključne besede: biotično varstvo, entomopatogene ogorčice, domorodna vrsta, Slovenija, *Heterorhabditis bacteriophora*, Heterorhabditidae, prva najdba

[1] Young researcher, B. Sc., University of Ljubljana, Biotechnical Faculty, Department of Agronomy, Jamnikarjeva 101, SI-1111 Ljubljana, email:ziga.laznik@bf.uni-lj.si

[2] Ph.D student, M. Sc., Vadastag 2, H-4244 Újfehértó, Hungary

[3] Ph. D, Vadastag 2, H-4244 Újfehértó, Hungary

[4] Assoc. Prof., Ph. D, Jamnikarjeva 101, SI-1111 Ljubljana

1 INTRODUCTION

The entomopathogenic nematode *Heterorhabditis bacteriophora* was first described in 1975 as a new species as well as a member of new genus, and family (Heterorhabditidae) of Rhabditida (Poinar, 1976). The infective juvenile (IJ) stage was found to transmit a specific Gram-negative bacterium in the anterior intestine to the hemocoel of insect hosts (Poinar *et al*., 1977). This symbiotic bacteria is *Photorhabdus luminescens* subspecies *luminescens* (Fischer-Le Saux *et al*., 1999). Until now several *Heterorhabditis* species have been described (Adams *et al*., 2006) and studied for their biological control potential (Selvan *et al*., 1993; Koppenhöfer *et al*., 2004).

Transmission of symbiotic bacteria by the IJ of entomopathogenic nematodes is significant for EPN to successfully parasitize insect host and to reproduce (Han and Ehlers, 2000). This relationship can also be described as an obligate (for nematode and bacteria) vector-born disease of insects. It is discussed upon symbiotic-mutualistic relationship because nematodes provide shelter and protection for bacteria in an exchange for killing the attacked insects (Han and Ehlers, 2000). Latter, bacteria also produce antibiotics, which prevent the development of intra- and interspecific competitors (Hu and Webster, 2000), which would also feed on cadavers. Bacteria transform the content of the host into feed, suitable for nematodes and also bacteria themselves are feed for nematodes (Kaya and Koppenhöfer, 1999).

Heterorhabditis bacteriophora life cycle includes an egg, four juvenile stages and the adult (Poinar, 1976). The third-stage juvenile is the only free-living form, which is able to attack and infect the insect. The infective third-stage juveniles move through the soil in search of an insect host. This stage is adapted to live without feeding for a prolonged time. When the host is found, the nematode can enter into it through natural openings, or uses a dorsal tooth or hook, to break the insect cuticle. After entrance the nematode releases the symbiotic bacteria (Milstead, 1979). The bacteria multiply in the insect hemocoel and in the period from 24 to 72 hours after the entrance of the entomopathogenic nematode insect usually dies (Ciche and Ensign, 2003).

In Slovenia, momentarily only two species of entomopathogenic nematodes, *Steinernema feltiae* and *S. carpocapsae*, have a status of indigenous species (MAFF, 2008ab); therefore only this species can be applied in the field. With the researches, which results we also present in this paper, we want to enlist as more species of entomopathogenic nematodes as it is possible, while in foreign countries they worth as alternatives to insecticides in controling pest insects (Schroer *et al*., 2005). The strain D54, which we present in a current paper, we plan to use in extensive experiments in the future; first in the laboratory and afterward, when its status will be administratively entrenched, also in the field.

2 MATERIALS AND METHODS

In August 2008, we examined 95 soil samples from 19 different locations on the occurrence of EPNs in Slovenia. The soil samples, five from each location, were taken in Prekmurje, Koroška and Štajersko region (eastern part of the country). We used »Galleria bait method«, which is the most frequently used method of EPNs detection from soil. After the death of greater wax moth (*Galleria mellonella* [Linnaeus]) larvae, we dried cadavers for 12 days and put them in so called »White trap« (Bedding and Akhurst, 1975) to separate the nematodes from death larvae. The suspension, which was acquired in this way, was used for artificial infection of the larvae of greater wax moth. Following procedure contained the use of centrifuge and 5 % concentration of sodium hypochlorate. The aim of this process was to acquire infective juveniles from the suspension. We confirmed the presence of nematodes in 11 soil samples from 9 locations. Only 1 positive sample, D54 (taken in the meadow near the city Dravograd (NW Slovenia, 46°35′N, 15°01′E, 390 m alt.) was identified to this time.

3 RESULTS

To confirm the identification of isolated nematodes from larvae of wax moth, a selected sample was analysed by molecular biological approach. Genomic DNA was extracted from individual nematode and PCR was performed to multiply ITS region using primers TW81 and AB28 after Hominick *et al*. (1997). PCR product were reisolated from 1 % TAE-buffered agarose gel using QIAquick Gel Extraction Kit (Qiagen, USA) (Fig. 1). Reisolated sample was sequenced in the laboratory of the Agricultural Biotechnological Research Centre, Gödöllő, Hungary. The sequence was submitted into GenBank public database (Accession Number: FJ477060).

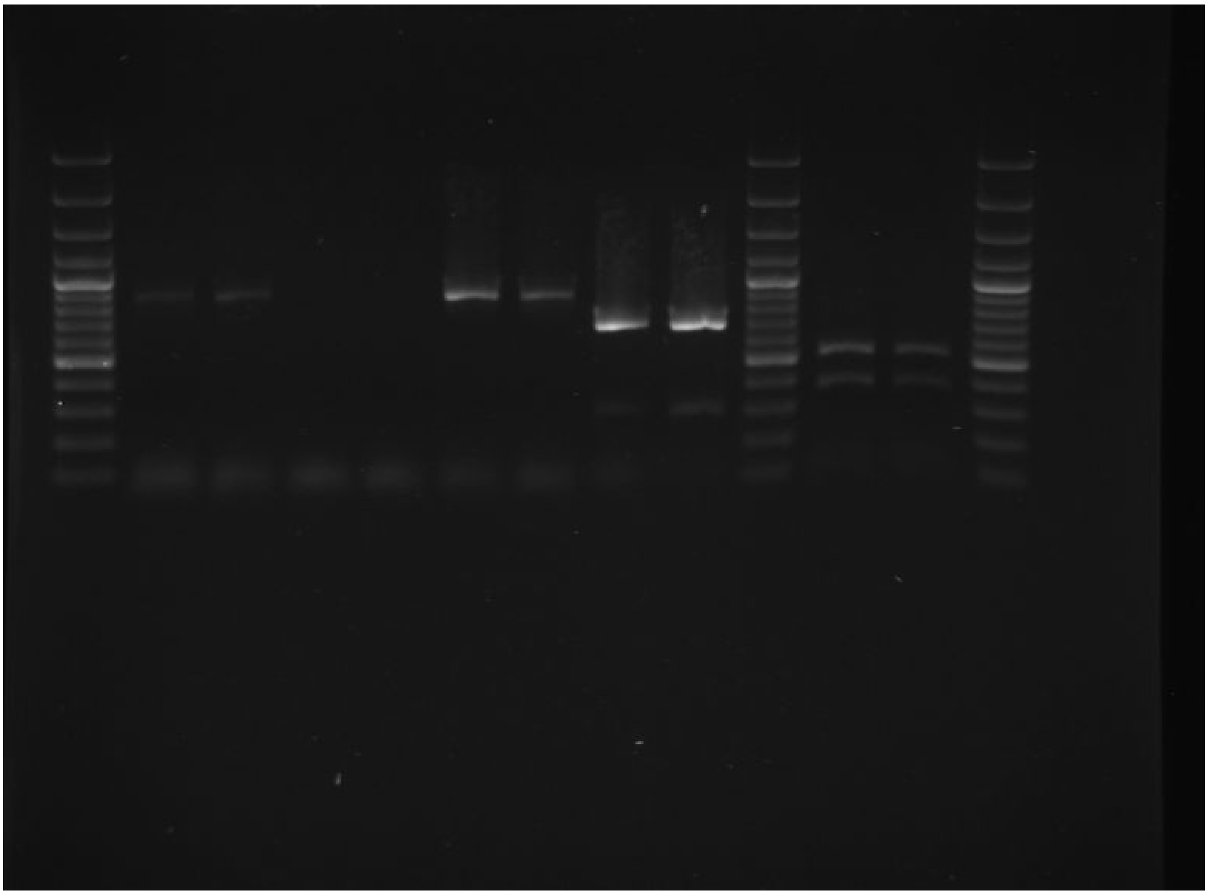


Figure 1*: 1 % TAE buffered agarose gel, in the 1st, 10th and 13th lanes: GeneRuler 100 bp DNA Ladder Plus (Fermentas), in the 6th and 7th lane: PCR product of our sample D54, using the primer pair specified in the text, 8th and 9th lane: PCR product of sample slug nematode – Alloionema appendiculatum. The two most strength fragment in the ladder are 500 and 1000 bps length.*

Sample DNA sequence was compared to sequences of species *Heterorhabditis* using BLAST search in National Centre for Biotechnology Information (NCBI) web site (www.ncbi.nlm.nih.gov). The sequences producing significant alignments and at least 99 % identity were derived from *Heterorhabditis bacteriophora*: GenBank Accession No. FJ346825 and EU921445 (Fig. 2).

```
FJ477060  1    CGCCGA-AACCTTAT--GGGT-AATGCTT-TG-AT-CACGAGAG-ATCGGTACCACT-GG  51
FJ346825  100  ......-........--....-.......-..-..-........-..........A.-..  150
EU921445  1                 ..--....-..-.-..CC.-..-........-..........A.-..  38
EF043440  190  ......-........--....-.......-..-..-.......T-..........A.-..  240

FJ47706   52   -AAT-CAG-GCT-T-G-TTCTT-GATTT-C-AATCGGTTT---CTCA-CCCCATCTAAGC  98
FJ346825  151  -...-...-...-.-.-.....-.....-.-.........---....-............  197
EU921445  39   -...-...-...-.-.-.....-.....-.-.........---....-............  85
EF043440  241  -...-...-...-.-.-.....-.....-.-.........---....-............  287

FJ477060  99   -TCAT-GGAG-A-GGTGT-CTAGT-CCCAAT-TGGAGTCGCTTTGAGTGA-C-GGCTAT-  148
FJ346825  198  -....-....-.-.....-.....-......-..................-.-......-  247
EU921445  86   -....-....-.-.....-.....-......-..................-.-......-  135
EF043440  288  -....-....-.-.....-.....-......-..................-.-......-  337

FJ477060  149  G-AAAATTGGGTATG---T-TCCC---CGTGAGGGTCGAGCATAGACTTTATGAACAGCT  200
FJ346825  248  .-.............---.-....---...............................-.  298
EU921445  136  .-.............---.-....---...............................-.  186
EF043440  338  .-.............---.-....---...............................-.  388

FJ477060  201  GCT-GG-AGCTGTCGCCTCACCAAAAAATCATC-GATAACT-GGTGGCTAT-G-TGTGAC  254
FJ346825  299  ...-..-..........................-.......-.........-.-......  352
EU921445  187  ...-..-..........................-.......-.........-.-......  240
EF043440  389  ...-..-..........................-.....G.-.........-.-......  442

FJ477060  255  ATT-AGTCACAT-AG-GTA-TC-TG-C-TGATGCAG-AGAG-CCTCTAATGAGTTGTT--  303
FJ346825  353  ...-........-..-...-..-..-.-........-....-...-............--  400
EU921445  241  ...-........-..-...-..-..-.-........-....-...-............--  288
EF043440  443  ...-........-T.-...-..-..-.-........-....-...-............--  490

FJ477060  304  C-GTGTCATC-TGACC-TACAA-CCGCCAG-TATCGGT--AAA-T-C--AACCCAA-TTA  351
FJ346825  401  .-........-.....-.....-.......-.......--...-.-.--.......-...  448
EU921445  289  .-........-.....-.....-.......-.......--...-.-.--.......-...  336
EF043440  491  .-........-.....-.....-......C-.......--...-.-.--.......-...  538

FJ477060  352  ACTTGTTTC-T-TG-TGTCGTGT-TAATACATAC-TGGCA-AAGTGTATTAGCTTTAGCG  405
FJ346825  449  .........-.-..-........-..........-.....-...................  502
EU921445  337  .........-.-..-........-..........-.....-...................  390
EF043440  539  .........-.-..-........-..........-.....-...................  592

FJ477060  406  ATGG-ATCGGTTGATTCGCGTATCGATGAAAAACGCAGCAAGC--TGCGTTATTTACCAC  462
FJ346825  503  ....-......................................--...............  559
EU921445  391  ....-......................................--...............  447
EF043440  593  ....-......................................--...............  649

FJ477060  463  GAATTGCAGACGCTTAGAGT-GGTGAAGTTTTGAACGCACAGCGCCGTTGGGTTTTCCCT  521
FJ346825  560  ....................-.......................................  618
EU921445  448  ....................-.......................................  506
EF043440  650  ....................-.......................................  708


FJ477060  522  TCGGCACGTCTGGCTCAGGGTTGTTTA-ATAAGCGAAAGTGTTGAAAGTTCATTAAACGA  580
FJ346825  619  ...........................-................................  677
EU921445  507  ...........................-................................  565
EF043440  709  ...........................-......-..-................G.....  765

FJ477060  581  GAGTTCGGTGATACTGACAACACTACGTCGAGCGGTGTACTGTTGAAAGTACCCCGTTCA  640
FJ346825  678  ............................................................  737
EU921445  566  ............................................................  625
EF043440  766  A.....A............G..T.G......T...C........................  825

FJ477060  641  AGTA--TCTTTATGGGGCAACATGTCTTCTATATGGAGACATGAAAGATATTAAGAGTAT  698
FJ346825  738  ....--......................................................  795
EU921445  626  ....--......................................................  683
```

```
EF043440  826  ..G.AA..........A................C....G.............T.......  885

FJ477060  699  ATACCTGTGGATGCCCACGTATGAAATATGACGTGTCGTATAC-ACGGCTAGGAGGTATG  757
FJ346825  796  ...........................................-................  854
EU921445  684  ...........................................-................  742
EF043440  886  ...........................................-................  944

FJ477060  758  TCTC-AGATGAA-TTT-G-TT-ATGCAACC-TGAGCTCAG  791
FJ346825  855  ....-.......-...-.-..T........-.........  889
EU921445  743  ....-...G...-..--.-..-........-.........  775
EF043440  945  ....-...-...A...-.A..-........-.........  979
```

Figure 2: *Multiple sequence alignment of the ITS rDNA region (including partial fragments of the 18S and 28S rDNA genes) of 4 Heterorhabditis species. Code FJ477060 correspond to the Slovenian isolate of Heterorhabditis bacteriophora (D54). Codes FJ346825 and EU921445 are Heterorhabditis bacteriophora strains from South Africa and Hungary. Code EFO43440 correspond to Heterorhabditis zealandica strain from Ireland.*

4 DISCUSSION

Genetic studies proved that the nematode species is *Heterorhabditis bacteriophora* (Poinar, 1976) (Fig. 2). The ITS1-5.8S-ITS2 region, including the partial 18S and 28S rRNA genes (flanked by above primers) of Slovenian isolate D54, was 791 bp long (Fig. 1). BLAST searches (Altschul *et al*., 1990) in GenBank showed that Slovenian isolate D54 (Fig. 2) has a high similarity (99 %) with those sequences available for *H. bacteriophora* populations (e.g. accession numbers FJ346825 and EU921445). Sequence of other species from *Heterorhabditis* group, namely *H. zealandica* was obtained from GenBank searches that exhibited a lesser degree of similarity with the Slovenian isolate and other *H. bacteriophora* populations (e.g. accesion number EFO43440) (Fig. 2). The present study constitutes the first report of *H. bacteriophora* in Slovenia. In Europe, the occurrence of *H. bacteriophora* was up to now confirmed in Bulgaria, Czech Republic, France, Germany, Hungary, Italy, Moldova, Poland, Portugal, Spain and Switzerland (Hominick, 2002). Only 4 species from genus *Heterorhabditis* were found in Europe; *H. bacteriophora* (11 countries), *H. megidis* (13 countries), *H. downesi* (3 countries) and *H. zealandica* (1 country) (Hominick, 2002).

Figure 3: *Infective juvenile (IJ) of Heterorhabditis bacteriophora from sample D54.*

The infective juveniles of *H. bacteriophora* are between 520 and 600 µm long (Fig. 3). Entomopathogenic IJs developed different foraging behaviours to infect insect host, cruiser and ambusher strategies (Lewis *et al*., 1995). *H. bacteriophora* is a cruiser forager, meaning that it actively searches its host. In addition to sensing CO_2 and volatile cues released by the host (O'Halloran and Burnell, 2002), IJs are attracted to ß-caryophyllene (Rasmann *et al*., 2005). This substance is a terpene, which is released, if the plant roots are damaged (Rasman *et al*., 2005). IJs developed chemosensory mechanisms not only to perceive the host, but also the locations where insect host are likely to be present.

H. bacteriophora IJs develop into hermaphrodites and this can lay eggs that develop into hermaphrodites, females or males. When the egg laying stops, nematodes can develop inside the maternal body with the process called *endotokia matricida* (Johnigk and Ehlers, 1999). Nematodes that are developed by *endotokia matricida* are predominantly hermaphroditic IJs (Dix *et al*., 1992).

Entomopathogenic nematode *H. bacteriophora* was proved to have big potential in biological control of insects (Selvan *et al*., 1993; Koppenhöfer *et al*., 2004). Some target pests that have been controlled by *H. bacteriophora* in field tests are white grubs, black vine weevil, strawberry root weevil, Colorado potato beetle, cucumber beetles and some others (Grewal *et al*., 2005). Some attempts have been made to test this nematode also against foliar pests, but the problem of desiccation, exposure to sunlight and high temperatures that are lethal to exposed nematodes have limited such applications (Grewal *et al*., 2005).

In Slovenia, momentarily only *Steinernema feltiae* and *S. carpocapsae* are on the domestic list and we are able to use them also in field experiments (Laznik *et al*., 2008ab). When also *H. bacteriophora* will shift from exotic agents list, we will test its activity against the pest insects in the open too. The most intensive experiments will be done against the insect pests for the control of which we do not have registered insecticides, their number is limited, and specially against the insects, which already developed the resistance to insecticides.

5 ACKNOWLEDGEMENTS

This work is a part of program Horticulture No P4-0013-0481 granted by Slovenian Research Agency, and the part of project CRP V4-0524 granted by Slovenian Research Agency and Ministry of Agriculture, Food and Forestry of R Slovenia.

6 REFERENCES

Adams, B.J., Fodor, A., Koppenhofer, H.S., Stackebrandt, E., Stock, S.P., Klein, M.G. 2006. Biodiversity and systematics of nematode-bacterium entomopathogens. Biol. Contr. 37: 32-49.

Altschul S.F., Gish W., Miller W., Myers E.W., Lipman D.J. 1990. Basic local alignment search tool. J. Mol. Biol. 215: 403 – 410.

Bedding R.A., Akhurst R.J. 1975. Simple technique for the detection of insect parasitic rhabditid nematodes in soil. Nematologica 21: 109-110.

Ciche, T.A., Ensign, J.C. 2003. For the insect pathogen *Photorhabdus luminescens*, which end of a nematode is out? Appl. Environ. Microbiol. 69: 1890-1897.

Dix, I., Burnell, A.M., Griffin, C.T., Joyce, S.A., Nugent, M.J., Downes, M.J. 1992. The identification of biological species in the genus *Heterorhabditis* nematode (Heterorhabditidae) by cross-breeding second generation amphimitic adults. Parasitology 104: 509-518.

Fischer-Le Saux, M., Viallard, V., Brunel, B., Normand, P., Boemare, N.E. (1999): Polyphasic classification of the genus *Photorhabdus* and proposal of new taxa: *P. luminescens* subsp. *luminescens* subsp. nov., *P. luminescens* subsp. *akhurstii* subsp. nov., *P. luminescens* subsp. *laumondii* subsp. nov., *P. temperate* sp. nov., *P. temperate* subsp. *temperate* subsp. nov and *P. asymbiotica* sp. nov. Int. J. Syst. Bacteriol. 49: 1645-1656.

Grewal, P.S., Ehlers, R.-U., Shapiro-Ilan, D.I. 2005. Nematodes as biocontrol agents. Wallingford, UK, CABI Publishing: 505 pp.

Han, R.C., Ehlers, R.-U. 2000. Pathogenicity, development and reproduction of *Heterorhabditis bacteriophora* and *Steinernema carpocapsae* under axenic *in vivo* conditions. J. Invertebr. Pathol. 75: 55-58.

Hominick W.M., Briscoe B.R., del Pino F.G., Heng J., Hunt D.J., Kozodoy E., Mracek Z., Nguyen K.B., Reid A.P., Spiridonov S., Stock P., Sturhan D., Waturu C., Yoshida M. 1997. Biosystematics of entomopathogenic nematodes: current status, protocols and definitions. J. Helminthol. 71: 271-298.

Hominick W.M. 2002. Biogeography. In: Gaugler R (ed) Entomopathogenic Nematology. CABI Publishing, Wallingford: 115-143.

Hu, K., Webster, J M. 2000. Antibiotic production in relation to bacterial growth and nematode development in *Photorhabdus-Heterorhabditis* infected *Galleria mellonella* larvae. FEMS Microbiol. Lett. 189: 219–223.

Johnigk, S.-A., Ehlers, R.–U. 1999. *Endotokia matricida* in hermaphrodites of *Heterorhabditis* spp. And the effect of the food supply. Nematology 1: 717-726.

Kaya K.H., Koppenhöfer A.M. 1999. Biology and ecology of insectidal nematodes. In: Optimal use of insecticidal nematodes in pest management. Poravarapu S. (ed.). New Jersey, Bluberry Cranberry Research and Extension Center: 1-8.

Koppenhöffer, A.M., Fuzy, E.M., Crocker, R., Gelernter, W., Polavarapu, S. 2004. Pathogenicity of *Steinernema scarabaei*, *Heterorhabditis bacteriophora* and *S. glaseri* to twelve white grub species. Biocontrol Sci. Technol. 14: 87-92.

Laznik, Ž., Tóth, T., Lakatos, T., Trdan, S. 2008a. Entomopathogenic nematode *Steinernema feltiae* (Filipjev) (Rhabditida: Steinernematidae) recorded for the first time in Slovenia. Acta Agric. Slov. 91: 37-45.

Laznik, Ž., Tóth, T., Lakatos, T., Trdan, S. 2008b. Entomopathogenic nematode *Steinernema carpocapsae* (Weiser) (Rhabditida:Steinernematidae), a new member of Slovenian fauna. Acta Agric. Slov. 91: 351-359.

Lewis, E.E., Selvan, S., Campbell, J.F., Gaugler, R. 1995. Changes in foraging behaviour during the infective stage of entomopathogenic nematodes. Parasitology 110: 583-590.

Ministry of Agriculture, Food, and Forestry of Republic Slovenia [MAFF]. 2008a: Decision on the change of the status of the exotic agent for biological control (no. 3430-9/2008/5): 2 p. [Slovenian]

Ministry of Agriculture, Food, and Forestry of Republic Slovenia [MAFF]. 2008b: Decision on the change of the status of the exotic agent for biological control (no. 3430-583/2008/2): 2 p. [Slovenian]

Milstead, J.E. 1979. *Heterorhabditis bacteriophora* as a vector for introducing its associated bacterium into the homocoel of *Galleria mellonella* larvae. J. Invertebr. Pathol. 33: 324-327.

O'Halloran, D.M., Burnell, A.M. 2002. Olfaction and odour discrimination in the insect parasitic nematode *Heterorhabditis bacteriophora*. Nematology 4: 206.

Poinar, G.O.J. 1976. Description and biology of a new insect parasitic rhabditoid, *Heterorhabditis bacteriophora* n. gen. n. sp. (Rhabditida: Heterorhabditidae n. fam.). Nematologica 21: 463-470.

Poinar, G.O.J., Thomas, G.M., Hess. R. 1977. Characteristics of the specific bacterium associated with *Heterorhabditis bacteriophora* (Heterorhabditidae: Rhabditida). Nematologica 23: 97-102.

Rasmann, S., Köllner, T.G., Degenhardt, J., Hiltpold, I., Toepfer, S., Kuhlmann, U., Gershenzon, J, Turlings, T.C.J. 2005. Recruitment of entomopathogenic nematodes by insect-damaged maize roots. Nature 434: 732-737.

Schroer, S., Sulistyanto, D., Ehlers, R.U. 2005. Control of *Plutella xylostella* using polymer-formulated *Steinernema carpocapsae* and *Bacillus thuringensis* in cabbage fields. J. Appl. Nematol. 129: 198-204.

Selvan, S., Gaugler, R, Campbell, J.F. 1993. Efficacy of entomopathogenic nematode strains against *Popillia japonica* (Coleoptera: Scarabaeidae) larvae. J. Econ. Entomol. 86: 353-359.

COBISS Code 1.01

DOI: 10.2478/v10014-009-0014-0

Agrovoc descriptors: aphidoidea; watermelons; citrullus lanatus; mulches; pest control; traps

Agris category code: H10

Aphid population in watermelon (*Citrullus lanatus* Thunb.) production

Katja ŽANIĆ[1], Dean BAN[2], Marisa ŠKALJAC[3], Gvozden DUMIČIĆ[4], Smiljana GORETA BAN[5], Dragan ŽNIDARČIČ[6]

Received: March 16, 2009; accepted: June 22, 2009.
Delo je prispelo 16. marca 2009; sprejeto 22. junija 2009.

ABSTRACT

The aim of this study was to compare the effect of PE black mulch with bare soil and hay cover against winged aphid number. In order to create management strategy in watermelon, flight dynamics of aphid population was recorded. The field experiment was set up as a randomized block design in three replications at Pula in Mediterranean region of Croatia. Aphids were collected weekly using yellow water metal traps. There were six sampling dates starting from 19 May until mulch was covered by plant canopy. We found significant difference in aphid number among the sampling dates as a result of their population dynamics on watermelon. The catches of two assessments in the second half of May were more numerous than during assessments in June. The flight maximum was recorded on 26 May and the population density significantly decreased from 9 June. There was not much effect of mulch on aphid number. However, at the peak of aphid population hay cover attracted 13% (26 May) and 18% (2 June) more aphids compared to bare soil.

Key words: Aphidae, watermelon, *Citrullus lanatus*, PE black film, hay mulch

IZVLEČEK

LISTNE UŠI NA LUBENICAH (*Citrullus lanatus* Thunb.)

Cilj naše raziskave je bil ugotoviti, kako PE črna folija v primerjavi z golimi tlemi in tlemi, prekritimi s senom, vpliva na razširjenost listnih uši na lubenicah. Tako smo z ugotavljanjem številčnega stanja uši želeli prilagoditi tehnolgijo gojenja lubenic v boju proti tem škodljivcem. Poljski poskus, ki je bil leta 2008 zasnovan po metodi naključnih blokov v treh ponovitvah, je bil postavljen v okolci Pulja v primorskem delu Hrvaške. Prisotnost uši smo s preštevanjem na rumenih kovinskih vabah ugotavljali vsak teden. Od 19. maja do trenutka, ko so listi lubenic prekrili tla, smo opravili šest preštevanj. Med posameznimi datumi smo ugotovili značilno razliko med številom uši na vabah, ki je bila posledica njihove populacijske dinamike na rastlinah. Število uši v dveh preštevanjih v drugi polovici maja je bilo znato večje od števila uši naštetih v juniju. Največji nalet uši je bil ugotovljen 26. maja. Njihova razširjenost pa se je značilno zmanjšala do 9. junija. Način zastiranja tal ni statistično značilno vplival na razširjenost uši. Poudariti pa je treba, da je na vrhuncu prisotnosti uši senena zastirka privabila 13 % (26. maja) oz. 18 % (2. junija) več uši, kot smo jih našteli v obravnavanjih na golih tleh.

Ključne besede: Aphidae, lubenice, *Citrullus lanatus*, PE črna folija, senena zastirka

1 INTRODUCTION

[1] Institute for Adriatic Crops and Karst Reclamation, Put Duilova 11, CR-21 000 Split; e-mail: Katja.Zanic@krs.hr
[2] Institute of Agriculture and Tourism, Carla Huguesa 8, CR-52 440 Poreč, Croatia
[3] Institute for Adriatic Crops and Karst Reclamation, Put Duilova 11, CR-21 000 Split
[4] Institute for Adriatic Crops and Karst Reclamation, Put Duilova 11, CR-21 000 Split
[5] Institute for Adriatic Crops and Karst Reclamation, Put Duilova 11, CR-21 000 Split
[6] Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, SI-1111 Ljubljana

Following the trends in cultural practice, many growers have employed mulching, as a common practice and the most often used soil cover is the black polyethylene (PE) mulch (Goreta et al., 2005). The use of polyethylene mulches increase early and total yield of many vegetable such as strawberry (*Fragaria X ananas* Duch.), tomato (*Lycopersicon esculentum* Mill.), pepper (*Capsicum annuum* L.), squash (*Cucurbita pepo* L.), potatoe (*Solanum tubeosum* L.) and melons (*Cucumis* and *Citrullus* spp.) (Soltani et al., 1995; Farias-Larios and Orozco-Santos, 1997b; White, 2003, 2004; Johnson et al., 2004). Many vegetable growers would prefer to use mulches that can be produced on-farm and incorporated into soil to build soil organic matter. Such organic plant waste include grasses, straw and hay.

According to Csizinszky et al. (1995), different mulch systems create a specific microenvironment around the plants. Compared to bare soil, changes in microenvironment include changes in root-zone temperature and in the quantity and quality of light reflected from the mulch surface back to leaves (Lamont, 1993).

The reflected energy from the mulches affects not only plant growth, development, yields, and the behaviour of insects that visit the plants (Kring and Shuster, 1992). Mulch systems may influence on aphid populations that landing in the crop. According to Farias-Larios and Orozco-Santos (1997a, 1997b) and Walters (1993), clear, black and white mulches reduce the aphid number compared to bare soil. Silver reflective mulch is superior to white, yellow, or black with yellow edges in reducing aphid population (Brown, 1993). The number of winged aphids per leaf is significantly higher on cantaloupe plants grown over bare soil than on those grown over reflective plastic or organic straw mulch (Summers et al., 2005). Straw mulch has been well studied in reducing pests infestation and virus incidence in several crops (Saucke and Döring, 2004; Trdan et al., 2008). Related to our observation, the use of straw mulch makes a problem in vegetable crops because of cereals germination. To avoid the cereals-weed appearance, organic mulch, hay was included in the experiment.

A number of aphid species have been recorded as Cucurbitaceae crops feeders (Millar, 1994; Farias-Larios and Orozco-Santos, 1997a; Stapleton and Summers, 2002). The aim of this study was to compare the effect of PE black mulch versus bare soil and hay cover on aphid number in watermelon crop.

2 MATERIAL AND METHODS

Field experiment with watermelon (*Citrullus lanatus* [Thunb.] Matsum & Nakai), cv. Farao (S&G Syngenta Seeds-Vegetables, Nederland/Belgie) was conducted at Valtura - Pula (44°52'N, 13°54'E, 10 m elevation) in Mediterranean region of Croatia, during 2008.

The treatments (PE black mulch, bare soil and hay cover) were arranged in a randomized complete block design with three replications. The hand planting was done on 9 May, 2008. The rows were 1.5 m apart and in-row plant spacing was 1.0 m. Each plot (4.5 m wide x 10 m long) was consisted of three rows (1.0 m wide x 10 m long). Black PE film was 0.02 mm thick and 120 cm width (Ginegar Plastics Products Ltd., Kibbutz Ginegar, Israel). The black mulch was applied using mulch-laying equipment, while the hay was spread by hand at 50 kg per plot in a thick layer (20 cm). Standard cultural and pesticide practice for commercial watermelon production were applied. The average growing period rainfall is 320.0 mm and cumulated temperatures were 520.6 °C.

In order to create management strategy in watermelon, flight dynamics of aphid population was recorded. Winged aphids were collected weekly using customized Moericke yellow water metal trap (60 cm x 60 cm x 12 cm). The metal pans, with a sink-hole and faucet in the middle of a small pyramidal bottom, were placed on legs 40 cm above soil surface in the middle of the plot. There were six sampling dates starting from 19 May until mulch became covered by the plant canopy. Depending on environmental conditions water was added in the pans during the week. Collected material was inspected and aphids were separated using a stereomicroscope (Zeiss, Stemi 2000).

Data were tested by ANOVA (Stat View) and treatments were compared with LSD test at $P \leq 0.05$.

3 RESULTS AND DISCUSSION

The significant difference in aphid number among the sampling dates was found as a result of their population dynamics on watermelon (Fig. 1). The catches of two assessments in the second half of May (19 and 26 May) were more numerous than during assessments in June. The flight maximum was recorded on 26 May and the population density significantly decreased from 9 June.

Compared to our unpublished data, the results obtained at Pula are not coincidence with aphid flight dynamic recorded at Opuzen (43°00'N, 17°34'E, 3 m elevation).

That results indicate the aphid flight in watermelon field at Opuzen starts at the beginning of May and increases at the beginning of June, with maximum at 9 June (2004, 2005).

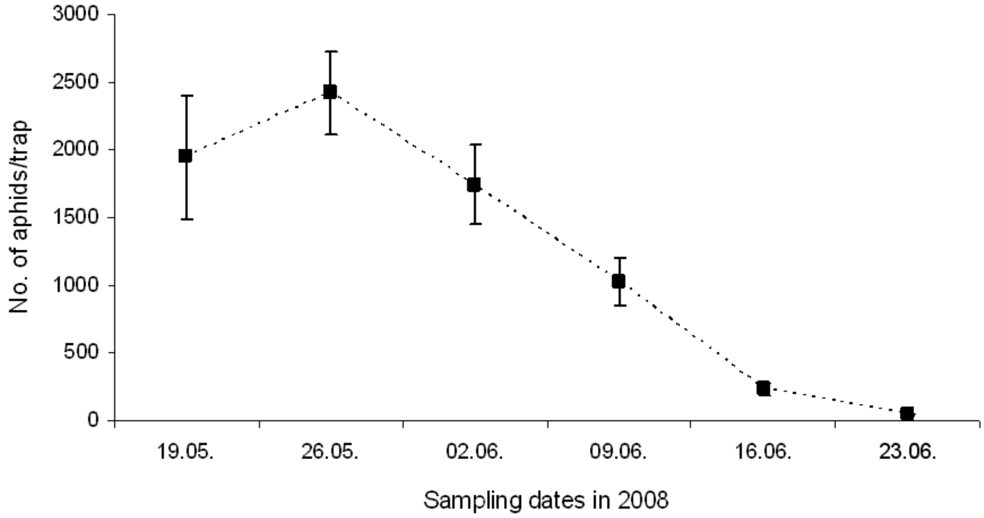


***Figure** 1: Aphid population dynamics in watermelon field at Pula (2008)*

There was not much effect of mulch on aphid number (Fig. 2). The numbers of aphids captures during the sampling were too variable to detect the differences between the mulches. The results were obtained under field conditions for the cultivation of watermelon crops, and probably are linked to aphid biology and ecology, sampling date and season, and the influence of environmental factors, which are particularly characterised by wind pressure.

However, at the peak of aphid population hay cover attracted 13% (26 May) and 18% (2 June) more aphids compared to bare soil. According to our unpublished data, the overall spring seasonal averages of aphid number showed that fewer winged aphids were consistently found on black and clear mulches compared to brown, green and white ones in 2004 and 2005 at Opuzen. The less attractiveness of black mulch to aphids was not confirmed in the experiment conducted at Pula.

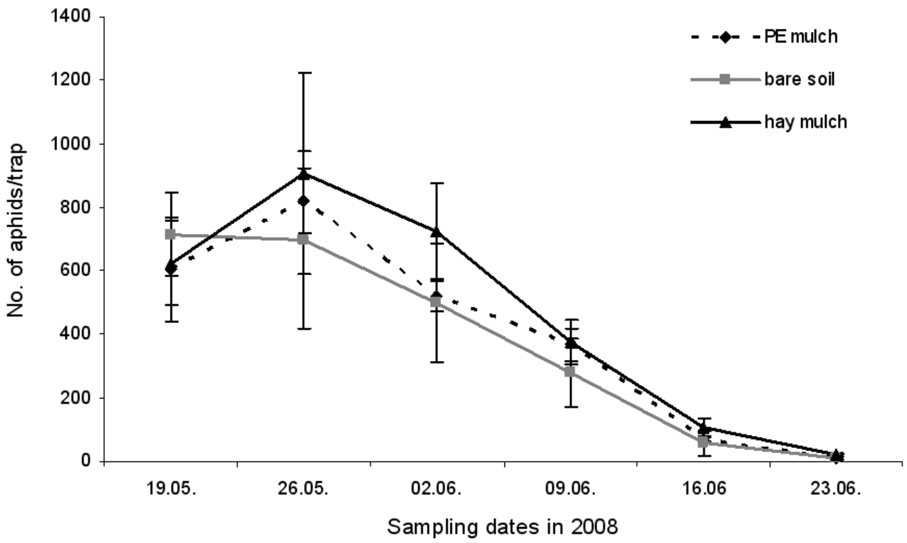


***Figure 2**: The number of winged aphids caught in yellow water traps in mulched watermelon or grown on bare soil at Pula (2008)*

4 CONCLUSIONS

The most imporant factors that reduce the productivity of the watermelon are high temperatures, high humidity, exces rain, pests and diseases. The results obtained in our study indicate that the use of different mulch system is a potential factor in aphids control on watermelons.

The aphids' flight maximum in watermelon growth at Pula in 2008 was occurred two weeks earlier than at Opuzen (2004, 2005). Ten days after the planting, during the first assessment, the aphid population density was equally as the recorded maximum. That indicates the observations of the visual traps are necessary, anon after the planting, in order to create the aphids control management strategy.

The effect of different mulches on aphid populations in vegetable crops has to be continued.

5 ACKNOWLEDGEMENT

The authors thank head of Valtura jail who gave up part of jail farm for carrying out this experiment and prisoners who were of valuable assistance during aphid sampling.

6 LITERATURE

Brown, J.E., Dangle, J.M., Woods, F.M., Tilt, K.M., Henshaw, M.D., Griffey, W.A., West, M.S. 1993. Delay in mosaic virus onset and aphid vector reduction in summer squash grown on reflective mulches. HortSci., 28, 9: 895–896.

Csizinszky, A.A., Schuster, D.J., Kring. J.B. 1995. Color mulches influence yield and insect pest populations in tomatoes. J. Amer. Soc. Hort. Sci., 120, 5: 778–784.

Farias-Larios, J., Orozco-Santos, M. 1997a. Color polyethylene mulches increase fruit quality and yield in watermelon and reduce insect pest populations in dry tropics. Gartenbauwissenschaft, 62, 6: 255–260.

Farias-Larios, J., Orozco-Santos, M. 1997b. Effect of polyethylene mulch colour on aphid populations, soil temperature, fruit quality, and yield of watermelon under tropical conditions. New Zeal. J. Crop Hort., 25, 369–374.

