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A comparative study of rainfall erosivity for eastern and western Slovenia

Andrej CEGLAR[1], Zalika ČREPINŠEK[2], Vesna ZUPANC[3], Lučka KAJFEŽ-BOGATAJ[4]

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ABSTRACT

Climate in Slovenia has changed notably over the past century. As regional temperatures have risen, a more vigorous hydrologic cycle ensued; in many places the intensity of rainstorms has become greater. The seasonal distributions of rainfall has changed with significant implications for patterns of vegetation growth and hence for soil erosion. Due to predicted climate change increased frequency of extreme precipitation events can be expected during the time when soil is without plant cover and exposed to the erosive forces. In addition to ample daily and several day precipitation events, water erosion occurs with heavy rainfalls that last from couple of minutes to several hours. Overview of rainfall intensity index and rainfall erosivity, calculated with adapted USLE (universal soil loss equation) method, is given for three meteorological stations in Slovenia for period 1991-2006. Analyzed locations are situated on different climate areas with noticeable different rainfall regime at western (Bilje at Nova Gorica, Rateče) and eastern (Murska Sobota) part of Slovenia.

Key words: rainfall intensity, rainfall erosivity, soil water erosion, Slovenia

IZVLEČEK

PRIMERJAVA EROZIVNOSTI PADAVIN V ZAHODNI IN VZHODNI SLOVENIJI

Meritve dokazujejo, da erozija na kmetijskih zemljiščih nikakor ni zanemarljiva in je najintenzivnejša na njivskih površinah. Podnebje se je v Sloveniji že spremenilo, temperature zraka in tal naraščajo, spreminja pa se tudi vodni cikel. Opažamo sezonsko preporazdelitev padavin, daljše in intenzivnejše poletne suše, pa tudi naraščanje intenzivnosti nalivov, kar vse močno vpliva na erozijske procese. Zaradi predvidenih klimatskih sprememb lahko pričakujemo povečano pogostost in intenziteto ekstremnih padavin v času, ko so tla brez rastlinskega

[1] Assistant., B.Sc.Met., University of Ljubljana, Biotechnical Faculty, Department of Agronomy, p.p. 2995, SI-1001, Ljubljana, Slovenia, andrej.ceglar@bf.uni-lj.si

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

[3] Assistant, Ph. D., ibid

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

pokrova in izpostavljena erozivnim silam. Poleg obilnih dnevnih in večdnevnih padavin povzročajo vodno erozijo tudi nalivi, ki trajajo od nekaj minut do nekaj ur. Za tri meteorološke postaje (Bilje pri Novi Gorici, Murska Sobota in Rateče), ki so na klimatsko različnih območjih Slovenije, je za obdobje 1991-2006 podan pregled ekstremnih količin padavin v različnih časovnih intervalih, indeks intenzitete dnevnih padavin ter erozivnost padavin, izračunana po prirejeni metodi univerzalne enačbe izgube tal (USLE).

Ključne besede: intenziteta padavin, erozivnost padavin, vodna erozija tal, Slovenija

1 INTRODUCTION

Soil erosion is a natural process that can be accelerated dramatically following improper land use and/or management. Human activities can result in erosion rates that are many times greater than natural rates. World-wide, erosion is considered to be the most widespread and serious form of soil degradation (Mabit and Bernard, 2007). With the decrease of agricultural land use in Slovenia due to natural, social and economic factors, the amount of material lost to erosion has decreased in the last few decades. However, field measurements proved that erosion on agricultural land is by no means negligible and is most intensive on cultivated fields (Komac and Zorn, 2005). Since this category of land use is constantly decreasing due to abandonment of agricultural practice, the existent agricultural areas and prevention measures against soil degradation are of utmost importance.

Climate in Slovenia has changed during last decades, air and soil temperatures have increased significantly, and water cycle is altering (Bergant et al., 2002; Bergant and Kajfež-Bogataj, 2005). Rearrangement of precipitation patterns, more vigorous and frequent long-duration droughts and rise of rainfall intensity, that influence noticeable erosion processes, are noticed recently. Average annually relative variability of precipitation is high in all climatic regions. There have been no significant changes in the amount of precipitation in last decades in Slovenia, but the greater intensity of showers and a lower number of days with snow cover were found. Precipitation regime within seasons has also changed; precipitation maximum in autumn is more expressive (ARSO, 2006). Regional scenarios of future climate change predict more intensive precipitation in a changed precipitation regime, more frequent and intense extreme weather events such as droughts, floods and thunderstorms during the time when soil is without plant cover and exposed more to the erosive forces (Kajfež-Bogataj and Bergant, 2005).

The study of mechanisms of water erosion brings out two characteristics of precipitation, which make it the dominating causative factor of the phenomenon: intensity and depth of amount (which depends on the intensity-duration combination) (WMO, 1983). Hudson (1995) defined three attributes of rain pertaining to erosion. Intensity of a rain, generally expressed as mm/h, is usually highly variable during the course of a rainstorm. The time–pattern of rain intensity also differs from storm to storm, from place to place and from season to season. The second attribute is the duration of a rain, the length of time from the start of a rainstorm to its ending. This is often arbitrarily determined due to alternating periods of stronger and weaker rain intensity of rainstorm events. According to Kolbezen

(1979), rainfall with intensity exceeding 40 mm/day can cause erosion. As the third parameter Hudson (1995) states the energy of a rainstorm, being the summation of the kinetic energies of all raindrops falling on a unit area. Direct measurements of the kinetic energy are possible (Hillel, 1998), but not very common. Rainfall intensity is parameter measured on standard meteorological stations and data are easily available.

Rainfall kinetic energy (*E*) in particular has often been suggested as an indicator of rainfall erosivity, i.e. ability of rainfall to detach soil particles (van Dijk et al., 2002). Wischmeier and Smith (1978) used in their empirical model of Universal Soil Loss Equation (USLE) rainfall erosivity *R* for estimation of rainfall capability to cause the soil loss. *R* customarily represents the average annual accumulated storm erosivity index (*EI*) (Lal, 1994). *EI* is calculated with method, that includes the sum of kinetic energy of individual storm and it is multiplied with the maximum precipitation amount in any given 30 min interval of a storm. The erosive power of the rain is statistically best related to the total storm energy multiplied by the maximum 30-minute storm intensity (Wischmeier, 1959). *EI* represents the combined effect of direct measurements; raindrop impact and surface flow for rainfall induced soil erosion (Römkens et al., 2002). Mikoš et al. (2006) used RUSLE (Revised Universal Soil Loss Equation) to estimate the *EI* for the Alpine climate of north Slovenia. The RUSLE method for *EI* computation was also used by Zorn and Petan (2007) in measurements of interrill soil erosion under different land use in Slovenian Istria. The purpose of this study was to determine the seasonal variability of kinetic energy of rainfall using measured rainfall rates and intensities for three different climatic regions of Slovenia.

2 MATERIAL AND METHODS

Precipitation data (ARSO, 2007) measured in various time intervals (breakpoints) for the 1991 – 2006 period were analyzed for meteorological stations Bilje at Nova Gorica, Murska Sobota and Rateče, representing three different climatic regions (mediterranean, continental and alpine) in Slovenia. Meteorological definition of seasons was applied: winter from December to February, spring from March to May, summer from June to August and autumn from September to November.

2.1 Rainfall intensity index

Rainfall intensity index (*I*) was calculated as a relationship between rainfall amount and number of days with rainfall in a certain period (mm/h), calculated values were compared considering average values of the index for the 1961 – 1990.

2.2 Number of days with rainfall amount exceeding 40 mm

For the considered period we determined number of days with rainfall amount higher than 40 mm.

2.3 Rainfall erosivity

Rainfall erosivity of 30 min rainfall events (EI_{30}) was calculated using method by Wischmeier and Smith (1978) as

$$EI_{30} = E \cdot I_{30} \quad (1)$$

where I_{30} is the maximum 30 min rainfall intensity index, E is rainfall kinetic energy (MJ/ha), calculated after Brown and Foster (1987) and Yin et al. (2007) as

$$E = \sum_{r=1}^{k} 0{,}29\left[1 - 0{,}72 \cdot \exp\left(-0{,}05 i_r\right)\right]\left(\Delta V_r\right) \quad (2)$$

where each storm is divided into k parts, k-part representing the breakpoint resolution of the pluviograph resolution, which is 5 min in Slovenia (ARSO, 2007), i_r (mm/h) is rainfall intensity for the r-th part of the storm, ΔV_r (mm) is the rainfall depth for the r-th part of the storm and I_{30} is the maximum 30 min rainfall intensity index. It is calculated as:

$$I_{30} = \frac{P_{30}}{0{,}5h} \quad (3)$$

where P_{30} is the maximum 30 min rainfall depth (Yin et al., 2007).

Storm is defined arbitrarily as one rainfall event separated from another rainfall event by more than six hours with less than 1 mm of rain (Lal, 1994) with intensity higher than 1.25 mm/h (Römkens et al., 2002). Storms with less than 13 mm of rain generally do not cause appreciable soil loss, defined as greater than or equal to 0.02 t/ha. However, short, intense bursts of rainfall less than 13 mm often exceed the infiltration rate of a plot soil and cause measurable soil loss. Therefore rains of less than 13 mm but with a 15 min intensity of 25 mm/h or greater are included (Lal, 1994) in calculation. Monthly rainfall erosivity (EI_m), which was the average of all computed EI_{30} values over a certain month, was calculated after Shamshad et al. (2008) as

$$EI_m = \frac{1}{n}\sum_{j=1}^{n}\left[\sum_{k=1}^{m}\left(E \cdot I_{30}\right)_k\right] \quad (4)$$

where j is the index for the number of years used to compute the average, k is the index of the number of storms in each year, n is the number of years to obtain average EI, and m is the number of storms in each year.

3 RESULTS

3.1 Number of days with rainfall amount over 40 mm

Table 1 and Figure 1 show number of days with rainfall amount exceeding 40 mm. Daily rainfall amounts over 40 mm were most frequent in the autumn at all discussing meteorological stations; the number of such days was the highest in Rateče. Number of days with intense rainfall is significantly smaller in Murska Sobota compared to the other two rain gauge stations. For northeast Slovenia it is a general rule that extreme rainfall events are extremely rare. Extreme rainfall occurs between longer lasting storms or if there are several consecutive storms in the period of one measurement. In the studied 16 years period we measured 1 – 2 days with rainfall over 40 mm in Murska Sobota, whereas in Rateče and Bilje over 10 such days were measured annually.

Table 1: Number of days with rainfall amount over 40 mm for Bilje, Rateče and Murska Sobota (1991–2006).

Year	Bilje				Rateče				Murska Sobota			
	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut
1991	0	1	3	6	0	2	2	5	0	0	2	0
1992	2	3	2	5	2	2	0	4	0	0	0	2
1993	3	0	0	9	2	3	1	7	0	0	0	0
1994	2	3	0	3	0	2	1	2	1	0	1	1
1995	3	3	4	2	2	0	1	2	0	1	1	1
1996	3	3	2	4	0	4	4	8	0	0	1	1
1997	2	1	4	4	0	1	0	3	0	0	1	0
1998	1	2	4	10	0	3	1	9	0	0	1	4
1999	0	1	0	1	0	3	3	5	1	0	0	0
2000	1	3	2	9	0	2	2	11	0	0	0	0
2001	0	1	1	2	0	4	1	2	0	0	0	0
2002	1	0	6	3	0	2	1	6	0	0	0	0
2003	6	0	0	4	1	6	4	5	0	0	0	0
2004	1	0	1	5	1	7	2	4	0	0	1	0
2005	2	1	2	4	0	2	1	2	0	0	2	0
2006	2	1	1	1	2	1	1	2	0	0	2	0

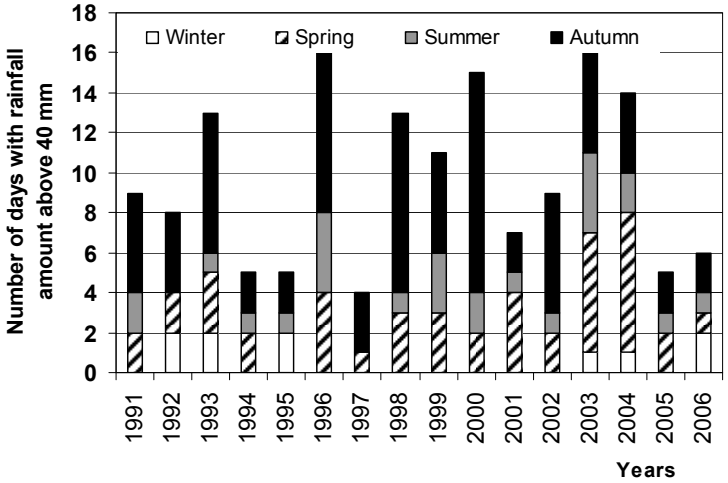


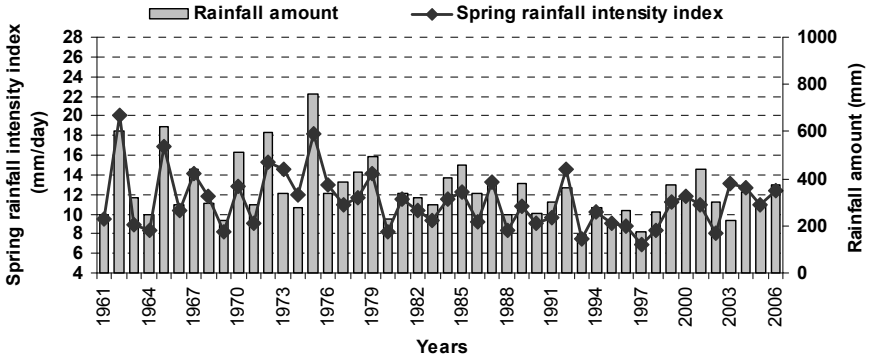
Figure 1: Number of days with rainfall amount over 40 mm for Rateče (1991 – 2006).

3.2 Rainfall Intensity Index

Rainfall intensity index and rainfall amount for spring and autumn in Rateče are shown on Figures 2a and 2b. Average spring rainfall amount was 377 mm for 1961-1990 and only 291 mm for 1991-2006, trend is significantly negative. Rainfall intensity index for spring also shows negative trend, which indicates less raining days. Maximum rainfall amount was measured during spring 1975 (760 mm), and maximum rainfall intensity index in 1962, when average rainy day had about 20 mm of rainfall. For Rateče maximum number of raining day was 42 in spring 1975 and

minimum number of raining days (17) was measured during spring 2003, which shows also the highest difference between rainfall amount and rainfall intensity index.

a)



b)

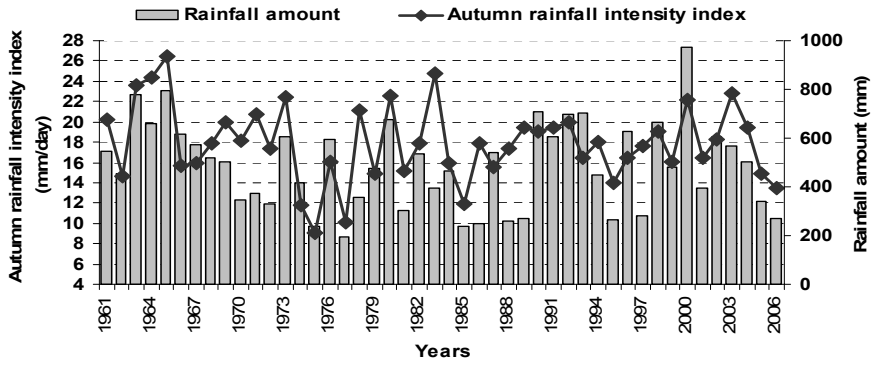
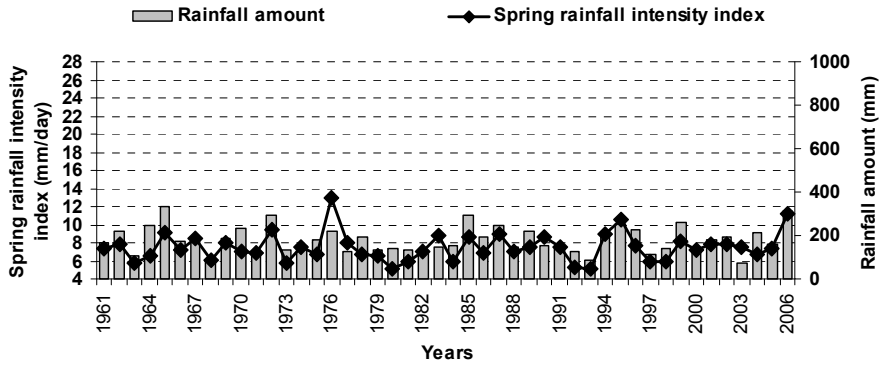


Figure 2: Rainfall intensity index and rainfall amount for spring (Fig. a) and autumn (Fig. b) for Rateče (1961-2006).

Average spring rainfall amount showed negative trend also in Bilje, but this is not the case for Murska Sobota (Fig. 3a, b; Fig. 4a, b). The wettest period in Rateče is autumn that is why rainfall intensity is correspondingly higher than in spring. Average autumn rainfall amount was 467 mm for 1961-1990 and 527 mm for 1991-2006 in Rateče, where the trends in the autumn rainfall amount and daily rainfall intensity are significantly positive ($\alpha = 0.05$). The wettest autumn was noticed in 2000 with 44 raining days, and the maximum rainfall intensity in 1965, when 800 mm of rainfall was measured in 30 raining days. The trends in the autumn rainfall amount are significantly positive also in Bilje and Murska Sobota.

a)



b)

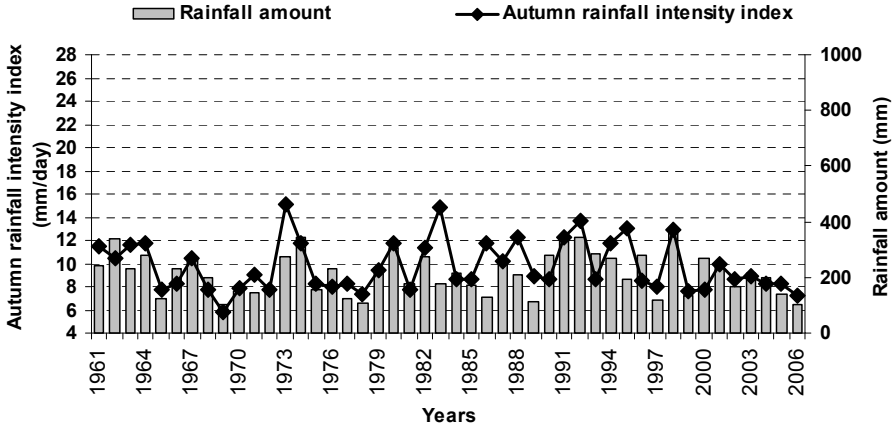
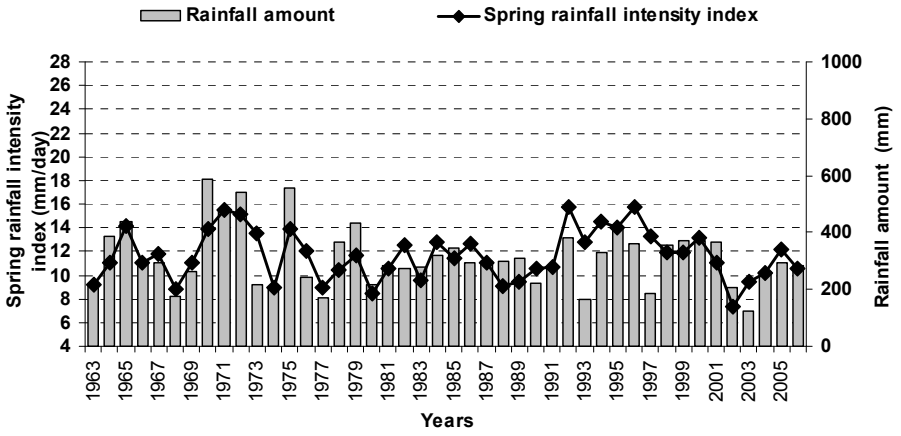


Figure 3: Rainfall intensity index and rainfall amount for spring (Fig. a) and autumn (Fig. b) for Murska Sobota (1961-2006).

a)



b)

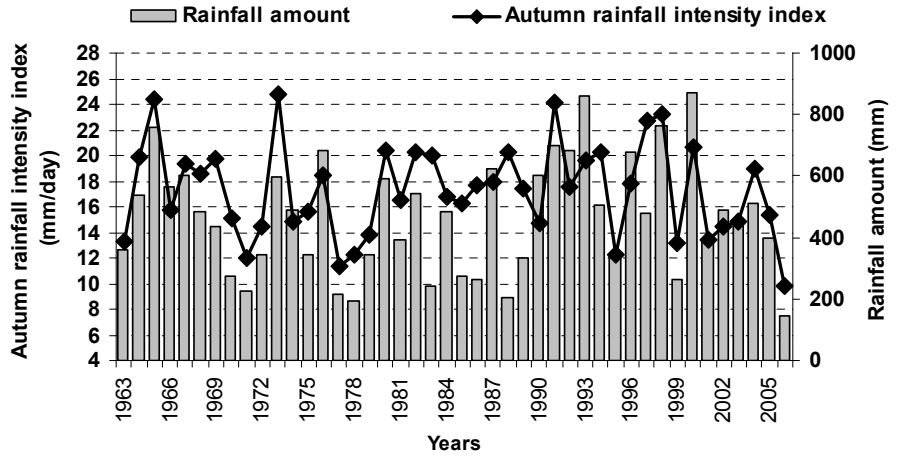


Figure 4: Rainfall intensity index and rainfall amount for spring (Fig. a) and autumn (Fig. b) for Bilje (1963-2006).

3.3 Rainfall erosivity

Monthly rainfall erosivity (EI_m) (eq. 4) for discussing stations is shown on the Figure 5. Winter months were not considered, as EI_m values for winter months are not reliable enough because snowfall causes higher error probability of the precipitation measurements. In the considered period, the highest EI_m was calculated for the rainfall station Bilje, where values from April to November exceed 100 $MJ \cdot ha^{-1} mm \cdot h^{-1}$. Ramos and Martinez-Casasnovas (2006) quoted that 28-55 % of rainfall amount is lost owing to surface flow at *EI* more than 140 $MJ \cdot ha^{-1} mm \cdot h^{-1}$, depending on characteristics of rainfall events. The highest deviation is estimated for September at Bilje (1280 $MJ \cdot ha^{-1} mm \cdot h^{-1}$). This high value was caused by a storm event on 14.9.1997, when rainfall amount

exceeded 50 mm in 30 minutes. At Murska Sobota and Rateče month with the highest EI_m was August (375 $MJ \cdot ha^{-1} mm \cdot h^{-1}$ and 508 $MJ \cdot ha^{-1} mm \cdot h^{-1}$). In early spring the rainfall erosivity is relatively low on all three stations. Zorn and Petan (2007) stated that a week in August 2005 with weekly *EI* of 1235.91 $MJ \cdot ha^{-1} mm \cdot h^{-1}$ contributed to 30 % of annually eroded material from olive orchard in maritime Slovenia, whereas in 2006 a storm event with *EI* of 650 $MJ \cdot ha^{-1} mm \cdot h^{-1}$ and max 30 min *I* of 25.5 mm, that contributed to 21 % of annual erosion on a field and 52 % on an overgrowing meadow, was measured.