Goreta, S., Perica, S., Dumičić, G., Bučan, L., Žanić, K. 2005. Growth and yield of watermelon on polyethylene mulch with different spacings and nitrogen rates. HortSci., 40, 2: 366–369.

Johnson, J.M., Hough-Goldstein, J.A., Vangesell, M.J. 2004. Effects of straw mulch on pest insects, predators, and weeds in watermelons and potatoes. Environ. Ent., 33, 6: 1632–1643.

Kring, J.B., Schuster, D.J. 1992. Management of insects on pepper and tomato with UV-reflective mulches. Fla. Entomol., 75, 1: 119–129.

Lamont, Jr.W.J. 1993. Plastic mulches for the production of vegetable crops. HortTehnology, 3, 1: 35–39.

Millar, I.M. 1994. A Catalogue of the Aphids (Homoptera: Aphidoidea) of Sub-Saharan Africa. Agricultural Research Council, Pretoria.

Saucke, H., Döring, T.F. 2004. *Potato virus Y* reduction by straw mulch in organic potatoes. Ann. Appl. Biol., 144, 3: 347–355.

Soltani, N., Anderson, J.L., Hamson, A.R. 1995. Growth analysis of watermelon plants grown with mulches and rowcovers. J. Amer. Soc. Hort. Sci., 120:1001–1009.

Stapleton, J.J., Summers, C.G. 2002. Reflective mulches for management of aphids and aphid-borne virus diseases in late-season cantaloupe (*Cucumis melo* L. var. *cantalupensis*). Crop Prot., 21, 891–898.

Summers, C.G., Mitchell, J.P., Stapleton, J.J. 2005. Mulches reduce aphid-borne viruses and whitefies in cantaloupe. Calif. Agr., 59, 2: 90–94.

Trdan, S., Žnidarčič, D., Kač, M., Vidrih, M. 2008. Yield of early white cabbage grown under mulch and non-mulch conditions with low populations of onion thrips (*Thrips tabaci* Lindeman). Int. J. Pest Manag., 54, 4: 309–318.

Walters, S.A. 2003. Suppression of watermelon mosaic virus in summer squash with plastic mulches and row covers. HortTehnology, 13, 2: 352–357.

White, J.M. 2003. Watermelon yield and size when grown on four mulch colors. Proc. Fla. State Hort. Soc., 116: 138–139.

White, J.M. 2004. Summer squash yield and fruit size when grown on eight mulch colors in central Florida. Proc. Fla. State Hort. Soc., 117: 56–58.

COBISS Code 1.01

Agrovoc descriptors: marshes; swamps; wetlands; fertilizer application; fertilizers; botanical composition; flora; mowing; harvesting; biomass

Agris category code: F01; F70; F04

Changes in floristic composition over three years of Ljubljana marsh grassland in relation to cutting and fertilising management

Matej VIDRIH[1], Jure ČOP[2], Stanislav TRDAN[3], Klemen ELER[4]

Received August 6, 2008, accepted July 8, 2009.
Delo je prispelo 6. avgusta 2008; sprejeto 8. julija 2009.

ABSTRACT

A research in Ljubljana marsh was conducted from 2004 to 2006 with the aim to determine how the regime of cutting and fertiliser application over several years influences on the floristic composition of meadow sward. Field sampling plots in split-plot design with four replications were set up on two different types of grassland, one belonging to *Arrhenatherion* (sampling plot T1), the other to *Molinion* alliances (sampling plot T2) in 1999. The main plots represented the frequency of 4 cutting regimes (2 cuts with normal and delayed first one, 3 and 4 cuts per year) and sub-plots represented the fertiliser regime (no fertiliser, PK and NPK fertiliser with two different amounts of N). After five years, the cutting, and especially fertiliser application, significantly altered the floristic composition. In floristic composition of *Arrhenatherion* plot more frequent cutting in combination with higher amount of N fertilisation increased the proportion of grasses (92.7 % on a fresh matter basis). This was mostly observed in 2004. Legumes proportion (15.4 %) increased mainly on plots where PK fertiliser was used and a first cut was retarded. When N fertiliser was used on *Molinion* plot in all treatments with cutting herbs (forbs) increased their proportion up to 65 % in average. The proportion of legumes in sward of this plot was neglecteable that's way treatments did not have any special effect on them.

Key words: Ljubljana marsh, grassland, cutting, fertilising, floristic composition, biomass

IZVLEČEK

SPREMEMBE V FLORISTIČNI SESTAVI RUŠE LJUBLJANSKEGA BARJA SKOZI TRI LETA V ODVISNOSTI OD ČASA KOŠNJE IN INTENZIVNOSTI GNOJENJA

Na Ljubljanskem barju smo v obdobju 2004-2006 opravili raziskavo, s katero smo želeli ugotoviti, kako vplivata število košenj in gnojenje skozi daljše obdobje na floristično sestavo ruše. Travniška poskusa v split-plot zasnovi s štirimi ponovitvami sta bila zasnovana na dveh tipih poskusnih ploskev, ki pripadata zvezama *Arrhenatherion* in *Molinion* v letu 1999. Glavne parcele so predstavljale štiri režime pogostnosti košnje (2-kosna raba z zapoznelo in standardno prvo košnjo, 3-kosna in 4-kosna raba), podparcele pa način gnojenja (negnojeno, gnojeno z gnojili PK in NPK, gnojeno z dvema različnima odmerkoma N). Po petih letih sta košnja in predvsem gnojenje zelo spremenili videz travišča in vplivala na floristične karakteristike travne ruše. V travni ruši poskusnih ploskev zveze *Arrhenatherion* je pogostejša košnja v kombinaciji z večjim odmerkom dušika vplivala na večji delež trav (92,7 % v svežem zelinju). Ta sprememba je bila najbolj izražena v letu 2004. Delež mase metuljnic (15,4 %) se je najbolj povečal po gnojenju s PK in zapoznelo prvo košnjo. Na poskusni parceli zveze *Molinion* se je najbolj povečal delež zeli (največ 65 %), in sicer v vseh postopkih košnje ter tedaj, kadar je bil uporabljen dušik. Delež metuljnic v tej ruši je bil zanemarljiv.

Ključne besede: Ljubljansko barje, travinje, košnja, gnojenje, floristična sestava, biomasa

[1] Teach. Assist., Ph. D., Jamnikarjeva 101, SI-1111 Ljubljana, e-mail: matej.vidrih@bf.uni-lj.si

[2] Assist. Prof., Ph. D., ibid.

[3] Assist. Prof., Ph. D., ibid.

[4] Teach. Assist., Ph. D., ibid.

1 INTRODUCTION

The Slovene grasslands, predominantly existing as semi-natural vegetation, cover 60 % of agricultural land (5000 km^2) (Čop, 2006). In addition 2700 km^2 of abandoned grasslands have reached different phases of plant succession toward forest climax vegetation for the last fifty years. On the managed grasslands the cutting system prevails with two to three cuts on mesotrophic, and one cut on oligotrophic karst and wet grasslands. Intensive cutting and grazing systems were also introduced on many farms during last few decades. Due to this development and abandoning of herbage production in marginal grassland areas many species-rich meadows and mountain pastures are endangered (Čop *et al.*, 2004). In temperate climate zone grassland management is a key factor which determines sward floristic composition (Hopkins and Holz, 2005). Generally, intensification of herbage production reduces sward plant diversity while improving its agronomic value (Plantureux *et al.,* 2005). Grasslands in marginal areas can be exception to this and preservation of the remaining species-rich grassland is a primary goal of nature conservation (Armbruster and Elsäßer, 1997; Mountford *et al*., 1993) The continuation of traditional ways of grassland management that would best preserve biodiversity is often not compatible with the requirements of intensive livestock production (Isselstein *et al*., 2005; Critchley *et al*., 2002; Hopkins *et al*., 1990). Therefore, we have been performing a long term field study to investigate effects of cutting regime and fertiliser inputs on sward floristic composition of two grassland types located in an environmentally sensitive area such as Ljubljana marsh area (Seliškar, 2000; Jogan *et al*., 2004; Hacin *et al*., 2001). Almost all grasslands represent unimproved and semi-improved hay meadows traditionally mowed twice a year. In the past there was also a combination of lax spring and autumn grazing along with summer cutting (Verbič, 2000). Undesired plant succession has occurred on many parts of Ljubljana marsh, area that can be assigned as typical environmentally sensitive one. Of its 160 km^2 surface app. 120 km^2 are covered by semi-natural grassland, which is highly diverse, often supporting considerable floristic diversity at a local scale, providing habitats for invertebrate and other animal groups and delivering a range of ecosystems and socio-economic functions. On this Ljubljana marsh *Arrhenatherion* alliance is a dominant vegetation. Much less grassland area belongs to *Molinion*, *Filipendulion*, *Magnocaricion*, *Caricion davallianae* and *Phragmition communis* alliances (Seliškar, 1986). Aiming for sustainable grassland production in this area, a research was conducted to test the effects of cutting and fertiliser treatments on herbage production and floristic composition of *Arrhenatheretum elatius* and *Molinia caerulea* grasslands. We wanted to test the influence of two typical grassland management measures on floristic changes in meadow sward.

2 MATERIAL IN METHODS

In March 1999, two sampling plots were established on semi-natural grassland of Ljubljana marsh (lat. 45°58’ N, long. 14°28’ E, alt. 295 m). One plot was on grassland with predominant *Arrhenatherum elatius* (T1) and the other on fen meadow with predominant *Molinia caerulea* (T2). Both plots were arranged in split-plot design with four replications. Three cutting regimes were allocated as the main plots and four fertiliser treatments as sub-plots. Cutting regimes for T1 were: 2 cuts with delayed first one, 3 cuts and 4 cuts per year, and for T2 were: 2 cuts with a 'normal' and delayed first one and 3 cuts per year. Fertiliser treatments were 0 NPK (= no), 35 kg P + 133 kg K $ha^{-1}yr^{-1}$ (= PK), 50 kg N $ha^{-1}cut^{-1}$ applied to the first cut only + 35 kg P + 133 kg K ha^{-1} yr^{-1} (= $N_{(1)}PK$) and 50 kg N ha^{-1} cut^{-1} applied to each of 2 or 3 or 4 cuts + 35 kg P + 133 kg K ha^{-1} yr^{-1} (=$N_{(c)}PK$). The sub-plot size was 2.5 × 4 m in T1, and 2 × 4 m in T2 (Čop *et al*., 2001). In the fourth trial year (2002), the soil was moderately acid (pH/$CaCl_2$ = 4.9 – 5.2) with low to moderate P and moderate to high K content (P = 1.9 – 5.5 mg, K = 10.6 – 29.5 mg) in T2. Fertilising with PK in previous years had a positive effect on soil nutrient status only on *Molinia caerulea* fen meadow (T2 sampling plot). The chemical properties of soil on *Arrhenatherum elatius* grassland (T1 sampling plot) in four most intensive treatments in the eight year are shown in Table 1.

Table 1*: Chemical properties of soil on four plots of sampling plot T1 in spring 2006 after 7 years of experiment (phosphorus and potash were determined by extraction in ammonium lactate).*

Treatment		pH/$CaCl_2$	P_2O_5/(mg/100 g)	K_2O/(mg/100 g)
four cut regime	no	7.0	3.5	11.8
	PK	6.9	14.9	21.1
	$N_{(1)}PK$	7.0	10.9	16.2
	$N_{(c)}PK$	6.9	15.6	16.4

Results presented here are derived from the first cut of the sixth, seventh and eight trial years and comprise proportions of floristic groups (grasses belonging to botanical family *Poaceae*, legumes belonging to botanical family *Fabaceae* and herbs belonging to remaining botanical families) in herbage. The analyses were performed by means of hand separation of fresh herbage samples into plant floristic groups which were afterwards weighted. The size of sampling area was 0.5 × 0.8 m. According to Braun-Blanquet method (1964) a floristical survey on species presence (a combine assesment of cover and abundance) was also conducted. Statistical analyses of data were done by ANOVA and only p values (significance level) are shown for both factors and their interaction. Data in proportions were transformed using an equation Y = 2*arcsine(sqrt(x)). Results for ANOVA are presented only for the eight (2006) trial year.

3 RESULTS

In 2006, we made a floristical survey at all 96 sub-plots (3 cutting regimes, 4 fertiliser treatments regimes, 4 replications) of sampling plots T1 and T2. The community of *Arrhenatherum elatius* grassland consisted in total of 89 species (Table 3), from most abundant to rare ones. The most frequent grasses were *Arrhenatherum elatius*, *Festuca rubra* and *Dactylis glomerata*. The group of legumes was represented by *Vicia cracca*, *Lathyrus pratensis* and *Trifolium pratense* whereas *Equisetum palustre*, *Galium mollugo* and *Ranunculus repens* prevailed in a group of herbs. The community of *Molinia caerulea* consisted in total of 85 species (Table 4). Three most frequent grasses were *Molinia caerulea, Anthoxanthum odoratum* and *Holcus lanatus*. From a group of legumes the most frequent were *Vicia cracca*, *Lotus uliginosus* and *Lotus corniculatus*, meanwhile the group of herbs was represented the most frequently by *Filipendula ulmaria*, *Galium mollugo* and *Potentilla erecta*. In sampling plot T1 a higher management intensity (special with four cuts per year and applying 50 kg of N at each cut) encouraged the group of grasses (Figure 1; bigger circles in ternary graphs), which is most noticeabled in year 2005. The highest fresh herbage proportion of grasses (92.7 %) was measured on plot with treatment of three cuts and N_{50}PK fertiliser in 2005. The highest proportion of legumes (15.4 %) was determined on plot with treatment of two cuts with delayed first cut and PK fertiliser in 2006 and the highest proportion of herbs (49.4 %) was measured on plot with treatment of two cuts with delayed first cut and no fertiliser in 2004. Cutting regimes had significant effect on proportion of grasses and legumes, fertiliser treatments had only on legumes and none of them on herbs proportion (Table 2). Due to the lack of legumes (important ones) in the sward none of the treatments came near to the recommended proportion of floristic groups (Fig. 1: triangle symbol in ternary graphs) in sward of semi natural grassland when looking from the forage production view (Dietl, 1982).

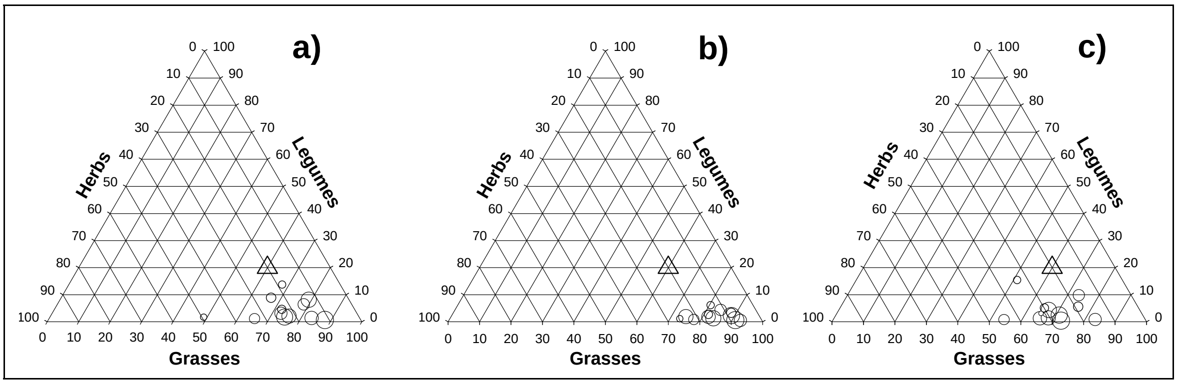


***Figure 1**: Influence of cutting and fertiliser application on floristic composition of Arrhenatherion sampling plot (T1) in 2004 (a), 2005 (b) and 2006 (c) (o-most extensive management, O-most intensive management) (4 cuts) and position of optimal proportion (△) of floristic groups in semi natural grassland.*

In sampling plot T2, a lack of legumes in sward was even more expressed. However sward on plots which received only PK fertiliser showed the increase in proportion of legumes and this fact led to the highest proportion of them (11.4 %) on plot with treatment of two cuts and PK fertiliser in 2005. On the other hand, with increasing intensity of management (specially with N fertiliser) of herbs (Figure 2; year 2005) which resulted in their highest proportion of herbs (85.0 %) on plot with treatment of two cuts and delayed first cut and applying 50 kg of N at each cut in 2004. Grasses reached the highest proportion (88.7 %) on plot with treatment of two cuts and no fertiliser in 2005.

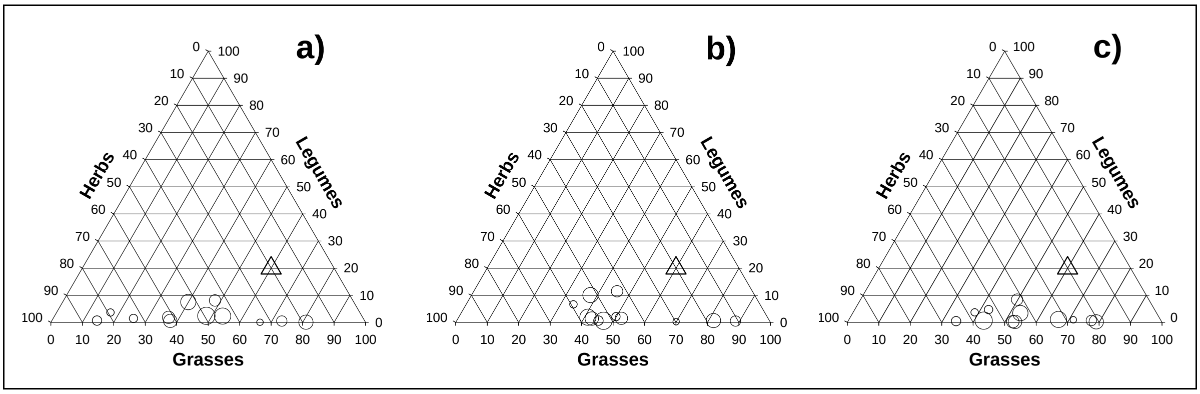


***Figure 2**: Influence of cutting and fertiliser application on floristic composition of Molinion sampling plot (T2) in 2004 (a), 2005 (b) and 2006 (c) (o-most extensive management, ○-most intensive management) (4 cuts) and position of optimal proportion (△) of floristic groups in semi natural grassland.*

The proportion of floristic groups on sampling plot T2, measured in eight year, first cut, was affected less by cutting than fertiliser application (Table 2). Interaction between cutting regime and fertiliser treatments had no significant effect on none of the floristic groups.

***Table 2**: Significance level (alpha risk) for the test of effects of the cutting regime (C) and fertiliser treatments (F) on floristic groups in herbage of the 1st cut in Arrhenatherion (T1) and Molinion (T2) sampling plots, 8th trial year.*

	Sampling plot T1			Sampling plot T2		
	Grasses	Legumes	Herbs	Grasses	Legumes	Herbs
Cutting regime (C)	0.002	0.033	0.455	0.041	0.454	0.064
Fertiliser treatments (F)	0.127	<0.001	0.117	0.001	<0.001	0.001
C x F	0.072	0.468	0.080	0.920	0.100	0.915

Table 3: Floristical survey of the *Arrhenatherum elatius* grassland after Braun-Blanquet method (sampling plot T1) according to cutting regime and fertilising (8th trial year) *.

	2 cuts (delayed)				3 cuts				4 cuts			
	no	PK	N_lPK	N_cPK	no	PK	N_lPK	N_cPK	no	PK	N_lPK	N_cPK
Anthoxanthum odoratum								1	+	+	+	+
Arrhenatherum elatius	2	2	2	3	+	3	3	3	+	2	1	3
Dactylis glomerata	1	+	+	1	+	1	1	1	+	1	1	1
Festuca pratensis	+	+			1	1	1	1		1	1	+
Festuca rubra agg.	2	1	1	+	2	1	1		3	1	3	+
Helictotrichon pubescens			+	+	2	1	2	2	1	1	1	1
Holcus lanatus	+	1	1	+							+	
Poa trivialis	+						+	+				1
Lathyrus pratensis	+	1	+	+		+		+				
Medicago lupulina		+								+		+
Trifolium pratense		+			1	1	1					+
Vicia cracca	+	+		+	+	+	+	+		+	+	+
Achillea millefolium	+	+	+	+	1	+	2	1	+	+	+	1
Ajuga reptans					+				+			+
Angelica sylvestris		+				+	+			+		
Calystegia sepium		+	+	+			+					
Campanula patula	+		+	+		+	+			+		
Centaurea jacea	+	+	+	+	+	+	+	1	+	+	1	+
Cerastium holosteoides								+			+	+
Cirsium oleraceum		+	+				+				+	
Convolvulus arvensis	+	+	+	+		+	+			+		+
Cruciata glabra		+	+	+		+				+		
Daucus carota	+		+	+	+			+				
Equisetum palustre	3	1	1	+	3	1	+	+	3	+	+	+
Erigeron annuus							+	+		+		
Galium mollugo	1	2	2	2	1	2	1	2	1	+	+	1
Glechoma hederacea				+		+						+
Leontodon hispidus	+				+	+			+	+		
Leucanthemum ircutianum	+	+	+	+	+	+	+	+	+	1	2	+
Lythrum salicaria	+	+		+	+		+					
Silene latifolia		+		+	+	+	+	+				
Mentha aquatica	+	+				+			+			+
Mentha longifolia			+	+				+				
Pastinaca sativa	+	+	+	+	+		+	+				
Pimpinella major	+	+	+							+	+	
Plantago lanceolata	+				1	+	1	1	1	+	+	+
Ranunculus acris	+	+			1		1	1	+	+	+	+
Ranunculus repens	+	+	+	+	+	+	+	+	+	+	+	+
Rumex acetosa							+	+	+		+	
Taraxacum officinale								+	+	+		+
Verbascum sp.				+		+	+		+			
Veronica persica	+			+			+		+	+	+	+
Total number of species	29	27	22	29	24	26	30	30	28	25	24	28

* Species with cover < 1 %, appeared in one or two treatments only, are not included in the table.

***Table 4**: Floristical survey of the Molinia caerulea fen meadow after Braun-Blanquet method (sampling plot T2) according to cutting regime and fertilising (8^{th} trial year)*.*

	2 cuts (delayed)				2 cuts				3 cuts			
	no	PK	N_lPK	N_cPK	no	PK	N_lPK	N_cPK	no	PK	N_lPK	N_cPK
Anthoxanthum odoratum	1	1	+	+	1	+	+	1	1	1	1	1
Arrhenatherum elatius				1		+	+					
Brachypodium pinnatum		2	2	+	+	2	2	2	+	+	1	
Briza media	+	+	+		+	+	+		+	+	+	
Carex flava	+				+	+			+	+	+	+
Dactylis glomerata						+	+	1		1		
Deschampsia cespitosa										+		1
Festuca ovina agg.									+	1		
Festuca pratensis		+	+	+		+	+	2			+	+
Festuca rubra agg.		1	+	1		1	1	1	1	2	2	2
Helictotrichon pubescens		+				+	2				+	+
Holcus lanatus	+	1	2	1	+	1	1			+	1	
Luzula campestris	+	+			+				+	+	+	
Molinia caerulea	4	+	+	+	4	+			3	+	+	+
Lotus corniculatus	+	1	+									
Lotus uliginosus	+	1	+		+	1			+	1	+	
Vicia cracca		1		+	1	+	+	+	+	+	+	+
Angelica sylvestris	+	+	+	+		+	+	+	+	+	+	+
Betonica officinalis	+	+	+	+	+	+	+	1	+	+		+
Centaurea jacea		+	+						+	+	+	+
Cirsium oleraceum										+	+	+
Cruciata glabra		+	+							+	+	+
Daucus carota												+
Equisetum palustre									1	+		
Filipendula ulmaria	2	1	1	2	1	1	2	1	1	+	1	1
Galium mollugo	+	1	1	2	2	2	1	3	1	1	2	2
Leucanthemum ircutianum	+	+	+	+				+		1	1	1
Lysimachia vulgaris		+										
Lythrum salicaria	+	+	+	+			+		+	+	+	
Plantago lanceolata		+	+	+	+	+		+	+	+	+	+
Potentilla erecta	1	+	+	+	+	+	+	+	1	+	+	+
Ranunculus acris	+	+			+					+	+	
Ranunculus repens	+	+								+	+	+
Rumex acetosa		+	+			+	+	+				+
Thymus alpestris	+				+				+	+	+	+
Total number of species	21	26	20	18	18	22	19	15	26	36	28	25

* Species with cover < 1%, appeared in one or two treatments only, are not included in the table.

4 DISCUSSION

In this study, we explored the possibility of combining agricultural and nature conservation objectives in threatened wet grasslands at the Ljubljana marsh by applying different cutting regimes and fertiliser amounts. Both factors were tested at low (no for fertiliser) to moderate levels to confirm their effects on the floristic composition of two seminatural unimproved meadows. After eight trial years the data show that the NPK and PK fertilising treatments improved floristic composition on T1 sampling plot regarding fodder quality, while on T2 sampling plot these two treatments increased the proportion of herbs, which are not the most appropriate for the nutrient poor grassland community as the one belonging to *Molinion* alliance. Grasses, especially the competitive *Arrhenatherum elatius*, *Dactylis glomerata* and *Festuca pratensis*, responded to moderate increasing number of cuts and fertiliser input with an increase in their proportion in the sward of sampling plot T1. This response is considered as typical and is described elsewhere (e.g. Tallowin, 1996; Wyss, 2002). Under similar treatment conditions, the stress tolerant *Molinia caerulea*, which initially prevailed in the sward of sampling plot T2, was replaced mainly by forbs (*Filipendula ulmaria* within delayed 2 cuts and *Plantago lanceolata* and *Galium mollugo* within other two cutting regimes) (Čop *et al*., 2004). Every fertiliser input increased proportion of tall grasses belonging to *Arrenatherum elatius* grassland and tall forbs belonging to *Molinia caerulea* fen meadow as was also got in the literature (Smith *et al*., 1996). But we should also not forget that amount of precipitation and solar radiation can have significant effect on grassland production. And also floristic composition of sward is only one variable in multi dimensional space in which other two important variables are dry matter yield (quantity) and nutrients yield (quality). For the last two it is known for a long time that they increase with management intensity of grassland sward.

5 ACKNOWLEDGEMENTS

This work was supported financially by the Municipal community of the city of Ljubljana, the Ministry of Agriculture, Forestry and Food of Slovenia and the Ministry of Science and Technology of Slovenia.

6 REFERENCES

Armbruster M., Elsäßer, M. 1997. Alternativen der Nutzung von Grünland im Europa-Reservat Federseeried. Karlsruhe: Landesanstalt für Umweltschutz Baden-Württemberg.

Braun-Blanquet J. 1964. Pflanzensociologie. Grundzuege der Vegetationskunde. Wien-New Work , 3. edition, Springer Verlag: 865 p.

Critchley C.N.R., Chambers B.J., Fowbert J.A., Bhogal A., Rose S.C., Sanderson R.A. 2002. Plant species richness, functional type and soil properties of grasslands and allied vegetation in English Environmentally Sensitive Areas. Grass Forage Sci., 57: 82-92.

Čop J., Sinkovič T., Hacin J. 2001. Cutting and fertilising alternatives in management of grassland on the peat/mineral soil of Ljubljana marsh, Slovenia. Grassl. Sci. Eur., 6: 203-206.

Čop J., Vidrih M., Sinkovič T. 2004. Influence of cutting and fertilising management on herbage floristic composition of Ljubljana marsh grasslands. Grassl. Sci. Eur., 9: 222-224.

Čop J. 2006. Kmetijska zemlišča in travinje v Evropski uniji. Naše travinje, 2: 4-7.

Dietel W. 1982. Oekologie und Wachstum von Futterpflanzen und Unkraeutern des Graslandes. Schweiz. Landwirtsch. Forsch., 21: 85-110.

Hacin J., Čop J., Mahne I. 2001. Nitrogen mineralization in marsh meadows in relation to soil organic matter content and watertable level. J. Plant Nutr. Soil Sci., 164,5: 503-509.

Hopkins A., Gilbey J., Dibb C., Bowling P.J., Murray P.J. 1990. Response of permanent and reseeded grassland to fertilizer nitrogen. 1. Herbage production and herbage quality. Grass Forage Sci., 45: 43-55.

Hopkins A., Holz B. 2005. Grassland for agriculture and nature conservation: production, quality and multi-functionality. Grassl. Sci. Eur., 10: 15-29.

Isselstein J., Jeangros B., Pavlu V. 2005. Agronomic aspects of extensive grassland farming and biodiversity management. Grassl. Sci. Eur., 10: 211-220.

Jogan N., Kaligarič M., Leskovar I., Seliškar A., Dobravec J. 2004. Habitatni tipi Slovenije HTS 2004. Ljubljana, Agencija Republike Slovenije za okolje: 64 p.

Mountford J.O., Lakhani K.H., Kirkham F.W. 1993. Experimental assessment of the effects of nitrogen addition under hay-cutting and aftermath grazing on the vegetation of meadows on a Somerset peat moor. J. Appl. Ecol., 30: 321-332.

Plantureux S., Peeters A., McCracken D. 2005 Biodiversity in intensive grasslands: effect of management improvement and challenges. Grassl. Sci. Eur., 10: 417-426.

Seliškar A. 1986. Vodna, močvirna in traviščna vegetacija Ljubljanskega barja (vzhodni del). Scopolia, 10: 1-41.

Seliškar A. 2000. Travišča in druga negozdna vegetacija zahodnega dela Ljubljanskega barja – Stanje in obeti. Vrhniški razgledi, 3: 79-90.

Smith R.S., Buckingham H., Bullard M.J., Shiel R.S.,Younger A. 1996. The conservation management of mesotrophic (meadow) grassland in northern England. 1. Effects of grazing, cutting date and fertilizer on the vegetation of a traditionally managed sward. Grass Forage Sci., 51: 278-291.

Tallowin, J.R.B. 1996. Effects of inorganic fertilizers on flower-rich hay meadows: a review using a case study on the Somerset Levels, UK. Grass Forage Abstr., 66: 147-152.

Verbič J. 2000. Kmetijstvo zahodnega dela Ljubljanskega barja v preteklem obdobju. Vrhniški razgledi, 3: 25-32.

Wyss, U. 2002. Bewirtschaftung beeinflusst Nahrwert von Gras. Agrarforsch., 9: 286-291.

COBISS Code 1.01

Agrovoc descriptors: pastures; karst; fertilizer application; fertilizers; phosphorus; botanical composition; flora; herbaceous plants

Agris category code: F60; F04

Fosfor v zemlji in zelinju kraškega pašnika

Matej VIDRIH[1], Anton VIDRIH[2], Milan POGAČNIK[3], Drago KOMPAN[4]

Delo je prispelo 26. januarja 2009; sprejeto 23. junija 2009.
Received: January 26 2009; accepted: June 23 2009.

IZVLEČEK

Predstavljeni so rezultati 7-letne raziskave o vplivu dodanega P na njegovo dostopnost v tleh, na vsebnost P v zelinju kraškega pašnika in na povečanje mase razpoložljivega zelinja pri stopnjujočem se odmerku uporabljenega gnojila (0, 90, 270 in 540 kg P_2O_5 ha^{-1} skupno v 3 letih). Koncentracija dostopnega P v tleh je bila v obravnavanju nizek odmerek (30 kg P_2O_5 ha^{-1} letno) večja za 2,4 mg P_2O_5 100 g^{-1} tal od kontrolnega obravnavanja. S trikrat večjim odmerkom gnojila je bila vsebnost P v tleh povečana za 4,4-krat. Vzorčenje zemlje do dveh globin (0 - 3 cm in 3 - 6 cm) je pokazalo, da je večji del razpoložljivega P za rast rastlin v vrhnji, zelo plitvi plasti zemlje. V petih rastnih sezonah po zadnjem gnojenju s P se je zmanjšala koncentracija dostopnega P v tleh od 0,4 mg do 3,6 mg P_2O_5 100 g^{-1} tal, odvisno od skupno uporabljenega gnojila. Zaradi izredne siromašnosti zemlje kraškega pašnika s P, je tudi njegova vsebnost v zelinju ruše zelo nizka. Zadošča le za polovično pokritje potreb pašnih živali po tej rudnini, zato je povečanje vsebnosti P v zelinju pri gnojenju s fosfati pomembnejše od povečanja pridelovalne zmogljivosti zemljišča. Z letnim odmerkom 90 kg P_2O_5 ha^{-1} se je v treh rastnih sezonah v povprečnem vzorcu zelinja koncentracija P povečala na 2,1 g P kg^{-1} SS. Uporabljen P je imel na maso zelinja razpoložljivega za pašo in na delež izkoriščenosti ruše majhen vpliv, najverjetneje zaradi kisle reakcije tal in počasnega izboljšanja floristične sestave ruše.

Ključne besede: fosfor, kraški pašnik, gnojenje, tla, zelinje

ABSTRACT

PHOSPHORUS IN THE SOIL AND IN THE HERBAGE OF THE KARST PASTURE

The results of P fertilization on karst pasture in a 7-year study are discussed. The changes of P availability for plants, the content of P in herbage and the yield increase at different rates of applied fertilizer (0, 90, 270 and 540 kg P_2O_5 ha^{-1} - total in 3 years) were measured. In treatment with low rate of P (30 kg P_2O_5 ha^{-1} $year^{-1}$), the concentration of available P in soil was increased for 40 %. At three times higher rate of applied P, the content in soil was increased for 4,4 fold. The most of available P was found in top layer of soil as show the results of soil sampling at two depths (0 - 3 cm and 3 - 6 cm). The contentration of P in soil decreased during five growing seasons for 0.4 mg to 3.6 mg P_2O_5 100 g^{-1} of soil, depending on rate of applied fertiliser. Because the soils of karst pasture are very poor on P, the concentration of P in herbage is very low too. Only one half of the animal's need for P can be covered this way. The increase of P concentration in herbage as a result of applied P is more important than the increase of the yield. At annual rate of 90 kg P_2O_5 ha^{-1} the average concentration of P in herbage was 2.1 g P kg^{-1} of DM. The effect of applied P on the yield of available and used herbage by grazing animals was small, due to low soil pH and slow improvement in floristic composition of the sward.

Key words: phosphorus, karst pasture, fertilizing, soils, herbage

[1] asist., dr., Biotehniška fakulteta, p.p. 2995, 1111 Ljubljana, matej.vidrih@bf.uni-lj.si

[2] prof., dr., Biotehniška fakulteta, p.p. 2995, 1111 Ljubljana

[3] prof., dr., Veterinarska fakulteta, Gerbičeva 60, 1115 Ljubljana

[4] doc., dr., Biotehniška fakulteta, p.p. 2995, 1111 Ljubljana

1 UVOD

Rušo kraškega travinja so v preteklosti ročno pokosili in pridelek odpeljali s travinja ter ga spravili kot mrvo tja, kjer so imeli domače živali za rejo mesa in mleka. Mrvo so uporabili za krmljenje v hlevih, saj so potrebovali veliko hlevskega gnoja za vzdrževanje dobre rodovitnosti zemlje vinogradov in zelenjavnih vrtov (Gruden, 1910). Ker je reja prežvekovalcev v zadnjih desetletjih na kraškem območju zelo upadla, so veliko mrve, pridelane na suhih traviščih krasa, prodali na druga območja v Sloveniji za potrebe reje konj in krav molznic. Tako se je izčrpavanje kraškega travinja nadaljevalo s premeščanjem rudnin na daljše razdalje s tistih zemljiščih, kjer je bila še mogoča strojna košnja ruše in odprodaja mrve. Zemljišča, kjer ni bila mogoča strojna košnja, so bila izčrpana že poprej zaradi občasnega požiganja grmovne vegetacije in nenadzorovane paše drobnice (Kaligarič in sod., 2006). Pomanjkanje rudnin v vrhnji plasti zemlje, ki je odločilnega pomena za dobro uspevanje rastlin ruše z večjo hranljivo vrednostjo za prehrano živali, je torej povzročil človek z načinom preteklega izkoriščanja kraškega travinja. Seveda so za gospodarnejše izkoriščanje kraškega travinja tudi druge omejitve, kot so razgibanost in kamnitost zemljišč, suha poletja in druge. Toda glavni razlog za opuščanje kmetijske rabe teh zemljišč, ki mu sledi širjenje grmovne zarasti ter slabega gozda in s čimer se povečuje požarna ogroženost območja, je nizka pridelovalna zmogljivost teh izčrpanih zemljišč in neustrezna kakovost pridelane krme za visoko proizvodne pasme prežvekovalcev (Ferčej, 1996), ki so jih v preteklosti prednostno širili na obravnavano območje.

Za rekultivacijo kraškega travinja obstajajo številni razlogi. Vendar je ne bo mogoče narediti z uvajanjem tradicionalnega načina kmetovanja zaradi pomanjkanja in drage delovne sile in tudi ne z uporabo postopkov konvencionalnega kmetovanja, ker bo vse več omejitev pri uporabi gnojil in drugih dosežkov sodobnega kmetovanja zaradi potrebe po varovanju naravnih virov na kraškem območju. Strah pred onesnaževanjem vodnih virov z rudninami (eutrofikacija), ki so s kmetijskih zemljišč lahko odplavljena, izprana ali odnešena v vodotoke, je vse pogosteje predmet mednarodnih predpisov o omejevanju uporabe gnojil (Csatho in sod., 2007). Vse bolj se uveljavlja spoznanje, da bo imela pašna reja domačih živali zelo pomembno vlogo pri rekultivaciji omenjenih kraških zemljišč (Vidrih in sod., 1995; Papanastasis, 1999; Rodriguez in sod., 2005). Zelo nizka vsebnost rastlinam dostopnega fosforja (P) v zemlji kraškega travinja je ovira za normalen razvoj pašnih živali in za povečanje deleža bele detelje (*Trifolium repens* L.) v ruši, ki je nujno potrebna za izboljšanje kakovosti zelinja in učinkovitejšo vezavo zračnega dušika za izdatnejšo rast ostalih rastlin v ruši kraškega pašnika (Scott, 2003; Caradus in sod., 1996). Rastnim razmeram območja se vegetacija vedno lahko prilagodi zaradi velike raznovrstnosti in številčnosti vrst rastlin. Pri domačih živalih te možnosti nimamo, saj je odbiranje pri njih potekalo predvsem na hitrejšo rast le pri treh vrstah živali. Poleg tega so pri izvajanju nadzorovane paše živali prostorsko omejene in ne morejo na zelo velikem območju poiskati takega zelinja, ki bi jim zagotovilo dovolj rudnin za normalen razvoj. Zato jim moramo zagotoviti kakovostno krmo in dovolj vseh potrebnih rudnin v obroku z zelinjem, ki bo zrastlo na rodovitnih tleh. Za potrebe pašne reje živali je bilo kraško travinje v preteklosti malo proučevano. Izčrpana in opuščena kmetijska zemljišča ne predstavljajo velikega potenciala za večjo ekonomičnost kmetovanja in dober zaslužek. Zaradi vsega omenjenega bo boljše poznavanje procesov, ki spremljajo uporabo rudnin na izčrpanih kmetijskih zemljiščih še vedno nujno potrebno, da kraško travinje ne bo preraslo grmovje in gozd slabe kakovosti, kar povečuje požarno ogroženost območja in s tem se podoba negovane pokrajine izgublja (Hočevar in sod., 2004). Namen raziskave je bil ugotoviti in spremljati spreminjanje koncentracije fosforja in ostalih makro- ter mikroelementov v tleh in zelinju kraškega pašnika na planini Vremščica.

2 MATERIAL IN METODE

Na območju planine Vremščica potekajo proučevanja rekultivacije opuščenih kraških zemljišč s pašno rejo drobnice. Vremščica je vegetacijsko in tudi floristično dokaj pestra, saj se nahaja na klimatsko prehodnem območju. Za južna pobočja planine je značilno toploljubno rastje, medtem ko so severni in severovzhodni deli precej hladnejši, mezofilnejši (Eler, 2007). Med travniško vegetacijo prevladujejo suha submediteransko-ilirska travišča iz razreda *Festuco-Brometea* Br.-Bl. et Tx. 43 (Kaligarič, 1997). Večina travišč Vremščice spada v makroasociacijo *Carici humilis-Centaureetum rupestris Ht. 31,* natančneje v montansko subasociacijo *Anthyllidetosum vulnerariae* Poldini *89* (Kaligarič, 1997). Ta je razvita na plitvih tleh (rendzinah), ki so večinoma v pašni rabi, redkeje se kosijo, danes pa so obsežna območja podvržena zaraščanju (Kaligarič, 1997). Del pašnikov na planini Vremščica je urejen s stalnimi elektroograjami za vodenje nadzorovane paše plemenskih ovc. Travniški poskus o tri letnem dodajanju P tlem in njegovem vplivu na spreminjanje njegove vsebnosti v zemlji in ostalih rudnin v zelinju v naslednjih letih je bil izveden na pašniku (lat. 45° 41' S, long. 14° 12' V, alt. 820 m), ki je bil razdeljen na šest ograd. Poskus je potekal v četrti ogradi in je obsegal štiri različne odmerke gnojenja s P, vsako obravnavanje je imelo štiri ponovitve in v obravnavani raziskavi so predstavljene izbrane meritve sedmih let. Osnovne parcele v poskusu so bile velike 40 m^2 (5 x 8 m), njihova razporeditev na zemljišču je bila izvedena na osnovi slučajnega bloka.

Obravnavanja s P v prvih treh letih trajanja poskusa so bila naslednja: 1- kontrola, negnojeno; 2- nizek odmerek fosforja: 30 kg P_2O_5 ha^{-1} vsako leto (v treh letih skupno 90 kg P_2O_5 ha^{-1}); 3- srednje visok odmerek fosforja: 90 kg P_2O_5 ha^{-1} vsako leto (v treh letih skupno 270 kg P_2O_5 ha^{-1}) in 4- visok odmerek fosforja: 270 kg P_2O_5 ha^{-1} vsako drugo leto (v treh letih skupno 540 kg P_2O_5 ha^{-1}). Gnojilo superfosfat (tripleks 45 % P_2O_5) (Petrokemija d.d., Kutina, Hrvaška) je bilo uporabljeno vsakokrat spomladi pred začetkom vegetacije. Ruša je bila vsa leta izkoriščana samo s pašo s plemenskimi ovcami, in sicer v vsakem obhodu ob visoki gostoti zasedbe (90 ovc ha^{-1}) in čim krajšem trajanju zasedbe (< 10 dni). Tako je bila dosežena enakomernejša razporeditev živalskih izločkov po vsej ogradi s poskusom. Pri tem smo merili maso razpoložljivega zelinja, ki pomeni tisto količino zelinja, ki nastane do začetka obhoda pašnih živali. Vzorčenje zemlje za klasično pedološko analizo je bilo izvedeno prvič spomladi (leto 1996) pred postavitvijo poskusa. Nato je sledilo obdobje treh let (leta 1996, 1997, 1998) gnojenja s stopnjujočim se odmerkom fosforja (30, 90 in 270 kg ha^{-1} P_2O_5). Ob koncu prve faze poskusa (leto 1998), to je po opravljenem gnojenju s celotnim odmerkom fosforja, je bilo izvedeno tudi vzorčenje tal s pedološko sondo in sicer od 0 - 3 cm in 3 - 6 cm na istem mestu vzorčenja. Pred analizo smo iz vzorcev odstranili delce organskega materiala s premerom več kot 1 mm in dolžino nad 5 mm. Naslednja štiri leta (od leta 1999 do 2003) so potekale meritve spreminjanja vsebnosti rastlinam dostopnega fosforja v tleh z vzorčenjem na jesen vsako drugo leto. Reakcijo tal smo določili elektrometrično v suspenziji 10 ml talnega vzorca in 50 ml 0,01 M $CaCl_2$ (SIST ISO 10390, 1996), fosfor in kalij po AL-metodi (Egner, 1960), organsko snov po metodi Walkley Black (SIST ISO 14235, 1999), skupni dušik po Kjeldahlu (Bremner in Mulvaney, 1982) in teksturo s sedimentacijsko pipetno metodo (Janitzky, 1986).

Vzorčenje zelinja ruše na obravnavanem poskusu za pridelek ter merjenje vsebnosti rudnin sta bila opravljena ob pričetku druge faze poskusa, to je v četrtem letu trajanja poskusa (leto 1999). V istem času je bilo vzorčeno zelinje različnih vrst rastlin izven poskusa, ki je lahko uporabljeno za prehrano prežvekovalcev v razmerah pomanjkanja kakovostnejše krme na pašniku. Podatki o založenosti tal z rudninami in proizvodnost zelinja, dobljeni v poskusu, so bili analizirani in statistično obdelani s programoma Microsoft Excel 2003 in Statgraphics 4,0. Statistično značilne razlike smo ugotavljali z Duncanovim testom pri 5 % tveganju.

3 REZULTATI IN DISKUSIJA

3.1 P v zemlji in njegov vpliv na rast zelinja

Podatki analize tal ob postavitvi poskusa (leto 1996) so pokazali, da je do globine 6 cm v povprečju samo 2,0 mg P_2O_5 100 g^{-1} tal in 20,8 mg K_2O 100 g^{-1} tal, vrednost pH pa je znašala 5,7. Na območju izvajanja obravnavanih proučevanj sta bila napravljena dva opisa pedološkega profila tal s pripadajočimi fizikalnimi in kemičnimi lastnostmi posameznih horizontov. Za proučevanje so bili vzeti vzorci iz debelejših plasti zemlje (horizont A1 0 - 16 cm). Zato je bila ugotovljena vsebnost dostopnega P v zemlji še mnogo nižja od vzorčenja do globine 0 - 6 cm. Bil je samo v sledovih, s tendenco višje vrednosti za A1 hrizont in manj v globljih plasteh. Zgornji horizont sprsteninaste rendzine je bil MI teksture, z globino pa je delež gline naraščal tako, da je mestoma A2 horizont bil težje MGI teksture. Zemlja je bila mrvičaste do drobno grudičaste strukture in propustna za vodo. Vrednosti pH se je gibala v območju kisle reakcije, stopnja nasičenosti talnega kompleksa je bila pod 50 %, manj kot polovico so zasedali kalcijevi (Ca) ioni. To kaže na izpranost karbonatov iz zgornjega horizonta, saj je znaša stopnja nasičenosti v A2 tudi do 76 % (Preglednica 1).

V treh letih gnojenja s P je bilo skupno uporabljeno v posameznem obravnavanju v poskusu 90, 270 in 540 kg P_2O_5 ha^{-1}. Dodan P je imel visoko značilen vpliv na njegovo dostopnost za rastline. Na kontrolnem postopku, kjer je bila vsa leta ruša samo izkoriščana s pašo ovc, se vsebnost dostopnega P v tleh ni bistveno spremenila v sedmih letih trajanja opazovanj. Izražen je bil zgolj rahel padec njegove vsebnosti proti koncu trajanja opazovanj. Ta pojav je mogoče delno razložiti z obnašanjem ovc pri paši. Večletna opazovanja njihovega obnašanja so pokazala, da se več časa zadržujejo na delu zemljišča, kjer je rodovitnost zemlje boljša, masa razpoložljivega zelinja za pašo večja in v ruši večji delež metuljnic kot posledica delovanja dodanega P. Domnevamo lahko, da je bilo na tistih delih poskusa, kjer je bilo gnojeno s P, puščenih več izločkov in da je bilo prisotno premeščanje rudnin iz kontrolnih parcel na gnojene parcele.

V obravnavanju nizek odmerek fosforja (30 kg P_2O_5 ha^{-1} letno) oziroma skupno 90 kg P_2O_5 ha^{-1} se je povečala vsebnost dostopnega P v tleh za 2,4 mg P_2O_5 100 g^{-1} tal (Preglednica 2). S trikrat večjim odmerkom gnojila (90 kg P_2O_5 ha^{-1} letno) oziroma skupno 270 kg P_2O_5 ha^{-1} je bila vsebnost P v tleh povečana za 6,5 mg P_2O_5 100 g^{-1} tal. Podobno povečanje vsebnosti P v tleh je bilo ugotovljeno tudi v obravnavanju z visokim odmerkom gnojila (540 kg P_2O_5 ha^{-1} skupno uporabljeno v treh letih).

Preglednica 1*: Pedološki profil dveh mest vzorčenja s pripadajočimi fizikalnimi in kemičnimi lastnostmi izbranih horizontov*
Table 1*: Pedological profile of two sampling places with physical and chemical properties of selected horizons*

Parametri kemične analize tal	Profil in horizonti				
	P I			P II	
	A1	A2	Brz1	A1	A2
Globina (cm)	0 - 8	8 - 47	47 - 70	0 - 16	16 - 28
Glina (%)	13,2	25,9	38,4	14,6	27,8
pH ($CaCl_2$)	4,5	4,4	4,2	4,6	6,2
P_2O_5 (mg 100 g^{-1} tal)	1,1	0,4	<0,1	<0,1	<0,1
K_2O (mg 100 g^{-1} tal)	7,5	4,4	7,5	8	7,6
Organska snov (%)	9,7	5,9	1,7	11,6	8,8
C (%)	5,6	3,4	1	6,7	5,1
CN razmerje	13,3	14,2	11,1	16,8	17
S (mmol 100 g^{-1} tal)	4,7	3	3,6	15,7	40,3
T (mmol 100 g^{-1} tal)	29,4	25,1	21,2	34,8	51,8
V (% nasičene)	16	12	17	45,1	77,8
Ca (%)	13,6	10,8	14,5	41,6	76,1
Mg (%)	1,6	0,3	1,1	2,4	0,9
K (%)	0,6	0,4	0,8	0,6	0,4
Na (%)	0,3	0,2	0,3	0,6	0,3
H (%)	84	88	82,8	54,9	22,1

Preglednica 2*: Spreminjanje vsebnosti za rastline dostopnega P v zemlji v času štirih let po zadnjem gnojenju s P (leto 0)*
Table 2*: Changes of plant available P in soil four years after the last fertilizing with P (year 0)*

Skupno uporabljeno v treh letih gnojenja s P_2O_5 kg ha^{-1}	Leto analiziranja zemlje in koncentracija mg P_2O_5 100 g^{-1} tal		
	1999 (leto 0)	2001 (leto 2)	2003 (leto 4)
kontrola - 0	1,9	1,9	1,8
90 - (3x30)	3,5	4,9	4,5
270 - (3x90)	8,4	9,2	7,8
540 - (2x270)	8,5	9,6	6,1

Ob koncu prve faze poskusa (leto 1998), to je po opravljenem gnojenju s celotnim odmerkom P, je bilo izvedeno tudi vzorčenje zemlje do dveh globin in sicer 0 - 3 cm in 3 - 6 cm na istem mestu vzorčenja. Iz dobljenih podatkov v Preglednici 3 je mogoče ugotoviti, da je bil večji del razpoložljivega P za rast rastlin v zelo plitvi plasti zemlje pri čemer je večji del dodanega P v obdobju treh let ostal vezan prav tam predvsem zaradi večjega deleža organske snovi. Razgradnja odmrlih delov rastlin v razmerah kraškega pašnika je zelo počasna zaradi kratke vegetacijske dobe, kisle reakcije v tej plasti zemlje in nezadostne učinkovitosti drobnoživk zaradi slabega zadrževanja padavinske vode v vrhnji plasti zemlje.

Rezultati ponovljene analize zemlje vzorčene do globine 6 cm čez dve leti (tri rastne sezone) so pokazali, da se je povečala dostopnost P za rastline, in sicer za 1,4 mg P_2O_5 100 g^{-1} tal pri nizkem odmerku, za 0,6 mg P_2O_5 100 g^{-1} tal pri srednjem odmerku in za 1,1 mg P_2O_5 100 g^{-1} tal pri visokem odmerku dodanega P (Preglednica 2). Naslednje vzorčenje tal v obravnavanem poskusu je bilo narejeno ponovno čez dve leti, to je štiri leta (pet rastnih sezon) po zadnjem gnojenju s P. Rezultati kažejo, da je prišlo v tem času do zmanjšanja vsebnosti dostopnega P v tleh. To zmanjšanje je znašalo v obravnavanju nizek odmerek 0,4 mg P_2O_5 100 g^{-1} tal, v obravnavanju srednji odmerek 1,4 mg P_2O_5 100 g^{-1} tal in v obravnavanju visok odmerek 3,6 mg P_2O_5 100 g^{-1} tal.

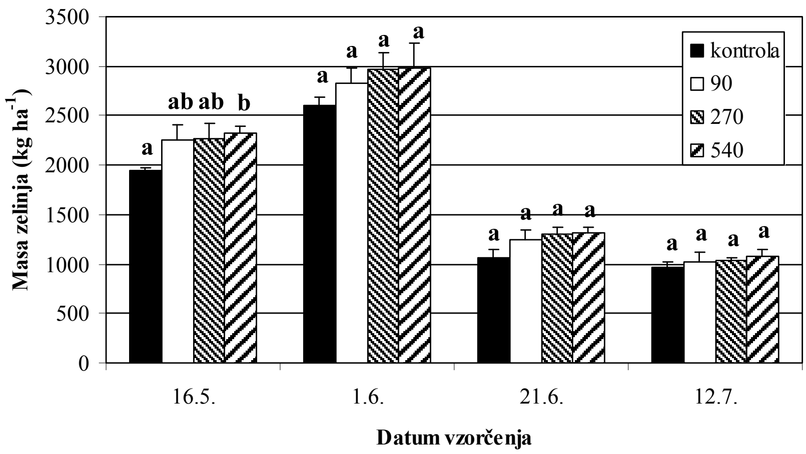
***Preglednica 3**: Podatki kemične analize tal vzorčenih na dveh globinah v poskusu gnojenja s P*
***Table 3**: Data of soil chemical analysis on two depths in the experiment with P fertilizing*

Skupni odmerek (kg P_2O_5 ha^{-1})	Globina vzorčenja (cm)	pH ($CaCl_2$)	P_2O_5 (mg 100 g^{-1} tal)	K_2O (mg 100 g^{-1} tal)	Organska snov (%)	C (%)	CN razmerje	N skupni (%)
0	0 - 3	5,6	3,8	35,5	14,4	8,3	14,8	0,56
0	3 - 6	5,1	0,4	13,7	8,5	4,9	13,2	0,37
90	0 - 3	5,7	4,5	44,9	16,6	9,6	16,0	0,60
90	3 - 6	5,9	0,8	15,6	9,6	5,6	12,7	0,44
270	0 - 3	5,6	10,2	35,0	16,4	9,5	13,6	0,70
270	3 - 6	5,2	2,6	16,6	8,2	4,7	15,5	0,57
540	0 - 3	5,1	12,7	24,5	13,1	7,6	14,9	0,51
540	3 - 6	5,1	3,1	12,1	7,8	4,5	12,9	0,35

Na hitrost rasti ruše in višino mase razpoložljivega zelinja za pašo spomladi je imelo gnojenje s P zelo majhen in neznačilen vpliv, čeprav se kaže težnja po boljši rasti ruše ob višjem odmerku P pri vseh meritvah v času rastne sezone (Slika 1). Slaba učinkovitost dodanega P na povišek pridelka je posledica kisle reakcije tal in dejstva, da spreminjanje floristične sestave ruše kraškega pašnika poteka zelo počasi.

3.4 Rudnine v zelinju

V četrtem letu trajanja poskusa so bili nabrani vzorci zelinja za potrebe določitve vsebnosti rudnin v obravnavanju negnojeno in v obravnavnaju srednji odmerek fosforja (skupno 270 kg P_2O_5 ha^{-1} v 3 letih). Vzorčeno je bilo zelinje ruše spomladi in poleti po metodi šopov, na podoben način kot pasejo živali. Zaradi siromašnosti zemlje kraškega pašnika s P, je tudi njegova vsebnost v zelinju ruše zelo nizka. Ugotovljeno je bilo 1,2 g P kg^{-1} suhe snovi (SS). Z letnim odmerkom 90 kg P_2O_5 ha^{-1} se je v treh rastnih sezonah njegova vsebnost povečala v povprečnem vzorcu zelinja na 2,1 g kg^{-1} SS (Preglednica 4). Tudi vsebnost Ca je bila povišana zaradi gnojenja s P, v pomladanskem zelinju pa tudi vsebnost natrija (Na). Vsebnost mikroelementov (cink - Zn, mangan - Mn, železo - Fe, baker - Cu) je bila višja v poletnem zelinju, ker je bil delež starejših rastlin in odmrle organske snovi v ruši večji zaradi pašnih ostankov od spomladi.



***Slika 1**: Masa razpoložljivega zelinja (16.5., 1.6., 12.7.) in pašnih ostankov (21.6.) na poskusu gnojenja s stopnjujočim se odmerkom P (v kg ha^{-1}) v letu 2002. Podana so povprečja ± SN, enaka črka nad stolpcem označuje obravnavanja, med katerimi ni statistično značilnih razlik (Duncanov test, p<0,05)*
***Figure1**: Mass of available herbage (16.5., 1.6., 12.7.) and sward residuals (21.6.) in phosphorus experiment with increased portion of P (in kg ha^{-1}) in 2002. Means ± SE are presented, different letters above columns mark statistically significant differences between the treatments (Duncan's test, p<0.05)*

Preglednica 4*: Vpliv gnojenja s P na vsebnost pomembnejših rudnin v zelinju kraškega pašnika spomladi in poleti in potrebna vsebnost v suhi snovi za ovce (Grace, 1983)*

Table 4*: The influence of P fertilizing on the concentration of more important minerals in the herbage of karst pasture in spring and summer and required content in dry matter for sheep diet (Grace, 1983)*

Čas vzorčenja	Pomlad		Poletje		Potrebna vsebnost rudnine v krmi za ovce
Odmerek kg P_2O_5 ha^{-1} v 3 letih	0	270	0	270	
Fosfor (g kg^{-1} SS)	1,18	2,15	1,16	2,14	2,5
Kalcij (g kg^{-1} SS)	11,51	14,94	12,31	14,03	3,2
Magnezij (g kg^{-1} SS)	2,00	2,98	2,16	3,20	1,2
Kalij (g kg^{-1} SS)	15,04	15,21	11,42	15,55	6,0
Natrij (g kg^{-1} SS)	0,27	0,50	0,36	0,31	0,9
Cink (mg kg^{-1} SS)	24,20	22,70	23,50	54,90	25,0
Mangan (mg kg^{-1} SS)	43,30	57,30	43,30	71,40	25,0
Železo (mg kg^{-1} SS)	73,30	78,20	153,30	190,40	40,0
Baker (mg kg^{-1} SS)	7,51	10,82	10,75	16,62	14,0

Katere vrste rastlin bodo zaužile živali pri paši, je pri nadzorovanem vodenju paše zelo odvisno od deleža določene rastline v ruši. Več kot je neke rastline v ruši, večji je njen delež v zaužitem obroku, če je ponudba zelinja za pašo približno vzklajena s potrebo živine po krmi. Zato so bile ločeno vzorčene tiste rastline, ki so od posamezne skupine predstavljale največji delež v ruši. Največ P je vseboval navadni regrat (*Taraxacum officinale* L.), manj črna detelja (*Trifolium pratense* L.) in najmanj rdeča bilnica (*Festuca rubra* L.). Gnojenje s P je vplivalo na povečanje vsebnosti P v vseh treh vrstah rastlin. Najbolj se je povečala njegova vsebnost pri črni detelji, in sicer za 52 %. Dodan P je vplival tudi na povečanje vsebnosti Na, ki ga v zelinju kraškega travinja običajno tudi zelo primanjkuje.

Preglednica 5*: Vpliv gnojenja s P na hranilno vrednost in vsebnost rudnin ob koncu pomladi v zelinju rastlin, ki so bile v ruši najbolj zastopane*

Table 5*: The influence of P fertilizing on nutrient value and mineral content in herbage of plants which were the most abundant at the end of spring*

Vrsta rastline	***RDEČA BILNICA***		***ČRNA DETELJA***		Navadni regrat	
Gnojeno s P_2O_5 kg ha^{-1}	0	270	0	270	0	270
Suha snov (g kg^{-1} zelinja)	381,2	359,9	280,2	273,4	174,8	174,4
Surove beljakavine (g kg^{-1} SS)	80,34	84,26	151,2	156,2	165,6	158,7
Surova vlaknina (g kg^{-1} SS)	356,60	355,4	321,2	320,8	152,2	152,1
Surovi pepel (g kg^{-1} SS)	42,54	43,56	62,87	59,53	105,9	101,1
Fosfor (g kg^{-1} SS)	1,15	1,95	1,60	2,44	1,96	3,16
Kalcij (g kg^{-1} SS)	4,49	3,40	14,63	13,98	19,77	16,63
Magnezij (g kg^{-1} SS)	1,01	1,17	2,79	3,54	3,80	4,72
Kalij (g kg^{-1} SS)	9,06	11,79	14,90	11,09	27,68	25,82
Natrij (g kg^{-1} SS)	0,41	0,34	0,56	0,71	0,83	1,42
Cink (mg kg^{-1} SS)	22,30	17,79	37,03	26,41	35,42	55,14
Mangan (mg kg^{-1} SS)	34,87	75,14	29,23	32,73	38,64	44,80
Baker (mg kg^{-1} SS)	7,39	7,56	14,04	13,57	15,61	17,54
Selen (mg kg^{-1} SS)	0,027	0,026	0,031	0,037	0,035	0,041

4 RAZPRAVA

Rezultati številnih kemičnih analiz zemlje za potrebe izdelave pedološke karte Slovenije (Stepančič in sod., 1980) ali za potrebe znanstveno raziskovalnega dela (Leskošek, 1965) ali za potrebe pridobivanja nepovratnih sredstev pri urejanju pašnikov na opuščenih zemljiščih (Vidrih in Kotnik, 1995) in neposrednih plačil v SKOP programu (Sušin, 2007) nedvoumno kažejo na zelo nizko vsebnost rastlinam dostopnega P v zemlji našega travinja (Leskošek, 1998), posebno tistega v hribovitem svetu in na krasu. Podobne razmere na travinju v hribovitem svetu so tudi v drugih geografskih območjih, posebno v Sredozemlju (Seligman, 1996). Tako je tudi v primeru travinja na planini Vremščica, kjer potekajo proučevanja rekultivacije opuščenih zemljišč s pomočjo živali kot orodjem (Vidrih in sod., 1995). Že s predhodnimi proučevanji na drugih območjih Slovenije je bilo potrjeno, da je povečanje vsebnosti dostopnega P v tleh nujno potrebno za izdatnejšo rast bele detelje in povečanje njenega deleža v ruši (Vidrih, 1990).

Višina letnega odmerka P za povečanje njegove vsebnosti v tleh je predmet številnih raziskav (Leskošek, 1978; Edmeades in sod., 1990; Dodd in sod., 1999). Večji del dodanega P preide najprej v netopnega in šele s povečanjem mikrobiološke aktivnosti v tleh se izboljša tudi oskrba rastlin s P. Živali z gaženjem lahko pospešijo ta proces (Djodjic in sod., 2005). Zadnji dve leti izvajanja proučevanj je bilo mogoče opaziti vse več glistin na površju tal tako v pomladanskem kot tudi jesenskem času. To je bil jasen znak o povečani aktivnosti deževnikov v zemlji, s čemer je prišlo do izdatnejšega mešanja vrhnje plasti zemlje s tisto pod njo, ki je še bolj siromašna s P. Tako je verjetno prišlo do učinka razredčitve na vsebnost P v vzorčeni plasti zemlje, saj je bilo ugotovljeno zmanjšanje vsebnosti ob koncu trajanja proučevanj, ki ga ni mogoče pojasniti samo z odvzemom za rast ruše.

Samo gnojenje s P je v začetku rekultivacije opuščenih zemljišč pravilna odločitev, ker je treba najprej povečati vsebnost P v zelinju, da bodo pašne živali dovolj oskrbljene s to rudnino. Glede na navedbe v literaturi (Grace, 1983) mora zelinje vsebovati najmanj 2,5 g P kg^{-1} SS, da so pokrite potrebe za normalen razvoj živali za rejo. V obravnavanju negnojeno je zelinje vsebovalo le polovico navedene vrednosti in pri gnojenju s srednjim odmerkom P je šele v tretji sezoni opazovanj vsebnost P v zelinju narasla do 2,1 g kg^{-1} SS. Istočasna uporaba apna za znižanje kislosti zemlje bi vplivala na povečanje pridelka in boljšo rast metuljnic v ruši, toda zvišanje vsebnosti P v zelinju bi bilo manjše, kot je bilo doseženo pri gnojenju samo s P (Albrecht, 2005). Izkušnje, ki jih imajo drugje z opustitvijo redne uporabe fosfatov na pašnikih v hribovitem svetu zaradi slabe ekonomske učinkovitosti kažejo na zmanjšanje pridelovalne zmogljivosti zemljišč in ponovno opuščanje kmetijske rabe na takih območjih (Gillingham in sod., 1990).

5 SKLEPI

Poglaviten razlog za opuščanje rabe kraškega travinja je zelo nizka vsebnost rastlinam dostopnega P v tleh. Ta je bil odvzet zemlji s pridelkom krme in premeščen v nižje ležeča območja tudi z erozijskimi procesi. Rekultivacijo kraškega travinja narekujejo številni razlogi, ki imajo vpliv na kakovost življenja na tem območju. Ponovno usposobitev opuščenih zemljišč za rabo in pridelavo funkcionalne hrane bo mogoče učinkovito izvajati samo z vodenjem nadzorovane paše domačih živali.

Dolgoletna in redna uporaba fosfatnih gnojil na kraškem pašniku je osnovna zahteva za rekultivacijo izčrpanih zemljišč s pomočjo pašnih živali. Pašne živali imajo velike in specifične potrebe po rudninah, ki jih z rušo siromašnega kraškega travinja ni mogoče pokriti. Zato je gnojenje teh zemljišč z letnim odmerkom 90 kg P_2O_5 ha^{-1} (39 kg P ha^{-1}) nujno potrebno, da bodo pašne živali ustrezno oskrbljene s P in bo rekultivacija opuščenih zemljišč uspešna ter njihova uporaba gospodarna tudi v slabših razmerah za kmetovanje kot so danes.

Siromašnost obravnavanih zemljišč s P je tudi glavna ovira za hitro in učinkovito povečanje njihove pridelovalne zmogljivosti, ki je nujna za ohranjanje teh zemljišč v funkciji pridelave hrane, negovane podobe pokrajine, zmanjšanje požarne ogroženosti območja in povečanje sposobnosti zemlje za neškodljivo recikliranje odpadnih snovi.

6 LITERATURA

Albrecht, W.A. 2005. Soil Fertility and Animal Health. Iowa, Fred Hahne Printing: 90 str.

Bremner, J.M., Mulvaney, C.S. 1982. Nitrogen total. V: Methods of soil analysis. Part 2: chemical and microbiological properties. Page A.L., Miller R.H., Keeney D.R. (eds.). Madison, Agronomy Monographs, 9: 595-624.

Caradus, J.R., Hay, R.J.M., Woodfield, D.R. 1996. The positioning of white clover cultivars in New Zealand. V: White clover: New Zealand Competitive Edge. Caradus, J.R., Woodfield, D.R. (eds.). Grassland Research and Practice Series No. 6: 45-49.

Csatho, P., Sisák, I., Radimszky, L., Lushaj, S., Spiegel, H., Nikolova, M. T., Nikolov, N., Čermák, P., Klir, J., Astover, A., Karklins, A., Lazauskas, S., Kopiński, J., Hera, C., Dumitru, E., Manojlovic, M., Bogdanović, D., Torma, S., Leskošek, M., Khristenko, A. 2007. Agriculture as a source of phosphorus causing eutrophication in Central and Eastern Europe. Soil Use and Management, 23,1: 36-56.

Djodjic, F., Bergstro, L., Grant, C. 2005. Phosphorus management in balanced agricultural systems. Soil use and management, 21: 94-101.

Dodd, M.B., Ledgard, S.F. 1999. Long term effect of withholding superphosphate application on North Island hill country: a 10-year update. Proceedings of the New Zealand Glassland Association, 61: 63 -68.

Edmeades, D.M., Wheeler, G.R.Y.S., Smith, N. 1990. Effect of pasture composition on lime and phosphorus responses on a dryland soil. Proceedings of the New Zealand Glassland Association, 52: 171-175.

Egner, H., Riem, H., Domingo, W.R. 1960. Untersuchungen ueber die chemische Bodenanalyse als Grundlage fuer Beurteilung des Naehrstoffzustandes der Boeden. II. Chemische Extraktionsmethoden zur Phosphor - und Kaliumbestimmung. Kungliga Landbrukshögskolans Annaler, 26: 199-215.

Eler, K. 2007. Dinamika vegetacije travišč v slovenskem submediteranu - vzorci in procesi ob spremembah rabe tal. Doktorska disertacija. Ljubljana, Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za agronomijo: 167 str.

Ferčej, J. 1996. Razvoj govedoreje in vplivi na okolje. Znanost in praksa v govedoreji, 20: 111-122.

Gillingham, A.G., Richardson, S., Power, I.L., Riley, J. 1990. Long term effect of withholding phosphate application on North Island hill country: Whatawhata Research Centre. Proceedings of the New Zealand Glassland Association, 51: 11-16.

Grace, N.D. 1983. The mineral requirements of grazing ruminants. New Zealand Soc. of Animal Production, Occ. Publication No. 9: 150 str.

Gruden, J. 1910. Zgodovina slovenskega naroda. Celovec, Družba sv. Mohorja: 1088 str.

Hočevar, M., Kušar, G., Cunder, T. 2004. Monitoring in analiza zaraščanja kraške krajine v GIS okolju. Zbornik gozdarstva in lesarstva, 75: 21-52.

Janitzky, P. 1986. Particle-size analysis. V: Field and laboratory procedures in a soil chronosequence study. Singer M.J., Janitzky P. (eds.). Reston, U.S. Geological Survey Bulletin: 11-16.

Kaligarič, M. 1997. Rastlinstvo primorskega Krasa in slovenske Istre: travniki in pašniki. Koper, Zgodovinsko društvo za južno Primorsko: 111 str.

Kaligarič, M., Culiberg, M., Kramberger, B. 2006. Recent vegetation history of the North Adriatic grasslands: expansion and decay of an anthropogenic habitat. Folia Geobotanica, 41: 241-258.

Leskošek, M. 1965. Vpliv fosfatov na pridelek ter na floristično in kemično sestavo mrve v Sloveniji. Doktorska disertacija. Ljubljana, Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za agronomijo: 183 str.

Leskošek, M. 1978. Versuche zum Vergleich verschidener P-Formen auf Wiesen in Slowenien. LDW. Forschung 30, II. Sonderheft: 112-122.

Leskošek, M. 1993: Gnojenje: za velik in kakovosten pridelek, za izboljšanje rodovitnosti tal, za varovanje narave. Ljubljana, Kmečki glas: 197 str.

Leskošek, M. 1998. Phosphorus in soil and phosphorus fertilization in Slovenia. Fragmenta Agronomica Tom, 3: 401-406.

Lobnik, F., Šporar, M., Hodnik, A., Vrščaj, B. 2002. Pedološke raziskave območja Vremščice. CRP projekt: Zaraščanje kmetijskih površin v Sloveniji, Ljubljana, Biotehniška fakulteta: 8 str.

Papanastasis, V.P. 1999. Grassland and woody plants in Europe with special reference to Greece. Grassland Science in Europe, 4: 15-24.

Rodriguez, R.A., Losada, M.R.M., Franco, R.R., Hernandez, M.P.G., Urtiaga, J.J.V. 2005. Silvopastoral systems as a forest fire prevention technique. V: Silvopastoralism and Sustainable Land Management. Losada, M.R.M., Riguerio, A., McAdam, J. (eds.). Wallingford, CABI publishing: 213-225.

Scott, D. 2003. Dryland legumes: perspective and problems. V: Legumes for dryland pastures. Moot, D.J. (ed.). Grassland Research and Practice Series No. 11: 27-36.

Seligman, N.G. 1996. Management of Mediterranean Grasslands. V: The Ecology and Management of Grazing Systems. Hodgson, J.; Illius, A.W. (eds.). Wallingford, CAB Int.: 359-391.

SIST ISO 10390. 1996. Kakovost tal - Ugotavljanje pH, SIST ISO: 5 str.

SIST ISO 14235. 1995. Določanje organskega ogljika z oksidacijo v kromžveplovi kislini. SIST ISO: 5 str.

Stepančič, D., Lobnik, F., Prus, T. 1980. Pedološka karta RS Slovenije, 1:25000, Biotehniška fakulteta, Center za tla in varstvo okolja.

Sušin, J. 2007. Kakšna mineralna gnojila potrebujemo v Sloveniji glede na oskrbljenost tal s fosforjem in kalijem. Ljubljana, Kmečki glas, 64, 4:1-3.

Vidrih, A. 1990. Effect of controled grazing and sod seeding of white clover on improvement of Nardus dominant hill pasture. V: Soil - grassland - animal relationship. Proceeding of 13th General Meeting of the EGF, Banska Bistrica, 25-29 junij 1990. Gaborčik, N., Krajčovič, V., Zimkova, M. (eds.). Banska Bistrica: 151-156.

Vidrih, A., Kotnik, T. 1995. Nadzorovana paša malih prežvekovalcev kot osnova za sonaravno kmetovanje. Sodobno kmetijstvo, 28, 5: 235-242.

Vidrih, A., Pogačnik, M., Kotar, M., Juntes, P., Kompan, D., Krek, V. 1995. Controlled grazing for small ruminants as a tool for sustainale management in karst grassland. Cahiers options méditerranéennes, 12: 139-142.

COBISS Code 1.01

Agrovoc descriptors: textiles; processed products; plant protection; plant protection equipment; protected cultivation; protective structures; plastics; mechanical properties; chemicophysical properties

Agris category code: F01; H01

Primerjava lastnosti polipropilenskih vlaken, namenjenih za izdelavo vrtnarskih vlaknovin

Andrej DEMŠAR[1], Dragan ŽNIDARČIČ[2], Diana GREGOR-SVETEC[3]

Delo je prispelo 19. februarja 2009; sprejeto 22. junija 2009.
Received: February 19, 2009; accepted: June 22, 2009.

IZVLEČEK

V intenzivnem vrtnarstvu se za vzgojo sadik in pridelavo vrtnin v vseh letnih časih uporablja različne oblike zavarovanega prostora. Najenostavnejša in najcenejša oblika zavarovanega prostora je neposredno prekrivanje rastlin z agrotekstilijami. Agrotekstilije so vlaknovine, izdelane iz tekstilnih vlaken, ki so navadno kemičnega izvora. Od agrotekstilij namenjenih za prekrivanje vrtnin, se zahtevajo primerna trdnost in dobre prepustne lastnosti, ki se pod vplivom vremenskih sprememb ne smejo bistveno poslabšati. Lastnosti agrotekstilij so odvisne od vlaken, iz katerih so agrotekstilje izdelane, ter od postopka in pogojev izdelave. Namen raziskave je bil analizirati dva tipa polipropilenskih (PP) vlaken (FiberVisions® HY-Comfort in UV-stabilizirana PP vlakna Trevon®), namenjenih za izdelavo vrtnarskih vlaknovin, primerjati rezultate z deklariranimi vrednostmi in predstaviti nekatere metode analize tekstilnih vlaken. Raziskava je pokazala, da prihaja med izmerjenimi in deklariranimi vrednostmi pri nekaterih lastnostih primerjanih vlaken do določenih razlik in da sta si preučevana tipa PP vlaken različna v tekstilno-mehanskih in strukturnih lastnostih.

Ključne besede: agrotekstil, polipropilenska vlakna, vlaknovina, mehanske lastnosti

ABSTRACT

THE COMPARISON OF PROPERTIES OF POLYPROPYLENE FIBRES INTENDED FOR THE PRODUCTION OF AGROTEXTILES

In the intensive horticulture various ways of protected area are used for the growth of seedlings and the cultivation of vegetables in all seasons. The easiest and the cheapest form of protected area is agrotextile which can be laid directly over field crops. Agrotextiles are nonwovens which are manufactured from textile fibers which are usually of chemichal origin. Textiles, used as a agrotextiles require suitable tensile strenght, and good permeability characteristics with no significant deterioration under the influence of weather changes. Properties of agrotextiles depend on the fibers made of and on the type and conditions of production. The aim of research was to analyse two types of polypropylene (PP) fibers (FiberVisions® HY-Comfort and UV-stabilised PP fibers Trevon®) which are used for the production of agrotextiles and to compare the results with the declared properties and to present some methods for the analysis of the textile fibers. The research showed that there is a difference between measured and declared properties and that two types of PP fibers are different regarding textile-mechanical and structural properties.

Key words: agrotextile, polypropylene fibers, nonwovens, mechanical properties

[1] Naravoslovnotehniška fakulteta, Univerza v Ljubljani, Oddelek za tekstilstvo, SI-1000 Ljubljana, Snežniška 5, e-pošta: andrej.demsar@ntf.uni-lj.si

[2] Biotehniška fakulteta, Univerza v Ljubljani, Oddelek za agronomijo, SI-1111 Ljubljana, Jamnikarjeva 101

[3] isti naslov kot [1]

1 UVOD

V intenzivnem vrtnarstvu se uporablajajo različne oblike zavarovanega prostora, ki omogoča vzgojo sadik in pridelavo vrtnin v vseh letnih časih. Najenostavnejša in najcenejša oblika zavarovanega prostora je neposredno prekrivanje rastlin z agrotekstilijami. Agrotekstilije so vlaknovine iz tekstilnih (navadno kemičnih) vlaken, ki se uporabljajo za neposredno prekrivanje rastlin, za tunele ali dopolnilne tunele v večjih objektih (Osvald in Kogoj Osvald, 1999). V proizvodnji vlaknovin se lahko uporabijo skoraj vse vrste vlaken, vendar imajo kemična vlakna veliko večji komercialni pomen kot naravna. Med kemičnimi vlakni se za izdelavo agrotekstilij večinoma uporabljajo polipropilenska (PP) vlakna. Ta vlakna uvrščamo med kemična vlakna iz sintetiziranih polimerov. Osnovna surovina za izdelavo polipropilena kot polimera je propilen, ki ga navadno dobijo pri pirolizi in krekiranju nafte iz lažjih in srednje težkih frakcij ali destilatov nafte, ki so stranski produkti rafinerij (Pajgrt in sod., 1983).