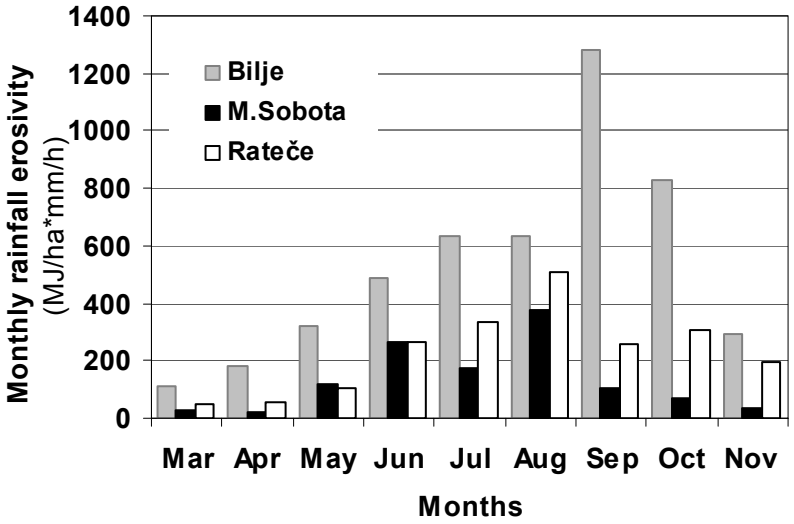


Figure 5: Monthly rainfall erosivity (EI_m) for Bilje, Murska Sobota and Rateče (1991–2006).

4 CONCLUSIONS

Extreme precipitation events are frequent in North-western Slovenia and extremely rare in North-eastern part, where extreme amounts of precipitation occur during longer lasting heavy storms or if there are several consecutive storms in the period of one measurement. Discussing agricultural areas are the most vulnerable in autumn, when number of days with rainfall amount exceeding 40 mm is the highest. This holds especially for Bilje, which has the highest EI_{30} in September and October. Monthly rainfall erosivity for Murska Sobota and Rateče was highest at the end of summer (August). Because of erosion, we lose yearly 5 – 10 mm of fertile agricultural soils (Mikoš and Zupanc, 2000), that amount loss to 80 – 100 t/ha/year. Due to predicted climate change increased frequency of extreme events can be expected, amongst also extreme precipitation events (Kajfež-Bogataj and Sušnik, 2007). Zorn and Petan (2007) showed that extreme events contribute to significant proportions of annual soil loss, which means that soil vulnerability to soil water erosion is likely to increase as well.

Rainfall intensity has increased recently at many locations in Slovenia (Sušnik et al., 2006). In spite of the fact, that direct measurements of soil erosion in Slovenia are very rare (Komac and Zorn, 2005; Suhadolc et al., 2006), agricultural practice shows that farmers are already forced to adapt to local conditions and that they are using different methods for prevention or reduction of soil erosion (selection of appropriate crops, grassing, no tillage, soil cultivation parallel with height contours, terracing, application of appropriate agricultural mechanisation, etc.). Erosion phenomena in Slovenia extend over 9000 km^2 or 44 % of the country's territory, mostly water erosion (Suhadolc et al., 2006). Soil is essentially a non-renewable resource with extremely slow formation and regeneration processes. Soil degradation rates can be potentially rapid and conditions are aggravated by climate change, therefore prevention, precaution and sustainable soil management should be at the core of soil protection policies.

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University of Ljubljana
Biotechnical Faculty
Department of Agronomy

Evaluation of different designs of temporary electric fence systems for the protection of maize against wild boar (*Sus scrofa* L., Mammalia, Suidae)

Matej VIDRIH[1], Stanislav TRDAN[2]

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ABSTRACT

Among free living animals in Slovenia, wild boar (*Sus scrofa*) damages agricultural land by rooting and primarily by directly feeding on open fields. In some areas of Slovenia this large wildlife animal causes more than 50% of all estimated damage to cultivated plants grown on arable and forage fields. Many techniques for controlling wild boar and preventing damage are known, but none of them is optimal. In a trial for preventing wild boar ingress into maize fields different designs of electric fence system were used. The trial in which we used an electric fence to prevent wild boar from entering a maize field was erected in the area of Šmihel near Postojna (Slovenia). We decided to erect the electric fence at the end of July, after the fertilization of the maize. The following designs of electric fence systems were used: 1) a plastic post with a polywire and two polytapes with spacings of 15, 15, and 30 cm between them; 2) a plastic post with polywire and a polytape with spacings 25 and 25 cm between them; 3) a steal post as a wire offset in an inverted L shape on which three screws on rod insulators were fixed at a height of 15, 30, and 55 cm from the ground. A polytape at a height of 30 cm acted as depth and it was a so-called three-dimensional design of electric fence. No breaks through fencing were observed until the harvesting time of the maize for silage, although boar tracks on the outside of the fenced field were observed. Damage to arable fields in the vicinity of the protected field was also recorded.

Key words: fencing, damage prevention, protective measures, crop, wildlife management

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

[2] Assist. Prof., Ph. D., Jamnikarjeva 101, SI-1111 Ljubljana

IZVLEČEK

UČINKOVITOST RAZLIČNIH POSTAVITEV ZAČASNE ELEKTROOGRAJE PRI VAROVANJU KORUZNIH NJIV PRED DIVJIM PRAŠIČEM (*Sus scrofa* L., Mammalia, Suidae)

Divji prašič (*Sus scrofa*) je v Sloveniji pomembna prostoživeča vrsta. Škodo povzroča na kmetijskih zemljiščih, in sicer z ritjem in neposrednim hranjenjem. Na nekaterih območjih Slovenije predstavlja škoda po divjem prašiču več kot 50 % vse s strani kmetov prijavljene škode. Ta je vezana tako na gojene kot samonikle rastline, namenjene za živež ali živalsko krmo. Za preprečevanje škode po divjem prašiču na poljščinah je znanih več načinov; ti pogosto niso dovolj učinkoviti, so predragi ali moteči pri oskrbi poljščin. Za preprečevanje vdora divjega prašiča na koruzno njivo smo v našem poskusu uporabili začasno elektroograjo. Na območju Šmihela pri Postojni je bil izveden poskus varovanja posevka (silažne) koruze pred divjim prašičem od konca julija (zadnje dognojevanje) do spravila pridelka. Uporabljene so bile naslednje tri postavitve začasne elektroograje: 1) plastični količek z elektrovrvico in dvema elektrotrakoma z razmiki 15,15 in 30 cm, 2) plastični količek z elektrovrvico in elektrotrakom z razmikoma 25 in 25 cm, in 3) železni količek v obliki distančnika (številke 7) in višino vrvice/trakov 15, 30 in 55 cm. Elektrotrak pri slednji postavitvi je na višini 30 cm deloval kot globina oziroma tretja dimenzija. Med poskusom vse do spravila pridelka ni prišlo do vdora divjih prašičev na ograjeni del zemljišča. Na zunanji strani ograje so bile opazne sledi divjega prašiča. Škoda zaradi preučevanega škodljivca je bila ugotovljena na sosednjih njivah, ki niso bile varovane.

Ključne besede: ograjevanje, preprečevanje škode, varstveni ukrepi, kmetijske rastline, upravljanje z divjadjo

1 INTRODUCTION

In the opinion of farmers and hunters, wild boar (*Sus scrofa* L., Mammalia, Suidae) is the most damaging wildlife species, which in some areas of Europe and Slovenia cause more than 50 % of the estimated damage to plants. Feeding and other activities of wild boar are very important reduction factors regarding the quantity and quality of cultivated and wild-growing plants (Schley and Roper, 2003). The damage which is done by wild boar on agricultural land often leads to disagreements between representatives of the local hunting association and farmers. The state is responsible for damage if the damage is spread over more than 50 % of agricultural land and for damage which does not exceed this share, the regional hunting association which manages the hunting grounds where damage is noticed is obliged to pay compensation. In the opinion of many people, the solution lies culling a greater number of this wildlife species, which is more and more widespread in Europe. But experts are unanimous that it is not possible to improve the present situation only by means of harvesting.

Currently wild boar has colonized 55 % of the territory of Slovenia and its potential habitat comprises 67 % of the country. The distribution and number of wild boar will likely further increase, particularly if the present trends of environmental changes continue (increasing temperature, woodiness, reduction of coniferous trees) (Jerina, 2006). With regard to the mentioned problems, the question is raised of how farmers can protect their arable fields in a way which is friendy to animals, nature, and people, and which is effective and reliable enough and also economically justified since silage and grain maize represent the greater part of the feedstuffs on

dairy and beef farms in Slovenia (Orešnik and Logar, 2001). Thus the yield loss of maize represents an additional problem to stock farmers, which forces them to purchase supplemental feed or diminishes the number of animals on their farms. Both solutions burden the farm budget and threaten its existence, even more so if the damage occurs over several consecutive years.

Until now farmers have used many different measures for damage prevention on cultivated or wild-growing plants due to wildlife species, namely conventional non-electric wire (barbed, smooth, high tensile, woven) fences, either with different repellents (Boh et al. 1999) or intensive harvest throughout the year. More recently farmers have started to erect electric fences, which are a known tool for keeping farm animals enclosed while grazing (McKillop and Sibly, 1988) and which has shown promising results regarding preventing wild boar from entering fields (McKillop *et al.*, 1992; Santilli and Stella, 2006). But the construction of permanent electric fences as one of a group of electric fences on small arable fields was not suitable with regard to other activities such as crop rotation, the migration of wildlife species during the non-vegetative period, and high building and maintenance costs.

With the aim of searching for proper solutions to preventing damage, in the year 2005 in an area of central Slovenia, we conducted a field experiment in which we tested different designs of temporary electric fencing in order to protect maize fields against wild boar. In the experiment we wanted to prove the effectiveness of temporary electric fencing with the intention to reduce damage due to wild boar. Additionally, we wanted to determine which such fence construction would be most cost effective and at the same time effective in preventing damage caused by wild boar.

2 MATERIALS AND METHODS

2.1 The hunting ground

The hunting ground, which is managed by the Hrenovice Regional Hunting Association, is a part of the Western High Karst hunting territory and it constitutes a border part of the territory. The area which is covered by Hrenovice Regional Hunting Association belongs to the Postojna administrative unit (45°47'N, 14°13'E, 542 m above sea level). The total area came to 4.915 ha of which 4.786 ha is intended for hunting activities. The hunting ground includes a self-contained population area of red deer (*Cervus elaphus* L.), chamois (*Rupicapra rupicapra* L.), mouflon (*Ovis* [*orientalis*] *musimon* Gmelin) and is the western part of the central population area of large carnivores in Slovenia.

2.2 The field experiment

We set up a field experiment in 2005 near the village Šmihel pod Nanosom (central Slovenia, 45°78' N, 14°22E', 581 m above sea level). We invited the Hrenovice Regional Hunting Association and a farmer whose arable fields were damaged in previous years by wild boar to participate. Namely, in the vicinity of the farmer's fields a stream, marsh, and more groves are located, which all offer wild boar good shelter.

In the experiment we fenced in an arable field on which wild boar have caused damage for many years. The size of the fenced in area was 12 hectares and an area of 1.5 hectares was unfenced and served as a control in the experiment. The damage which occurred on the latter area was evidence of wild boar presence in the observed terrain. Furthermore, damage to the meadows which surround the tested field provided evidence of wild boar presence.

In order to determine the most appropriate temporary electric fence design we tested three types of construction: 1) a plastic post with a polywire and two polytapes with spacings of 15, 15, and 30 cm between them as a three-strand fence design; 2) a plastic post with polywire and a polytape with spacings 25 and 25 cm between them as a two-strand fence design; 3) a steal post as a wire offset in an inverted L shape on which three screws on rod insulators were fixed at a height of 15, 30, and 55 cm from the ground as a three-strand offset fence design (Figure 1).

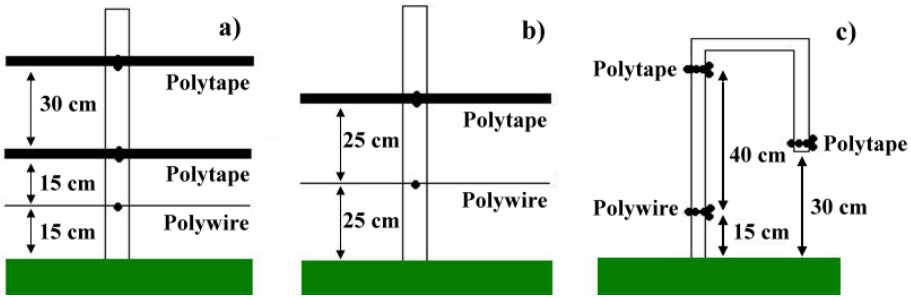

Figure 1: The three fence designs used in the experiment: a) a fence with two polytapes and a polywire, b) a fence with a polytape and a polywire (both front view), and c) an offset inverted L shape fence with polytapes and a polywire (side view).

All lines were positively charged (hot) and were white to increase the likelihood of wild boar seeing them at night. The fences were powered by a Horizont energizer of 6 joules of stored energy, run on a battery of 55 Ah, as this was enough to maintain a sufficient voltage of 5.5 kV in the strands. On the first strainer post we installed a lightning diverter because lightning can damage an energizer if it strikes the fence. On the fence we also mounted a livelite, a warning device that warns of fence operation, in this case as a flash each time a pulse of more than 2.5 kV was sent from the energizer to the wires. Shorting-out of the fence by vegetation growth was prevented, when necessary, by trimming along the fence line to create a clear strip about 50 cm wide. Fence maintenance and voltage checks were conducted weekly and batteries replaced when voltage fell below 3.5 kV.

We erected the electric fence designs on July 23 and this is also the date of our observations and at that time the maize was in the early milk stage. From a starting point we erected in both directions of the field all three fence designs. We conducted observations in 5 day intervals while checking if the fence voltage was adequate; if it was not, we changed the battery and wild boar tracks could be observed. We concluded the experiment when the owner harvested the crop for the silage (October 18). As an indication of wild boar presence in the vicinity of our experimental site, during the season a great deal of damage was caused to nearby meadows.

3 RESULTS

3.1 The activity of wild boar on the plot and in the vicinity

On the July 9 2005 we observed the first damage due to wild boar on a wheat field in the near vicinity of the experimental field. The field was protected with an acoustic diverting mechanism, but it looked like it did not work. On August 11 wild boar entered the maize field. According to the tracks, only piglets crossed the fence for a short time and sows stayed on the other side because there was no break in the fence, otherwise they would have followed the young due to maternal instinct.

We observed extensive damage to the grassland in the vicinity of the electric fence on August 15. Wild boar tracks were not found near the fence, but around 6 m^2 of

grass sward was rooted. On the September 2 we noticed damage on the maize field which served as a test field, and so was not protected. The extent of the damage to the maize field was 10 m^2. Also a week later we noticed a significant amount of further damage to the unprotected surrounding maize fields and to the grassland and it lasted until the conclusion of the experiment. The only time wild boar tried to enter the maize field protected by electric fencing was on September 16. This happened on the section of two-strand fence design.

3.2 Material used and a cost comparison of the three electric fence designs

On the basis of the known facts regarding the differences between permanent and temporary electric fences (Conover, 2002) and the advantages which temporary electric fence designs have (Huygens and Hayashi, 1999), when erecting fencing around arable fields in the growing season, we wanted to further reduce the cost of erecting the latter by opting for a third design. Table 1 presents the type of material and its quantity and costs per hectare. The materials ranged from 87 to 110 euros per hectare or from 22 to 27 euro cents per meter, not including the price of the energizer. The third (three-strand offset) electric fence design appeared to be the least expensive also because a part of it can be manufactured at a farm workshop, i.e. steel posts and it can be more durable.

Table 1: Cost calculation of three temporary fence designs, without energizer

	three-strand fence		two-strand fence		three-strand offset fence	
Material	Quantity	EUR	Quantity	EUR	Quantity	EUR
Polywire	400 m	9.58	400 m	9.58	400 m	9.58
Polytape (12.5 mm)	800 m	38.36	400 m	19.18	800 m	38.36
Plastic post	50 pieces	62.07	50 pieces	62.07	-	-
Steel post	-	-	-		50 pieces	24.24
Screw-on rod insulator	-	-	-		150 pieces	15.00
Total per ha (EUR)		110.20		90.83		87.19

4 DISCUSSION

During the experiment, no wild boar successfully raided a fenced-in field of maize. All three temporary electric fence designs were 100 % successful in keeping wild boar from entering the maize field. Others have reported approximately similar results in studies and experiments when testing electric fences to exclude other wildlife species - Asiatic black bear (*Ursus thibetanus* G. Cuvier) (Huygens and Hayashi, 1999), Eurasian badger (*Meles meles* L.) (Poole *et al.*, 2002), and red deer (Gasparik *et al.*, 1993) from crop fields. However, the 100 % fence effectiveness in our case can also be explained by the possibility that the wild boar bypassed our experimental field and found food on other unprotected crop fields, which also seemed to be the case in our study. We expected the third design (Goddard *et al.*, 2001) to be the most efficient, as beside the characteristics of the former two designs

it also has an additional characteristic, i.e. a third dimension (depth). And it has been known for some time (VerCauteren *et al.*, 2006) that this fence design can reduce the possibility of all other wildlife species entering so-protected fields.

When erecting any kind of electric fence it is important to pay attention to some measures and also to keep the fence in good condition during the whole period of field protection. In particular, an opening between the ground and the first wire can present a chance for an animal to enter the field. As stated by those who have to a broader extent investigated damage on farmland caused by wildlife species which root into the ground (Geisser and Reyer, 2004; Herrero *et al.*, 2006) than was carried out here, the methods which attempt to reduce the damage are intensive harvesting, supplemental food offers in the forest, and the installation of electric fences (Geisser and Reyer, 2004). Our experiment in central Slovenia verified that the last method works. The next step to have better control over damage caused by wild boar is to upgrade the three-strand offset design of the temporary electric fencing.

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Agrovoc descriptors: nematoda; insect nematodes; new species; fauna; population structure; identification; population distribution; biological control

Agris category code: H10

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University of Ljubljana
Biotechnical Faculty
Department of Agronomy

Entomopathogenic nematode *Steinernema carpocapsae* (Weiser) (Rhabditida: Steinernematidae), a new member of Slovenian fauna

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

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ABSTRACT

In April 2008, 120 soil samples from 24 locations were collected in Gorenjska, Notranjska and Primorska regions as well as in Ljubljansko barje. The presence of entomopathogenic nematodes was confirmed in 9 samples from 6 locations. Only the sample C101, which was taken in the village Svino in the area of Breginjski kot (western part of Slovenia, the vicinity of Italian border), was sent to genetic analysis. Molecular biological analysis was proved the identity of the sample with the species *Steinernema carpocapsae* (Weiser). This was the first record of *Steinernema carpocapsae* in Slovenia. In preceding researches on the fauna of entomopathogenic nematodes in Slovenia, which started in 2007, we already established the occurrence of *Steinernema affine* (Bovien) and *Steinernema feltiae* (Filipjev).

Key words: entomopathogenic nematodes, Slovenia, *Steinernema carpocapsae*, biological control

IZVLEČEK

ENTOMOPATOGENA OGORČICA *Steinernema carpocapsae* (Weiser) (Rhabditida: Steinernematidae), NOVI PREDSTAVNIK SLOVENSKE FAVNE

V aprilu 2008 smo na območju Gorenjske, Notranjske, Primorske in Ljubljanskega barja na 24 lokacijah nabrali 120 talnih vzorcev. Zastopanost entomopatogenih ogorčic smo ugotovili v 9

[1] Young researcher, B. Sc., 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] Assist. Prof., Ph. D, Jamnikarjeva 101, SI-1111 Ljubljana

vzorcih s 6 lokacij. V nadaljnjo genetsko analizo smo poslali le vzorec C101. Ta je bil odvzet v vasi Svino na območju Breginjskega kota (skrajni zahod Slovenije na meji z Italijo). Z molekulsko analizo smo identificirali vrsto *Steinernema carpocapsae* (Weiser). Gre za prvo odkritje omenjene vrste entomopatogene ogorčice pri nas. V predhodnjih raziskavah preučevanja faune entomopatogenih ogorčic v Sloveniji, ki potekajo od leta 2007, smo ugotovili zastopanost vrst *Steinernema affine* (Bovien) in *Steinernema feltiae* (Filipjev).

Ključne besede: entomopatogene ogorčice, Slovenija, *Steinernema carpocapsae*, biotično varstvo

1 INTRODUCTION

It is well known that entomopathogenic nematodes, which are classified into Steinernematidae and Heterorhabditidae families, have great potential as biological control agents in plant protection (Klein, 1990). Their activity against different pest insects is already well studied (Kaya in Gaugler, 1993; Ebssa, 2005). Entomopathogenic nematodes are soil organisms, which live with bacteria in symbiotic-mutualistic relationship. For the first time their importance in biological control was discovered in the United States of America in the thirties of past century (Laznik in Trdan, 2008).

At the time of the first record of entomopathogenic nematodes, a hypothesis was raised that these agents by themselves cause death of attacked insects (Gaugler in Kaya, 1990). In 1937, Bovien first mentioned a possibility of symbiotic bacteria to live in mutualistic relationship with entomopathogenic nematodes. His hypothesis was confirmed in 1955 by Dutky and Weiser (Weiser, 1955). In 1982, Boemare gave a proof for production of toxic substances by the nematodes from genus *Steinernema*. These substances have negative influence on the immune system of infected insect and could also cause death of the host without the presence of symbiotic bacteria. Until now no evidence was given that nematodes from genus *Heterorhabditis* are capable for their own production of toxins, which would be able to influence a poor viability of invaded insects (Klein, 1990).

It is discussed upon symbiotic-mutualistic relationship because nematodes provide shelter and protection for bacteria in an exchange for killing the attacked insects. Latter, bacteria also produce antibiotics, which prevent the development of intra- and interspecific competitors, 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 in Koppenhöfer, 1999). Nematodes from the family Steinernematidae live in symbiosis with bacteria from genus *Xenorhabdus*, meanwhile it is well know for the ones from the family Heterorhabditidae that they have the same association with bacteria from genus *Photorhabdus* (Forst *et al*., 1997).

In Slovenia, momentarily only entomopathogenic nematode *Steinernema feltiae* has a status of indigenous species (MAFF, 2008); 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. The strain C101, 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 April 2008, we examined 120 soil samples from 24 different locations on the occurrence of EPNs in Slovenia. The soil samples, four from each region, were taken in Gorenjska, Notranjska and Primorska region as well as in Ljubljansko barje. 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 9 soil samples of 6 locations. Only 1 positive sample, C101 (taken on the arable field near village Svino in Breginjski kot (NW Slovenia, 46°14′N, 13°33′E, 285 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 nematodes 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). Reisolated sample was sequenced in the laboratory of Biological Research Centre in Szeged, Hungary. The sequence was submitted into GenBank public database (Accession Number: EU914854). Sample DNA sequence was compared to sequences of species *Steinernema* 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 *Steinernema carpocapsae*: GenBank Accession No. AY171282 and EU122951 (Spiridonov *et al*., 2004) (Fig. 1).