Osnovna značilnost PP vlaknovin, ki se uporabljajo v vrtnarstvu, so nizka masa (17–60 g/m^2), velika elastičnost in dobra prepustnost za sončne žarke (80–94 %). Vlaknovine blažijo temperaturne ekstreme. Voda prek mikropor počasi pronica in enakomerno zaliva rastline, hkrati pa prek mikropor izhlapeva, zaradi česar ne nastaja kondenz (Rekowska in sod., 1999). Poleg tega vlaknovine zadržujejo prah in varujejo rastline pred vetrom, škodljivimi žuželkami in virusi (Dierickx, 1999).

Mnoge raziskave poročajo o pozitivnem vplivu PP vlaknovin na pridelek vrtnin. Tako so Wadas in sod. (2004) v hladni pomladi s prekrivanjem krompirja (*Solanum tuberosum* L.) dosegli dvakrat tolikšni pridelek gomoljev z več suhe snovi in škroba kot pri nepokritih rastlinah. Do podobnih razultatov so s siljenjem krompirja pod vlaknovino prišli tudi Sawicka in Mikos-Bielak (2000) in Lachman in sod. (2003). Večji pridelek so pod vlaknovino dosegle tudi številne druge rastline, kot npr. okra (*Hibiscus esculentus* L.) (Brown in Channell-Butcher, 1999), zimska solata (*Lactuca sativa* L.) (Iwata in Kobayashi, 1999), dinje (*Cucumis melo* L.) (Ibarra in sod., 2001), paradižnik (*Lycopersicon esculentum* Mill.) (Žnidarčič in sod., 2003), por (*Allium porrum* L.) (Kołota in Adamczewska-Sowińska, 2007) in kolerabice (*Brassica napus* var. *gongylodes*) (Biesiada, 2008).

Namen raziskave je bil analizirati lastnosti dveh tipov PP vlaken, ki se uporabljata za izdelavo vrtnarskih vlaknovin, in ugotoviti razliko med deklariranimi (s strani proizvajalca) in izmerjenimi lastnostmi. Namen prispevka je tudi predstaviti nekatere metode, namenjene za analizo lastnosti tekstilnih vlaken.

2 MATERIAL IN METODE

V raziskavi smo uporabili dva tipa PP vlaken:

- PP vlakna, FiberVisions® HY-Comfort,
- UV-stabilizirana PP vlakna Trevon®.

Dolžino izravnanih vlaken (l) smo določali po standardu SIST ISO 6989. Posamezno vlakno smo s pomočjo dveh pincet izravnali ob merilu in odčitali dolžino.

Vrednost dolžinske mase vlaken (T_t) smo odčitali na vibroskopu Zweigle S-150 po standardu SIST EN ISO 1973. Dolžinska masa je definirana kot masa vlakna na določeno dolžinsko enoto in jo zato imenujemo tudi linearna gostota. Mednarodni sistem merskih enot SI določa kot osnovno enoto za dolžinsko maso kg/m, kot dovoljeno pa tudi tex = g/km (dtex = g/10 km).

Stopnjo kodravosti (K_{st}) smo izračunali iz razmerja med dolžino izravnanega in dolžino skodranega vlakna (ASTM D3937, 2007).

Pretržne sile in pretržne raztezke vlaken v nateznem poskusu smo merili na dinamometru Instron 6022 (SIST ISO 5079). Rezultate meritev smo ovrednotili s pomočjo računalniškega program DINARA (Bukošek, 1989). Računalniški program nam poleg vrednosti napetosti, raztezka, integrala, prvega, drugega in tretjega odvoda v celotnem območju raztezkov poda rezultate numerične analize. Omogoča tudi prikaz naraščanja napetosti in deformacije od ničelne vrednosti do pretrga vzorca v obliki grafa in integralno analizo krivulje specifična napetost – raztezek.

$$\sigma_{pr} = \frac{F_{pr}}{T_t} \quad \text{(cN/dtex)} \tag{1}$$

$$\sigma_{dpr} = \sigma_{pr} \cdot \left(1 + \frac{\varepsilon_{pr}}{100}\right) \quad \text{(cN/dtex)} \tag{2}$$

σ_{pr}.... *specifična pretržna napetost (cN/dtex)*
σ_{dpr}... *dejanska specifična pretržna napetost (cN/dtex)*
ε_{pr}..... *pretržni raztezek (%)*
F_{pr}..... *pretržna sila (cN)*
T_t ...... *dolžinska masa (dtex)*

Termične lastnosti smo določili po termomikroskopski metodi, ki jo je opisala Prelog (2003).

Dvolomnost smo merili s polarizacijskim mikroskopom Meopta, opremljenim z nitnim križem v okularju, merilnim okularjem in vstavljivim Ehringhausovim kompenzatorjem (Prelog, 2003).

$$\delta = \Delta n \cdot d \cdot \frac{2\pi}{\lambda} = \frac{\Gamma_{550}}{d \cdot 10^3} \quad (3)$$

δ .... *fazni premik, ki ga merimo s kompenzatorjem*
λ .... *valovna dolžina svetlobe (nm)*
Δn ..... *dvolomnost*
d .... *premer vlakna (nm)*
Γ_{550} ..... *fazna razlika pri valovni dolžini 550 nm*

$$f_{or} = \frac{\Delta n}{\Delta n_i} \quad (4)$$

f_{or}..... *faktor srednje orientacije*
Δn_i ..... *dvolomnost idealno orientiranega kristalinega vlakna (PP = 0.045)*

Gostoto in stopnjo kristalinosti smo določali s temperaturo lebdenja vlaken v tekočini enake gostote in nihajnega časa tekočine, vode in zraka (Juilfs, 1959).

Gostote merjenih vzorcev so ustrezale naslednji mešanici tekočin s pripadajočo enačbo, ki podaja linearno odvisnost gostote od temperature:

$$\rho_v = -0{,}0007789454451449 \cdot T + 0{,}9216578425963 \quad (5)$$

Iz gostote smo izračunali volumski in masni delež kristalinosti:

$$x_v = \frac{\rho_v - \rho_{am}}{\rho_{kr} - \rho_{am}} \quad (6)$$

$$x_w = \frac{\rho_{kr} \cdot (\rho_v - \rho_{am})}{\rho_v \cdot (\rho_{kr} - \rho_{am})} \quad (7)$$

x_V......... *volumski delež kristalinosti*
x_W........ *masni delež kristalinosti*
ρ_{kr}........ *gostota popolno kristaline faze (PP = 0,938 g/cm^3)*
ρ_{am}....... *gostota popolno amorfne faze (PP = 0,8545 g/cm^3)*
ρ_v........ *izmerjena gostota vzorca (g/cm^3)*

3 REZULTATI IN DISKUSIJA

Dolžina vlaken, ki jo deklarira prozvajalec (40 mm), se je zelo dobro ujemala z izmerjeno dolžino vlaken pri vzorcu FiberVisions, medtem ko je pri vzorcu Trevon prišlo do odstopanja za več kot 8 %. S srednjo vrednostjo 36,7 mm so bila vlakna vzorca Trevon za okoli 8 % krajša od vlaken vzorca FiberVisions (Preglednica 1). Dolžina vlaken močno vpliva na lastnosti vlaknovine, kot so trdnost, raztezek, neenakomernost, prepustnost, otip in videz. Krajša kot so vlakna, več je vlaken na maso tekstilnega izdelka. Podoben vpliv kot dolžina ima na mehanske lasnosti vlaknovine tudi dolžinska masa vlaken. Navedena dolžinska masa vlaken je 2,20 dtex (dovoljeno odstopanje ± 0,65 dtex za FiberVisions in 0,21 dtex za Trevon). Izmerjena dolžinska masa je bila pri obeh vzorcih višja od deklarirane, in sicer pri vzorcu FiberVisions za 35 % in pri vzorcu Trevon za 8,6 %. Pri obeh vzorcih je bila tako dolžinska masa na zgornji še dovoljeni deklarirani meji oz. ob upoštevanju odstopanja že izven nje. Vlakna vzorca Trevon (2,38 dtex) so imela za okoli 20 % nižjo vrednost izmerjene dolžinske mase v primerjavi z vzorci FiberVisions.

***Preglednica 1**: Deklarirana dolžina (l'), izmerjena dolžina (l), deklarirana dolžinska masa (T'_t) in izmerjena dolžinska masa (T_t) vlaken*

***Table 1**: Declarated length (l'), measured lenghth (l), declarated linear density (T'_t) and measured linear density (T_t) of fibers*

Vzorec	l' (mm)	l (mm)	T'_t (dtex)	T_t (dtex)
FiberVisions	40,00 ± 3,00	39,80 ± 0,47	2,20 ± 0,65	2,97 ± 0,16
Trevon	40,00 ± 3,00	36,67 ± 0,22	2,20 ± 0,21	2,38 ± 0,06

Oba vzorca sta imela podobno kodravost (Preglednica 2), in sicer vzorec FiberVisions 10,4 kodrov/cm in vzorec Trevon 9,7 kodrov/cm (pri obeh je bilo odstopanje od srednje vrednosti 2 kodra/cm). Tudi videz kodrov je bil pri obeh vzorcih podoben, kodri so bili neenakomerni, ob večjih so se pojavljali tudi bolj stisnejni, majhni kodri. Stopnja kodravosti, podana z razmerjem med dolžino razkodranega vlakna in dolžino zravnanega, še kodrastega vlakna, je bila nizka.

***Preglednica 2**: Število kodrov (K), stopnja kodravosti (K_{st}) in standardno odstopanje (s)*

***Table 2**: Number of curls (K), curling degree (K_{st}) and standard deviation (s)*

Vzorec	K (kodri/cm)	s (kodri/cm)	K_{st} (*l*)	s (*l*)
FiberVisions	10,40 ± 0,55	2	1,16 ± 0,03	0,08
Trevon	9,70 ± 0,55	2	1,17 ± 0,05	0,14

Od nateznih lastnosti vlaken je odvisen odziv vlaken na zunanje sile in deformacije. Natezne lastnosti so najlaže določljive lastnosti, ki vplivajo na obnašanje vlaken pri predelavi in uporabi. Pretržni raztezek je bil pri obeh vzorcih velik, saj je znašal pri vzorcu FiberVisions 399,16 %, pri vzorcu Trevon pa 273,37 % (Preglednica 3). Izmerjene vrednosti so bile pri vzorcu FiberVisions za več kot 1 % višje in pri vzorcu Trevon za več kot 23 % nižje od deklarirane vrednosti. Izmerjena specifična pretržna napetost je bila pri vzorcu Trevon v primerjavi z vzorcem FiberVisions za okoli 30 % večja. V primerjavi z deklariranimi pa so bile izmerjene vrednosti pri obeh vzorcih zelo podobne.

***Preglednica 3**: Deklarirani pretržni raztezek (ε_{pr}'), izmerjeni pretržni raztezek (ε_{pr}), deklarirana specifična pretržna napetost (σ_{pr}') in izmerjena specifična pretržna napetost (σ_{pr})*

***Table 3**: Declarated breaking strain (ε_{pr}'), measured breaking strain (ε_{pr}), deklarated specific breaking stress (σ_{pr}') and measured specific breaking stress (σ_{pr})*

Vzorec	ε_{pr}' (%)	ε_{pr} (%)	σ_{pr}' (cN/dtex)	σ_{pr} (cN/dtex)
FiberVisions	395 ± 80	399,16 ± 19,93	1,70 ± 0,20	1,72 ± 0,20
Trevon	356 ± 60	273,37 ± 28,33	1,90 ± 0,14	2,08 ± 0,10

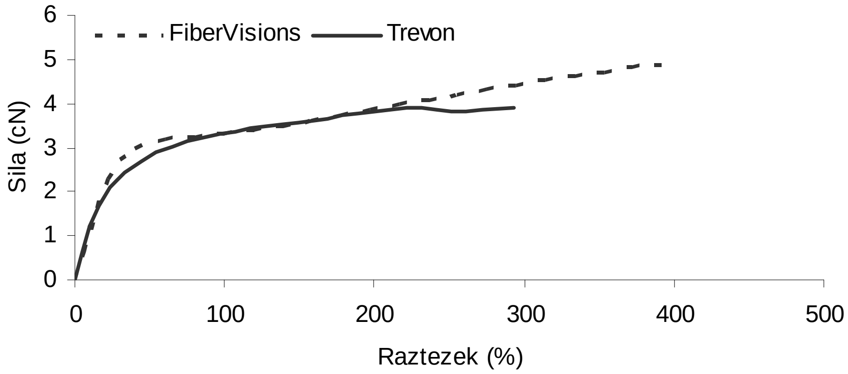
Medtem ko je specifična pretržna napetost podana z razmerjem pretržne sile in dolžinske mase, je korigirana specifična pretržna napetost podana kot razmerje med pretržno silo in dolžinsko maso v trenutku pretrga. Ker se dolžinska masa med obremenjevanjem z natezno silo zmanjša, to povzroči povečanje napetosti v vlaknih in s tem višjo dejansko specifično pretržno napetost. Iz Preglednice 4 je razvidno, da je bila korigirana specifična pretržna napetost nekajkrat višja od specifične pretržne napetosti pri obeh vzorcih in da je bila pri vzorcu Trevon višja kot pri vzorcu FiberVisions.

Visokoelastične lastnosti (Preglednica 4 in Slika 1) sodijo med pomembnejše lastnosti, ki opredeljujejo uporabno kakovost vlaken, ker vplivajo na potek proizvodnega procesa in končne lastnosti tekstilnega izdelka. Podobno kot trdnost je bil tudi modul elastičnosti obeh vzorcev nizek. Vzorec Trevon je imel več kot dvakrat višjo vrednost modula elastičnosti, kar pomeni, da bo začetni upor na delovanje sile pri tem vzorcu večji kot pri vzorcu FiberVisions. Polzišče na krivulji specifične napetosti proti raztezku je točka, kjer se konča elastično območje in začne viskoelastično obnašanje vlaken, ki je povezano z delnimi trajnimi deformacijami. Podajamo ga s specifično napetostjo in pripadajočim raztezkom v tej točki. Polzišče je nastopilo pri vzorcu Trevon prej in pri nižji napetosti kot pri vzorcu FiberVisions, pri obeh vzorcih pa je potem sledilo viskoelastično območje, kjer je bil upor na delovanje sile majhen in že majhne obremenitve so povzročile veliko raztezanje vlaken.

***Preglednica 4**: Korigirana specifična pretržna napetost (σ_{kpr}), specifična pretržna napetost v polzišču (σ_{pol}), pretržni raztezek v polzišču (ε_{pol}), modul elastičnosti (E_0)*

***Table 4**: Corrected specific breaking stress (σ_{kpr}), specific breaking stress at yield point (σ_{pol}), breaking strain at yield point (ε_{pol}), elasticity modulus (E_0)*

Vzorec	σ_{kpr} (cN/dtex)	σ_{pol} (cN/dtex)	ε_{pol} (%)	E_0 (GPa)	A_{sp} (kJ/kg)	f_A (/)
FiberVisions	10,12	0,79	40,52	0,10	742,2	0,87
Trevon	13,41	0,58	23,58	0,23	845,7	0,87



***Slika 1**: Sila v odvisnosti od raztezka vzorcev FiberVisions in Trevon*

***Figure 1**: Force as a function of strain of samples FiberVisions and Trevon*

Z dovajanjem toplote nastopi pri dovolj veliki toplotni energiji fazni prehod I. reda – taljenje kristalinih predelov strukture. Pri vlaknih je dokaj težko natančno določiti vrednost kritične temperature prvega reda, to je tališče, ker je težko razločiti zmehčanje (mehansko tekoče stanje polimera) od začetnega trenutka taljenja, kar je tudi razvidno iz rezultatov meritev, podanih v Preglednici 5. Tališče je odvisno od kemične sestave, popolnosti in velikosti kristalitov ter od orientacije molekul. Temperatura zmehčišča vzorca FiberVisions je bila višja za 1,5 °C od temperature zmehčišča pri vzorcu Trevon. Začetek taljenja za vzorec FiberVisions je bil pri 158,8 °C, za vzorec Trevon pa pri 161,7 °C. Interval taljenja, povezan z velikostjo in popolnostjo kristaline strukture, je bil pri vzorcu FiberVisions širši, kar ob nižji temperaturi začetka taljenja pomeni, da so pri teh vlaknih prisotni manjši in manj popolni kristaliti ter nižja stopnja orientacije.

***Preglednica 5**: Zmehčišče vlaken (T_z), tališče vlaken (T_{tal}) in interval taljenja (T_i)*

***Table 5**: Softening point (T_z), melting point (T_{tal}) and melting interval (T_i)*

Vzorec	T_z (°C)		T_{tal} (°C)	T_i (°C)
FiberVisions	155,08 ± 1,53	začetek t.	158,83 ± 0,46	10,72
		konec t.	169,55 ± 1,42	
Trevon	155,08 ± 1,53	začetek t.	161,71 ± 0,29	8,87
		konec t.	170,58 ± 0,81	

Optična dvolomnost je odvisna od orientacije polimernih molekul in stopnje kristalinosti vlaken. Večja dvolomnost je bila izmerjena pri vzorcu Trevon in v povezavi s tem je pri tem vzorcu višji tudi faktor orientacije, izračunan iz dvolomnosti (Preglednica 6). Razlika med vzorcema je bila velika, saj je znašala 20

%. Rezultati meritev dvolomnosti so pokazali, da sta višja trdnost in modul elastičnosti vlaken v vzorcu Trevon posledica višje orientacije polimernih molekul in višjih strukturnih gradnikov teh vlaken.

Preglednica 6: Dvolomnost vlaken (Δn), faktor orientacije vlaken (f_{or}) in standardno odstopanje (s)

Table 6: Birefringence of fibers (Δn), orientation factor (f_{or}) and standard deviation (s)

Vzorec	Δn (/)	s (/)	f_{or} (/)	s (/)
FiberVisions	0,0276 ± 0,0024	0,0040	0,613 ± 0,055	0,088
Trevon	0,0350 ± 0,0016	0,0048	0,778 ± 0,036	0,036

Stopnja kristalinosti je ob stopnji orientacije najpomembnejši faktor, ki določa mehanske lastnosti vlaken. Z večanjem kristalinosti se povečujeta trdnost in modul elastičnosti vlaken. Rezultati izmerjenih vrednosti gostote in iz nje izračunani utežna in volumska stopnja kristalinosti so podani v Preglednici 7. Razlike v gostoti vzorcev FiberVisions in Trevon niso bile velike in v povezavi s tem so bile razlike v stopnji kristalinosti majhne. Nekoliko višjo kristalinost, in sicer za 3 %, je imel vzorec FiberVisions. Razlika v stopnji kristalinosti med vzorcema je bila premajhna, da bi občutno vplivala na razlike v mehanskih lastnostih vlaken.

***Preglednica 7**: Gostota vlaken (ρ_v), utežna stopnja kristalinosti vlaken (x_w) in volumska stopnja kristalinosti vlaken (x_v)*

***Table 7**: Density of fibers (ρ_v), weight degree of crystalinity (x_w) in volume degree of crystalinity (x_v)*

Vzorec	ρ_v (g/cm^3)	x_w (%)	x_v (%)
FiberVisions	0,89946 ± 0,00034	59,8 ± 0,4	57,5 ± 0,4
Trevon	0,89796 ± 0,00024	58,1 ± 0,3	55,8 ± 0,3

4 SKLEPI

Poznavanje lastnosti vlaken, iz katerih je izdelana vrtnarska vlaknovina, je zelo pomembno tako za proizvajalca kot za uporabnika vlaknovine. Namen raziskave je bil primerjati dva tipa PP vlaken, namenjenih za izdelavo vlaknovin, med seboj in hkrati primerjati dobljene vrednosti z deklariranimi.

Primerjava lastnosti vlaken, ki jih navaja proizvajalec, z lastnostmi, ki jih je pokazala naša raziskava, kaže, da prihaja med izmerjenimi in deklariranimi vrednostmi do določenih razlik. Raziskava je pokazala tudi na razlike v tekstilno-mehanskih in strukturnih lastnostih med obema tipoma PP vlaken. Vlakna vzorca Trevon so za okoli 8 % krajša in imajo 20 % nižjo dolžinsko maso v primerjavi z vlakni FiberVisions.

Vzorec Trevon ima občutno nižji raztezek, višjo specifično pretržno napetost in višji modul elastičnosti v primerjavi z vzorcem FiberVisions. Polzišče je nastopilo pri vzorcu Trevon prej in pri nižji napetosti kot pri vzorcu FiberVisions.

Večja dvolomnost je bila izmerjena pri vzorcu Trevon in v zvezi s tem je pri tem vzorcu višji tudi faktor orientacije, izračunan iz dvolomnosti. Rezultati meritev dvolomnosti so pokazali, da sta višja trdnost in modul elastičnosti vlaken v vzorcu Trevon posledica višje orientacije polimernih molekul in višjih strukturnih gradnikov teh vlaken.

Temperatura zmehčišča vzorca FiberVisions je bila višja od temperature zmehčišča vzorca Trevon. Interval taljenja, povezan z velikostjo in popolnostjo kristaline strukture, je bil pri vzorcu FiberVisions širši, to pa ob nižji temperaturi začetka taljenja pomeni, da so pri teh vlaknih prisotni manjši in manj popolni kristaliti ter nižja stopnja orientacije.

5 VIRI

ASTM D3937, 2007. Standard test method for crimp frequency of manufactured staple fibers. ASTM Book of Standards, Vol. 04.13, 1999, ASTM, Philadelphia, PA.

Dierickx, W. 1999. Opening size determination of technical textiles used in agricultural applications. Geotext. Geomemb., 17: 231–245.

Biesiada, A. 2008. Effect of flat covers and plant density on yielding and quality of kohlrabi. J. Elementol., 13, 2: 167–173.

Brown, J.E., Channell-Butcher, C. 1999. Effect of three row covers and black plastic mulch on the growth and yield of 'Clemson Spineless' okra. J. Veg. Crop Prod., 5, 2: 67–71.

Bukošek, V. 1989. Računalniško vrednotenje visokoelastičnih lastnosti vlaken, filamentov, prej, tkanin, trakov, folij in ploskih izdelkov iz nateznih in tlačnih poskusov. Razvoj metode in programske opreme DINARA©, Ljubljana, 55 str.

Call, R.E., Courter, J.W. 1989. Response of bell pepper to raised beds, black plastic mulch, spunbonded row cover and trickle irrigation. Proceed. of 21st NAPC: 140–146.

Ibarra, L., Flores, J., Diaz-Perez, J.C. 2001. Growth and yield of muskmelon in response to plastic mulch and row covers. Sci. Hortic., 87: 139–145.

Iwata, H., Kobayashi, S. 1999. Application of row cover in winter lettuce cultivation. Kinki Chugoku Agr. Res., 98: 32–37.

Juilfs, J. 1959. Meilland Textile Ber., 40: 963–966.

Kołota, E., Adamczewska-Sowińska, K. 2007. The effects of flat covers on overwintering and nutritional values of leeks. Veget. Crops Res. Bull., 66: 11–16.

Lachman, J., Hamouz, K., Hejtmankova, A., Dudjak, J., Orsak, M., Pivec, V. 2003. Effect of white fleece on the selected quality parameters of early potato (*Solanum tuberosum* L.) tubers. Plant Soil Environ., 49, 8: 370–377.

Osvald, J., Kogoj Osvald, M. 1994. Gojenje vrtnin v zavarovanem prostoru. ČZP Kmečki glas, Ljubljana, 126 str.

Pajgrt, O., Reichstader, B., Ševčik, F. 1983. Production and application of polypropylene fibers. Elsewier Sc. Pub. Co., New York, 22. str.

Prelog, T. 2003. Svetlobna obstojnost polipropilenskih vlaknovin. Diplomsko delo. Univerza v Ljubljani, Naravoslovno tehniška fakulteta, Oddelek za tekstilstvo, 103 str.

Rekowska, E., Orlowski, M., Slodkowski, P. 1999. Wpływ stosowania osłon oraz terminów zbioru na plonowanie ziemniaka wczesnego. Zesz. Probl. Post. Nauk Roln., 466: 181–189.

Sawicka, B., Mikos-Bielak, M. 2000. Wpływ nawoŜenia azotem i uprawy pod osłonami na wartość konsumpcyjną bulw ziemniaka. Konf. Nauk. "Ziemniak spoŜywczy i przemysłowy oraz jego przetwarzanie". AR Wrocław, Polanica Zdrój: 132–133.

Wadas, R., Jabłońska-Ceglarek, R., Kosterna, E. 2004. Effect of plastic covering and nitrogen fertilization on yield and quality of early potatoes. Folia Hort., 16, 2: 41–48.

Žnidarčič, D., Trdan, S., Zlatič, E. 2003. Impact of various growing methods on tomato (*Lycopersicon esculentum* Mill.) yield and sensory quality. Res. Rep., Biotech. Fac., Univ. Ljublj., 81: 341–348.

COBISS Code 1.01

Agrovoc descriptors: lettuces; lactuca sativa; conventional tillage; cultivation; organic agriculture; integrated plant production; cultural methods; crop yield; profit; price formation

Agris category code: F01; E16

Vpliv agroekoloških razmer na ekonomsko upravičenost ekološkega pridelovanja solate (*Lactuca sativa* L.)

Milan OPLANIČ[1], Dean BAN[2], Stanislav TRDAN[3], Dragan ŽNIDARČIČ[4]

Delo je prispelo 23. marca 2009; sprejeto 22. junija 2009.
Received: March 23, 2009; accepted: June 22, 2009.

IZVLEČEK

Cilj raziskave je bil primerjati ekonomsko uspešnost gojenja solate v konvencionalnem in ekološkem načinu pridelave v celinskem in sredozemskem delu Republike Hrvaške. V letih 2002 in 2003 je bil poskus postavljen na družinskih kmetijah v okolici Pulja (sredozemsko območje) in v okolici kraja Otočac (celinsko območje). Dobljeni rezultati kažejo na to, da ima gojenje solate v ekološki pridelavi za posledico manjši pridelek, kar je še bolj izrazito v celinskem podnebju. Da bi bila pridelava solate iz takega načina gojenja ekonomsko opravičljiva, je treba zanjo doseči višjo prodajno ceno v primerjavi s solato iz konvencionalne pridelave. Iz istega razloga bi morala biti tudi prodajna cena ekološko pridelane solate na celinskem območju višja kot cena solate, pridelane ob morju.

Ključne besede: konvencionaln pridelava, ekološka pridelava, solata, *Lactuca sativa*, Hrvaška

ABSTRACT

THE IMPACT OF AGROECOLOGICAL CONDITIONS ON ECOLOGICALLY SOUND AND ECONOMICALLY VIABLE PRODUCTION OF LETTUCE (*Lactuca sativa* L.)

The aim of research was to compare the economic performance of growing lettuce in the conventional and ecological crop management of production in the mainland and the Mediterranian part of Croatia. In the years 2002 and 2003 the experiment was carried out on family farms in the vicinity of Pula (the Mediterranian area) and in the vicinity of Otočac (the mainland area). The obtained results show that the cultivation of lettuce in the ecological crop management in lower yields, which is even more apparent in continental climate. In order to justify the ecological crop management of lettuce economically, it is essential to achieve a higher sales price in comparison with the lettuce cultivated according to the conventional system. For that reason, the sales price of ecolgical grown lettuce in the mainland should be higher than in the Mediterranean.

Key words: conventional crop management, integrated crop management, lettuce, *Lactuca sativa*, Croatia.

1 UVOD

V vrtnarski pridelavi je konvencionalno gojenje vrtnin še vedno najbolj razširjeno. Za ta način pridelave so značilni velika poraba kemičnih sredstev, visoki pridelki in nizki stroški na enoto površine (Abdul-Baki, 1998; Shennan, 1992). Po drugi strani pa tak način pridelave lahko vodi do povečane onesnaženosti okolja in preobremenitve hrane s pesticidi (Bašić, 1996). V zadnjih dvajsetih letih postaja glavna tema političnih, socialnih in ekonomskih gibanj naravi prijazna pridelava, ki ima za cilj ohranjanje narave ob

[1] Institute of Agriculture and Tourism, Carla Huguesa 8, CR-52 440 Poreč; e-mail: milan@iptpo.hr

[2] isti naslov kot [1]

[3] Biotehniška fakulteta, Univerza v Ljubljani, Jamnikarjeva 101, SI-1111 Ljubljana

[4] isti naslov kot [3]

upoštevanju socialnih in kulturnih danosti (Zagata, 2007). Tako se je npr. v zadnjih nekaj letih kot posledica povečanega povpraševanja obseg trgovanja z ekološkimi živili v večini članic EU izjemno povečal, in sicer po stopnjah med 5 in 30 odstotkov (Raterman, 1997). Rast tržišča z ekološkimi pridelki je pogojena s povečanim povpraševanjem po zdravi hrani, z zahtevami po varstvu narave in s spodbujanjem biotske raznovrstnosti (Thompson, 1998). Takšne težnje so najmočnejše predvsem v razvitih državah (države EU, ZDA), kjer vse bolj narašča povpraševanje po ekološko pridelanih svežih in predelanih vrtninah (Oplanić in sod., 2009).

Raziskave, ki so jih opravili Ban (2001), Bullock in sod. (2002) ter Elliot in Mumford (2002) kažejo na možnost gojenja vrtnin z alternativnimi načini, ki so okolju prijaznejši, hkrati pa taka pridelava še vedno daje zadovoljive ekonomske rezultate.

Zaradi specifičnih naravnih in gospodarskih razmer ima Hrvaška ugodne prostorske in klimatske možnosti za ekološko pridelavo vrtnin, še posebno na območjih, in teh je na pretek, kjer doslej niso bila uporabljena kemična sredstva. Cilj naše raziskave je bil primerjati ekonomsko uspešnost gojenja solate v konvencionalnem in ekološkem načinu pridelave v celinskem in sredozemskem delu Republike Hrvaške.

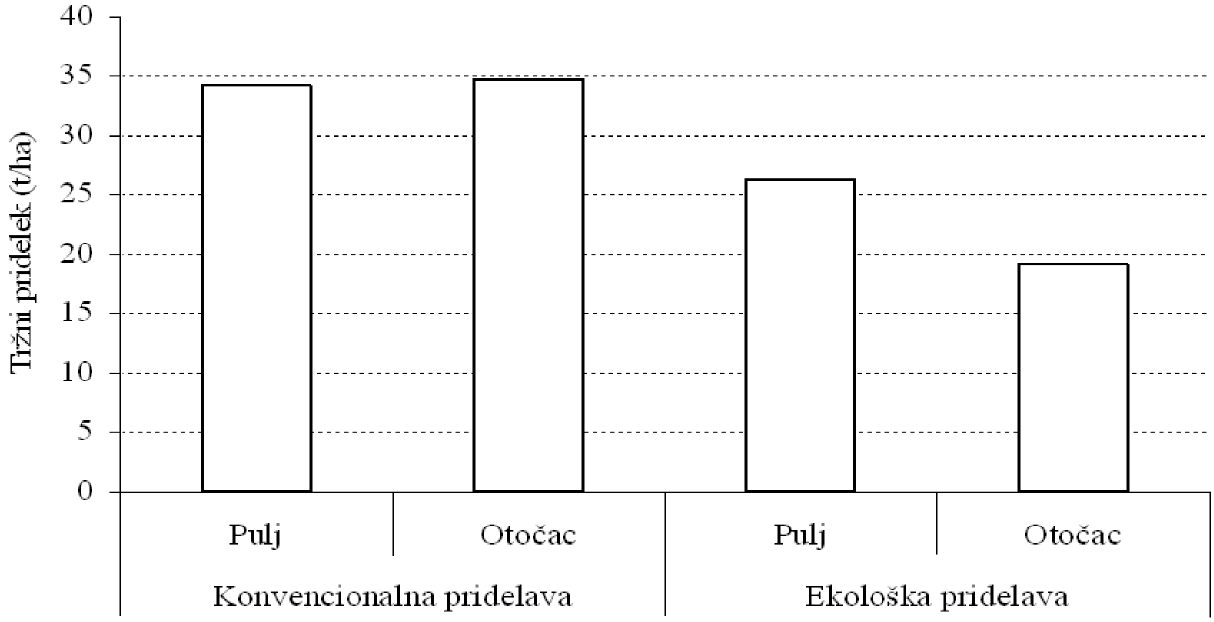
2 MATERIAL IN METODE

V letih 2002 in 2003 je bila raziskava z gojenjem solate (*Lactuca sativa* L.) opravljena na družinskih kmetijah v okolici Pulja (sredozemsko območje) in v okolici kraja Otočac (celinsko območje). Poskusne parcelice so bile v treh ponovitvah razporejene po metodi naključnih blokov. Proučevana sta bila dva dejavnika in sicer konvencionalno in ekološko gojenje solate. Na parcelicah namenjenih ekološki pridelavi smo predhodno zaorali hlevski gnoj (30 t/ha) in posejali krmni grah (*Pisum sativum* L.), ki je pokošen služil kot zastirka. Parcelice namenjene konvencionalnemu gojenju so bile pognojene z mineralnim gnojilom NPK 15-15-15 (300 kg/ha) in poškropljene s herbicidom Kerb 50-W (3 kg/ha). Na „konvencionalne“ parcelice je bil poleg PE črne folije položen tudi sistem cevi za kapljično namakanje in fertiirigacijo. Plevel je bil na „ekoloških“ parcelicah odstranjen z dvakratnim pletjem, medtem ko smo na „konvencionalnih“ parcelicah uporabili herbicid Boom efekt (3 l/ha) za zatiranje plevela med folijami. Za varstvo rastlin pred boleznimi in škodljivci smo na „ekoloških“ parcelicah uporabili dovoljene pripravke na osnovi metaldehida, ekstrakta dalmatinskega bolhača (*Chrysanthemum cinerariifolium* [Trevir.] Vis.) in bakrene pripravke. Na „konvencionalnih“ parcelicah pa smo za varstvo uporabili sintetična kemična sredstva, ki so dovoljena v konvencionalni pridelavi.

Ekonomska analiza konvencionalnega in ekološkega gojenja solate je bila narejena s tehniko kalkulacije, ki predstavlja sestavni del „cost/benefit“ analize (Key in Edwards, 1999). Pri ugotavljanju skupnih stroškov pridelave so bile uporabljene kalkulacije pri katerih so stroški specificirani znotraj štirih osnovnih skupin in sicer so to stroški uporabe delovnih strojev (vključena je tudi amortizacija), stroški neposrednega dela, materialni stroški in drugi stroški (stroški nabave in prodaje, najem zemljišča, stroški certificiranja v ekološki pridelavi …). Skupni prihodki pa predstavljajo zmnožek skupne količine tržnega pridelka in povprečne tržne cene solate v posameznem letu. Tržno ceno konvencionalno pridelane solate je bila pridobljena iz poročila strokovnih služb Ministrstva za kmetijstvo (http://www.tisup.mps.hr/). Zaradi nerazvitosti hrvaškega trga z ekološkimi kmetijskimi pridelki smo tržno ceno ekološko pridelane solate določili s pomočjo cenovne premije za katero je bila povečana tržna cena konvencionalno pridelane solate. Cenovna premija za ekološke pridelke se namreč oblikuje na podlagi dejstva, da so kupci za njih pripravljeni plačati več kot za pridelke iz konvencionalne pridelave. Ekološki pridelki naj bi bili po navedbah Smitha in sod. (2004) zdravstveno neoporečni, ker naj ne bi vsebovali ostankov pesticidov in mineralnih gnojil ter naj ne bi bili genetsko spremenjeni. Višino cenovne premije v naši raziskavi smo določili glede na priporočila Richmana (1999) ter Brumfielda in sod. (2000) in je znašala 30 %.

3 REZULTATI IN DISKUSIJA

Dobljeni tržni pridelki v konvencionalnem načinu gojenja so bili zelo izenačeni na obeh lokacijah in so znašali okrog 34,5 t/ha (Slika 1). Pridelki so bili v okviru pričakovanj, saj se po podatkih iz literature pridelki solate gojene na prostem gibljejo med 25 in 40 t/ha (Lešić, 2002) oz. med 20 in 60 t/ha (Aybak, 2002), kar pa je predvsem pogojeno s sorto, gostoto sajenja, vremenskimi pogoji in tehnologijo pridelovanja.



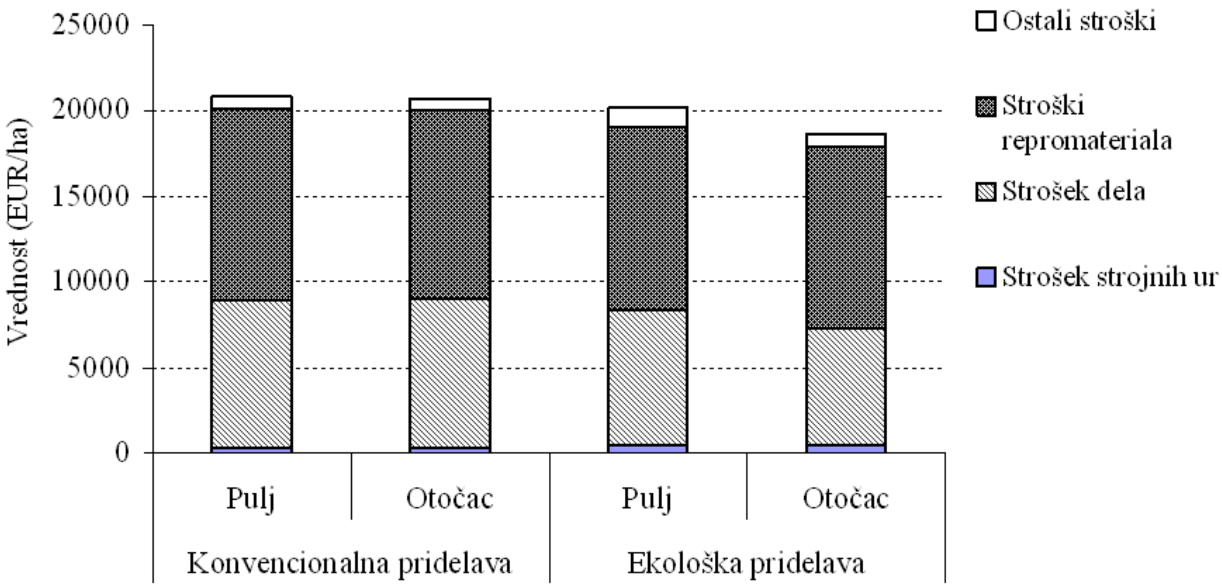
Slika 1: *Tržni pridelek solate gojene na konvencionalni in ekološki način na dveh lokacijah*

Figure 1: *Marketable yield of lettuce under conventional and organic production systems in two locations*

Tržni pridelki solate iz ekološke pridelave so bili nižji za 34 % in so v povprečju znašali 22,7 t/ha. Pri tem načinu pridelave so bile opazne tudi pomembne razlike v pridelku med lokacijama, tako je znašal pridelek v Pulju 26,4 t/ha, kar je za 38 % več kot v Otočcu (19,2 t/ha). V sredozemskem območju so bili pridelki, v primerjavi s celinskim območjem, višji zaradi ugodnejših agroklimatskih pogojev, ki so pogojevali tudi manjši napad solatne plesni (*Bremia lactucea* L.).

Skupni stroški gojenja solate so se gibali med 18.650 EUR/ha pri ekološki pridelavi v Otočcu do 20.796 EUR/ha pri konvencionalni pridelavi v Pulju (Slika 2). Medtem, ko je znašala razlika v stroških med obema načinoma gojenja v Pulju 5 %, so bili stroški v Otočcu pri konvencionalnem načinu gojenja za 17 % višji kot pri ekološkem gojenju. Večja razlika v stroških pridelave je povezana z dejstvom, da so rastline v konvencionalni pridelavi dosegale za 82 % večje pridelke kot v ekološki pridelavi.

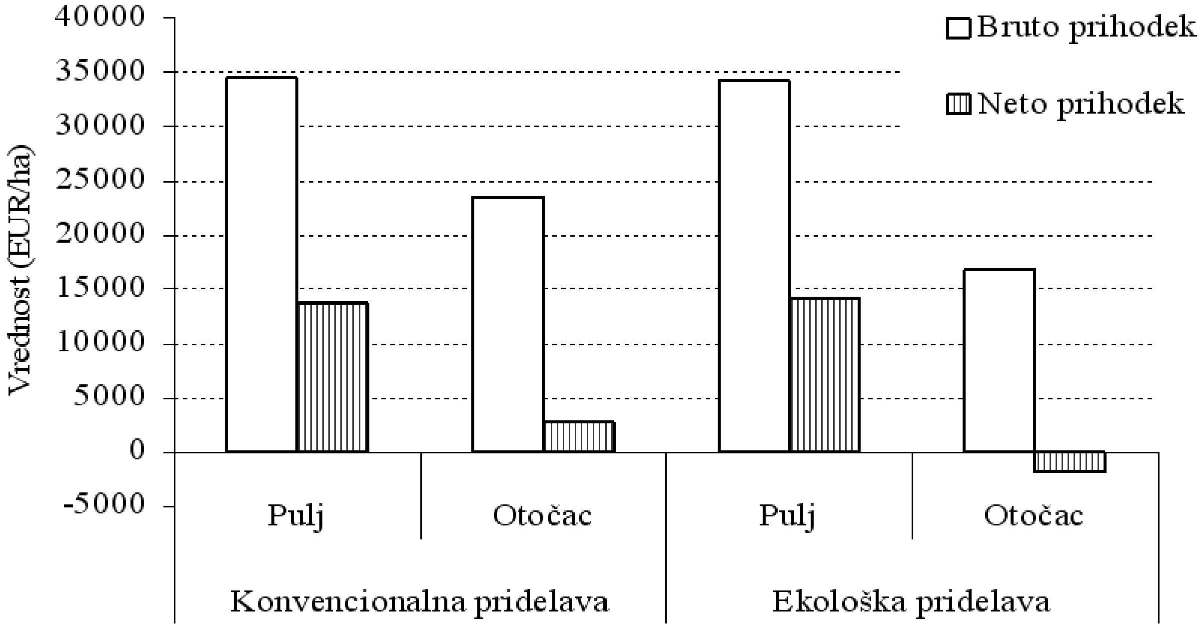
Lastna cena za solato iz konvencionalne pridelave je bila za obe lokaciji podobna in se je gibala okrog 0,60 EUR/kg. Lastna cena ekološko pridelane solate v Otočcu pa je znašala 0,98 EUR/kg in je bila za 25 % višja kot enako gojena solata v Pulju.



Slika 2*: Stroški strojnih ur, stroški dela, stroški repromateriala in ostali stroški gojenja solate na konvencionalni in ekološki način na dveh lokacijah*

Figure 2*: Mechanization, labor, repromaterial and other cost in lettuce production under conventional and organic production systems in two locations*

Povprečna veleprodajna cena solate iz ekološke pridelave v Pulju je znašala 1,01 EUR/kg, medtem ko je bila v Otočcu za 33 % nižja in je dosegala 0,68 EUR/kg. Višja cena solate kot tudi ostalih kmetijskih pridelkov v sredozemskem območju je bila pričakovana zaradi večjega povpraševanja, še posebej med turistično sezono in zaradi večje kupne moči lokalnih prebivalcev. Kot je bilo že omenjeno smo do prodajne cene ekološko pridelane solate prišli z upoštevanjem 30 % cenovne premije. Tako je ekološko pridelana solata v Pulju dosegla 1,32 EUR/kg, v Otočcu pa 0,88 EUR/kg. Na osnovi teh prodajnih cen so bili ugotovljeni skupni prihodki in finančni rezultat pridelave solate pri obeh načinih gojenja in na obeh lokacijah (Slika 3).



Slika 3: *Bruto in neto prihodek od gojenja solate na konvencionalni in ekološki način na dveh lokacijah*

Figure 3: *Gross and net income of lettuce under conventional and organic production systems in two locations*

Bruto prihodek od pridelave solate je bil v Pulju izenačen pri obeh načinih gojenja in je znašal okrog 34.500 EUR/ha. Iz tega je razvidno, da se okrog 30 % nižji pridelki ekološko vzgojene solate nadomestijo z višjo prodajno ceno. V Otočcu je solata iz konvencionalne pridelave dala za 32 % nižji bruto prihodek, kar je bilo izključno posledica nižje prodajne cene. Ekološko pridelana solata v Otočcu je v primerjavi z enako pridelano solata v Pulju dala za 51 % nižji bruto prihodek, kar je bilo pogojeno z nižjimi pridelki in nižjo prodajno ceno.

Pri pridelavi solate v Pulju smo dosegli približno enak neto prihodek pri obeh načinih gojenja in je znašal okrog 14.000 EUR/ha. V Otočcu je solata v konvencionalni pridelavi dosegla 2.803 EUR/ha neto prihodka, medtem, ko je ekološka pridelava prinašala izgubo v višini 1.829 EUR/ha.

4 SKLEPI

Na podlagi naše raziskave lahko sklenemo, da na ekonomsko uspešnost pridelave solate v večji meri vpliva lokacija kot pa način gojenja. Boljši finančni rezultati so bili doseženi v sredozemskem območju (Pulj), kjer smo s pridelavo solate ustvarili za 10.893 EUR/ha (konvencionalna pridelava) oz. za 16.003 EUR/ha (ekološka pridelava) večji prihodek. Nižji prihodki oz. izgube v celinskem območju (Otočac) so bile predvsem posledica nižjih prodajnih cen.

5 VIRI

Abdul-Baki, A.A. 1998. Vegetable production system. Annual convention and trade show. Proceedings: Cultivating ideas. November 19-20, Pasco, Washington: 9–16.

Aybak, H.C. 2002. Lettuce growing. Istanbul: Hasad.

Ban, D. 2001. Biljni malč u ekološki prihvatljivijem uzgoju rajčice. Doktorska disertacija. Agronomski fakultet Zagreb, 141 str.

Bašić, F. 1996. Mjere usmjerene održivosti poljoprivrede. Hrvatska poljoprivreda na raskrižju – nacionalno izvješće Republike Hrvatske: 225–230.

Brumfield, R.G. 2000. An examination of the economics of sustainable and conventional horticulture. HortTehnology 10, 4: 687–691.

Brumfield, R.G., Rimal, A., Reiners, S. 2000. Comparative cost analyses of conventional, integrated crop management, and organic methods. HortTehnology 10, 4: 785–793.

Bulluck, L.R., Brosius, M., Evanylo, G.K., Ristaino, J.B. 2002. Organic and synthetic fertility amendaments influence soil microbial, physical and chemical properties on organic and conventional farms. Applied Soil Ecology 19, 2: 147–160.

Elliot, S.L., Mumford, J.D. 2002. Organic, integrated and conventional apple production: why consider the middle ground? Crop Protection 21, 5: 427–429.

Kay, R.D., Edwards, W.M. 1999. Farm management. 4th edition. McGraw-Hill, New York.

Lešić, R., Borošić, J., Buturac, I., Ćustić, M., Poljak, M., Romić, D. 2002. Povrćarstvo. Zrinski. Čakovec.

Ministarstvo poljoprivrede i šumarstva Republike Hrvatske. 2005. //http: www.tisup.mps.hr/ (02. Mar. 2009).

Oplanić, M., Ban, D., Gogala, M., Trdan, S., Žnidarčič, D. 2009. Analiza gospodarnosti konvencionalnega in ekološkega gojenja solate (*Lactuca sativa* L.) v različnih agroekoloških razmerah. Izvlečki referatov/9. slovensko posvetovanje o varstvu rastlin, 4.-5. marec 2009, Nova Gorica, Slovenija, Ljubljana, Društvo za varstvo rastlin Slovenije: 139–140.

Raterman, K. 1997. Market overview '96: Contradictions propel industry growth. Natural Food Marchandiser 28, 1: 26–30.

Richman, A. 1999. Organic products at the crossroad. Whole Foods Magazine 22, 10: 41–49.

Smith, E.G., Clapperton, M.J., Blackshaw, R.E. 2004. Profitability and risk of organic production systems in the northern Great Plains. Renewable Agriculture and Food Systems 19, 3: 152–158.

Thompson, G. 1998. Consumer demand for organic foods: What we know and what we need to know. American Journal of Agricultural Economics 80: 1113–1118.

Zagata, L. 2007. Bio cash-cow? Context and content of Czech organic farming. Agricultural Economics – Czech 53, 1: 45–53.

COBISS Code 1.01

Agrovoc descriptors: Brassica oleracea; cabbages; saturated fatty acids; polyunsaturated fatty acids; proximate composition

Agris category code: F60

Vsebnost esencialnih maščobnih kislin v zelju (*Brassica oleracea* L.)

Dragan ŽNIDARČIČ[1], Rajko VIDRIH[2]

Delo je prispelo 23. marca 2009; sprejeto 22. junija 2009.
Received: March 23, 2009; accepted: June 22, 2009.

IZVLEČEK

Namen raziskave je bil preučiti in s prehranskega vidika ovrednotiti maščobnokislinsko sestavo 12 kultivarjev zelja (*Brassica oleraceae* L.). Vzorce smo homogenizirali in jim z liofilizacijo odstranili vodo. Maščobnokislinsko sestavo smo določili z izolacijo metilnih estrov in z analizo na plinskem kromatografu. Iz rezultatov je razvidno, da zelje vsebuje malo nasičenih maščobnih kislin. Analiza nenasičenih maščobnih kislin kaže na to, da zelje v povprečju vsebuje 18,8 mg/100 g SS α-linolenske, 17,1 mg/100 g SS linolne in 14,8 mg/100 g SS oleinske kisline. Zeljne glave vsebujejo v največji meri ravno obe najpomembnejši esencialni maščobni kislini (n-6 in n-3), kar zelju daje visoko prehransko vrednost. Vsebnost posameznih nenasičenih maščobnih kislin se med kultivarji zelja značilno razlikuje. Največji delež α-linolenske kisline ima cv. 'Maestro' (29,9 mg/100 g SS), linolna kislina je najbolj zastopana v cv. 'Holandsko pozno zelje' (30,6 mg/100 g SS) in oleinska v cv. 'Galaxy' (29,9 mg/100 g SS) in cv. 'Vestri' (26,1 mg/100 g SS).

Ključne besede: zelje, *Brassica oleraceae*, nasičene maščobne kisline, nenasičene maščobne kisline

ABSTRACT

CONTENT OF ESSENTIAL FATTY ACIDS IN CABBAGE (*Brassica oleracea* L.)

The main objectiv of research was to study and evaluate the composition of essential fatty acids of 12 cultivars of cabbage (*Brassica oleraceae* L.). All samples were homogenised and liophilised. The fatty acids content was determined by the extraction of fatty acid methyl esters and analyses by means of gas chromatography. The obtained results show that cabbage is not a good source of saturated fatty acids. The unsaturated fatty acids in cabbage are composed of α-linolenic acid (18.8 mg/100 g DW), linoleic acid (17.1 mg/100 g DW) and oleic acid (14.8 mg/100 g DW). The high content of both essential fatty acids (n-6 and n-3) in cabbage heads contribute to their nutritional value. There are significant differences between cabbage cultivars in the unsaturated fatty acid pattern. Cv. 'Maestro' contains the highest part of α-linolenic acid (29.9 mg/100 g DW). The highest concentration of linoleic acid contains cv. 'Holandsko pozno zelje' (30.6 mg/100 g DW) and the highest concentration of oleic acid contain cv. 'Galaxy' (29.9 mg/100 g DW) and cv. 'Vestri' (26.1 mg/100 g DW).

Key words: cabagge, *Brassica oleraceae*, saturated fatty acids, unsaturated fatty acids

1 UVOD

Čeprav so maščobe za življenje in zdravje pomembna in nepogrešljiva sestavina, jim javno mnenje ni naklonjeno, saj sodi čezmerno uživanje nasičenih živalskih maščob in neuravnoteženo uživanje rastlinskih maščob med glavne dejavnike tveganja za nastanek in razvoj bolezni srca in ožilja ter rakastih obolenj (Bruckner, 1992; Connor, 2000). V prehrani bi maščobe namreč morale tvoriti od 15 do 20 % kalorične vrednosti, dejansko pa se te vrednosti gibljejo med 40 in 50 % (WHO, 2003).

[1] Biotehniška fakulteta, Univerza v Ljubljani, Oddelek za agronomijo, SI-1111 Ljubljana, Jamnikarjeva 101; e-mail: dragan.znidarcic@bf.uni-lj.si

[2] Biotehniška fakulteta, Univerza v Ljubljani, Oddelek za živilstvo, SI-1111 Ljubljana, Jamnikarjeva 101; e-mail: rajko.vidrih@bf.uni-lj.si

Maščobe so sestavljene iz triacilglicerolov oz. trigliceridov (sestavljajo jih pretežno maščobne kisline in nekaj glicerola), v manjših količinah (2–5 %) pa vsebujejo tudi negliceridne komponente (neumiljive snovi). Maščobne kisline se med seboj razlikujejo po številu ogljikovih atomov v molekuli in številu dvojnih vezi v verigi. Alkilna veriga kisline je lahko popolnoma nasičena, tj. vsebuje samo enojno vez (nasičene maščobne kisline), ali pa je nenasičena in vsebuje eno ali več dvojnih vezi (enkrat oz. večkrat nenasičene maščobne kisline) (Nawar, 1996). Na splošno so nenasičene maščobne kisline dvakrat pogosteje zastopane kot nasičene in to tako v živalskih kot v rastlinskih lipidih (Klofutar, 1992). V rastlinskih masteh prevladujejo nasičene (C12:0, C14:0 in C16:0), v oljih pa nenasičene maščobne kisline (C18:0, C18:2 in C18:3) (Jamnik, 1992).

Maščobe so v prehrani nujne kot določena količina esencialnih maščobnih kislin in pri zelo velikih potrebah po energiji za povečanje energijske gostote hrane. Poleg tega se iz prehrane, ki vsebuje premalo maščob, ne morejo iz črevesja v kri in limfo absorbirati v maščobah topni vitamini (Rogelj, 2007). Esencialne maščobne kisline ali njihovi derivati so maščobne kisline, ki so potrebne za splošno delovanje organizma, slednji pa jih ne more sintetizirati v zadostnem obsegu, zato jih moramo v telo vnesti s prehrano. Pravi esencialni maščobni kislini sta linolna (C18:2, n-6) in α-linolenska (C18:3, n-3), pogojno esencialne maščobne kisline pa so derivati esencialnih maščobnih kislin – arahidonska (C20:4, n-6), dokozaheksaenojska (C22:2, n-3) in eikozapentanojska (C20:5, n-3) maščobna kislina (Unsaturated fatty acids, 1992).

Že nekaj desetletij se znanstveniki zelo intenzivno ukvarjajo s preučevanjem, kako vplivajo n-6 in n-3 maščobne kisline na potek fizioloških procesov v človeškem organizmu in s tem na človekovo zdravje. Še posebno veliko pozornost posvečajo ustreznemu razmerju med maščobnimi kislinami, saj se je v sodobnem času povečal zlasti delež nasičenih in n-6, zmanjšal pa delež n-3 maščobnih kislin. Ta sprememba je tudi spodbudila povečanje civilizacijskih bolezni (Pokorn, 2005). Razmerje med n-6 in n-3 maščobnimi kislinami naj bi bilo med 5 : 1 in 10 : 1 (Referenčne vrednosti, 2004). Po mnenju Salobirja (2001) bi bilo ljudi, ki uživajo hrano s širšim razmerjem, kot je 10 : 1 treba spodbuditi k uživanju obrokov, bogatih z n-3 maščobnimi kislinami, kot so morski sadeži, stročnice in vrtnine.

Poleg že znanih virov esencialnih maščobnih kislin so predhodne raziskave pokazale, da tudi v zelenolistni zelenjavi lahko najdemo nezanemarljivo količino esencialnih maščobnih kislin (Hitchock in Nickhols, 1971; Ghafoorunissa in Pangreaker, 1993; Šertel, 2000; Pereira in sod., 2001; Brumen, 2005). Namen naše raziskave je bil ovrednotiti maščobnokislinsko sestavo lipidov v pri nas najbolj razširjeni vrtnini – zelju (Žnidarčič in sod., 2007), ki sicer sodi med vrtnine z nižjo energijsko vrednostjo (Černe, 1998).

2 MATERIAL IN METODE

Dvanajst kultivarjev zelja ('Atria', Semenarna; 'Delus', Semenarna; 'Galaxy', Semenarna; 'Hinova', Beyo; 'Holandsko pozno rdeče', Semenarna; 'Lennox', Agracasol; 'Vestri', Semenarna; 'Destiny', Agracasol; 'Tucana', Semenarna; 'Hermes', Semenarna; 'Maestro', Agrocasol in 'Delphi', Semenarna) smo leta 2007 pridelali na Laboratorijskem polju Biotehniške fakultete Oddelka za agronomijo v Ljubljani.

2.1 Določanje maščobnih kislin kot metilnih estrov v zelju

Za določitev vsebnosti maščobnih kislin v vzorcu smo uporabili metodo, pri kateri najprej poteka predhodna ekstrakcija maščob, sledita pa ji transesterifikacija maščob in določanje maščobnih kislin kot metilnih estrov. V vialo smo odtehtali približno 200 mg liofiliziranega oz. homogeniziranega zmletega vzorca in 100 µl internega standarda, ki smo mu dodali mešanico metanola in heptana. Kot interni standard smo uporabili heptadekanojsko kislino (C17:0). Masa internega standarda v vsaki viali je znašala cca 3 mg, natančno količino pa smo izračunali iz skupne količine internega standarda in mase raztopine (100 µl), ki smo jo odpipetirali za vsako vialo.

Po dodatku internega standarda smo v vsako vialo dodali še 3,2 ml mešanice reagentov (metanol, benzen, 2,2 dimetoksi propan in H_2SO_4 v volumskem razmerju 37 : 20 : 5 : 2) in 1,8 ml heptana. Viale smo nepredušno zaprli in jih 120 minut segrevali v vodni kopeli pri 80 °C. Zmes v vialah smo ohladili, zgornjo heptansko fazo pa analizirali s plinsko kromatografijo.

Izračun mase posamezne maščobne kisline:

$$C\ (mg/100\ g) = (Ai.\ x\ F_{Ai}\ x\ m_{17}\ x\ 100)/(A_{17}\ x\ F_{Ai17}\ x\ m_{vz.})$$

C = koncentracija posamezne VMK (mg/100 g);
Ai. = površina posamezne VMK;
F_{Ai} = koeficient posamezne VMK (molska masa VMK/molsko maso metilnega estra VMK);
m_{17} = masa internega standarda (C17:0);
A_{17} = površina internega standarda;
F_{Ai17} = koeficient internega standarda (molska masa C17:0/molsko maso metilnega estra heptadekanojske kisline C17) = 0,9508;
$m_{vz.}$ = masa vzorca.

2.2 Plinska kromatografija

Maščobnokislinsko sestavo metilnih estrov maščobnih kislin smo določili s pomočjo plinske kromatografije po metodi Garces in Mancha (1993), ki se uporablja za analize lahko hlapnih vzorcev, ki jih ločujemo in detektiramo v plinski fazi. Pri tej kromatografiji pomeni mobilno fazo inertni nosilni plin (dušik ali helij), stacionarna faza pa je nehlapna organska tekočina, ki je porazdeljena na inertnem nosilcu, ki je v dolgi tanki koloni. Osnova separacije je porazdelitev med obe fazi, pri čemer se posamezne analizirane komponente različno porazdelijo in potujejo z različnim časom ter hitrostjo, zaznamo pa jih z detektorjem. Detektor je običajno plamensko ionizacijski in zaznava že zelo majhne količine preiskovane snovi, ki zapuščajo kolono.

Ločevanje in detekcija sta potekala pri naslednjih pogojih:

Plinski aparat: Agilend Technologies 6890 N;
kolona: SUPLESCO – SPB PUFA 30 m x 0,25 mm x 0,2 µm;
detektor: FID;
temperatura kolone: 210 °C;
temperatura detektorja: 260 °C;
temperatura injektorja: 250 °C (split 1:100);
Tlak na injektorju: 31,6 psi;
nosilni plin: He, pretok: 1 ml/min;
pretok N_2: 45 ml/min;
pretok H_2: 40 ml/min;
pretok zraka: 450 ml/min;
volumen injiciranja: 0,1 µl
program za obdelavo podatkov: GC Chem Station

Rezultate, zbrane v raziskavi smo uredili v programu EXCEL XP in jih statistično obdelali s programskim paketom SAS/STAT (SAS Software. Version 8.01, 1999). Pri obdelavi podatkov s statističnim modelom smo uporabili proceduro GLM (General Linear Models). Ocenjene srednje vrednosti za poskusne skupine so bile izračunane z uporabo Duncanovega testa ob 5-odstotnem tveganju.

3 REZULTATI IN DISKUSIJA

V Preglednici 1 so podane vsebnosti treh nasičenih maščobnih kislin v različnih kultivarjih zelja (v mg/100 g sušine vzorca). Delež nasičenih maščobnih kislin je bil v lipidih zelja zelo nizek oz. je bil prisoten le v sledovih, zato smo podali le vsebnosti palmitinske (C16:0), stearinske (C18:0) in arahidinske (C20:0) maščobne kisline. Največ nasičenih kislin je vseboval cv. 'Galaxy' (39,18 mg/100 g SS), medtem ko cv. 'Delphi' in cv. 'Vestri' nista dosegla meje 30 mg nasičenih kislin/100 g SS.

Palmitinska kislina je bila količinsko najbolj zastopana nasičena maščobna kislina. Tudi Komaitis in Mellisari-Panagiotu (1990) sta v zeljnih glavah določila največ palmitinske kisline. Med našimi kultivarji zelja je največ te kisline vseboval cv. 'Galaxy' (31,3 mg/100 g SS), najmanj pa cv. 'Delphi' (20,7 mg/100 g SS). Stearinske kisline so zeljne glave v povprečju vsebovale 4,8 mg/100 g SS zelja, od tega je je značilno največ imel cv. 'Lennox' (8,3 mg/100 g SS), najskromnejši s to kislino pa je bil cv. 'Hinova' (2,8 mg/100 g SS). V analizah, ki so jih opravili Souci in sod. (2000), je bila povprečna prisotnost stearinske kisline v zelju večja (26,6 mg/100 g SS). Vzroke za razlike lahko iščemo v genetskih lastnostih kultivarjev, pedoklimatskih razlikah, načinu shranjevanja pridelka in drugih dejavnikih. Še bolj skromni pa so bili vzorci zelja z arahidinsko kislino, ki so je v povprečju vsebovali le 2,5 mg/100 g SS. Še največ je arahidinske kisline vseboval cv. 'Atria' (4,3 mg/100 g SS), najmanj pa cv. 'Holandsko pozno rdeče zelje' (1,5 mg/100 g SS)

***Preglednica 1**: Vsebnost nasičenih maščobnih kislin v zelju (mg/100 g SS)*

***Table 1**: The content of saturated fatty acids in cabbage (mg/100 g DW)*

KULTIVAR	MAŠČOBNA KISLINA (mg/100 g SS)			
	C16:0	C18:0	C20:0	Skupaj
Atria	24,1 ± 0,7	4,1 ± 0,1	4,3 ± 1,8	32,6 ± 0,8
Delus	23,3 ± 1,1	6,9 ± 0,4	3,1 ± 0,5	33,4 ± 0,7
Destiny	28,0 ± 4,1	5,7 ± 0,2	2,8 ± 1,1	36,5 ± 1,8
Hermes	29,2 ± 3,4	4,8 ± 0,1	3,1 ± 3,6	37,1 ± 2,4
Hinova	28,1 ± 3,9	2,8 ± 0,1	2,5 ± 0,3	33,5 ± 1,5
Holandsko pozno	30,2 ± 2,2	3,8 ± 0,9	1,5 ± 0,8	35,5 ± 1,3
Maestro	24,8 ± 2,8	4,3 ± 0,1	2,5 ± 1,8	31,8 ± 1,5
Galaxy	31,3 ± 1,7	5,1 ± 0,4	2,8 ± 0,7	39,1 ± 1,0
Delphi	20,7 ± 4,0	4,5 ± 0,3	3,3 ± 0,7	28,7 ± 1,7
Lennox	25,4 ± 0,9	8,3 ± 0,7	3,7 ± 0,9	37,5 ± 0,8
Tucana	27,1 ± 1,9	5,8 ± 0,1	3,1 ± 0,3	35,9 ± 0,8
Vestri	22,3 ± 2,1	4,8 ± 0,3	2,5 ± 0,8	29,7 ± 1,0
Povprečje	24,3 ± 2,4	5,1 ± 0,3	2,9 ± 1,1	32,4 ± 1,3

Tudi pri deležu nenasičenih maščobnih kislin smo ugotovili značilne razlike med vzorci zelja. Rezultati o vsebnosti enkrat in večkrat nenasičenih maščobnih kislinah so podani v Preglednici 2. Najmanjši delež nenasičenih kislin je dosegal cv. 'Delus' (61,6 mg/100 g SS, najvišje izmerjene vrednosti nenasičene kislin pa smo ugotovili pri cv. 'Holandsko pozno zelje' (74,2 mg/100 g SS). Količinsko najbolj zastopani sta bili obe najpomembnejši esencialni kislini: α-linolenska – C18:3, n-3 (18,8 mg/100 g SS) in linolna kislina – C18:2, n-6 (17,1 mg/100 g SS), le nekoliko manjši delež pa je dosegla oleinska kislina – C18:1 (14,8 mg/100 g SS). Tudi Hitchock in Nickhols (1971) ter Kim in Kim (2001), menijo da so to najbolj pogosto zastopane nenasičene maščobne kisline v zelenih delih rastlin. Poleg naštetih pa so naše analize zaznale še γ-linolensko (C18:3, n-6), gadoleinsko (C20:1), eikozadienojsko (C20:2, n-9), dihomo-γ-linolensko (C20:3, n-6) in eikozatrienojsko kislino (C20:3, n-9).

Po vsebnosti oleinske kisline sta se od drugih razlikovala cv. 'Vestri' (26,1 mg/100 g SS) in cv. 'Galaxy' (26,1 mg/100 g SS). Po mnenju Brumnove (2005) se vrtnine, ki vsebujejo vsaj 30 mg oleinske kisline/100 g SS uvrščajo med vrtnine z velikim deležem te kisline. Omenjena kultivarja sta se zelo približali temu kriteriju. Najmanj oleinske kisline pa smo ugotovili pri rdečem zelje cv. 'Holandsko pozno zelje' (7,5 mg/100 g SS). Nasprotno pa je cv. 'Holandsko pozno zelje' med vsemi analiziranimi vzorci vseboval največ linolne kisline (30,6 mg/100 g SS), medtem ko smo najmanj te kisline določili v cv. 'Vestri' (9,5 mg/100 g SS). Pri analizi α-linolenske kisline smo največji delež te kisline izmerili v srednje zgodnjem rdečem zelju za svežo upurabo cv. 'Maestro' (26,9 mg/100 g SS), najmanj pa v poznem zelju za kisanje cv. 'Lennox' (14,7 mg/100 g SS).

Delež preostalih nenasičenih maščobnih kislin je bil komaj opazen in se je v povprečju gibal med 1,6 mg/100 g SS (γ-linolenska kislina) in 4,1 mg/100 g SS (dihomo-γ-linolenska kislina).

Preglednica 2: *Vsebnost nenasičenih maščobnih kislin v zelju (mg/100 g SS)*

***Table 2**:* *The content of unsaturated fatty acids in cabbage (mg/100 g DW)*

KULTIVAR	MAŠČOBNA KISLINA (mg/100 g SS)								
	C18:1	C18:2, n-6	C18:3, n-6	C18:3, n-3	C20:3, n-9	C20:2, n-9	C20:3, n-6	C20:3, n-3	Skupaj
Atria	11,1 ± 0,1	12,5 ± 0,4	2,4 ± 0,1	17,2 ± 0,5	5,3 ± 0,4	5,3 ± 2,3	8,2 ± 0,3	4,3 ± 0,2	66,4 ± 0,2
Delus	10,8 ± 0,3	17,9 ± 0,4	1,2 ± 0,1	20,3 ± 0,3	3,2 ± 0,7	2,3 ± 0,1	4,0 ± 0,9	1,7 ± 0,2	61,6 ± 0,2
Destiny	15,4 ± 1,4	14,3 ± 1,6	1,4 ± 0,4	16,4 ± 1,6	3,2 ± 1,9	3,9 ± 2,2	4,6 ± 2,7	4,0 ± 1,1	63,4 ± 1,1
Hermes	11,7 ± 0,5	14,8 ± 1,3	1,9 ± 0,3	20,3 ± 2,1	4,3 ± 0,9	3,0 ± 0,8	4,4 ± 3,1	2,0 ± 1,5	62,8 ± 1,5
Hinova	15,1 ± 1,4	18,6 ± 2,1	1,6 ± 0,4	18,9 ± 1,3	2,7 ± 0,7	5,2 ± 4,3	3,1 ± 2,3	0,9 ± 1,1	66,3 ± 1,1
Hol. pozno	7,5 ± 0,1	30,6 ± 2,7	1,0 ± 0,5	22,7 ± 2,7	1,6 ± 0,2	5,6 ± 2,2	3,1 ± 1,9	1,8 ± 0,8	74,2 ± 0,8
Maestro	9,4 ± 0,3	23,1 ± 1,5	1,4 ± 0,4	26,9 ± 1,5	1,7 ± 1,1	1,3 ± 0,3	2,1 ± 2,2	2,0 ± 0,5	68,1 ± 0,5
Galaxy	26,1 ± 1,8	12,6 ± 0,7	1,5 ± 0,4	15,0 ± 1,1	4,4 ± 0,2	3,5 ± 0,5	4,4 ± 2,5	3,4 ± 0,3	71,8 ± 0,3
Delphi	19,4 ± 2,1	11,6 ± 1,3	1,9 ± 0,6	15,1 ± 2,1	5,2 ± 1,4	5,2 ± 1,8	8,1 ± 3,8	3,7 ± 6,4	70,6 ± 6,4
Lennox	11,8 ± 2,9	22,7 ± 6,2	1,6 ± 0,7	14,7 ± 1,3	3,4 ± 0,9	2,2 ± 1,2	2,4 ± 0,8	3,7 ± 1,9	62,4 ± 1,9
Tucana	14,1 ± 0,3	16,3 ± 0,4	1,5 ± 0,5	18,1 ± 0,5	3,7 ± 0,7	4,2 ± 0,7	2,9 ± 2,3	2,9 ± 0,1	64,1 ± 0,1
Vestri	26,1 ± 1,9	9,5 ± 0,7	1,6 ± 0,2	19,5 ± 1,1	3,2 ± 0,8	3,6 ± 0,4	2,4 ± 2,4	3,8 ± 1,3	70,1 ± 1,3
Povprečje	14,8 ± 1,1	17,1 ± 1,6	1,6 ± 0,4	18,8 ± 1,3	3,5 ± 0,8	3,8 ± 1,4	4,1 ± 2,1	2,8 ± 1,3	66,7 ± 1,3

4 SKLEPI

Splošno znano je, da ima zelje nizko energijsko vrednost, hkrati pa je vir enostavnih in kompleksnih ogljikovih hidratov, vlaknin, mineralov, vitaminov in sekundarnih metabolitov. V naši raziskavi pa smo želeli ugotoviti, ali je zelje tudi vir esencialnih maščobnih kislin (α-linolenske in linolne kisline), ki jih človekov organizem ne more sam proizvesti in jih lahko pridobi le s primerno prehrano. Rezultati so pokazali, da večino maščob v zelju sestavljajo nenasičene maščobne kisline, med katerimi je največ prav α-linolenske in linolne kisline. Zaradi velike prehranske vrednosti zelja bi bilo v nadaljnjih raziskavah smiselno ugotoviti, kako to kapusnico uporabiti v povezavi z drugimi rastlinskimi olji, kot dopolnilo oz. funkcionalno živilo v vsakdanji prehrani.

5 VIRI

Bruckner, G. 1992. Biological effects of polyunsaturated fatty acids. V: Fatty accids in food and their health implication. Chow C.K. (ed.), New York, Bassel, Hong Kong, Marcel Dekker: 631–643.

Brumen, B. 2005. Določanje vsebnosti esencialnih maščobnih kislin v zelenjavi in stročnicah. Dipl. delo. Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za živilstvo, 88 str.

Connor, W.E. 2000. Importance of n-3 fatty acids in health and disease. Am. J. Clin. Nutr., 71: 171–175.

Černe, M. 1998. Kapusnice. Ljubljana. Kmečki glas: 83–157.

Garces, R., Mancha, M. 1993. One-step lipid extraction and fatty acid methyl esters preparation from fresh plant tissues. Anal. Biochem., 211: 139–143.

Ghafoorunissa, C., Pangreaker, J. 1993. Vegetables as source of α-linoleinic acid in Indian diets. Food Chem., 47: 121–124.

Hitchock, C., Nickhols, B.W. 1971. Plant lipid biochemistry. London. Academic Press: 279–305.

Jamnik, S. 1992. Olja in masti rastlinskega porekla. V: Lipidi. 14. Bitenčevi živilski dnevi. Ljubljana, 4. in 5. junij 1992. Biotehniška fakulteta, Oddelek za živilstvo: 57–69.

Kim, Y.S., Kim, J.G. 2001. Studies on the rutin content and fatty acid composition of buckwheat sprouts. The proceeding of the 8th ISB: 561–563.

Klofutar, C. 1992. Fizikalno kemijske lastnosti triacilgliceridov. V: Lipidi. 14. Bitenčevi živilski dnevi. Ljubljana, 4. in 5. junij 1992. Biotehniška fakulteta, Oddelek za živilstvo: 11–16.

Komaitis, M.E., Mellisari-Panagiotu, E. 1990. Lipid levels in cabbage leaves (*Brassica oleraceae*). J. Sci. Food Chem., 38: 2137–2139.

Nawar, W.W. 1996. Chemistry. V: Bailey's industrial oil and fat products. 5th ed. vol. 1. Edible oil and fat products: general applications. Hui Y.H. (ed.). New York, John Wiley & Sons, Inc.: 397–420.

Pereira, C., Li, D., Sinclair, A.J. 2001. The α-linoleinic acid content of green vegetables commonly available in Australia. Int. J. Vit. Nutr. Res., 71, 4: 223–228.

Pokorn, D. 2005. Prhrana. V: Interna medicina. Ljubljana, Založba Littera Picta, d. o. o.: 646–665.

Referenčne vrednosti za vnos hranil, 2004. 1. izdaja. Ljubljana, Ministrstvo za zdravje Republike Slovenije: 37–49.

Rogelj, M. 2007. Vsebnost esencialnih maščobnih kislin v semenih kosmulje (*Ribes suva-crispa* L.), črnega ribeza (*Ribes nigrum* L.) in rdečega ribeza (*Ribes rubrum* L.). Mag. delo. Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za živilstvo, 81 str.

Salobir, K. 2001. Prehransko fiziološka funkcionalnost maščob. V: Funkcionalna hrana. 21. Bitenčevi živilski dnevi. Portorož, 8. in 9. november 2001. Biotehniška fakulteta, Oddelek za živilstvo: 121–134.

Sourci, S.W., Fachmann, W., Kraut, H. 2000. Food composition and nutrition tables. 6th rev. ed. Scherz H., Senser F. (ed.). Stuttgart, Medpharm, CRC Press: 635–689.

Šertel, A. 2000. Zelenjava kot vir esencialnih maščobnih kislin. Dipl. delo. Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za živilstvo, 68 str.

WHO, 2003. Diet, nutrition and prevetion of chronic diseases, Geeva, WHO: 81–90.

Unsaturated fatty acids, 1992. Nutritional and physiological significance. The Report of the British Nutrition Foundation's task force. London, Chapman & Hall: 35–47.

Žnidarčič, D., Kacjan-Maršić, N., Osvald, J., Požrl, T., Trdan, S. 2007. Yield and quality of early cabbage (*Brassica oleracea* L. var. *capitata*) in response to within-row plant spacing. Acta agric. Slov., 89, 1: 15–23.

COBISS Code 1.02

Agrovoc descriptors: plants; growth; crop yield, yield forecasting; simulation models; meteorology; water balance; monitoring; maize; Zea mays

Agris category code: F01; P40; F62

WOFOST: model za napovedovanje pridelka – 1. del

Tjaša POGAČAR[1], Lučka KAJFEŽ-BOGATAJ[2]

Prispelo 22. januarja 2009, sprejeto 22. junija 2009
Received January 22, 2009; accepted June 22, 2009

IZVLEČEK

Model WOFOST je bil odgovor Alterre in centra Plant Research International (oboje Wageningen, Nizozemska) na potrebe po agrometeorološkem simulacijskem modelu za 10-dnevno kvantitativno napovedovanje pridelka na državni ali regionalni ravni in kvalitativni monitoring pogojev za rast različnih poljščin za celotno EU. Celo družino modelov, v katero spada tudi WOFOST, so razvijali v Wageningnu v šoli C. T. de Wita. Prvič je bil dokumentiran leta 1986 (Wolf in sod.), njegov prvotni namen je bil preučevanje potencialnega pridelka različnih poljščin v tropskih državah, s čimer so se ukvarjali van Keulen, Wolf in van Diepen. Uspešne verzije WOFOST-a se že več kot 10 let uporabljajo v različnih raziskavah. Različne aplikacije so bile prilagojene za analizo tveganja pri pridelku, variabilnosti pridelka skozi leto, variabilnosti zaradi različnih tipov tal ali zaradi raznovrstnih agrohidroloških pogojev in razlik med kultivarji, relativne pomembnosti faktorjev, ki določajo rast, setvenih strategij, vplivov podnebnih sprememb, kritičnih period za uporabo agrikulturne mehanizacije in drugega. Trenutno je dostopna verzija WOFOST 7.1.2.