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9833      1    GGAA-GA-CATTATTGAGCTAATATT-TTCC-TTTTCT-ATCAAGT-
TTTCGCTGCTCGT  54
AY171282  1                 ............-....-....-.A.......-
........T....  43
EU122951  103  ....G..T................-....-....-.A.......-
........T....  158
AY171280  1                 ..........-..C....A....-A-
....G..C...-....T....  43

9833      55   TTCTAAGCTTTAACTTGACCTC-
TAACGGCTTTGAAAGGTTTCTACAGATGTTTGGAGCA  113
AY171282  44   ................T...-
.....................................  102
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EU122951  159  ................-G...-
.................................  216
AY171280  44   ........A..G...C..--..-.---
T........T........T...C.........  97

9833      114  GTTG-TAT-GAGCGTGACTGTGCTGATGAA-
CATTGTACATTGTTATCTAAGC-GTTTCG  169
AY171282  103  ....-...-....................-
.....................-......  158
EU122951  217  ....-...-....................-
.....................-......  272
AY171280  98   ..CA-.-.CA...........G....-..G.G..T...T...C.-
.-.---..A.-....  149

9833      170  AT-
GTTTCTAGAATGCTTAGTGATGAGAATTAAAGAGGTCTGCTGACTCGCCATTCTTTG  228
AY171282  159  ..-
.....................................................  217
EU122951  273  ..-
.....................................................  331
AY171280  150  -
.C......T..........C..............A..................-....
207

9833      229
ATTGCTAACAAAAACGTTTTGTTTCGATAATTGTGTCACTCGTTGATGCATTTTTTAAA-
287
AY171282  218
.....................................................T-
276
EU122951  332  ..............-......G..-.......-.....-
...........-.....-..-  384
AY171280  208
.....................T...TT.........T......A....A..C..T-
266

9833      288  NATC-
AAGTCTTATCGGTGGATCACTCGGTTCGTAGGTCGATGAAAAACGGGGCAAAAAC  346
AY171282  277  T...-
.....................................................  335
EU122951  385  TT..-......A.............................-
..........-.....  441
AY171280  267  T...-
.....................................................  325

9833      347
CGTTATTTGGCGTGAATTGCAGACATATTGAGCGCTAAAATTTTGAACGCAAATGGCACT
406
AY171282  336
.....................................................
395
EU122951  442  .....................-.............-
.................  499
```

```
AY171280  326
..........................................................
385

9833      407
AACAGGTTTTTATCTGTTAGTATGTTCAATTGAGGGTCTTTTGACTAGAATCTGGCAATC
466
AY171282  396
..........................................................
455
EU122951  500  ......-
.....................................................  558
AY171280  386  ......G..--
.............................................  443

9833      467  CGCTGTGATTGCTTTTTCGGTAA-GCTACTTTGCT-T-T--T-----
--G---T-G--AA  508
AY171282  456  G.....................-..........-.-.--.-----
--.---.-.--..  497
EU122951  559  G.....................-..........-.-.--.-----
--.---.-.--..  600
AY171280  444  G............C.....A..-...........-.-AG.-----
--.---.A.TG..  490

9833      509
GTACCTTTTCNGTATGGCTATTTGATTGTCTAACGGATGTCTGGCTAGCTGCTTCTTTGC
568
AY171282  498
..........G.....................T.................T........
557
EU122951  601
..........G.....................T.................T........
660
AY171280  491
..........G.................A...T..........T......T........
550

9833      569  TAGACGTCTGCAATCATTCGGCATTGCGTAGTGTTTGATTAAT-
GGTTTAGCGCGTTTCT  627
AY171282  558  ................T.......................-
..............  616
EU122951  661  ................T.......................-
..............  719
AY171280  551
................T...T.............AC...A....-..........
609

9833      628
TGCTAACTGACTTTTACACAAGCAAGTGTAATACGTTTCTTAAAGTCAGCTCATTAATCA
687
AY171282  617
..........................................................
676
```

```
EU122951  720
..........................................................
779
AY171280  610
..............G..............T........G.........-....T...
668

9833      688  ATGTGGTTTTCTGACTTGATTTGTC-
GGTCAATTGTGCTATGCTCTG-CTAATCTTTTCG  745
AY171282  677  ........................-
.....................-...........  734
EU122951  780  ........................-
.....................-...........  837
AY171280  669  ..T............C.C......-
...TT.C.............T.-..........  726

9833      746  AACT-AGACCTCAATT-GAGC  764
AY171282  735  ....-.......           745
EU122951  838  ....-...........T....  857
AY171280  727  ....-.........         739
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Figure 1: Multiple sequence alignment of the ITS rDNA region (including partial fragments of the 18S and 28S rRNA genes) of 4 *Steinernema* species. Code 9833 correspond to the Slovenian isolate of *Steinernema carpocapsae* (C101). Codes AY171282 and EU122951 are *Steinernema carpocapsae* strains from Russia and Iran, respectively. Code AY171280 correspond to *Steinernema tami* strain from Vietnam.

4 DISCUSSION

Genetic studies proved that the nematode species is *Steinernema carpocapsae* (Weiser, 1955) (Fig. 1). The ITS1-5.8S-ITS2 region, including the partial 18S and 28S rRNA genes (flanked by above primers) of Slovenian isolate C101 is 746 bp long. BLAST searches (Altschul *et al*., 1990) in GenBank showed that Slovenian isolate C101 (Fig. 2) has a high similarity (99 %) with those sequences available for *S. carpocapsae* populations (e.g. accession numbers AY171282 and EU122951). Sequence of other species from *carpocapsae* group, namely *S. tami* was obtained from GenBank searches that exhibited a lesser degree of similarity with the Slovenian isolate and other *S. carpocapsae* populations (e.g. accesion number AY171280) (Fig. 1). The present study constitutes the first report of *S. carpocapsae* in Slovenia. *S. carpocapsae* has a wide distribution in temperate regions, being one of the most common species found in Europe (overall in 15 countries), and in many other parts of the world (for a detailed EPN species distribution see Hominick, 2002).

We can place mentioned species into »*carpocapsae* group« of nematodes from genus *Steinernema* (Nguyen, 2006); for infective juveniles it is known that they are less than 600 µm long (Fig. 2). This nematode lives in symbiosis with bacterium *Xenorhabdus nematophila* (Akhurst, 1980). The nematode was first recorded in

1955. *Steinernema carpocapsae* is the most studied, available, and versatile of all entomopathogenic nematodes (Gaugler, 2002).

Figure 2: Entomopathogenic nematode *Steinernema carpocapsae* (strain C101).

Important attributes include ease of mass production and ability to formulate in a partially desiccated state that provides several months of room-temperature shelf-life (Gaugler et al., 2002). Particularly effective against lepidopterous larvae, including various webworms, cutworms, armyworms, girdlers, and wood-borers (Georgis *et al*., 1991). This species is a classic sit-and-wait or "ambush" forager, standing on its tail in an upright position near the soil surface and attaching to passing hosts (Campbell *et al*., 2003). Consequently, *S. carpocapsae* tends to be most effective when applied against highly mobile surface-adapted insects. Highly responsive to carbon dioxide once a host has been contacted, the spiracles are a key portal of host entry. It is most effective at temperatures ranging from 22 to 28 °C (Georgis *et al*., 1991).

In Europe, the occurrence of *S. carpocapsae* was up to now confirmed in Austria, Bulgaria, Czech Republic, France, Germany, Great Britain, Italy, Norway, Poland, Portugal, Slovakia, Spain, Sweden and Switzerland (Hominick, 2002). Among entomopathogenic nematodes only *Steinernema feltiae* has a status of indigenous species for the time being (Laznik et al., 2008; MAFF, 2008). While in Slovenia, the effectiveness of this species was already tested in the field experiment (Laznik, 2008, unpubl.), this was yet not the case for *S. carpocapsae*. When also the latter species 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 these insect pests against 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

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Epicuticular wax content in the leaves of cabbage (*Brassica oleracea* L. var. *capitata*) as a mechanical barrier against three insect pests

Dragan ŽNIDARČIČ[1], Nevenka VALIČ[2], Stanislav TRDAN[3]

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ABSTRACT

Flea beetles (*Phyllotreta* spp.), cabbage stink bugs (*Eurydema ventrale*) and onion thrips (*Thrips tabaci*) cause significant economic problems to cabbage growers in Slovenia. The aim of our study was to assess the potential effect of the epicuticular wax on leaves as defence mechanism against these three cabbage pests. The impact of epicuticular wax content in relation to damage levels of cabbage pests was studied under field conditions at the Experimental Field of the Biotechnical Faculty in Ljubljana on 12 cabbage cultivars (*Brassica oleracea* L. var. *capitata*). These insect pests showed weak preference on cabbage heads with high epicuticular wax. There was a strong negative relationship between epicuticular wax content and the level of plants infested (r^2 = –0.8399 for flea beetles, r^2 = –0.7413 for cabbage stink bugs and r^2 = –0.7042 for onion thrips). The cv.'Holandsko pozno rdeče', showed itself to be the most resistant to the cabbage stink bugs and onion thrips, while cv. 'Red Dinasty' was the most resistant against flea beetles.

Key words: cabbage, *Brassica oleracea*, flea beetles, *Phyllotreta* spp., cabbage stink bugs, *Eurydema ventrale*, onion thrips, *Thrips tabaci*, epicuticular wax, damage

IZVLEČEK

VSEBNOST EPIKUTIKULARNIH VOSKOV NA LISTIH ZELJA (*Brassica oleracea* L. var. *capitata*) KOT MEHANSKA OVIRA PRED NAPADOM TREH ŠKODLJIVIH ŽUŽELK

Kapusov bolhač (*Phyllotreta* spp.), pisana stenica (*Eurydema ventrale*) in tobakov resar (*Thrips tabaci*), povzročajo gospodarsko pomembne težave pridelovalcem zelja v Sloveniji. Cilj naše raziskave je bil oceniti potencialni učinek epikutikularnega voska na listih kot obrambnega mehanizma proti naštetim škodljivcem. Vpliv količine epikutikularnega voska na poškodbe, ki jih povzročajo škodljivci, smo proučevali na 12 kultivarjih zelja (*Brassica oleracea* L. var. *capitata*), vzgojenih na Laboratorijskem polju Biotehniške fakultete v Ljubljani. Škodljivci so pokazal majhno preferenco do zeljnih glav, ki imajo visoko vsebnost epikutikularnega voska. Med koncentracijo epikutikularnega voska in poškodovanimi listi je bila namreč ugotovljena močno

[1] M. Sc. Agr., Biotechnical Faculty, University of Ljubljana, SI-1111 Ljubljana, Jamnikarjeva 101; E-mail: dragan.znidarcic@bf.uni-lj.si

[2] B. Sc., ibid

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

značilna negativna povezava (r^2 = –0.8399 za kapusovega bolhača, r^2 = –0.7413 za pisano stenico in r^2 = –0.7042 za tobakovega resarja). Cv.'Holandsko pozno rdeče', se je pokazal kot najbolj odporen kultivar ob napadu tobakovega resarja in pisane stenice, medtem, ko je bil cv. 'Red Dinasty' najmanj odporen proti napadu kapusovega bolhača.

Ključne besede: zelje, *Brassica oleracea*, kapusov bolhač, *Phyllotreta* spp., pisana stenica, *Eurydema ventrale*, tobakov resar, *Thrips tabaci*, epikutikularni vosek, poškodbe

INTRODUCTION

Cabbage (*Brassica oleracea* L. var. *capitata*) is an important vegetable crop grown in many countries in the world. By far the greatest commercial production of cabbage takes place in Slovenia (Žnidarčič et al., 2007a; Žnidarčič et al., 2007b). The majority of the insect pests on cabbage which are economically important belong to five orders: Lepidoptera, Homoptera, Coleoptera (Stoner, 1992), Thysanoptera (Trdan et al., 2005) and Heteroptera (Trdan et al., 2006). These insect pests can cause damage directly by chewing or sucking sap from leaves and roots or indirectly by transmitting diseases. Moreover, they can also lower the value of the cabbage heads by causing unsightliness such as the presence of insect cast skins and detritus.