WOFOST je fizikalni model, ki razlaga rast pridelka na osnovi procesov, ki se dogajajo v rastlini in upošteva, kako na te procese vplivajo okoljske razmere. Osnova za izračune produkcije suhe snovi je stopnja asimilacije CO_2 v rastlinski odeji, ki je odvisna od absorbirane energije sevanja in je funkcija vpadajočega sevanja in listne površine poljščine. Izbiramo lahko med potencialno in dejansko (omejena količina vode) simulacijo. Meteorološke podatke moramo pripraviti v pravilnem formatu.
WOFOST uporablja vodno bilanco, ki v danem časovnem obdobju primerja količino vode, ki pride v koreninsko cono, s tisto, ki gre iz nje, ter določi razliko med njima za spremembo vsebnosti vode v tleh. Upošteva infiltracijo, evaporacijo, transpiracijo, perkolacijo in kapilarni dvig. Pri tem se moramo zavedati, da model ni namenjen natančni fizični obdelavi gibanja vode v tleh, temveč le oceni dostopnosti vode za rastlino. Vpiv hranil (dušik, fosfat in kalij) na pridelek se računa na letnem nivoju na osnovi dela Janssena in sod. iz leta 1990. WOFOST izračuna fenološko fazo iz dnevne temperature in korekcijskega faktorja. Temperaturne vsote, potrebne za doseganje določene faze, so določene v datotekah, ki opisujejo posamezne poljščine. V posebnih prilogah k opisu modela si lahko natančno preberemo vse o enačbah, ki jih model uporablja, o izračunih energije globalnega obsevanja, Gaussovi integraciji, linearni interpolaciji z AFGEN funkcijo, določanju datuma setve, CGMS (Crop Growth Monitoring System) bazi podatkov, uporabi meteoroloških podatkov ter podatkov o poljščinah in tleh v CGMS-u.

Ključne besede: WOFOST, razvoj modela, vhodni podatki, vodna bilanca, pridelek, koruza

ABSTRACT

WOFOST: CROP GROWTH SIMULATION MODEL – 1ST PART

The WOFOST crop growth simulation model was selected, when the JRC (i.e. European Commission) requested Alterra (formerly SC-DLO) and Plant Research International (formerly AB-DLO) in Wageningen, The Netherlands, to develop, adapt and calibrate new or existing agro-meteorological simulation models for 10-day routine quantitative forecasting of national and regional yields and qualitative monitoring of the growth conditions for the whole EU for different kinds of crops. WOFOST is a member of the family of crop growth models developed in Wageningen by the school of C.T. de Wit. The first WOFOST model has been documented by Wolf et al. (1986) and it was originally developed to assess yield potential of various annual crops in tropical countries (van Keulen & Wolf, 1986; van Diepen et al., 1988; van Keulen & van Diepen, 1990). Over the last ten years, the successive WOFOST versions have been used in many studies. WOFOST has been applied as a tool for the

[1] univ. dipl. meteor., ARSO, Ljubljana, tjasa.pogacar@gov.si

[2] prof., dr., Biotehniška fakulteta, p.p. 2995, 1001 Ljubljana, lucka.kajfez.bogataj@bf.uni-lj.si

analysis of yield risk and inter-annual yield variability, of yield variability over soil types, or over a range of agro hydrological conditions, of differences between cultivars, of relative importance of growth determining factors, of sowing strategies, effects of climate change, critical periods for use of agricultural machinery and others. Recently, the version WOFOST 7.1.2. is in use.

WOFOST is a mechanistic model that explains crop growth on the basis of the underlying processes, such as photosynthesis, respiration and how these processes are influenced by environmental conditions. Crop growth depends on the daily net assimilation, which on its turn depends on the intercepted light. The intercepted light is determined by the level of incoming radiation and the leaf area of the crop. We can choose between potential and water-limited simulation. We have to prepare meteorological data in the requested format.

WOFOST uses a water balance, which compares for a given period of time, incoming water in the rooted zone with outgoing water and quantifies the difference between the two as a change in the stored soil moisture amount. Several processes are included: infiltration, evaporation, transpiration, percolation and capillary rise. We have to keep in mind that the model is not meant to calculate the water balance in first place. The procedure which calculates the nutrient requirements is based on the work of Janssen et al. (1990). Phenological phase is calculated from daily temperature and correction factor. Temperature sums needed for each phase are determined in crop files. Appendices to the model description include equations, description of the global radiation calculation, Gauss integration, linear interpolation with AFGEN function, sowing date determination, CGMS (Crop Growth Monitoring System) data base, use of meteorological, crop and soil data in CGMS.

Key words: WOFOST, model development, input data, water balance, crop yield, maize

1 UVOD

Slovensko kmetijstvo se bo v prihajajočih letih spopadalo s številnimi izzivi, kot so mednarodna konkurenca, nadaljnja liberalizacija trgovinske politike in upadanje prebivalstva. Zaradi podnebnih sprememb bo stiska še večja, izzivi pa težji in dražji. Predvidene podnebne spremembe bodo prizadele pridelek, živinorejo in lokacijo proizvodnje, kar bo zelo ogrozilo kmetijski prihodek in morda povzročilo opustitev zemljišč v nekaterih predelih. Proizvodnja hrane je lahko ogrožena zaradi vročinskih valov, suše in škodljivcev, vse pogostejši pa bodo tudi izpadi pridelka. Kljub opaženim spremembam se ne izvajajo meritve in opazovanja vodne bilance, od katere je v veliki meri odvisna količina in kakovost kmetijskega pridelka. Na nacionalnem nivoju je trenutno v uporabi vodnobilančni model IRRFIB (ARSO), žal pa nimamo razvitih ali umerjenih modelov za simulacijo in napovedovanje kmetijskega pridelka. V tujini za napoved pridelka že uporabljajo modele, ki temeljijo na vodnih razmerah v tleh, pri simulaciji pa upoštevajo tudi fenološki razvoj rastlin, saj je modeliranje sodoben način kvantificiranja odnosov med biološkimi procesi in dejavniki okolja (Scharrer in Schmidt, 1998). Eno izmed načel pri agrometeoroloških modelih je parsimoničnost ali preprostost modelov (Landau in sod., 2000). Hodges (1991) navaja, da je za učinkovit prenos znanja (modela) do uporabnika, ki bo lahko to znanje uporabil za rešitev praktičnega problema ali načrtovanje kmetijske proizvodnje, potrebno izpolniti nekatere minimalne zahteve:

- program mora biti uporaben za ljudi, katerim je namenjen, to je tistim, ki bi od njega naj imeli koristi. Če je potrebno za učinkovito uporabo modela veliko izkušenj s področja računalništva ali znanja najnovejših znanstvenih dosežkov agronomske znanosti, potem bo relativno malo število potencialnih uporabnikov lahko izkoristilo še tako dober program,
- program mora potrebovati samo tiste vhodne podatke, do katerih bodo uporabniki lahko prišli z relativno malo napora in stroškov glede na koristi, ki jih bodo imeli ob uporabi modela,
- program naj zagotovi natančne in pravočasne uporabne informacije za rešitev problema, za katerega smo iskali modelsko rešitev.

Tekom zadnjih desetletij je agrometeorološko modeliranje doživelo razcvet in v literaturi najdemo tako zelo kompleksne kot tudi preprostejše matematične modele za napovedovanje rasti in razvoja kmetijskih rastlin (Whisler in sod., 1986; Boote in sod., 1996). Teoretične osnove modeliranja sta zelo nazorno povzela Thornley in Johnson (1990). Med najbolj razširjenimi starejšimi modeli so CERES (Ritchie and Otter, 1984), ARCWHEAT (Weir et al., 1984) EPIC: (Williams et al., 1989) in SUCROS (van Keulen and Seligman, 1987), ki so bili verificirani, kalibrirani in uporabljeni za različne regije sveta, tudi Evropo. Model CERES za koruzo smo preizkušali tudi v Sloveniji (Kajfež-Bogataj, 1996). Obstaja tudi kar nekaj generičnih modelov, ki lahko simulirajo rast in razvoj več kmetijskih rastlin hkrati, kar jim omogočajo različni podmodeli in sicer WOFOST, INTERCOM (van Ittersum et al., 2003), STICS (Brisson et al., 2003) in CropSyst (Stöckle et al., 2003).

V članku podrobneje predstavljamo model WOFOST (WOrld FOod STudy), ki je bil razvit na Nizozemskem, kjer je trenutno v široki uporabi. Mnoge izmed evropskih držav so model prilagodile na svoje razmere. Med drugim je bil na primer uporabljen tudi v študiji vpliva klimatskih sprememb na potencialni pridelek pšenice in koruze na območju Evropske unije (Wolf in van Diepen, 2007). V prvem delu predstavljamo predvsem razvoj in osnove izračunov modela WOFOST, kar v večini povzemamo po internetni predstavitvi modela, ki sta jo pripravila Supit in van der Goot (2008). V drugem delu (Pogačar in Kajfež Bogataj, 2009) pa bomo predstavili kratka navodila za uporabo in konkreten primer izračunov.

2 ZGODOVINA IN RAZVOJ MODELA WOFOST

Vladne službe, podjetja in proizvajalci želijo čim prejšnje informacije o pričakovanem pridelku, kar jim omogoča planiranje transporta, marketinga, uvoza ... Globalno gledano so cene pridelkov odvisne od zalog in porabe dobrin. Glavno je zanimanje za pšenico, ječmen, koruzo za zrnje, riž, krompir, oves, sladkorno peso, stročnice, sojo, oljčno repico, sončnice, tobak in bombaž. Urad za statistiko pri Evropski Komisiji (EUROSTAT) zbira informacije o rabi tal, spremembah le-te in pridelku, ki pa so dostopne šele po enem ali dveh letih, kar je za uporabnike seveda prepozno.

Tako je Alterra (raziskovalni inštitut Univerze Wageningen na Nizozemskem) v sodelovanju z raziskovalnim centrom Plant Research International (PRI, prav tako Wageningen) za raziskovalni center Evropske Komisije JRC (Ispra) dobila navodilo, da razvije, prilagodi in umeri nov ali obstoječ agrometeorološki simulacijski model za 10-dnevno kvantitativno napovedovanje pridelka na državni ali regionalni ravni in kvalitativni monitoring pogojev za rast pšenice, ovsa, koruze, riža, krompirja, sladkorne pese, stročnic, soje, oljčne repice, sončnic, tobaka in bombaža za celotno EU.

Izbrali so WOFOST – model za simulacijo rasti poljščin, ki v kombinaciji z GIS-om in rutino za napoved pridelka tvori CGMS (Crop Growth Monitoring System). Kombiniran je z mapo tal, parametri kultur in prostorsko informacijo o rastiščih ter uporablja dnevne meteorološke podatke za oceno statusa rastlin. Prvo verzijo sta razvila Centre for World Food Studies (CWFS) in Research Institute for Agrobiology and Soil Fertility (AB-DLO) – sedanjim PRI (van Diepen et al., 1989). Implementacijo v CGMS in strukturo je opisal Supit s sod. (1994). Tehnične opise in navodila za uporabo so pripravili van Raaij in van der Wal (1994), van der Wal (1994) ter Hooijer in sod. (1993). Po ukinitvi CWFS leta 1988 so z razvojem nadaljevali pri DLO-Winand Staring Centre (današnja Alterra) v sodelovanju s PRI in WAU-TPE (Department of Theoretical Production Ecology of the Wageningen Agricultural University).

Celo družino modelov, v katero spada tudi WOFOST, so razvijali v Wageningnu v šoli C. T. de Wita. Sorodni so SUCROS modeli (Simpel and Universal Crop Simulator), Arid Crop, Spring wheat, MACROS in ORYZA1. Prvič je bil WOFOST dokumentiran leta 1986 (Wolf in sod.). Vsi ti modeli sledijo hierarhični razliki med potencialno in omejeno produkcijo in si delijo podobne podmodele za rast poljščin z intercepcijo svetlobe in asimilacijo CO_2 kot gonilnima procesoma ter fenološkim razvojem kot procesom, ki kontrolira rast. Precej pa se razlikujejo podmodeli, ki opisujejo vodno bilanco tal in privzem hranil iz tal – tako v pristopu, kot tudi v stopnji natančnosti.

Prvotni namen WOFOST-a je bil preučevanje potencialnega pridelka različnih poljščin v tropskih državah, s čimer so se ukvarjali van Keulen, Wolf in van Diepen. Poskušali so ohranjati čim bolj enostavno obliko vhodnih podatkov – uporabljali so povprečja, a so kmalu ugotovili, da je potrebno kljub vsemu upoštevati variabilnost okoljskih parametrov v prostoru in času, povprečuje pa se lahko kvečjemu rezultate.

3 APLIKACIJE

Uspešne verzije WOFOST-a se že več kot 10 let uporabljajo v različnih raziskavah. Prilagojen je bil za analizo tveganja pri pridelku, variabilnosti pridelka skozi leto, variabilnosti zaradi različnih tipov tal ali zaradi raznovrstnih agrohidroloških pogojev in razlik med kultivarji, relativne pomembnosti faktorjev, ki določajo rast, setvenih strategij, vplivov podnebnih sprememb in kritičnih period za uporabo agrikulturne mehanizacije. Model so uporabljali tudi za napovedovanje v smislu vrednotenja potencialnega pridelka regionalnih kmetijskih površin, ocen učinkovitosti namakanja in uporabe umetnih gnojil. Nekateri uporabniki so ga prilagodili za uporabo pri gozdnih in travnatih površinah ter zamenjali modul za izračune vode v tleh z bolj razčlenjenim. Celotnega pregleda vseh aplikacij na žalost ni, saj ni nikoli bilo uradne mreže za izmenjavo izkušenj, podatkov in aplikacij. V nadaljevanju na kratko predstavljamo nekaj večjih raziskav.

Z verzijo WOFOST 3.1 so na CWFS na željo FAO preučevali povečanje potencialne produkcije hrane zaradi uporabe umetnih gnojil v treh afriških državah. Raziskava je pokazala, da bi se pridelek v Burkini Faso, Gani in Keniji lahko povečal z uporabo umetnih gnojil brez zahtev po dodatnem namakanju (CWFS, 1985).

V okviru projekta AGRISK je Mellaart (1989) raziskoval tveganja v Burkini Faso – analiziral je strategije za spopadanje s sušo glede na tip tal, poljščino in kultivar, datum setve, površinski odtok in lokacijo polj. Bakker (1992) pa je v okviru ICRISAT-ove študije preučeval razmere glede padavin v Indiji.

Pri projektu MARS (Monitoring Agro-ecological resources with Remote sensing and Simulation) za JRC je bil WOFOST 4.1 predlagan za ocenjevanje pridelka in kot sistem za zgodnje opozarjanje o prehranski varnosti v Zambiji, pri čemer bi uporabljali model v kombinaciji z GIS-om, vhodne podatke pa bi črpali iz meteoroloških satelitov. Zato so WOFOST 4.1 kalibrirali in testirali za koruzo. Isto verzijo so prilagodili za vrednotenje vodnih strategij (namakanje, ohranjanje) kot podpore ruralnega razvoja v majhnih razvodjih v Perujskih Andih.

WOFOST 4.3 je postal referenčni model za analizo pridelka pri NASREC programu, pri katerem sodeluje 11 držav. Leta 1991 so pripravili nov, prijazen uporabniški vmesnik.

Z verzijo WOFOST 4.4 je pripravil Roetter l.1993 kalibracijsko-validacijsko raziskavo za koruzo v Keniji. Z uporabo podatkov z eksperimentalnih polj je model pridelek napovedal s 15% napako (RMSE), kar je bilo glede na kakovost vhodnih podatkov precej dobro.

Nova verzija, WOFOST 5.3, je bila uporabljena za ocene potencialne regionalne produkcije poljščin na velikih poljih v EU v odvisnoti od tal in klimatskih razmer (De Koning in van Diepen, 1992; van Lanen in sod., 1992). Razvili so jo za pšenico, koruzo, oljčno repico, krompir in sladkorno peso ter dodali ločeno verzijo za travo. Eden od zaključkov je bil ta, da bi v Evropi lahko vsaj 30 % kmetijske zemlje odvzeli, ne da bi ogrozili prehransko varnost ali tvegali večji vpliv na politiko.

Van Diepen in sod. (1987), Wolf in van Diepen (1991) in Wolf (1993) so ocenjevali vpliv podnebnih sprememb na rast poljščin. Model je posebej primeren za določanje kombiniranega vpliva sprememb CO_2, temperature, padavin in sončnega obsevanja na razvoj in rast poljščin ter porabo vode, saj vse pomembne procese simulira ločeno, a upošteva njihovo medsebojno interakcijo.

Verzijo WOFOST 6.0 so pripravili za novo študijo v okviru projekta MARS: "Modeli za napovedovanje pridelka", katere namen je bil generiranje indikatorjev rasti poljščin za oceno kvalitete trenutne kmetijske sezone po celi EU v primerjavi s kvaliteto preteklih sezon. V tem času je bil WOFOST registriran pri Crop Growth Monitoring (Hooijer and van der Wal, 1994; van Diepen, 1992), samostojna verzija se je obdržala za poučevanje, demonstracije, teste in validacije ter kot izhodišče za nove aplikacije in druge raziskave.

Poleg glavne smeri razvoja različnih verzij pa se je veliko aplikacij razvilo na osnovi verzije WOFOST 4.1. Na primer SWACROP2, pri katerem so WOFOST povezali z modelom SWATRE in transpiracijskim modelom (Huygen, 1992). Groot je leta 1987 vključil dinamiko hranil pri rastlinah in tleh. Poels in Bijker (1993) sta ustvarila model TROPFOR za simulacijo rasti in porabe vode v tropskem deževnem gozdu, De Ruijter in sod. (1993) pa so model pripredili za simulacijo rasti tulipanov. Trenutno je dostopna verzija WOFOST 7.1.2.

4 OSNOVE IZRAČUNOV, KI JIH UPORABLJA WOFOST

4. 1 Splošni pregled

WOFOST je fizikalni model, ki razlaga rast pridelka na osnovi procesov, ki se dogajajo v rastlini (fotosinteza, dihanje ...), in upošteva, kako na te procese vplivajo okoljske razmere. Napovedi takih modelov ne ustrezajo vedno našim pričakovanjem, saj imajo ocene vseh parametrov in formulacije procesov svoje napake, ki se akumulirajo pri končni napovedi pridelka.

Osnova za izračune produkcije suhe snovi je stopnja asimilacije CO_2 v rastlinski odeji, ki je odvisna od absorbirane energije sevanja in je funkcija vpadajočega sevanja in listne površine poljščine. Del nastalih ogljikovih hidratov se porabi za zagotavljanje energije za vzdrževanje že obstoječe žive biomase (bazalni metabolizem), ostali pa se pretvorijo v gradbeni material.

Nastala suha snov se porazdeli med korenine, liste, stebla in založne organe, pri čemer model uporabi porazdelitvene faktorje, ki so funkcija fenološke faze (Spitters in sod., 1989). Del, ki se porazdeli k listom, določa razvoj listne površine in s tem dinamiko intercepcije svetlobe. Suho težo rastlinskih organov dobimo z integracijo njihove stopnje rasti po času.

Listna masa je razdeljena v starostne razrede. Tekom razvoja del biomase odmre zaradi starosti. Na nekatere rastne procese (maksimalna fotosinteza, bazalni metabolizem) vpliva temperatura, na druge (porazdelitev asimilatov ...) pa fenološka faza, ki je funkcija okoljske temperature in dolžine dneva.
Akumulacija in distribucija suhe snovi po rastlini je simulirana od setve do dozoretja na bazi fizioloških procesov, kot jih določajo odzivi poljščin na dnevne vremenske situacije, stanje vode v tleh (odraža ga Ta/Tp) in setvena praksa (gostota setve ipd.).

Vodna zaloga v koreninski coni, infiltracija, površinski odtok, perkolacija in prerazporejanje vode v enodimenzionalnem profilu so določeni iz hidravličnih značilnosti in kapacitete tal za vodo.

Izbiramo lahko med potencialno in dejansko (omejena količina vode) simulacijo. Potencialna je definirana s temperaturo, dolžino dneva, sončnim obsevanjem in karakteristikami poljščin (dinamika listne površine, karakteristika asimilacije, porazdeljevanje suhe snovi ...). Dejansko pa določa še dostopnost vode, računana iz značilnosti korenin, fizikalnih lastnosti tal, količine padavin in evapotranspiracije. V obeh primerih predvidevamo optimalno zalogo hranil in računamo celotno količino nadzemne suhe snovi in suhe snovi v semenih na hektar.

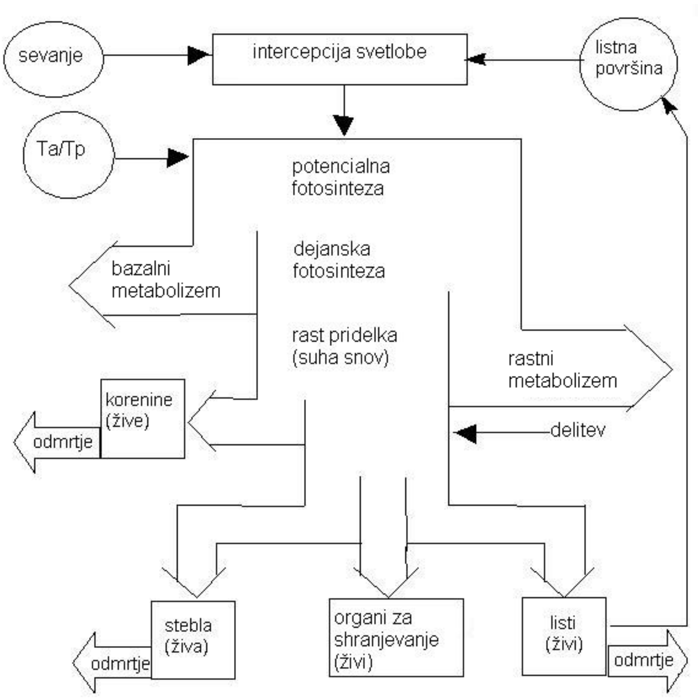
V simulacijo niso vključene morebitne morfološke ali fiziološke prilagoditve rastlin na spremenjene okoljske razmere. Prav tako ni erozije, zmrzali, škodljivcev, bolezni, izgub pri shranjevanju ipd. Zavedati se moramo, da bi moral biti model testiran na širokem naboru različnih okoljskih razmer, vendar pa je meritev še vedno precej malo. Poleg tega pa od neke točke naprej s povečevanjem kompleksnosti modela povečujemo tudi napako. Zato je verjetno bolje, da nepreverljivih, nezanesljivih ali težko določljivih faktorjev ne vključimo.

4. 2 Meteorološki vhodni podatki

WOFOST izmed meteoroloških parametrov uporablja maksimalno in minimalno temperaturo [°C], globalno obsevanje (ni nujno) [J/m^{2}d], povprečno dnevno hitrost vetra na višini 2 m [m/s] – preračunano z logaritemsko transformacijo z višine 10 m, kjer so meritve, povprečni dnevni pritisk vodne pare [hPa] in količino padavin [mm]. Ker se večina podatkov pridobiva na dnevni bazi, je tudi časovni korak v modelu 1 dan.

Evapotranspiracijo računa po Penmanovi metodi. JRC verzija ponuja še druge možnosti za izračun evapotranspiracije, obe pa za oceno obsevanja (ko nimamo meritev) ponujata po Prescottu prirejeno Ångströmovo formulo, pri kateri potrebujemo informacijo o trajanju sončnega obsevanja. Če tudi tega nimamo, lahko pri JRC verziji globalno obsevanje ocenimo po Supitovi (1994) ali malo manj natančni Hargreavesovi formuli (1985). Empirične koeficiente za Ångströmovo formulo mora v splošni verziji zagotoviti uporabnik, v JRC verziji pa so ocenjeni na podlagi meteoroloških postaj z znanimi vrednostmi (Supit, 1994; Supit in van Kappel, 1997) z uporabo interpolacijske metode, ki jo je l. 1997 razvil van der Goot. Za rastlinsko odejo računamo maksimalno evaporacijo iz zasenčenega površja tal, maksimalno evporacijo iz zasenčenega vodnega površja, maksimalno in dejansko transpiracijo poljščin. Uporabljamo Penmanovo metodo, prilagojeno po Choisnelu in sod. (1992). Računa nam referenčne vrednosti, zato uporabljamo še korekcijski faktor za poljščine (koeficient rastline), upoštevati moramo odvisnost od listne površine.

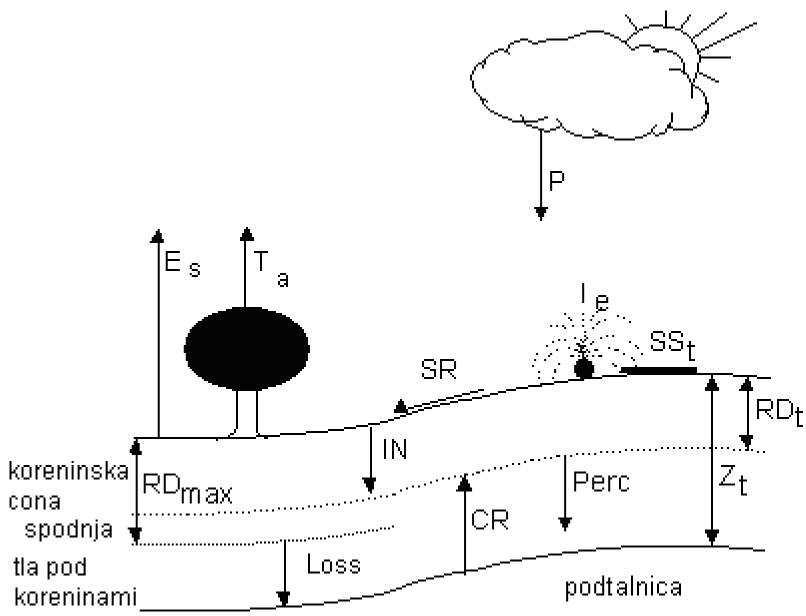
Spremenljivke imamo določene na meteoroloških postajah, zato jih interpoliramo v mrežo 50 x 50 km za EU. Za uporabo na nivoju posameznih držav je mogoče dodati gostejšo mrežo. Pri tem je pomembno, da izberemo ustrezne meteorološke postaje, ki so reprezentativne za posamezne celice. Dejanska interpolacija je enostavno povprečje, popravljeno zaradi razlik v nadmorski višini. Le pri padavinah vzamemo kar podatke z najbolj primerne postaje. Izračuni po celicah predstavljajo povprečne pogoje in ne odražajo vrednosti, ki bi bile na primer izmerjene v sredini celice.



Slika 1: *Proces rasti poljščin, kot jo simulira WOFOST. Ta in Tp sta dejanska in potencialna transpiracija.*
Figure 1: *Simplified general structure of a dynamic, explanatory growth model (Ta - actual and Tp - potential transpiration).*

4. 3 Vodna bilanca

Za simulacijo rasti mora model slediti količini vode v tleh, da lahko določi kdaj in kako zelo je poljščina izpostavljena vodnemu stresu. WOFOST uporablja vodno bilanco, ki v danem časovnem obdobju primerja količino vode, ki pride v koreninsko cono, s tisto, ki gre iz nje, ter določi razliko med njima za spremembo vsebnosti vode v tleh. Loči tri situacije. Prva se pojavi, ko je voda v tleh dosegla poljsko kapaciteto in pri tem rast dosega svoj potencialni nivo. V drugem primeru pride v poštev vpliv evapo(transpi)racije in perkolacije na vsebnost vode v tleh. Produkcija je zaradi manjše dostopnosti vode zmanjšana. Pri zadnji možnosti pa poleg evapo(transpi)racije in prekolacije upošteva še vpliv podtalnice (te možnosti pri JRC verziji ni).



***Slika 2**: Shematski prikaz različnih komponent vodne bilance tal.*
***Figure 2**:* Schematic representation of the different components of a soil water balance.

Dejansko količino vode v tleh izračuna model po (Driessen, 1986):

$$\theta_t = \frac{IN_{up} + (IN_{low} - T_a)}{RD} \Delta t ,$$

$$IN_{up} = P + I_e - E_s + SS_t / \Delta t - SR$$

in

$$IN_{low} = CR - Perc$$

kjer sta:

***Tabela 1**: Spremenljivke, ki nastopajo v izračunu vode v tleh.*
***Table 1**: Variables in the soil moisture equation.*

kjer so	θ_t	:	dejanska količina vode v koreninski coni ob času t	[$cm^3\ cm^{-3}$]
	IN_{up}	:	neto pritok skozi zgornjo mejo koreninske cone	[$cm\ d^{-1}$]
	IN_{low}	:	neto pritok skozi spodnjo mejo koreninske cone	[$cm\ d^{-1}$]
	T_a	:	dejanska transpiracija poljščine	[$cm\ d^{-1}$]
	RD	:	dejanska globina koreninske cone	[cm]
	P	:	količina padavin	[$cm\ d^{-1}$]
	I_e	:	efektivno dnevno namakanje	[$cm\ d^{-1}$]
	E_s	:	evaporacija iz tal	[$cm\ d^{-1}$]
	SS_t	:	voda na površini	[cm]
	SR	:	površinski odtok	[$cm\ d^{-1}$]
	CR	:	kapilarni dvig	[$cm\ d^{-1}$]
	Perc	:	perkolacija	[$cm\ d^{-1}$]
	Δt	:	časovni korak	[d]
	Z_t	:	globina podtalnice	[cm]

Procesi, ki direktno vplivajo na količino vode v koreninski coni, so definirani kot:

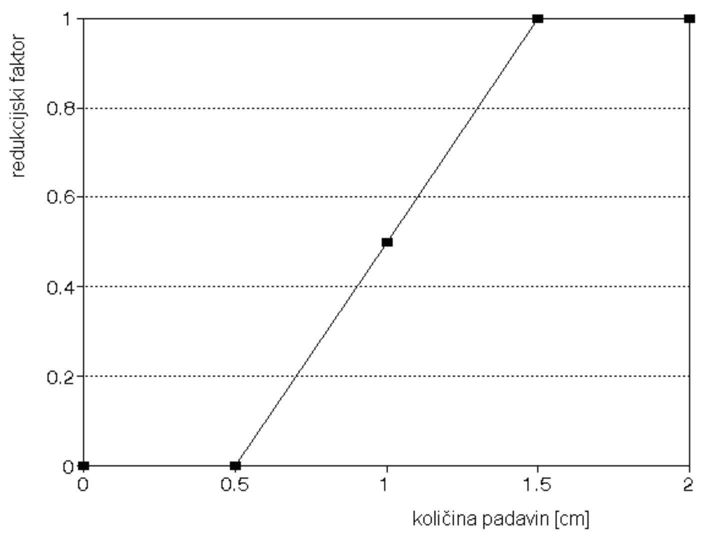
- Infiltracija: transport vode s površja v koreninsko cono.
- Evaporacija: izguba vode v atmosfero.

- Transpiracija rastlin: izguba vode iz notranje koreninske cone.
- Perkolacija: transport vode iz koreninske cone v plast pod njo.
- Kapilarni dvig: transport vode navzgor v koreninsko cono.

Zaradi vodnega stresa se transpiracija zmanjša, izračunati moramo dejansko evapotranspiracijo. Težko je oceniti, do katere količine vode v tleh uspejo rastline še vzdrževati potencialno transpiracijo. Po tej kritični točki pa potencialno transpiracijo množimo s faktorjem, manjšim od ena, odvisnim od količine vode v tleh. WOFOST uporablja empirično določeno formulo za izračun lahko dostopnega dela vode v tleh, pri tem pa moramo vedeti, v katero skupino rastlin se uvršča naša poljščina.

Privzeto je, da je na začetku od zadnjega dežja minilo 0 dni, v primeru, da je količina vode v tleh enaka polovici poljske kapacitete, pa 5 dni. Upoštevamo še, da ne dosežejo vse padavine tal (nekaj prestrežejo listi, stebla ...), poleg tega pa nekaj vode tudi odteče po površini (večinoma do 20 %).

WOFOST za določen dan izračuna, kolikšen del padavin se bo infiltriral. Graf (Slika 3) predstavlja faktor redukcije v odvisnosti od količine padavin. Model ponuja dve možni infiltracijski situaciji: delež padavin, ki se infiltrirajo v tla, je lahko konstanten ali pa je odvisen od intenzitete padavin. Delež padavin, ki se ne infiltrira v tla, ostane na površju, izpostavljen kasnejšemu izhlapevanju, odtoku ali infiltraciji. V primeru odvisnosti infiltracije od količine padavin se predpostavlja, da ob močnejših padavinah delež infiltrirane vode upada. Največji delež padavin, ki se ne infiltrira (NOTINF), je tu pomnožen z deležem NINFTB (ta se giblje med 0 in 1), ki je odvisen od količine padavin. Če je količina padavin manjša od 5 mm/dan, potem se vsa voda infiltrira (delež NINFTB je enak 0), če je količina padavin med 5 in 15 mm/dan, delež NINFTB linearno narašča, ob količini padavin nad 15 mm/dan pa je enak 1.



***Slika 3**: Redukcijski faktor za del padavin, ki se ne infiltrira, v odvisnosti od količine padavin.*
***Figure 3**:* Reduction factor of the non infiltrating fraction as a function of rainfall.

Če je vode več kot je poljska kapaciteta tal, pride do perkolacije. Na infiltracijo in perkolacijo vpliva tudi hidravlična prevodnost mokrih tal, ki je odvisna od vrste tal. Maksimalna infiltracija je določena iz izgub vode in dostopnega prostora med porami. Ko je presežena meja za zadrževanje vode na površju, se začne površinski odtok. Pri izračunih upoštevamo tudi rast korenin, s čimer se veča dostopnost vode v tleh.

Imamo možnost, da upoštevamo tudi stres zaradi pomanjkanja kisika v koreninski coni ob preobilici vode.

Pri vsem tem se moramo zavedati, da model ni namenjen natančni fizični obdelavi gibanja vode v tleh, temveč le oceni dostopnosti vode za rastlino.

Pri WOFOST-u lahko izbiramo med tremi podrutinami:

- Potencialna produkcija
- Omejena produkcija brez vpliva podtalnice
- Omejena produkcija z vplivom podtalnice

Pri računanju potencialne produkcije ne upoštevamo padavin, namakanja, kapilarnega dviga in drenaže, saj je količina vode v tleh ves čas na poljski kapaciteti in ne simuliramo vodne bilance tal. Tako prideta v poštev le evaporacija iz površja in transpiracija poljščine.

Ko ne upoštevamo podtalnice, računamo infiltracijo, zadrževanje vode na površju, perkolacijo in izgube vode pod koreninsko cono. Talni profil je sestavljen iz treh plasti: dejanska koreninska cona, spodnja koreninska cona (od dejanske do maksimalne globine korenin) in tla pod koreninsko cono. V tem primeru ne upoštevamo kapilarnega dviga.

Kadar upoštevamo tudi podtalnico, delimo tla na dejansko koreninsko cono, cono med končno globino korenin in podtalnico ter na tla pod podtalnico do globine 10 m. Natančnih izračunov ne bomo opisovali, saj dobrih podatkov o podtalnicah nimamo in teh izračunov ne uporabljamo.

4. 4 Hranila

Vpiv hranil (dušik, fosfat in kalij) na pridelek se računa na letnem nivoju na osnovi dela Janssena in sod. iz leta 1990. Rutino sestavljajo štirje koraki. Najprej izračunamo potencialne zaloge hranil iz razmerja med kemijskimi lastnostmi zgornje plasti tal (0-20 cm) in maksimalno količino tistih hranil, ki jih poljščina lahko absorbira. Predvideva se, da pridelek ni omejen s hranili in rastnimi faktorji. V drugem koraku izračunamo dejansko asimilacijo vsakega hranila kot funkcijo potencialne zaloge tega hranila, upoštevajoč potencialno zalogo ostalih dveh. V tretjem koraku dobimo tri območja možnega pridelka, kot so odvisna od dejanske asimilacije dušika, fosforja in kalija (obravnavano neodvisno). V četrtem koraku pa ta tri območja pridelka združimo po parih in za končno oceno pridelka povprečimo ocene le-teh. Splošna verzija WOFOST-a ponuja še statistiko in izračun dejanske produkcije pri omejeni količini hranil.

4. 5 Rast in razvoj rastlin

Pri fenološkem razvoju je najpomembnejši prehod iz vegetativnega v reproduktivno stanje rastline, pri čemer se suha snov v večini preusmeri v druge organe. Za enoletne poljščine je faze razvoja je najlažje predstaviti brezdimenzijsko kot 0 za vznik, 1 za cvetenje in 2 za zrelost (van Heemst in sod., 1986).
Kot začetek rastne sezone lahko izberemo datum setve ali vznika, vendar v primeru, da izberemo setev, WOFOST sam določi datum vznika in s tem začetek simulacije rasti poljščine. Čas vznika je lahko določen kot funkcija efektivne dnevne temperaturne vsote od setve dalje. Ko le-ta preseže določen prag, ki mora biti definiran za vsako poljščino posebej, se začne simulacija.

WOFOST izračuna stopnjo razvoja iz dnevne temperature in korekcijskega faktorja. Z integracijo stopnje razvoja po času pa določi razvojno fazo, pri čemer mora pri določenih kulturah upoštevati tudi dolžino dneva. Pri tem naj omenimo, da so novejše sorte precej manj občutljive na spremembe svetlobe kot tradicionalne, zato večinoma podatkov o dolžini dneva ne potrebujemo. Simulacija se zaključi, ko poljščina doseže razvojno fazo, v kateri bo požeta.

Temperaturne vsote, potrebne za doseganje določene faze, so določene v datotekah, ki opisujejo posamezne poljščine. Tako je na primer za koruzo med setvijo in vznikom potrebna temperaturna vsota 70 °C (za pšenico 0 °C), med vznikom in cvetenjem 750 °C (za pšenico 1000 °C) ter med cvetenjem in zrelostjo 859 °C (za pšenico 950 °C).

Rast je odvisna od neto dnevne asimilacije, ta pa je odvisna od prestrežene svetlobe. Svetlobo določimo iz sevanja, ki ga rastlina prejema, in listne površine poljščine. Dnevne vrednosti potencialne fotosinteze izračunamo iz absorbiranega sevanja in fotosintetskih karakteristik posameznih listov.