Up to a few years ago cabbage growers have relied heavily on insecticides to control insect pests in order to reduce economic losses. However, the heavy use of nonselective insecticides has led to well-known problems, such as development of insect resistance to these chemicals, the resurgence of secondary insect pests, and the persistence of residues that are toxic to humans, animals and other nontarget organisms (Hardin et al., 1995).

Nowadays, the trend in insect control is to decrease the use of conventional insecticides not only because of the cost but also to minimize environmental disruption and avoid the development of pesticide resistance. Plant resistance to insects, integrated with other bio control strategies, should be one of the principal means of nonchemical control of pests (Wiseman, 1994).

Host plant resistance to insect pests is a vital component of integrated pest management (Panda and Khush, 1995) because of low impact on nontarget organisms and the environment. Painter (1951) classified the cause of host plant resistance to herbivores as »non-preference« (renamed »antixenosis« by Kogan and Ortman, 1978), »antibiosis« and »tolerance«.

One of the most promising examples of plant-based resistance (»antixenosis«) is the reduced survival of pests on »waxy« plant species (Eigenbrode and Shelton, 1990; Jenks and Ashworth, 1999; Eigenbrode and Pillai, 1998; Trdan et al., 2005). Waxes differ widely among plant species and among the organs and tissues of a single plant, attesting to the genetic diversity and developmental influences (Rutledge and Eigenbrode, 2003). Plant epicuticular waxes are complex mixtures of primarily very-long-chain aliphatics including primary alcohols (*n*-alkan-1-ols), aldehydes,

fatty acids (*n*-alkanoic acids) and alkyl esters, all of which occur predominantly with even-numbered chain lengths, and hydrocarbons, secondary alcohols and ketones with predominance of odd-numbered chain lengths (Walton, 1990). The chemical composition of the epicuticular wax found on plant surfaces is critically important in the decision of an insect to feed, probe or oviposit on a plant.

Therefore, the aim of the present research was to study the defence mechanism of cabbage cultivars against most phloem-feeding insect pests in Slovenia (flea beetles, *Phyllotreta* spp., cabbage stink bugs, *Eurydema ventrale* Kolenati and onion thrips, *Thrips tabaci* Lindeman) and in particularly the epicuticular wax responses since the epicuticular wax has an important role as antiinsect.

MATERIAL AND METHODS

Host plant preference trials were conducted at the Experimental Field (46° 04' N, 14° 31' W, 300 m above sea level) of the Biotechnical Faculty in Ljubljana, Slovenia. The field experiment was performed during spring-summer of 2007 on naturally occurring populations.

The trials followed lettuce breakcrops to minimise the detrimental effects of cabbage insect pests and were managed as for high yielding commercial crops. Individual plots consisted of single rows, 40-cm row spacing, each 4.5-m in length, arranged in a randomized complete block design with 12 different cabbage cultivars as treatments ('Vestri', 'Delphi', 'Destiny', 'Green rich', 'Pandion', 'Ixxion', 'Tucana', 'R1-Cross', 'Cheers', 'Red Dinasty', 'Erfurtsko rdeče' and 'Holandsko pozno rdeče').

The plants were single harvested when the majority of the heads reached maturity stage (initiation of the first head splitting). Ten plants in each plot were randomly selected and recorded for damage incidence (percentage of damaged leaf area). Leaves that were attacked by sucking insect pests could be recognized by necrosis and twisting of leaf blades. The frequency of leaves attacked by pests was transformed into damage rating scale according to EPPO directive (OEPP/EPPO, 2002) for *Phyllotreta* spp., according to Trdan et al. (2006) for *Eurydema ventrale* Kolenati and according to Stoner and Shelton (1988) for *Thrips tabaci* Lindeman.

Epicuticular waxes were extracted from the outermost fresh leaves following methodology of O'Neal et al. (2002) and Trdan et al. (2004). As the stage of plant maturity are thought to influence epicuticular wax content, the leaves of similar age were taken and washed in n-hexane for 1 min. The n-hexane extracts were filtered and dried in order to calculate weight of wax. An individual leaf area was measured with an Acer ScanPrisa 1240 UT desktop scanner. The resulting digital pictures were analyzed with the graphics software package Adobe Photoshop 7.0. The leaf area was calculated by transferring pixels to standard units (milimetres). All the results of epicuticular wax represent averages of triplicate determinations and are expressed on a μg cm^{-2} leaf area.

To examine the effects of host cultivar on the infestation of insect pests, data were analyzed with two-way ANOVA ($P<0.05$), testing for effects of host cultivar and block. Analyses were carried out on the mean character per plant for each treatment for each block. Comparisons of host cultivars were carried out using Duncan's multiple rang test. A regression analyses was used to determine the relationship between epicuticular wax content and pest damage.

RESULTS AND DISCUSSION

Infestation of cabbage leaves caused a significant reduction in their dry weights (data not shown). This might be due to the fact that the drain of phloem sap

assimilates towards the insect away from the other plant parts which may contribute to metabolic reduction (Miles, 1989).

The phloem-sucking insect pests in field tests demonstrated variation in feeding preference among different cabbage cultivars (Table 1). The results of evaluation of the extent of damaged leaf area, caused by feeding of flea beetles (*Phyllotreta* spp.), on leaves of cabbage showed statistically significant differences between cultivars. The early red cultivars of cabbage 'Red Dinasty' and 'Erfurtsko rdeče' had a significantly lowest number of feeding holes caused by *Phyllotreta* spp. On the contrary, early white cultivars 'Green rich', 'Tucana' and 'Delphi' had a significantly highest number of feeding holes. Almost similar results were obtained by cabbage stink bugs (*Eurydema ventrale* Kolenati). The red early cultivars 'Red Dinasty' and 'Erfurtsko rdeče' and red late cultivar 'Holandsko pozno rdeče' were significantly less attractive to *Eurydema ventrale* Kolenati, while mid-early fresh market cultivar 'Vestri' was significantly the most attractive to *Eurydema ventrale* Kolenati. By conducting the analysis of the »silver damage rate« on outer leaves we were able to demonstrate that the damage is a result of the onion thrips (*Thrips tabaci* Lindeman) feeding reaching the 7th leaf of the cabbage head. However, the commercially significant damage is between the 2nd and 4th outer leaf of the head (data not shown). Cv. 'Ixxion' (a white cultivar with a very early maturity) was being more susceptible to *Thrips tabaci* Lindeman than the other cultivars. The index of feeding damaged leaf area by cv. 'Ixxion' was 2.42. On the other side, the lowest damage rating was found in cv. 'Holandsko pozno rdeče', 'Cheers' and 'Erfurtsko rdeče' with index damaged between 1.12 and 1.23. The weight loss of yield (removed outer leaves) due to insect pest damage on the cabbage heads varied between cultivars. The loss of yield due to damage on the outer leaves from pests was between 6.0% (cv. 'Holandsko pozno rdeče') to 47.8% (cv. 'Destiny').

Table 1: Influence of insect pest damage on cabbage heads characteristics

Cultivar	Damage ratings scale (1–5)			Removed leaves
	Phyllotreta spp.	*Eurydema ventrale*	*Thrips tabaci*	(% head^{-1})
'Vestri'	1.63 bc	2.85 c	1.81 bc	33.3 b
'Delphi'	1.98 c	2.50 b	2.13 c	41.1 bc
'Destiny'	1.66 bc	2.50 b	2.00 c	47.8 c
'Green rich'	1.88 c	2.50 b	2.13 c	24.5 b
'Pandion'	1.85 bc	2.43 b	2.18 c	29.5 b
'Ixxion'	1.63 bc	2.41 b	2.42 d	34.7 b
'Tucana'	1.96 c	2.75 bc	2.30 cd	37.9 bc
'R1-Cross'	1.73 bc	2.48 b	1.56 b	26.8 b
'Cheers'	1.78 bc	2.75 bc	1.12 a	9.3 a
'Red Dinasty'	1.26 a	2.03 a	1.71 b	31.4 b
'Erfurtsko rdeče'	1.28 a	2.00 a	1.23 a	20.2 b
'Hol. pozno rdeče'	1.45 b	1.98 a	1.12 a	6.8 a

Within a column, values are not significantly different ($P<0.05$) if followed by the same letter.

The quantitative comparison of epicuticular wax of cabbage cultivars is shown in Fig. 1. The content of the epicuticular wax in the leaves differs among 12 cultivars tested, but for the most cultivars the content is the lowest between the third and the

sixth outer leaf in the heads (data not shown). According to Trdan et al. (2005), the value of this potential parameter of plant resistance against phytophagous insects is the highest in the first two outer leaves and grows from the 6th outer leaf of the head towards inside of the head. Overall, a higher concentration of epicuticular wax was present in the leaves of plants of cv. 'Red Dinasty' (48.78 µg cm^{-2}), 'Erfurtsko rdeče' (49.25 µg cm^{-2}) and of cv. 'Holandsko pozno rdeče' (51.71 µg cm^{-2}) compared to other cultivars.

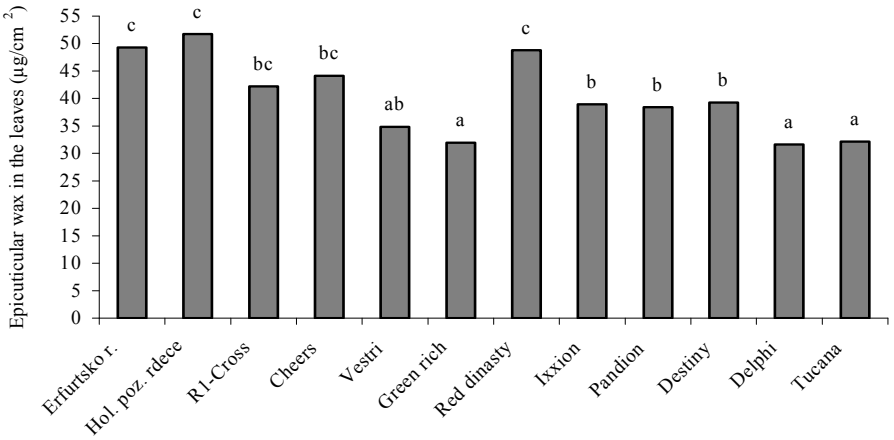

Figure 1: Comparison of epicuticular wax content on leaf surface among different cultivars of cabbage plants. Means within a coloumn followed by the same letter are not significantly different based on Duncan multiple range test ($P<0.05$).

The damaged cabbage leaves, compared to healthy one, exhibited less epicuticular wax. According to Khattab (2007) such effect may be attributed to the enzymatic effect of insect lipases which digest the wax.

The relationship between the index of leaves damaged and content of epicuticular waxes in leaves is illustrated in Fig. 2. Based on the data, the relationship is satisfactorily described by a linear function of the general form: $y = ax + b$. The mean index of leaves damaged was the dependant variable (y) and the epicuticular waxes was the independent variable (x). The correlation coefficients indicated that there was a close correlation between the two variables. The content of epicuticular waxes in the leaves of cabbage plants correlated negatively with the damaged index of *Phyllotreta* spp. ($r^2 = –0.8399$), *Eurydema ventrale* Kolenati ($r^2 = –0.7413$) and *Thrips tabaci* Lindeman ($r^2 = –0.7042$). Insect pest damage to cabbage declined with an increase in epicuticular wax rate. For example, in our research mean *Thrips tabaci* Lindeman damage was 2.42 for cv. 'Ixxion' at 38.93 µg cm^{-2}, but this decreased to 1.12 for cv. 'Holandsko pozno rdeče' at 51.71 µg cm^{-2}.