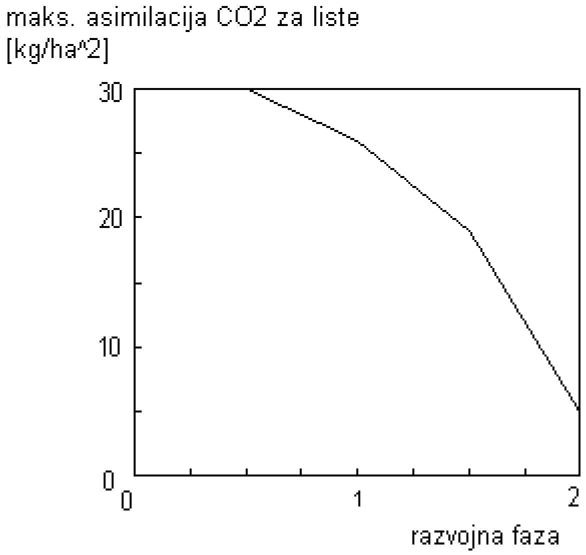
Rastline prilagajajo odprtost listnih rež. Asimilacijski proces je lahko omejen zaradi neoptimalnih temperaturnih pogojev in/ali zmanjšane dostopnosti CO_2 zaradi zaprtosti rež pri težnji po zmanjšanju transpiracije. Na grafu lahko vidimo, kako je maksimalna stopnja asimilacije CO_2 za liste odvisna od razvojne faze.

Maksimalna asimilacija pa mora biti popravljena s korekcijskim faktorjem za neoptimalne dnevne temperature, ki ga dobimo iz dnevnih temperatur in značilnosti posameznih poljščin. Poleg tega na asimilacijo vplivajo tudi nizke nočne temperature. Ponoči se asimilati, ki so nastali čez dan, transformirajo v biomaso za izgradnjo, vendar pa nizke temperature ta proces ovirajo. Tudi to upošteva WOFOST z dodatnim korekcijskim faktorjem. Pri vodnem stresu model upošteva zmanjšano asimilacijo v odvisnosti od dejanske transpiracije.

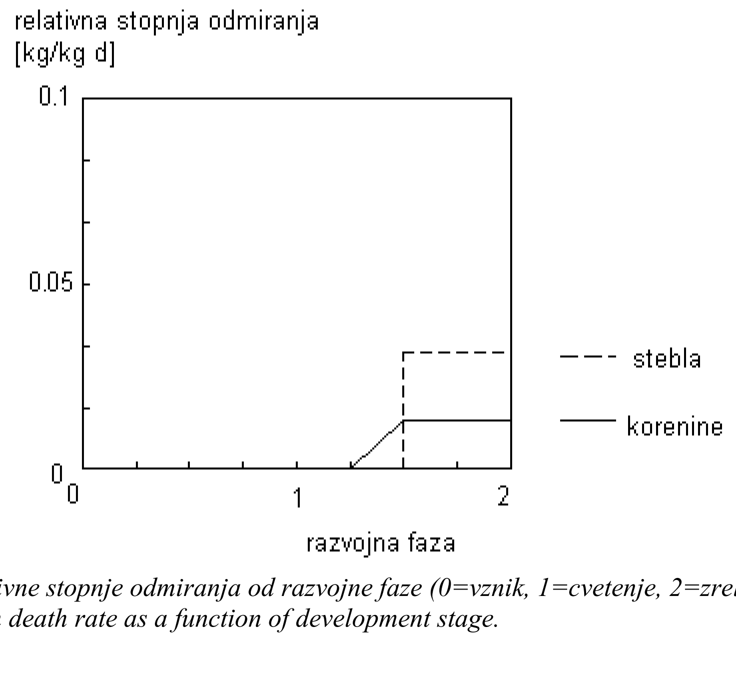
Pri bazalnem metabolizmu se porablja energija iz nastalih ogljikovih hidratov (15 – 30 % vseh) za vzdrževanje obstoječih biostruktur (resinteza razgrajenih proteinov, vzdrževanje protonskih gradientov ...). Večja kot je metabolna aktivnost, višji so stroški. Zaradi precejšnjega deleža ogljikovih hidratov, ki se tu porabi, mora biti proces v modelu dobro opisan. Odvisen je od količine suhe snovi in hranil, razvojne faze, dnevnih temperatur (za 10 °C višja temperatura pomeni 2-kratno povečanje respiracije – faktor Q10). To vnaša v model kar nekaj nezanesljivosti.

Ostali ogljikovi hidrati se porabijo kot gradbeni material, upoštevati pa je potrebno tudi stroške transporta. Rastni metabolizem tako določimo iz dnevne asimilacijske stopnje, kateri odštejemo bazalni metabolizem. Učinkovitost pretvorbe ogljikovih hidratov v gradbeni material za rastlino izračunamo kot uteženo povprečje učinkovitosti za posamezne organe. Rast suhe snovi določimo nato iz faktorja učinkovitosti in stopnje rastnega metabolizma.

Model upošteva še stopnjo odmiranja posameznih rastlinskih organov, ki je funkcija razvojne faze in je vrstno ter po organih specifična. Pri tem WOFOST predvideva, da založni organi ne odmirajo. Stopnja odmiranja je definirana kot dnevna količina žive biomase, ki ne sodeluje več v rastlinskih procesih. Pri steblih in koreninah jo določimo kot funkcijo razvojne faze.

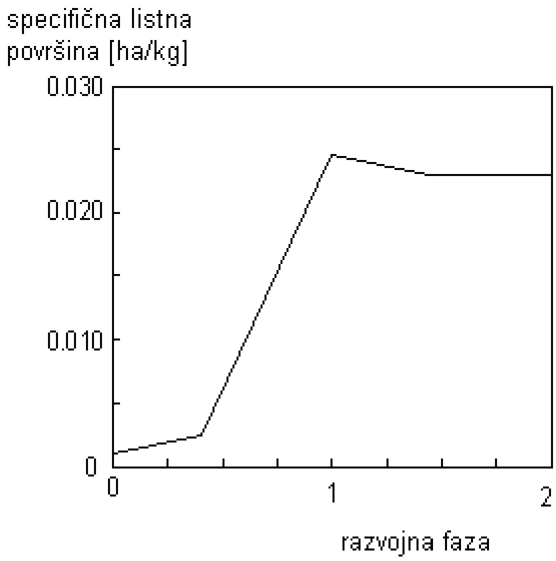


***Slika 4**: Odvisnost maksimalne asimilacije CO_2 za liste od razvojne faze (0=vznik, 1=cvetenje, 2=zrelost).*
***Figure 4**:* Maximum leaf CO_2 assimilation rate as a function of development stage.



***Slika 5**: Odvisnost relativne stopnje odmiranja od razvojne faze (0=vznik, 1=cvetenje, 2=zrelost).*
***Figure 5**: Root and stem death rate as a function of development stage.*

Pri listih je nekoliko bolj zapleteno, predvsem zaradi senčenja, vodnega stresa in preseganja življenjske dobe. Listno površino in s tem indeks listne površine računa model na precej zapleten način, v katerega se tu ne bomo spuščali, lahko pa vidimo potek razvoja na grafu.



***Slika 6**: Odvisnost specifične listne površine od razvojne faze (0=vznik, 1=cvetenje, 2=zrelost).*
***Figure 6**:* Specific leaf area as a function of development stage.

Poleg tega določa WOFOST še indeks zelene listne površine stebel in založnih organov, ki prav tako absorbirajo določen del sevanja, zaradi česar ga moramo dodati indeksu listne površine.

V posebnih prilogah k opisu modela si lahko natančno preberemo vse o enačbah, ki jih model uporablja, o izračunih energije globalnega obsevanja, Gaussovi integraciji, linearni interpolaciji z AFGEN funkcijo, določanju datuma setve, CGMS bazi podatkov, uporabi meteoroloških podatkov ter podatkov o poljščinah in tleh v CGMS-u.

5 ZAKLJUČEK

Model WOFOST nam omogoča zelo različne izračune, pri katerih imamo tudi precej proste roke, katere vhodne podatke vstavimo. Izračuni so kompleksni, različne komponente se med seboj prepletajo. V model so zajeta tla, vreme in rastline, kar od nas zahteva velik nabor meritev, hkrati pa nam tudi ponuja najrazličnejše izhodne rezultate.

V drugem delu bomo predstavili uporabo modela in pripravili nekaj izračunov. Z vidika podnebnih sprememb bi model kasneje (ko bi ga že na umerili ali pa vsaj ocenili napako) lahko uporabili za študijo primernosti različnih poljščin pri pričakovanih novih vremenskih razmerah na slovenskih tleh. Glede na trenutno stanje, ko so izgube v kmetijstvu zaradi suš, toče, neurij ... velike, je takšno raziskovalno delo zelo perspektivno, predvsem pa bi moralo biti tudi podprto in kasneje uporabljeno s strani poljedelcev. Za uresničitev take vizije pa bi potrebovali tudi intenzivno in kvalitetno obveščanje in motiviranje uporabnikov.

[1] univ. dipl. meteor., ARSO, Ljubljana, tjasa.pogacar@gov.si

[2] prof., dr., Biotehniška fakulteta, p.p. 2995, 1001 Ljubljana, lucka.kajfez.bogataj@bf.uni-lj.si

5 LITERATURA

Bakker, E. J., 1992. Rainfall and risk in India's agriculture. An ex-ante evaluation of rainfall insurance. Groningen theses in economics, management & organization (1992).

Boogaard, H. L., Diepen C. A. van, Rötter R. P., Cabrera J. M. C. A., Van Laar H. H., 1998. WOFOST 7.1; User's guide for the WOFOST 7.1 crop growth simulation model and WOFOST Control Center 1.5. Wageningen DLO Winand Staring Centre. Technical Document 52 (1998). 142 str.

Boote, K.J., J.W. Jones, and N.B. Pickering, 1996. Potential uses and limitations of crop models. Agronomy Journal, 88, 704-716

Brisson, N., Gary, C., Justes, E., Roche, R., Mary, B., Ripoche, D., Zimmer, D., Sierra, J., Bertuzzi, P., Burger, P., Bussiere, F., Cabidoche, Y.M., Cellier, P., Debaeke, P., Gaudillere, J.P., Henault, C., Maraux, F., Seguin, B. and Sinoquet, H., 2003. An overview of the crop model STICS. Eur. J. Agron. 18, pp. 309–332

Diepen, C. A. van, Wolf, J., Keulen, H. van., 1989. WOFOST: a simulation model of crop production. Soil Use and Management, 5 (1989):16-24.

Diepen, C. A. van, Keulen, H. van, Penning de Vries, F. W. T., Noij I. G. A. M., Goudriaan, J., 1987. Simulated variability of wheat and rice in current weather conditions and in future weather when ambient CO_2 has doubled. Simulation reports CABO-TT 14. CABO-DLO, WAU-TPE, Wageningen (1987).

Driessen, P. M. The water balance of the soil. V: Keulen, H. van in Wolf, J. (Eds.), 1986. Modelling of agricultural production: weather, soils and crop. Simulation Monographs (1986): 76-116.

Hargreaves, G. L., Hargreaves G. H., Riley, J. P. Irrigation water requirement for Senegal River Basin. Journal of Irrigation and Drainage Engineering, ASCE 111, 3 (1985):265-275.

Heemst, H. D. J. van, 1986a. The distribution of dry matter during growth of a potato crop. Potato Research, 29 (1986):55-66.

Hooijer, A. A., Bulens, J. D., Diepen, C. A. van, 1993. SC technical document 14.1. CGMS version 1.1. System description. Technical document 14.2 CGMS version 1.1. User manual. Technical document 14.3. CGMS version 1.1. Program description. DLO Winand Staring Centre, Wageningen in the Joint Research Centre, Ispra (1993).

Hooijer, A. A., Wal, T. van der, 1994. CGMS version 3.1, user manual. Technical document 15.1. SC-DLO, Wageningen (1994).

Huygen, J., 1992. SWACROP2, a quasi-two-dimensional crop growth & soil water flow simulation model. User's guide. WAU, Dept. of water resources, SC-DLO, Wageningen (1992).

Janssen, B. H, Guilking, F. C. T., Eijk, D. van der., Smaling, E. M. A., Wolf J., Reuler, H. van., 1990. A system for quantitative fertility of tropical soils (QUEFTS). Geoderma, 46 (1990):299-318.

Kajfež-Bogataj, L., 1996. Effects of climate warming on ceres-maize yield in Slovenia : sensitivity study. Zb. Bioteh. fak. Univ. Ljubl., Kmet. 1996 (67): 11-18

Keulen, H. van, Wolf, J., (Eds.), 1986. Modelling of agricultural production: weather, soils and crops. Simulation Monographs, Pudoc, Wageningen (1986).

Koning, G. H. J. de, Diepen, C. A. van.,1992. Crop production potential of the rural areas within the European Communities. IV: Potential, water-limited and actual crop production. Technical working document W68. Netherlands scientific council for government policy, The Hague (1992).

Lanen, H. A. J, Diepen, C. A. van, Reinds, G. J., Koning, G. H. J. de, Bulens, J. D., Bregt, A. K. 1992. Physicalland evaluation methods and GIS to explore the crop growth potential and its effects within the European Communities. Agricultural systems, 39 (1992):307-328.

Mellaart, E. A. R., 1989. Toepassing van gewasgroei-simulatiemodellen voor risico-studies in sahellanden (The application of crop-growth simulation models for risk-studies in Sahelian countries). V: Huijbers, C.,

Lingsma, S. P. in Oudkerk, J. C. (Eds.) Informatica toepassingen in de agrarische sector, voordrachten VIAS-Symposium (1989): 141-154.

Poels, R. L. H., Bijker, W., 1993. TROPFOR, a computer programme to simulate growth and water use of tropical rain forests developed from the "WOFOST" programme. Wageningen University, Dept. of Soil science and geology (1993).

Pogačar, T. in Kajfež Bogataj, L., 2009. WOFOST: model za napovedovanje pridelka – 2. del. Acta agric. Slov. [Tiskana izd.], 2009, let. xx, št. x, str. xxx

Prescott, J. A. , 1940. Evaporation from a water surface in relation to solar radiation. Transactions of the Royal Society of South Australia, 64 (1940):114-118.

Raaij, B. F. T. van, Wal, T. van der, 1994. CGMS 3.1. technical description. SC technical document 15.3. Q-Ray Agrimatica and DLO Winand Staring Centre, Wageningen in the Joint Research Centre, Ispra (1994).

Ritchie J.T., Otter, S., 1984. Description and performance of CERES-Wheat a user-oriented wheat yield model USDA-ARS-SR Grassland Soil and Water Research Laboratory Temple RX, 159–175.

Spitters, C. J. T., Keulen, H. van, Kraalingen, D. W. G. van, 1989. A simple and universal crop growth simulator: SUCROS87. V: Rabbinge, R., Ward, S. A. in Laar, H. H. van (Eds.). 1989. Simulation and systems management in crop protection. Simulation Monographs, Pudoc, Wageningen (1989).

Stöckle, C., Donatelli, M. and Nelson, R., 2003. CropSyst, a cropping systems simulation model. Eur. J. Agron. 18, pp. 289–307

Supit, I., 1994. Global radiation. Publication EUR 15745 EN of the Office for Official Publications of the EU (1994).

Supit, I., Goot, E. van der, 2008. Updated system description of the WOFOST crop growth simulation model., dokument za Evropsko komisijo. http://supit.net/main.php?q=aXRlbV9pZD01OQ== [Uporabljeno 23. 7. 2008].

Supit, I., Hooijer, A. A., Diepen, C. A. van, (Eds), 1994. System description of the WOFOST 6.0 crop simulation model implemented in CGMS. Publication EUR 15956 EN of the Office for Official Publications of the EU (1994).

Supit, I., Kappel, R. R. van., 1998. A simple method to estimate global radiation. Solar Energy, 63:147-160.

Thornley, J.H.M. and Johnson, I.R., 1990. Plant and crop modelling: a mathematical approach to plant and crop physiology .Oxford University Press, 684 p.

van Ittersum, M.K., Leffelaar, P.A., van Keulen, H., Kropff, M.J., Bastiaans, L. and Goudriaan, J., 2003. On approaches an applications of the Wageningen crop models. Eur. J. Agron. 18, pp. 201–234.

van Keulen H. and N.G. Seligman, 1987. Simulation of water use nitrogen nutrition and growth of a spring wheat crop. Simulation Monograph, Pudoc, Wageningen (1987).

Wal, T. van der, 1994. Data installation guide and operators manual. SC tee chnical document 15.2., DLO Winand Staring Centre, Wageningen in Joint Research Centre, Ispra (1994).

Weir P.L. Bragg, J.R. Porter and J.H. Rayner, 1984. A winter wheat crop simulation model without water or nutrient limitations. J. Agric. Sci. Cambridge 102 (1984), pp. 371–382.

Whisler, R., B. Acock, D.N. Baker, R.E. Fye, H.F. Hodges, J.R. Lambert, H.E. Lemmon, J.M. McKinion and V.R. Reddy, 1986. Crop simulation models in agronomic systems. Adv. Agron. 40 (1986), pp. 141–208.

Williams, J.R., C.A. Jones, J.R. Kiniry and D.A. Spanel, 1989. The EPIC crop growth model. Trans. ASAE 32 (1989), pp. 497–511

Wolf, J., Diepen, C. A. van, 1991. Effects of climate change on crop production in the Rhine basin. Report 52. RIZA, SC-DLO, Wageningen (1991).

Wolf, J., Diepen, C. A. van., 2007. Effects of climate change on yield potential of wheat and maize crops in the European Union. Studies in Environmental Science, Volume 65, Part 2 (2007): 745-750.

Wolf, J., 1993. Effects of climate change on wheat and maize production potential in the EC. V: Kenny, G. J., Harrison, P. A. in Parry, M. L. (Eds.). The effect of climate change on agricultural and horticultural potential in Europe. Research report 2. Environmental change unit, University of Oxford (1993).

Wolf, J., Berkhout, J. A. A., Diepen C. A. van, Immerzeel, C. H. van , 1998. A study on the limitations to maize production in Zambia using simulation models and a geographic information system. V: Bouma, J. in

Brecht, A. K. (Eds.). Land qualities in space and time, proceedings of a symposium organized by the International society of soil science (ISSS), Pudoc, Wageningen (1989): 209-215.

COBISS Code 1.02

Agrovoc descriptors: plants; growth; crop yield, yield forecasting; simulation models; meteorology; water balance; monitoring; maize; Zea mays

Agris category code: F01; P40; F62

WOFOST: model za napovedovanje pridelka – 2. del

Tjaša POGAČAR[1], Lučka KAJFEŽ-BOGATAJ[2]

Prispelo 23. januarja 2009, sprejeto 23. junija 2009
Received January 23, 2009; accepted June 23, 2009

IZVLEČEK

Model WOFOST (WOrld FOod STudy) je precej enostaven za prvo uporabo. Za nastavitve imamo na voljo pet zavihkov: splošno, poljščina, vreme, tla, ponovitve. Izbiramo med potencialno simulacijo, dejansko simulacijo pri omejeni količini vode in dejansko simulacijo pri omejeni količini hranil. Za obravnavo izbrane poljščine moramo dobro poznati njene karakteristike ali pa si izberemo poljščine, ki so že definirane v modelu. Določamo tudi datum setve in žetve ali pa prepustimo modelu, da izbere najprimernejša. Meteorološke podatke moramo za obravnavan kraj pripraviti v zahtevanem formatu. Tudi podatki o različnih tipih tal so že pripravljeni, lahko pa dodamo svoje. WOFOST nam med drugim izračuna fenološke faze, suho težo korenin, listov, stebel in založnih organov, celotno nadzemsko produkcijo, žetveni indeks, evapo(transpi)racijo, asimilacijo, bazalni metabolizem, globino dejanske koreninske cone, vsebnost vode v tleh ter sušne in mokre dni.

Naši izračuni za primer koruze kažejo stanje sušnosti, kot je po izbranih letih od 2003 do 2006 tudi pričakovano – izrazito sušno leto 2003, sušnejše 2006, zmerno 2005 in precej mokro leto 2004. Razlike v vsebnosti vode v tleh se kažejo po koncu maja. Najhitreje je koruza dozorela v najbolj sušnem letu 2003 in najpočasneje v najbolj namočenem 2004. Vidimo lahko še, da na začetku rasti evaporacija iz tal prevladuje nad transpiracijo, med glavno rastno sezono prevladuje transpiracija, na koncu pa zopet evaporacija iz tal. Daleč najmanjša je produkcija leta 2003 zaradi precejšnih težav s sušo, sledi leto 2006 in praktično enaka pridelka v letih 2004 in 2005, ko večjega pomanjkanja dežja ni bilo.

Pokazali smo še, da je število sušnih dni precej različno pri različnih tipih tal. Na tleh s slabo zadrževalno sposobnostjo je več sušnih let, kot na boljših tleh, v splošnem pa so bila najbolj sušna leta 2001, 1992, 1971, 1988, 2003 in 1993 (izračuni do leta 2005).

Ključne besede: WOFOST, napovedovanje pridelka, vhodni podatki, suša, rastlinska produkcija

ABSTRACT

WOFOST: CROP GROWTH SIMULATION MODEL – 2ND PART

WOFOST (WOrld FOod STudy) model is with its user friendly preface very simple to use. It has five tabs: general, crop, weather, soil and reruns, where we determine the calculation parameters. The simulation can base on potential, water-limited or nutrition-limited conditions. Crop parameters have to be quite well known or we can choose pre-determined crop from the model, similar it is with the soil data. There is also possible to set the date of sowing and harvesting (maturity), but we can let the model to choose the more appropriate ones, which are based on meteorological conditions. The format for meteorological data is determined, so we have to prepare them correctly. WOFOST model calculates among others phenological stages, dry weight of roots, leaves, stems and storage organs, total above ground production, harvesting index,

[1] univ. dipl. meteor., ARSO, Ljubljana, tjasa.pogacar@gov.si

[2] prof., dr., Biotehniška fakulteta, p.p. 2995, 1001 Ljubljana, lucka.kajfez.bogataj@bf.uni-lj.si

evapo(transpi)ration, assimilation, maintenance respiration, actual root zone depth, soil moisture and dry/wet days.

Our calculations for maize (pre-defined) give us the estimation of the effect of drought on crop yield for the period 2003-2006. Year 2003 was extremely dry, dry was also 2006, 2005 was moderate and 2004 was wet. Major differences in soil moisture between years came out at the end of May. Maize reached maturity the earliest in 2003 and the latest in 2004. At the beginning of the growth season there is higher soil evaporation than transpiration, in the middle is higher transpiration and at the end again soil evaporation. Crop production is also depending on water conditions, so it is much smaller in 2003, a bit bigger in 2006, in 2004 and 2005 it was quite the same – there were no problems with the water shortage. We have also shown that the number of dry days strongly depends on the soil type; there are much more dry days on the soil with low water holding capacity. In general, the driest years were 2001, 1992, 1971, 1988, 2003 in 1993 (until 2005).

Key words: WOFOST, yield prediction, input data, drought, crop production

1 UVOD

V prvem delu (Pogačar in Kajfež-Bogataj, 2009) smo podrobneje predstavili nizozemski model WOFOST (Bouman et al., 1996; Diepen et al., 1989; Hooijer and van der Wal, 1994), tokrat pa prikazujemo konkretno uporabo modela. Gre za konkretne napotke in komentarje za uporabo modela ter primere izračunov.

Z implementacijo in prilagoditvijo modela WOFOST na slovenske razmere bi izračune vodne bilance tal lahko nadgradili z oceno kmetijskega pridelka in tako omogočili boljše prilagajanje kmetijske pridelave v Sloveniji novemu podnebju (Reidsma e tal., 2009; Kajfež in Sušnik, 2007. Hkrati bi lahko preučili kompleksne interakcije med klimatskim sistemom in fenološkim razvojem (sprememba datuma nastopa ter trajanja posameznih fenoloških faz) ter količino pridelka, kar s poljskimi poskusi ni možno (Wolf in van Diepen, 1994; Wegehenkel, 2000). Poleg tega bi lahko z modelom preučevali tudi vodno bilanco kmetijskih tal in rezultate primerjali z vodnobilančnima modeloma IRRFIB (Sušnik, 2006; Ceglar in sod., 2008) ter SIMPEL (Hörmann, 1997; Ipavec in Kajfež Bogataj, 2008). Vodno bilanco kmetijskih tal so z modelom WOFOST preučeval že Eitzinger s sodelavci (2004) ter Todorović s sodelavci (2009).

2 PRIKAZ UPORABE MODELA

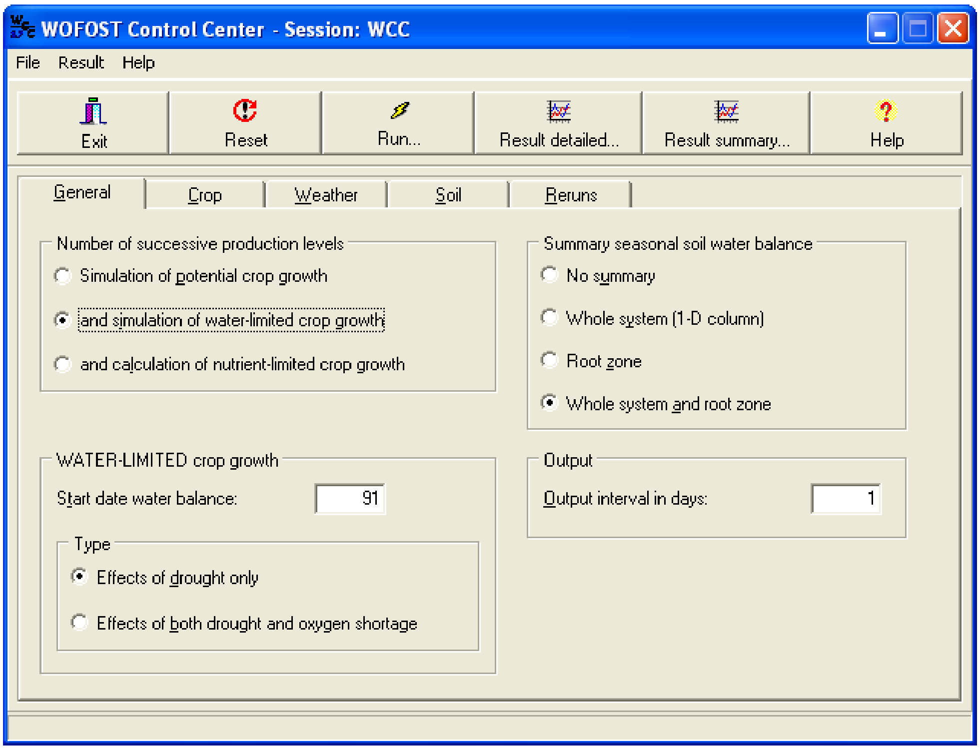
Model WOFOST ima prijazen uporabniški vmesnik, zato je precej enostaven za uporabo (Supit et al., 2008). Za nastavitve imamo na voljo pet zavihkov: splošno, poljščina, vreme, tla, ponovitve.

Pri splošnem (Slika 1) si izberemo, kakšno simulacijo želimo: potencialno, dejansko pri omejeni količini vode ali dejansko pri omejeni količini hranil. Določimo, kateri dan v letu (julijanski dan) naj se začne simulacije vodne bilance tal in ali bomo upoštevali le vpliv suše ali tudi primanjkljaja kisika (preveč vode). Za izpis rezultatov določimo, za kateri del tal želimo povzetek vodne bilance: za cel sistem, za koreninsko cono, za oboje ali pa ne želimo povzetka. Izberemo še časovni interval (v dnevih) za izpis.

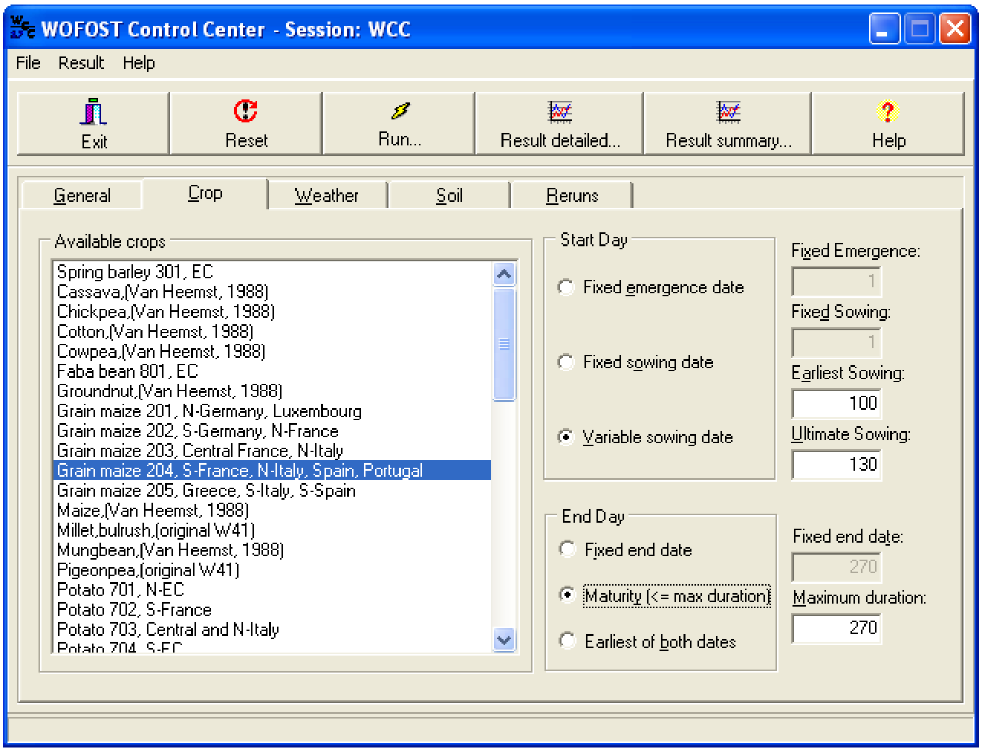
Nato pri zavihku 'poljščina' (Slika 2) izberemo, katero poljščino bomo obravnavali. Veliko jih že imamo na izbiro, lahko pa tudi dodamo svojo, vendar moramo zelo dobro poznati njene karakteristike. Navodila za dodajanje so priložena modelu. Definirati moramo tudi začetni in končni dan simulacije rasti.

Pri začetnem dnevu se lahko odločimo za točen datum setve ali vznika, ki ga kot julijanski dan vpišemo v polje, ali pa izberemo spremenljiv datum setve, pri čemer moramo vpisati spodnjo in zgornjo mejo za ta datum, model pa bo poiskal najprimernejši čas glede na simulirane razmere.

Pri končnem dnevu lahko prav tako vpišemo točen datum, lahko pustimo poljščino rasti do zrelosti, a pri tem vpišemo maksimalno trajanje, ali pa pustimo modelu, da izbere zgodnejšega izmed obeh datumov.



***Slika 1**: Zavihek 'splošno' pri nastavitvah modela WOFOST 7.1.2.*
***Figure 1**: WOFOST model – tab 'General'.*



***Slika 2**: Zavihek 'poljščina' pri nastavitvah modela WOFOST 7.1.2.*
***Figure 2**: WOFOST model – tab 'Crop'.*

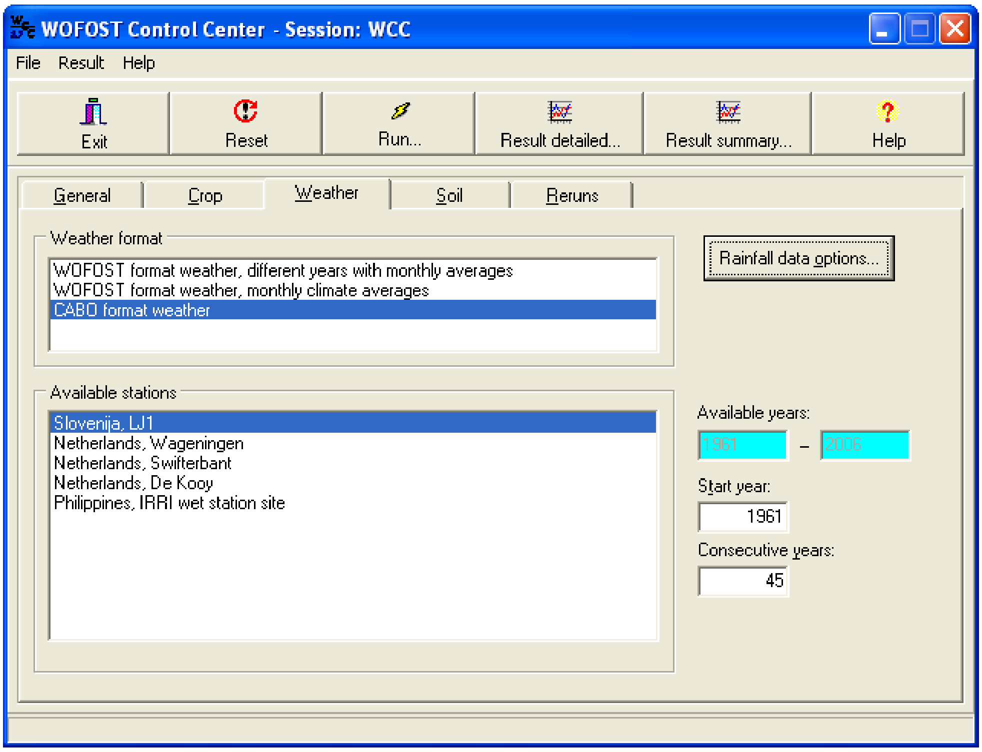
Zavihek 'vreme' (Slika 3) nam omogoča, da izberemo format, v katerem imamo meteorološke podatke, dodatne možnosti imamo še za podatke o količini padavin (če so v drugačnem formatu). Na voljo so podatki s treh nizozemskih postaj in ene na Filipinih, lahko pa dodamo svojo – kot že lahko vidimo možnost izbire Ljubljane. Pri tem uporabimo CABO format z dnevnimi vrednostmi spremenljivk, ki je opisan v navodilih.

Vpisati moramo še začetno leto obravnave in število zaporednih let, za katera želimo izračune.

Pri zavihku 'tla' (Slika 4) imamo na razpolago na tri različne načine definirana tla s 4, 5 oz. 6 tipi tal. Tudi tu lahko na precej zapleten način (potrebujemo veliko podatkov o tleh) dodamo nov tip tal.

Vpisati moramo začetno količino vode, ki se zadržuje na površju, največjo možno količino vode na površju, začetno dostopno količino vode v tleh in maksimalno količino vode v začetni koreninski coni. Če izberemo upoštevanje vpliva podtalnice, ne potrebujemo zadnjih dveh podatkov, temveč začetne podatke o podtalnici, poleg tega pa lahko izberemo še drenažo in v tem primeru vpišemo globino drenaže.

Definirati moramo tudi maksimalno globino koreninske cone in maksimalni delež padavin, ki se ne infiltrira. Izberemo lahko še ali se infiltrira določena količina padavin ali pa so vrednosti infiltracije določene glede na velikost nevihte (količino padavin).

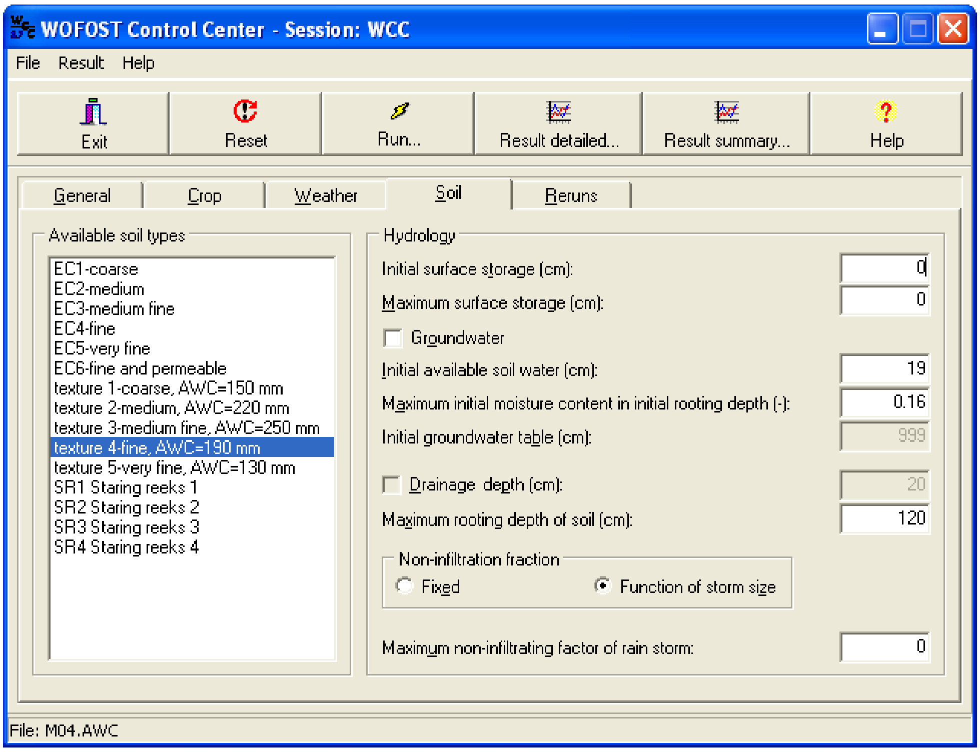


***Slika 3**: Zavihek 'vreme' pri nastavitvah modela WOFOST 7.1.2.*
***Figure 3**: WOFOST model – tab 'Weather'.*

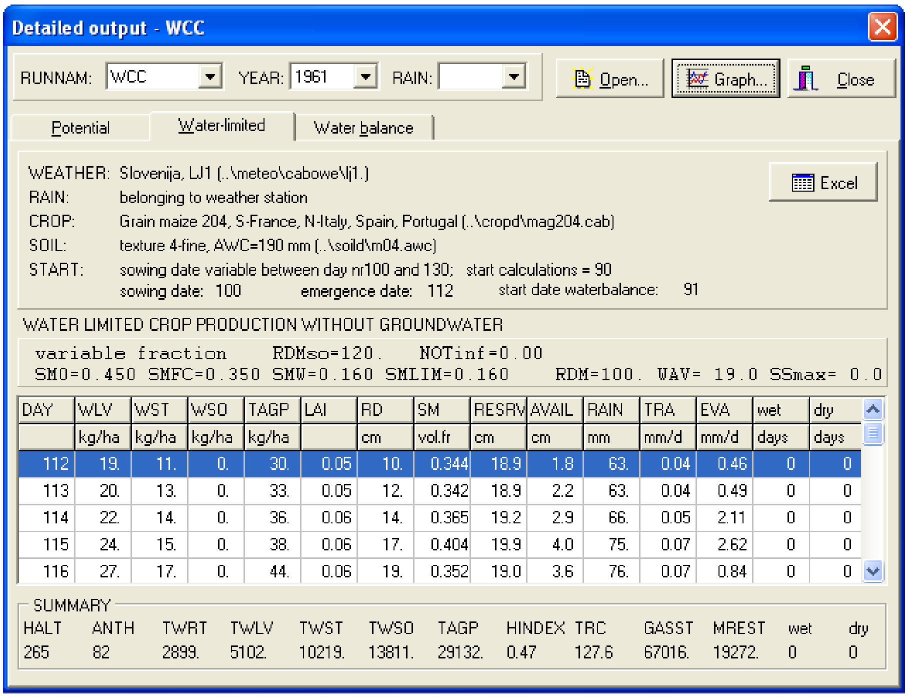
Zadnji zavihek nam omogoča, da si nastavimo ponovitve simulacij s spremenjenimi parametri, ki si jih sami izberemo.