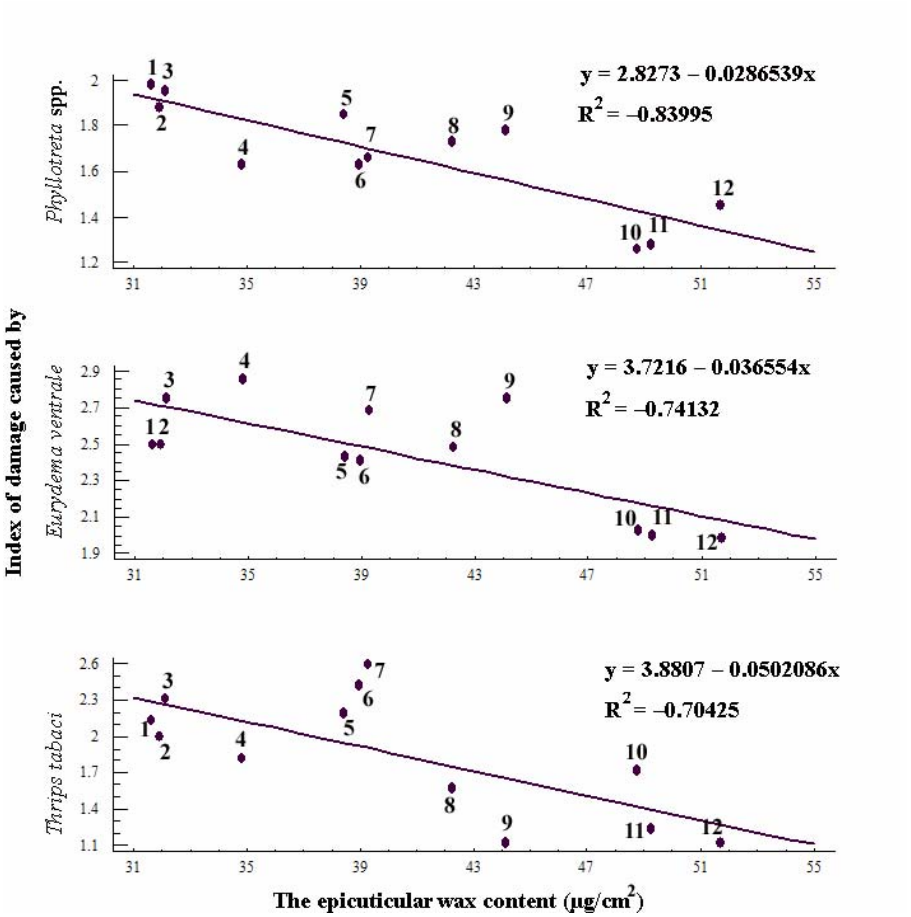

Figure 2: Regression analyses of the relationship of index of leaves damaged to content of epicuticular wax (µg cm^{-2} leaf area) in cabbage leaves. Each point represents single cabbage cultivar (1='Delphi', 2='Green rich', 3='Tucana', 4='Vestri', 5='Pandion', 6='Ixxion', 7='Destiny', 8='R1-Cross', 9='Cheers', 10='Red Dinasty', 11='Erfurtsko rdeče', 12='Holandsko pozno rdeče').

There have been a number of reports about insect respond to chemicals on the leaf surface as obtained from experiments using surface extracts of leaves or pure chemicals that are known to occur on leaf surfaces. Sanford et al. (1991), reported that behaviour of neonate diamondback (*Plutella xylostella* L.), moth larvae on resistant cabbage leaves was affected by leaf waxes. As a conclusion, leaf waxes chemistry and their physical attributes act together with some plant characteristics, to affect neonate diamondback behaviour on cabbage plants. They showed that the larvae spent significantly more time walking, walked more frequently, and walked significantly faster on leaves of »waxy« resistance cabbage than on the susceptible. Stok (1980) reported that mustard beetle (*Phaedon cochleariae* Fabricius) stick fast to cabbage cultivars that do not have heavy wax bloom than to those with a bloom.

In »bloom« cultivars, the culm is heavily waxed and the neonate larvae experience considerable difficulty in climbing, their prolegs get stuck in the wax and the larvae never reach the feeding site (Bernays et al., 1983). Our results agree with the findings of Eigenbrode et al. (1999), Gorb and Gorb (2002) and Trdan et al. (2005) who mentioned that epicuticular wax crystals produce the waxy bloom observable on some plant surfaces and epicuticular wax blooms can render plants slippery for insects.

Although results obtained from our experiment provide substantial evidence for epicuticular wax playing a major role in cabbage resistance for insect pests, insect resistance in »waxy« crops is not well understood. It tends not to be expressed reliably in greenhouse or laboratory studies (Eigenbrode, 1990); with the implication that field conditions are necessary. Three factors have been examined. First, reduced epicuticular wax could make plants more vulnerable to water stress, leading to stress-induced increases in defences. This effect helps to explain greater resistance of reduced »waxy« cabbage to the cabbage aphid (*Brevicoryne brassicae* L.) when the plants are water stressed (Cole and Riggall, 1992). A similar effect may occur for pea aphid (*Acyrthosiphon pisum* Halliday) on reduced wax pea under xeric conditions (Rutledge et al., 2003). Second, some insect species may prefer plants with relatively prominent epicuticular wax bloom. In contrast to the psyllid (*Ctenarytaina spatulata*), which prefers Eucalyptus with reduced epicuticular wax bloom (*C. eucalypti* Maskell) prefers to settle and mate on juvenile leaves of *Eucalyptus globuli*, which have a prominent epicuticular wax bloom, and rejects adult leaves that have a reduced epicuticular wax bloom (Brennan et al., 2001). A third factor that could cause apparent resistance to insect herbivores on reduced epicuticular wax plants in the field could be related to attachment by their insect natural enemies. Way and Murdie (1965) seem to have been the first to suggest that increased predation on a reduced epicuticular wax crop variety could cause an apparent resistance to herbivores. Epicuticular wax bloom may be the reason why some predators fall frequently or forage ineffectively on plants with epicuticular wax blooms (Kareiva and Sahakian, 1990; Grevstad and Klepetka, 1992). Supporting this possibility, genetically reduced epicuticular wax on cabbage and pea improves the effectiveness and mobility of some predators. In laboratory studies with caged plants, three predator species from three taxonomic orders (Neuroptera; Hemiptera; Coleoptera) kill up to six times more prey (diamondback moth, *Plutella xylostella* L. on cabbage, or pea aphid, *Acyrthosiphon pisum* Harris on pea) on a reduced epicuticular wax genotypes of these crops. Each predator species spends a greater proportion of its time walking and falls less frequently from the reduced epicuticular wax plant genotype tested, suggesting that the epicuticular wax blooms disrupt attachment and hence the mobility of these predators.

CONCLUSIONS

The use of resistant cultivars of cabbage is one of the most effective tools for reducing pest insect damage. In our research we demonstrated that physical characteristics, of cabbage, in particular epicuticular wax content, may have dramatic impacts on pests. We concluded that cultivars of cabbage plants varied not only in their overall levels of antixenotic resistance but also in the form of

relationship between damage and antixenotic resistance (the norm of reaction to damage). The plant surface waxes influence cabbage insect pests' behaviour and effectiveness and potentially population dynamics. Namely, cabbage leaves exhibited a decline in the rate of epicuticular wax as compared to that of healthy one.

Cultivars that respond at lower levels of damage (such as cv. 'Holandsko pozno rdeče') might have an adventage over cultivars that do not respond until higher levels of damage (such as cv. 'Green rich'), since insect pests could be driven off to other, not-yet-induced plants.

The results of our research could have important implications for the integrated management of insect pests in the commercial production of cabbage in Slovenia. Growing resistant cultivars may not completely eliminate the need for insecticidal intervention, but in the fields where pests' infestations are chronic, implementing these strategies should enable growers to substantially reduce insecticide use in cabbage production.

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Influence of carbon dioxide, inoculum rate, amount and mixing of casing soil on *Agaricus blazei* fruiting bodies yield

Andrej GREGORI[1], Bojan PAHOR[2], Roman GLASER[3], Franc POHLEVEN[4]

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ABSTRACT

Influence of carbon dioxide concentration during compost and casing soil overgrowth, inoculum rate, casing soil depth and mixing on *Agaricus blazei* fruiting bodies yield was determined. Compost composed of chicken manure and wheat straw which is used for commercial button mushrooms cultivation in Slovenia showed to be appropriate for *A. blazei* fruiting bodies production. Out of the parameters tested in our experiments, casing soil depth and inoculum rate had the biggest positive effect on fruiting bodies production. For *A. blazei* fruiting bodies production higher rates of inoculum and at least 8.5 kg of commercial casing soil per square meter of compost surface should be used. Higher carbon dioxide concentrations shoved to be beneficial for attaining higher yields of *A. blazei* fruiting bodies.

Key words: *Agaricus blazei,* casing soil, mushroom cultivation, compost

[1] B.A. agronomy, SRC Bistra Ptuj, Slovenski trg 6, 2250 Ptuj, Slovenia

[2] dr.., Perutnina Ptuj d.d., Potrčeva cesta 10, 2250 Ptuj, Slovenia

[3] dr.., Perutnina Ptuj d.d., Potrčeva cesta 10, 2250 Ptuj, Slovenia

[4] Prof. dr., Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Rožna dolina, Cesta VIII/34, 1000 Ljubljana, Slovenia

All experiments were performed at the mycology laboratory of Institute of Natural Sciences, Podkoren 72, 4280 Kranjska gora.

* Address all corespondence to Andrej Gregori, SRC Bistra Ptuj, Slovenski trg 6, 2250 Ptuj, Slovenia, E-mail: andrej.gregori@gmail.com

IZVLEČEK

VPLIV OGLJIKOVEGA DIOKSIDA, KOLIČINE GLIVNEGA VCEPKA IN KOLIČINE TER MEŠANJA KROVNE PRSTI NA PRIDELEK GOB VRSTE *Agaricus blazei*

Raziskovan je bil vpliv koncentracije ogljikovega dioksida med preraščanjem komposta in krovne prsti (pokrivke), količine glivnega vcepka primešanega kompostu ter količine krovne prsti in mešanje le-te po preraščanju s podgobjem na obrod gob *Agaricus blazei*. Kompost pripravljen iz kurjega gnoja ter pšenične slame, ki ga izdelujejo ter na območju Slovenije uporabljajo za komercialno gojenje šampinjonov, se je izkazal kot primeren za gojenje gob vrste *A. blazei*. Med testiranimi parametri gojenja sta na povečanje pridelka vplivali predvsem količina krovne prsti in koncentracija glivnega vcepka vmešanega v kompost. Za uspešno gojenje je potrebno uporabiti vsaj 8,5 kg komercialne krovne prsti na kvadratni meter komposta. Višje koncentracije ogljikovega dioksida in pokrivke pozitivno vplivajo na obrod gob.

Ključne besede: *Agaricus blazei,* pokrivka, gojenje gob, kompost

1 INTRODUCTION

The biggest Slovenian poultry producer Perutnina Ptuj d.d. is facing a problem caused by large quantities of poultry manure. One of potential solutions for solving this problem is its use as a mushroom compost component. Cultivated mushrooms could be used as an additive in human food products produced by Perutnina Ptuj d.d., raising the quality of this products if medicinal mushrooms like *A. blazei* were to be used. Cultivation of this mushroom could represent an excellent solution for conversion of poultry manure into more stable form, solving problems with disposal and also creating a place for additional activities – working places, new product fabrication, raising quality of old products, additional income etc.