Ko nastavimo vse vhodne parametre, zaženemo model ('Run...'). Rezultati se nam izpišejo v obliki tabele, ki nam jo model lahko tudi prenese v Excel.

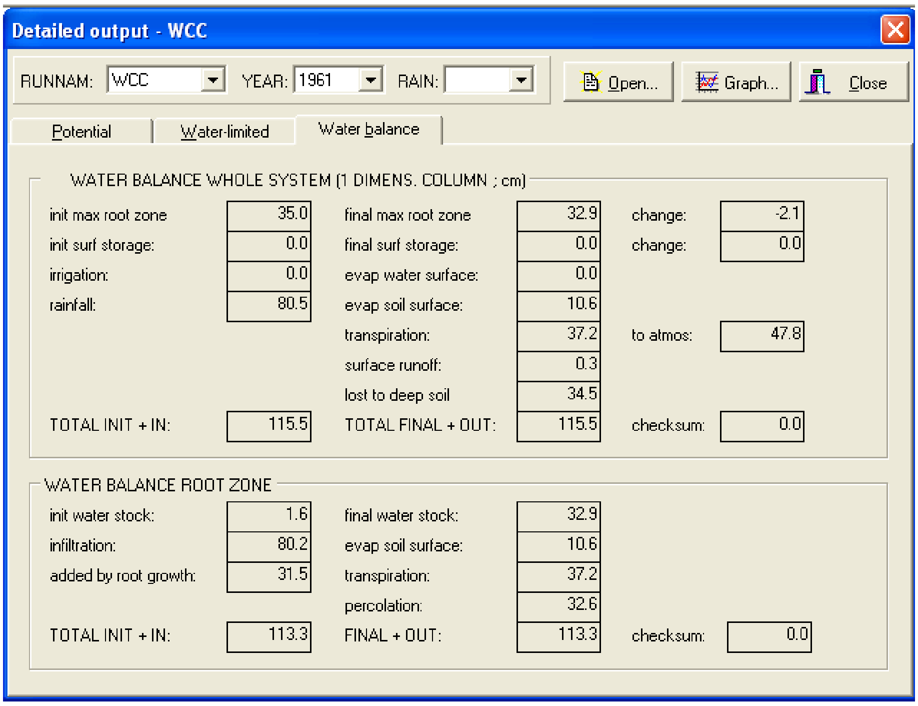
Izbiramo lahko med razčlenjenim izpisom po dnevih ('Result detailed...') in povzetkom rezultatov ('Result summary...').



***Slika 4**: Zavihek 'tla' pri nastavitvah modela WOFOST 7.1.2.*
***Figure 4**: WOFOST model – tab 'Soil'.*



***Slika 5**: Prikaz rezultatov v modelu WOFOST 7.1.2.*
***Figure 5**: WOFOST model: detailed output – tab 'Water-limited'.*



Slika 6*: Zavihek, ki prikazuje vodno bilanco.*
Figure 6*: WOFOST model: detailed output – tab 'Water balance'.*

Pri razčlenjenem izpisu (Slika 5) izberemo leto, za katerega želimo izpis. Na voljo imamo zavihke z rezultati za potencialno simulacijo ('Potential'), simulacijo pri omejeni količini vode ('Water-limited') in z vodno bilanco ('Water balance'). Pri vodni bilanci so predstavljene glavne komponente le-te za celotni sistem in za koreninsko cono (Slika 6).

V tabeli predstavljamo spremenljivke, ki se kot rezultat izpišejo pri potencialni simulaciji.

Pri rezultatih simulacije pri omejeni količini vode imamo prav tako spremenljivke, ki so v tabeli 1 odebeljene, poleg njih pa še dodatne, ki so predstavljene v tabeli 2.

Pri povzetku rezultatov prav tako lahko izbiramo med zavihkoma z rezultati za potencialno simulacijo ('Potential') in simulacijo pri omejeni količini vode ('Water-limited'). Rezultati se nam izpišejo po posameznih letih, poleg tega pa dobimo tudi izračun povprečij, standardnih odklonov in variacijskih koeficientov za simulirano obdobje (dolžina obdobja je navedena pod spremenljivko DUR) za spremenljivke, ki so v tabeli 3 odebeljene.

V tabeli 3 so zbrane in opisane vse spremenljivke, ki so izračunane pri potencialni simulaciji (večinoma so enake kot pri razčlenjenem izpisu).

***Tabela 1**: Spremenljivke pri razčlenjenem izpisu rezultatov potencialne simulacije.*
***Table 1**: Variables in detailed output of the potential simulation.*

ime spremenljivke	enote	pomen
DAY		julijanski dan v letu
IDSEM	d	št. dni od vznika
DVS		razvojna faza poljščine
TSUM	°C	termalni čas
WLV	kg/ha	suha teža živih listov
WST	kg/ha	suha teža živih stebel
WSO	kg/ha	suha teža živih založnih organov
TAGP	kg/ha	celotna nadzemska produkcija
LAI	m^2/m^2	indeks listne površine
TRA	mm/d	stopnja transpiracije
GASS	kg(CH_2O)/ha/d	stopnja asimilacije
MRES	kg(CH_2O)/ha/d	stopnja bazalnega metabolizma
DMI	kg/ha/d	stopnja rasti suhe snovi
v povzetku še:		
HALT		dan žetve
ANTH	d	št. dni do cvetenja
TWRT	kg/ha	celotna suha teža korenin
TWLV	kg/ha	celotna suha teža listov
TWST	kg/ha	celotna suha teža stebel
TWSO	kg/ha	celotna suha teža založnih organov
HINDEX		žetveni indeks: teža založnih org./teža nadzemnega dela poljščine
TRANSP	cm	celotna transpiracija
TRC		transpiracijski koeficient: kg(H_2O)/kg(suha snov)
GASST	kg(CH_2O)/ha	celotna asimilacija
MREST	kg(CH_2O)/ha	celotni bazalni metabolizem

***Tabela 2**: Preostale spremenljivke pri razčlenjenem izpisu rezultatov simulacije pri omejeni količini vode.*
Table 2*: The rest of variables in detailed output of the water-limited simulation.*

ime spremenljivke	enote	pomen
RD	cm	globina dejanske koreninske cone
SM	cm^3/cm^3	vsebnost vode v tleh
RESRV	cm	količina dostopne vode v potencialni koreninski coni
AVAIL	cm	količina dostopne vode v dejanski koreninski coni
RAIN	mm	celotna količina padavin v simulacijskem obdobju
EVA	mm/d	stopnja evaporacije iz tal ali iz vode na površju
wet	kg/ha	št. dni z zmanjšano rastjo poljščin zaradi pomanjkanja kisika
dry	kg/ha	št. dni z zmanjšano rastjo poljščin zaradi pomanjkanja vode

Pri dejanski simulaciji z omejeno količino vode se poleg že znanih pojavijo še spremenljivke, ki so zbrane v tabeli 4.

Pri razčlenjenih rezultatih nam model sam izriše tudi grafe posameznih spremenljivk, hkrati za vsa simulirana leta (kar je nekoliko nepregledno, če si izberemo daljše obdobje). Žal pa grafov ne moremo izvoziti.

Tabela 3: *Spremenljivke pri povzetku rezultatov potencialne simulacije.*
Table 3: *Variables in summary output of the potential simulation.*

ime spremenljivke	enote	pomen
YR		leto
RUNNAM		oznaka simulacijskega zagona
SOW		dan setve
→	d	št. dni med setvijo in vznikom
EM		dan vznika
ANT	d	št. dni do cvetenja
FLWR		dan, ko poljščina zacveti
HALT		dan žetve
TWRT	kg/ha	celotna suha teža korenin
TWLV	kg/ha	celotna suha teža listov
TWST	kg/ha	celotna suha teža stebel
TWSO	kg/ha	celotna suha teža založnih organov
TAGP	kg/ha	celotna nadzemska produkcija
LAIM	ha/ha	maksimalni indeks listne površine
HINDEX		žetveni indeks: teža založnih org./teža nadzemnega dela poljščine
TRC		transpiracijski koeficient: kg(H_2O)/kg(suha snov)
GASST	kg(CH_2O)/ha	celotna asimilacija
MREST	kg(CH_2O)/ha	celotni bazalni metabolizem
TRANSP	cm	celotna transpiracija
EVSOL	cm	celotna evaporacija iz površja tal

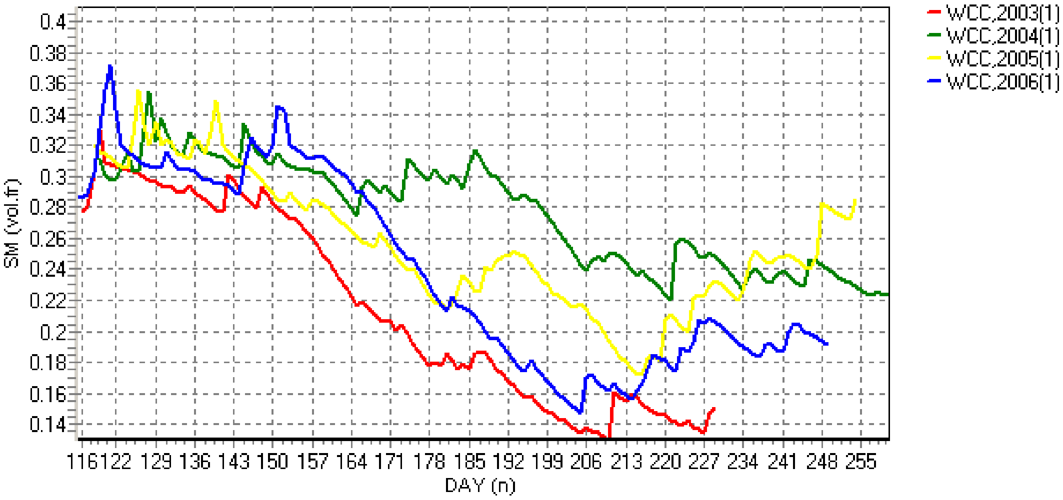
4 PRIMER IZRAČUNOV

V nadaljevanju si poglejmo nekaj rezultatov vodno-bilančnih izračunov z modelom WOFOST za koruzo v letih od 2003 do 2006.

Slika 7 kaže stanje sušnosti kot je po izbranih letih tudi pričakovano – izrazito sušno leto 2003, sušnejše 2006, zmerno 2005 in precej mokro leto 2004. Razlike v vsebnosti vode v tleh se kažejo po 150. dnevu, torej nekje po koncu maja. Kot vidimo na vseh grafih, se simulacijsko obdobje vsako leto drugače konča, saj smo nastavili naj model računa do zrelosti poljščine (ali najdlje do 270. dneva). Najhitreje je koruza dozorela v najbolj sušnem letu 2003 in najpočasneje v najbolj namočenem 2004.

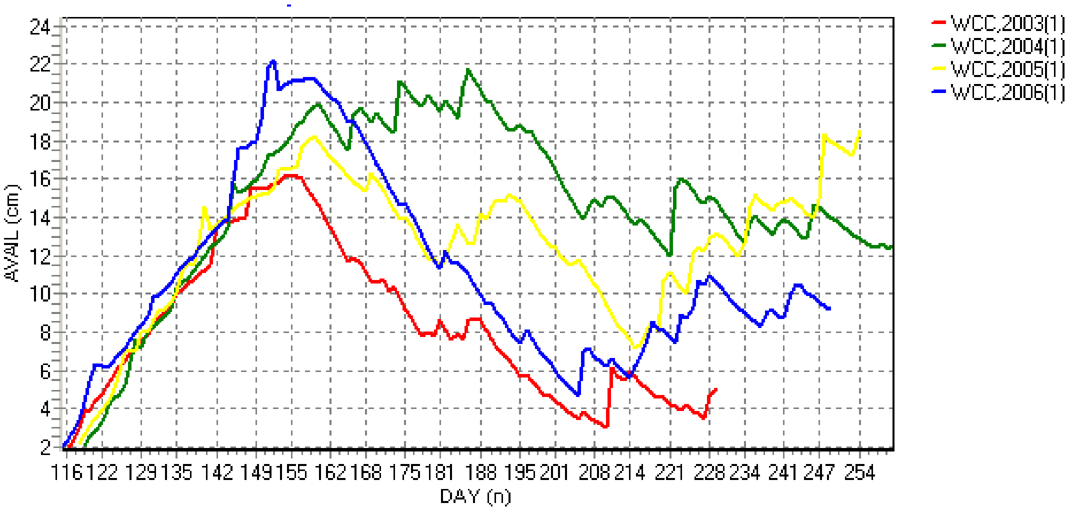
Slika 8 je precej podobna prejšnji, saj kaže količino dostopne vode v dejanski koreninski coni. Tu so rezultati prikazani v centimetrih, medtem ko so na sliki 13 v volumskih odstotkih.

Na slikah 9 in 10 sta grafa transpiracije in evaporacije iz tal, ki se med seboj nekako dopolnjujeta. Jasno lahko vidimo, da je na začetku rasti glavni proces evaporacija iz tal, kasneje med rastno sezono prevladuje transpiracija, na koncu pa zopet evaporacija iz tal. Rezultati so prikazani v milimetrih, transpiracija doseže tudi še enkrat višje vrednosti kot evaporacija.



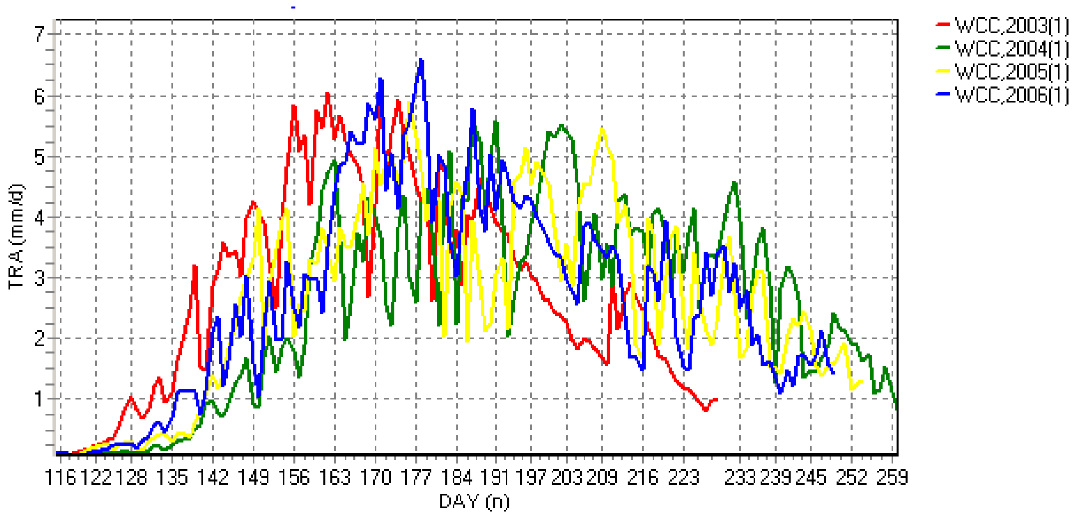
***Slika 7**: Vsebnost vode v dejanski koreninski coni v modelsko določenem vegetacijskem obdobju za leta od 2003 do 2006.*

***Figure 7**: Soil moisture content in actual root zone during the simulated period in years 2003-2006.*

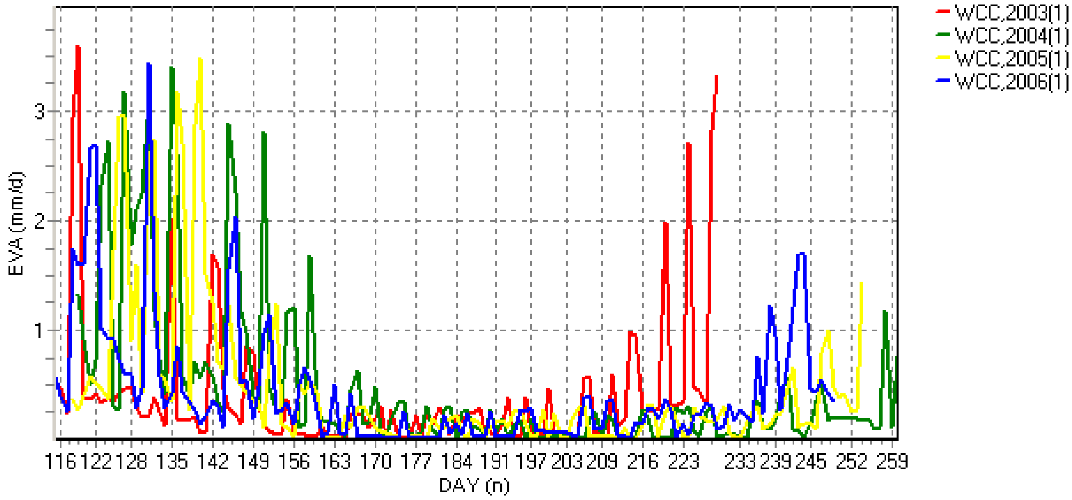


***Slika 8**: Količina dostopne vode v dejanski koreninski coni v modelsko določenem vegetacijskem obdobju za leta od 2003 do 2006.*

***Figure 8**: Amount of water available in actual root zone during the simulated period in years 2003-2006.*



***Slika 9**: Stopnja transpiracije v modelsko določenem vegetacijskem obdobju za leta od 2003 do 2006.*
***Figure 9**: Transpiration rate during the simulated period in years 2003-2006.*

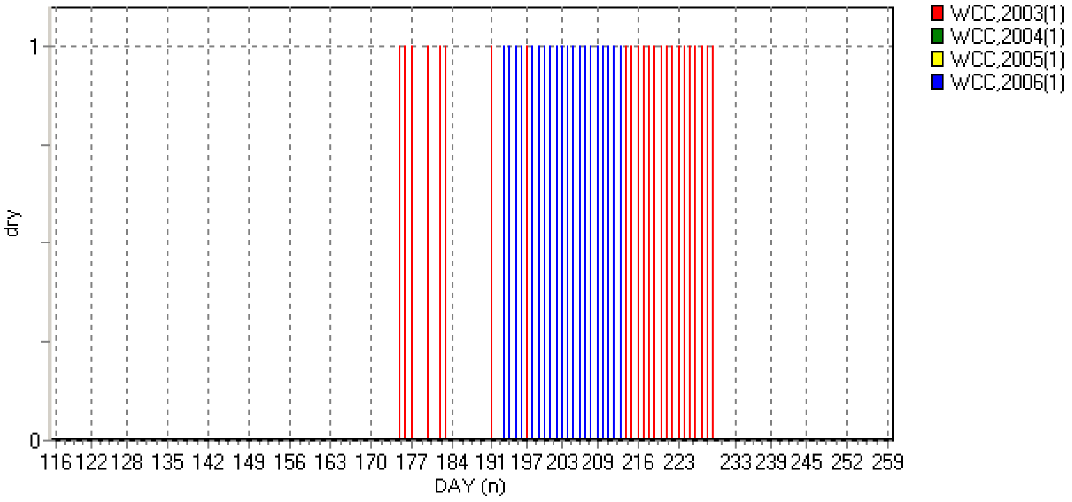


***Slika 10**: Stopnja evaporacije iz tal v modelsko določenem vegetacijskem obdobju za leta od 2003 do 2006.*
***Figure 10**: Soil evaporation rate during the simulated period in years 2003-2006.*

Prikažemo lahko tudi število sušnih ali mokrih dni. Tako imamo na grafu na sliki 11 označene dneve z zmanjšano rastjo poljščin zaradi pomanjkanja vode (dnevov z zmanjšano rastjo zaradi pomanjkanja kisika v teh letih ni bilo).

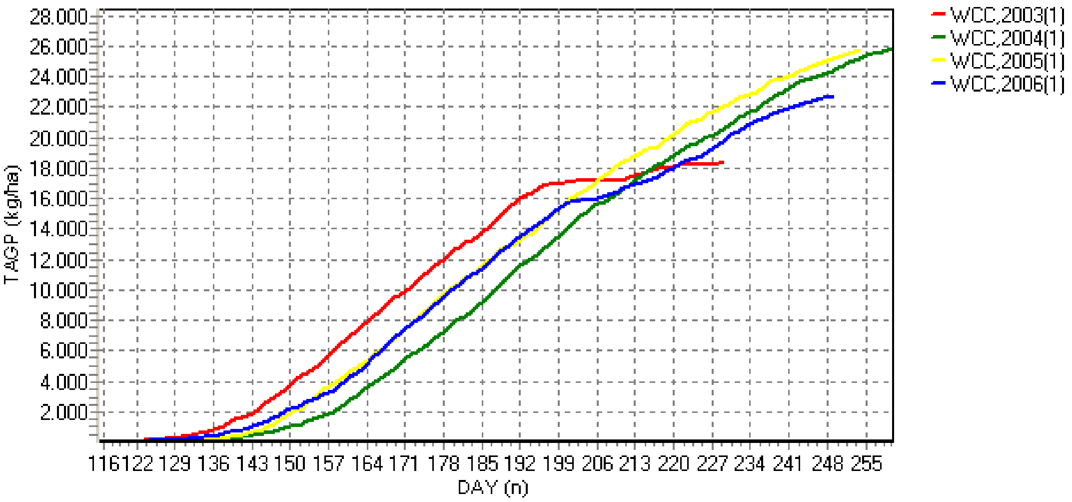
Na sliki 12 je rastlinska produkcija v kilogramih na hektar, ki je odvisna od vseh prej prikazanih dejavnikov ter ostalih spremenljivk, ki smo jih predstavili pred tem. Daleč najmanjša je produkcija leta 2003 zaradi precejšnih težav s sušo, sledi leto 2006 in praktično enaka pridelka v letih 2004 in 2005, ko večjega pomanjkanja dežja ni bilo.

Graf na zadnji sliki (Slika 13) pa je sam po sebi zgovoren o primernosti različnih tal za izbrano kulturo (v našem primeru je to koruza). Število sušnih dni je namreč precej različno pri različnih tipih tal. Na tleh s slabo zadrževalno sposobnostjo (le 130 mm rezervoarja za vodo) je precej več sušnih let, kot na boljših tleh, v splošnem pa so bila najbolj sušna leta 2001, 1992, 1971, 1988, 2003 in 1993 (nismo računali za leta po l. 2005).



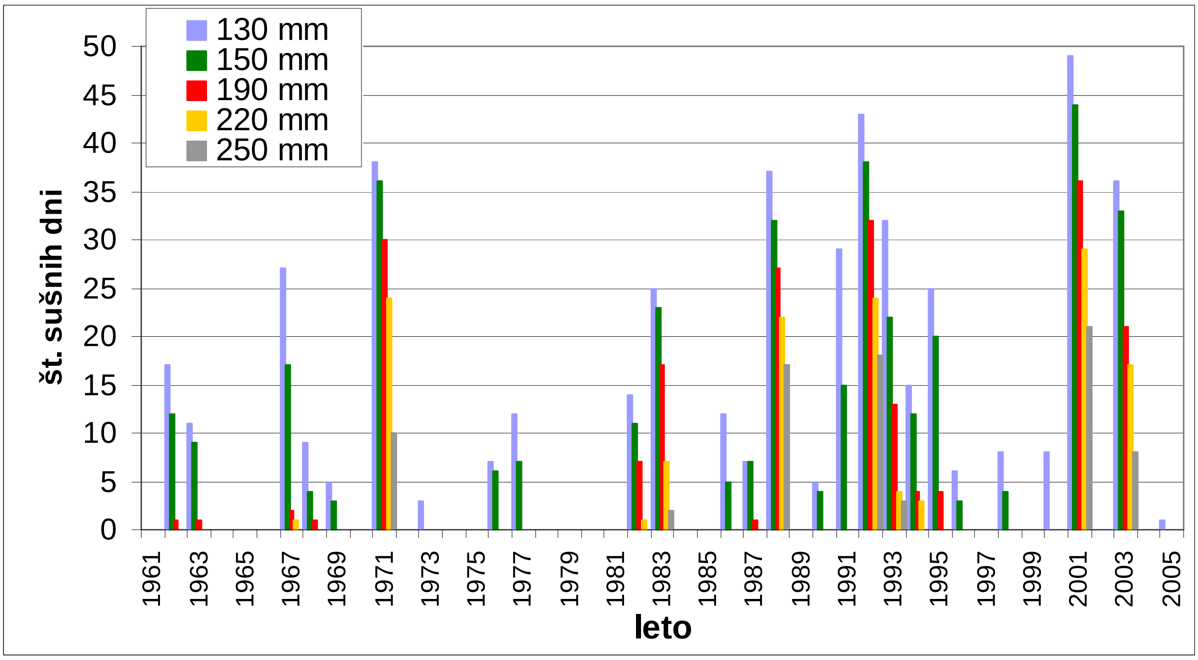
***Slika 11**: Dnevi z zmanjšano rastjo poljščin zaradi pomanjkanja vode v modelsko določenem vegetacijskem obdobju za leta od 2003 do 2006.*

***Figure 11**: Days characterizied by reduced crop growth due to water shortage during the simulated period in years 2003-2006.*



***Slika 12**: Celotna nadzemska produkcija v modelsko določenem vegetacijskem obdobju za leta od 2003 do 2006.*

***Figure 12**: Total above ground production during the simulated period in years 2003-2006.*



***Slika 13**: Število dni z zmanjšano rastjo poljščin zaradi pomanjkanja vode v modelsko določenem vegetacijskem obdobju za leta od 1961 do 2005 pri petih različnih tipih tal (različne barve predstavljajo različno sposobnost zadrževanja vode v tleh).*

***Figure 13**: Number of days characterizied by reduced crop growth due to water shortage on different soil typs during the simulated period in years 1961-2005.*

4 ZAKLJUČEK

Prikazali smo osnovno upravljanje z modelom WOFOST. Potrebujemo precej vhodnih podatkov, a kadar vseh parametrov ne poznamo, lahko testiramo in poskušamo smiselno uporabiti parametre, ki jih ima model že definirane. Zavedati se moramo, da se ob tako velikem številu podatkov akumulirajo tudi napake leteh, kar nam lahko precej pokvari naše končne izračune.

Izračuni, ki smo jih prikazali, delujejo na prvi pogled zelo dobro, saj nakazujejo stvari kot smo jih pričakovali. Vendar se moramo zavedati, da smo uporabili že definirano vrsto koruze (ki ni nujno povsem primerna) in že definirana tla, ki se gotovo nekoliko razlikujejo od slovenskih.

Za Slovenijo bi bilo potrebno model dobro preizkusiti in kalibrirati. Tu se kot ponavadi zatakne pri pomanjkanju meritev. Čeprav zato ne moremo umerjati posameznih komponent, pa lahko kljub vsemu preverjamo končne rezultate. Potem bomo rezultate lahko dejansko uporabili, morda bolje pripravili svoje baze podatkov in se lotili napovedovanja pridelka.

5 LITERATURA

Boogaard, H. L., Diepen C. A. van, Rötter R. P., Cabrera J. M. C. A., Van Laar H. H. WOFOST 7.1; User's guide for the WOFOST 7.1 crop growth simulation model and WOFOST Control Center 1.5. Wageningen DLO Winand Staring Centre. Technical Document 52 (1998). 142 str.

Bouman, B.A.M., van Keulen, H., van Laar, H.H., Rabbinge, R., 1996. The 'School of de Wit' crop growth simulation models: a pedigree and historical overview. Agr. Syst. 52, 171–198.

Ceglar, A., Sušnik,, A., Črepinšek, Z., Kajfež-Bogataj, L., 2008 Uporaba modela IRRFIB pri analizi vodne bilance breskev in travinja v Sloveniji v obdobju 1991-2006. V: Hudina, M. (ur.). Zbornik referatov 2. Slovenskega sadjarskega kongresa z mednarodno udeležbo, Krško, 31. januar - 2. februar 2008. Ljubljana: Strokovno sadjarsko društvo Slovenije, 2008, str. 109-117

Diepen, C. A. van, Wolf, J., Keulen, H. van., 1989. WOFOST: a simulation model of crop production. Soil Use and Management, 5 (1989):16-24.

Eitzinger, J., M. Trnka, J. Hosch, Z. Zalud, M. Dubrovsky, 2004. Comparison of CERES, WOFOST and SWAP models in simulating soil water content during growing season under different soil conditions, Ecological Modelling, Vol. 171 (3): 223-246

Hooijer, A. A., Wal, T. van der, 1994. CGMS version 3.1, user manual. Technical document 15.1. SC-DLO, Wageningen (1994).

Hörmann, G., 1997: SIMPEL - ein einfaches, benutzerfreundliches Bodenwassermodell zum Einsatz in der Ausbildung. Deutsche Gewässerkundliche Mitteilungen 41(2):67-72,

Ipavec, T., Kajfež Bogataj, L., 2008. Možni vplivi podnebnih sprememb na vodno bilanc tal v Sloveniji = Potential climate change impacts on water balance in Slovenia. Acta agric. Slov., 2008, let. 91, št. 2, str. 427-441.

Kajfež-Bogataj, L., Sušnik, A. 2007. Challenges to agrometeorological risk management - regional perspectives: Europe. In: SIVAKUMAR, Mannava V.K. (Ed.), MOTHA, Raymond P. (Ed.). Managing weather and climate risks in agriculture. Springer Verlag; Berlin; Heildelberg; New York, 114-124.

Pogačar, T. in Kajfež Bogataj, L., 2009. WOFOST: model za napovedovanje pridelka – 1. del. Acta agric. Slov.. [Tiskana izd.], 2009, let. xx, št. x, str. Xxx

Reidsma, P. F. Ewert, H. Boogaard, K. van Diepen, 2009.Regional crop modelling in Europe: The impact of climatic conditions and farm characteristics on maize yields, Agricultural Systems, Vol. 100, Issues 1-3 : 51-60.

Supit, I., Goot, E. van der, 2008. Updated system description of the WOFOST crop growth simulation model., dokument za Evropsko komisijo. http://supit.net/main.php?q=aXRlbV9pZD01OQ== [Uporabljeno 23. 7. 2008].

Sušnik, A., 2006. Vodni primanjkljaj v Sloveniji in možni vplivi podnebnih sprememb. Magistrsko delo. Biotehniška fakulteta, Oddelek za agronomijo, Ljubljana, 147 s.

Todorović, M., R. Albrizio, L. Zivotic, M.-T. Abi Saab, C. Stockle, and P. Steduto. 2009. Assessment of AquaCrop, CropSyst, and WOFOST models in the simulation of sunflower growth under different water regimes. Agron. J. 101:509–521

Wegehenkel, M., 2000. Test of a modelling system for simulating water balances and plant growth using various different complex approaches, Ecological Modelling, Volume 129, (1): 39-64

Wolf, J. and C.A van Diepen, 1994. Effects of climate change on silage maize production potential in the European community, Agricultural and Forest Meteorology, Volume 71, Issues 1-2 : 33-60

CONTENT ANALYSIS OF THE PAPERS IN THE ACTA AGRICULTURAE SLOVENICA

VSEBINSKA OBDELAVA PRISPEVKOV V ACTA AGRICULTURAE SLOVENICA let. 93 št. 2

Tomaž BARTOL[a], Karmen STOPAR[b],

SUBJECT INDEX BY AGROVOC DESCRIPTORS
PREDMETNO KAZALO PO DESKRIPTORJIH AGROVOC

a Ph. D., M. Sc.., B. Sc., Jamnikarjeva 101, SI-1000 Ljubljana, P. O. Box 95

b B.Sc., M.Sc., ibid

SUBJECT INDEX BY AGRIS CATEGORY CODES
VSEBINSKO KAZALO PO SKUPINAH ZNANJA (PREDMETNIH KATEGORIJAH)

NAVODILA AVTORJEM

Prispevki

Sprejemamo izvirne znanstvene članke, predhodne objave in raziskovalne notice s področja agronomije, hortikulture, rastlinske biotehnologije, raziskave živil rastlinskega izvora, agrarne ekonomike in informatike ter s sorodnih področij v slovenskem, angleškem in nemškem jeziku, znanstveno pregledne članke samo po poprejšnjem dogovoru. Objavljamo prispevke, podane na simpozijih, ki niso bili v celoti objavljeni v zborniku simpozija. Če je prispevek del diplomske naloge, magistrskega ali doktorskega dela, navedemo to in tudi mentorja na dnu prve strani. Navedbe morajo biti v slovenskem in angleškem jeziku.

Pri prispevkih v slovenskem jeziku morajo biti preglednice, grafikoni, slike in priloge dvojezični, povsod je slovenščina na prvem mestu. Naslovi grafikonov in slik so pod njimi. Slike in grafikoni so v besedilu. Priloženi morajo biti tudi jasno označeni izvirniki slik. Na avtorjevo željo jih vračamo, s tem da je želja pisno sporočena ob oddaji gradiva in ponovno v teku 30 dni po izidu. Latinske izraze pišemo ležeče. V slovenščini uporabljamo decimalno vejico, v angleščini decimalno piko. Prispevki v angleščini morajo imeti povzetek v slovenščini in obratno. Prispevki v nemščini morajo imeti tudi povzetka v slovenščini in angleščini.

Prispevki naj bodo strnjeni, kratki, praviloma največ 12 strani. Uporabljamo Microsoft Word 97 (Windows); pisava Times New Roman, velikost strani 16,2 x 23,5 cm, velikost črk besedila 10, v obsežnih preglednicah je lahko 8; izvlečki in metode dela Arial velikost 8, levi in desni rob 2,1 cm, zgornji rob 1,3 cm, spodnji rob 1,6 cm,

Prva stran

Na prvi strani prispevka na desni strani označimo vrsto prispevka v slovenščini in angleščini, sledi naslov prispevka, pod njim avtorji. Ime avtorjev navedemo v polni obliki (ime in priimek). Vsak avtor naj bo označen z indeksom, ki ga navedemo takoj pod avtorji, in vsebuje polni naslov ustanove ter znanstveni in akademski naslov; vse v jeziku prispevka. Navedemo sedež ustanove, kjer avtor dela. Če je raziskava opravljena drugje, avtor navede tudi sedež te inštitucije. Na željo avtorjev bomo navedli naslov elektronske pošte.

Pod naslovi avtorjev je datum prispetja in datum sprejetja prispevka, ki ostaneta odprta. Sledi razumljiv in poveden izvleček z do 250 besedami. Vsebuje namen in metode dela, rezultate, razpravo in sklepe. Sledijo ključne besede.

Izvlečku v jeziku objave sledi naslov in izvleček s ključnimi besedami v drugem jeziku.

Viri

V besedilu navajamo v oklepaju avtorja in leto objave: (priimek, leto). Če sta avtorja dva, pišemo: (priimek in priimek, leto), če je avtorjev več, pišemo: (priimek in sod., leto). Sekundarni vir označimo z “navedeno v” ali “cv.”. Seznam virov je na koncu prispevka, neoštevilčen in v abecednem redu. Vire istega avtorja, objavljene v istem letu, razvrstimo kronološko z a, b, c. Primer: 1997a. Navajanje literature naj bo popolno: pri revijah letnik, leto, številka, strani; pri knjigah kraj, založba, leto, strani. Za naslove revij je dovoljena uradna okrajšava, za okrajšanimi besedami naj bodo vedno pike. Navedbo zaključimo s piko. Za primere upoštevajte objave v Zborniku BFUL.

Oddaja

Avtorji prispevke oddajo v dveh izvodih, enega z dvojnim razmakom med vrsticami in največ 35 vrst na strani, in na disketi. Priložijo tudi izjavo s podpisi vseh avtorjev, da avtorske pravice v celoti odstopajo reviji.

Prispevke recenziramo in lektoriramo. Praviloma pošljemo mnenje prvemu avtorju, po želji lahko tudi drugače. Če uredniki ali recenzenti predlagajo spremembe oz. izboljšave, vrne avtor popravljeno besedilo v 10 dneh v dveh izvodih, enega z dvojnim razmakom. Ko prvi avtor vnese še uredniške pripombe, odda popravljeno besedilo v enem izvodu in na disketi ter vrne izvod z uredniškimi popravki.

Prispevke sprejemamo vse leto.

NOTES FOR AUTHORS

Papers

We publish original scientific papers, preliminary communications and research statements on the subject of agronomy, horticulture, plant biotechnology, food technology of foods of plant origin, agricultural economics and informatics; in Slovenian, English and German languages while scientific reviews are published only upon agreement. Reports presented on conferences that were not published entirely in the conference reports can be published. If the paper is a part of diploma thesis, master of science thesis or dissertation, it should be indicated at the bottom of the front page as well as the name of the supervisor. All notes should be written in Slovenian and English language.

Papers in Slovenian language should have tables, graphs, figures and appendices in both languages, Slovenian language being the first. Titles of graphs and figures are below them. Figures and graphs are part of the text. Clearly marked origins of figures should be added; they can be returned if author desires. Latin expressions are written in italics. Decimal coma is used in Slovenian and decimal point in English. Papers in English should contain abstract in Slovenian and *vice versa*. Papers in German should contain abstracts in German, Slovenian and English.

The papers should be condensed, short and usually should not exceed 12 pages. Microsoft Word 97 (Windows) should be used, fonts Times New Roman, paper size 16.2 x 23.5 cm, font size in main text 10; in large tables size 8 could be used, abstracts and material and methods Arial size 8, right and left margin 2.1 cm, upper margin 1.3 cm and lower margin 1.6 cm.

First page

The type of the paper should be indicated on the first page on the right side in Slovenian and English language following by title of the paper and authors. Full names of authors are used (first name and surname). Each name of the author should have been added an index, which is put immediately after the author(s), and contains address of the institution and academic degree of the author, in the language of the paper. The address of the institution in which the author works is indicated. If the research was realised elsewhere, the author should name the headquarters of the institution. E-mail is optional.

Under the address of the authors some space for dates of arrival and acceptance for publishing should be left. A comprehensive and explicit abstract up to 250 words follows indicating the objective and methods of work, results, discussion and conclusions. Key words follow the abstract.

The abstract in the language of the paper is followed by the title, abstract and key words in another language.

References

References should be indicated in the text by giving author's name, with the year of publication in parentheses, e.g. (surname, year). If authors are two, the following form is used: (surname and surname, year). If authors are several, we use (surname *et al.*, year). Secondary literary sources should be quoted in the form "cited in". The references should be listed at the end of the paper in the alphabetical order and not numbered. If several papers by the same author and from the year are cited, a, b, c, etc. should be put after the year of the publication: e.g. 1997a. The following form of citation is used: for journals volume, year, number, page; for books place of publication, publisher, year, pages. For journals official abbreviated forms can be used. A full stop should be put after the abbreviated words. Each reference is also closed by a full stop. Examples are in previous issues.

Delivery

Papers should be delivered in two copies, double-spacing and 35 rows per page are required, and on a diskette. A statement signed by all authors transfers copyrights on the published article to the Journal.

Papers are reviewed and edited. First author receives a review. If reviewers suggest some corrections, the author should forward them in 10 days and in two copies, one of them with double space. After the first author considers the editor’s notes, the corrected paper should be sent in one copy and on a diskette.

Papers are accepted all year.