Brazilian blazei mushroom has been referred to by various names, most commonly as *Agaricus blazei* Murrill (*sensu* Heinemann) and recently as *Agaricus brasiliensis* (Kerrigan, 2005). The mushroom is best known in Japan as Himematsutake or Kawariharatake, in China as Gee Song Rong or Brazilian mushroom, and in Brazil as mushroom of God (Cogumelo de Deus) or mushroom of the Sun (Cogumelo do Sol). Cultivation centers of *A. blazei* are now well-established in Brazil, Japan, China and Korea. There are also growers in Thailand and throughout the Far East, Denmark and the Netherlands, as well as the United States. Today, Japan is the number one in consumption, and is the most sought-after market for *A. blazei*, one of the most expensive gourmet medicinal mushrooms in Japan (Chen, 2003). Its ingredients and numerous medicinal effects have been reviewed by Mizuno (2002). *A. blazei* cultivation was described by Chen et al. (1999), Royse (2001), Park (2001), Choi (2002) and Mendonca et al. (2004).

According to Kwon (2001), cultivation of *Agaricus blazei* mushroom differs from others in the following:

- *A. blazei* cultivation is quite similar to white button mushroom (*A. bisporus*) cultivation, but it favors higher temperature and lighting (even during spawn run),
- *A. blazei* is a secondary saprophyte, which grows on material already partially degraded by microorganisms, requiring fermented compost as substrate, unlike

other primary saprophytes such as Shiitake (*Lentinula edodes*), Maitake (*Grifola frondosa*) and Reishi (*Ganoderma lucidium*),
- *A. blazei* is less prone to mold-infestation than other mushroom species.

In natural habitats, these mushrooms are found on organic litter which has already been occupied by the first stage decomposers capable of digesting complex lignocellulosic components. Being a second-stage decomposer, *A. blazei* can only be cultivated on fermented substrates after the complex basal components are partially broken down into simpler ones (Chen, 2003). Much of the cultivation technology for *A. blazei* has been adapted from growing *A. bisporus*, the white button mushroom. The major differences between growing the two species are the higher temperature needed for *A. blazei* and the light needed for fruiting bodies development (Stamets, 2000).

The aim of our experiment was to determine which cultivating parameters influence *A. blazei* fruiting bodies yield the most. Carbon dioxide concentration during compost and casing soil overgrowth, casing soil depth, mixing of overgrown casing soil and concentration of spawn mixed into the compost were tested.

2 MATERIALS AND METHODS

2.1 Fungal culture

Fungal culture strain 7700 used in our experiment was purchased at Mycelia Company (Nevele, Belgium) and maintained on Potato Dextrose Agar (PDA) at 24 °C.

2.2 Compost preparation

Compost was prepared in commercial compost producing facility of the Fungus d.o.o. Company (Ribnica na Pohorju, Slovenia). The preparation technique was the same as for white button mushroom compost production. Compost was prepared by mixing 80 parts of chicken manure, 100 parts of wheat straw and 3 parts of gypsum. After wetting the mixture was composted outside for seven days, pasteurized for six days and conditioned for six days in a pasteurization chamber.

2.3 Fungal inoculum preparation

Wheat grains were soaked in excess water overnight and then boiled until 50 % moisture content was achieved. Cooked grains were mixed with $CaCO_3$ (0.6 % dry weight) and gypsum (1.8 % dry weight) and filled into 2.4 liter glass jars. Jars were covered with metal lids having 14 mm diameter hole filled with cotton for gas exchange and sterilized for three hours at 121 °C.
When PDA surface was overgrown with fungal culture it was used for inoculation of sterilized grains.
Inoculated grains were briskly shaken to achieve even distribution of fungal culture and incubated one month in a dark place at 24 ± 1 °C. When grains were completely overgrown by mycelia they were used as a spawn for compost inoculation.

2.4 Experiment design

3 kg of compost was filled into round 25 cm high and 30 wide black plastic containers with holes in the bottom. Tests were performed in triplicates. Compost had 61 % moisture content (determined with drying for 24 hours at 103 °C). Different proportions (1, 2, and 5 %) of spawn were mixed into compost (Table 1.). Where higher CO_2 during mycelia overgrowth was tested, Styrofoam boards (1 cm thickness) were laid on top of containers, disabling active gas exchange between interior of the container and surrounding environment.

Table 1. Experimental design

		spawn rate (%)
2.4 kg casing soil	no mixing	1
		2
		5
	mixing	1
		2
		5
	stirofoam	1
		2
		5
1.4 kg casing soil	no mixing	1
		2
		5
	mixing	1
		2
		5
	stirofoam	1
		2
		5

Containers filled with inoculated compost were placed in a dark place with constant temperature of 22 ± 1 °C and 80 % relative humidity. Aeration was set to minimum (1600 ppm CO_2). When compost was completely overgrown with mycelia the casing soil with 76.8 % water content was applied. 2.4 and 1.4 kg of casing soil was applied.

When mycelia completely overgrown the casing soil it was mixed in one third of the containers. Afterwards containers filled with casing soil were exposed to the temperature of 17 ± 1 °C for fruiting bodies induction. After cold shock treatment containers were moved back into the growth room with air exchange set to maximum, 10 hours of daily light period and 90 % relative humidity.

Fruiting bodies were harvested when caps were closed, with partial veil unbroken. Their weight was determined.

All the experiments were conducted at the mycological laboratory of Institute of Natural Sciences (Podkoren, Slovenia).

3 RESULTS AND DISCUSSION

In compost inoculated with 1 % of *A. blazei* spawn during the whole cultivating procedure fruiting bodies yields were the highest when 2.4 kg of casing soil and covering of containers with Styrofoam or mixing was used. Yield was the lowest when 1.4 kg of casing soil was used and containers were covered with Styrofoam (Picture 1.).

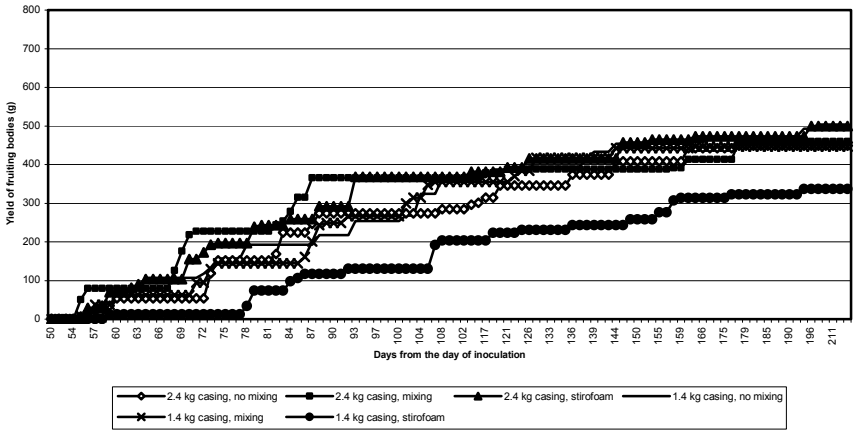

Figure 1: Fruiting bodies yield on compost inoculated with 1 % spawn rate during the whole cultivation period

When 2 % spawn rate was used at the beginning of the cultivation procedure yields were higher in containers with 2.4 kg of casing soil without mixing. At the end of cultivation (after day 211) the yield was higher in containers with 2.4 kg of casing soil covered with Styrofoam during faze of overgrowth. Yields were the lowest when 1.4 kg of casing soil was used and containers were covered with Styrofoam (Picture 3.).

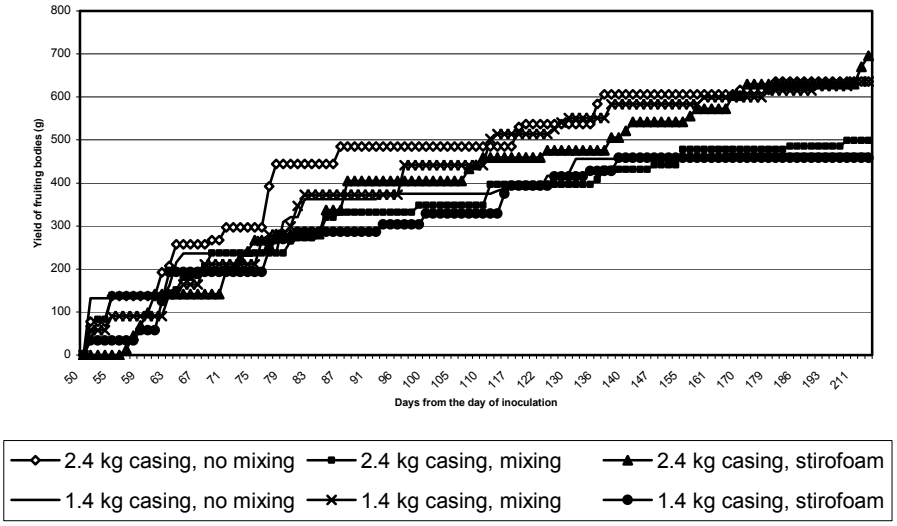

Figure 2: Fruiting bodies yield on compost inoculated with 2 % spawn rate during the whole cultivation period

When 5 % spawn rate was used at the start of the cultivation procedure yields were higher in containers with 1.4 kg of casing soil with mixing. From the day 91 yield was the highest in containers with 2.4 kg of casing soil covered with Styrofoam during faze of overgrowth. Yields were the lowest when 1.4 kg of casing soil was used and containers were covered with Styrofoam boards (Picture 3.).

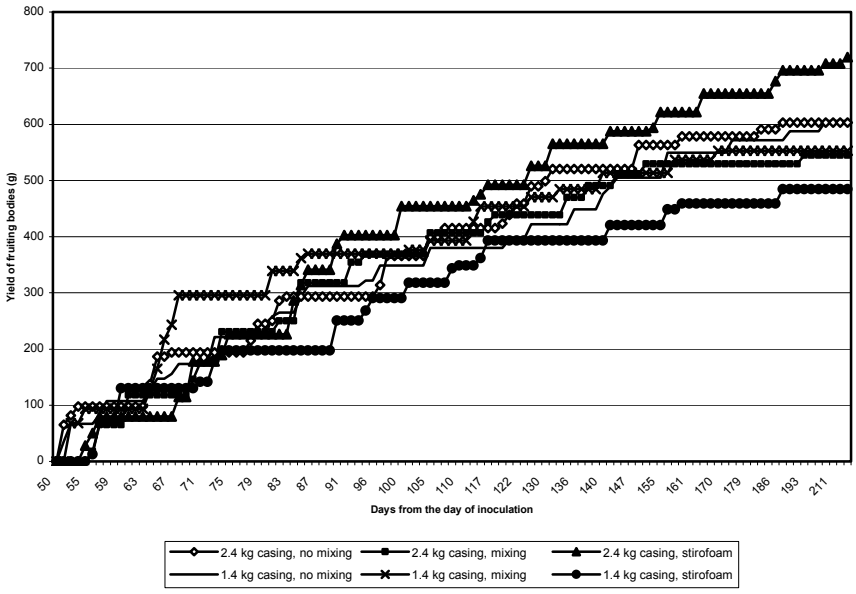

Figure 3: Fruiting bodies yield on compost inoculated with 5 % spawn rate during the whole cultivation period

At higher CO_2 concentrations during the incubation phase casing soil tends to plays an important role in fruiting bodies development. Yields were 49 % higher in average when 2.4 kg instead of 1.4 kg of casing soil was used.

When 2.4 kg of casing soil was used mixing had a negative influence on yield when 2 % (22 % yield reduction) and 5 % (10 % yield reduction) of spawn rate was used. When 1 % spawn rate was used yield was increased for 2 % in mixed casing soil.

At 1.4 kg of casing soil, mixing had a negative effect on fruiting bodies yield when 1% (11 % yield reduction) and 5 % (9 % yield reduction) spawn rate was used (Picture 1., Picture 3.). When 2 % spawn rate was used yield was greatly increased (36 %) in mixed casing soil (Picture 2., Picture 4.).

The major influence on *A. blazei* yield is caused by casing soil depth and spawn quantity used for compost inoculation. When higher rates of spawn are used for compost inoculation yields tend to be higher. Yields are 26 % higher in average when instead of 1 % 2 % of inoculum were used and 3 % in average if instead of 2% 5 % inoculum rate was used (Picture 4.).

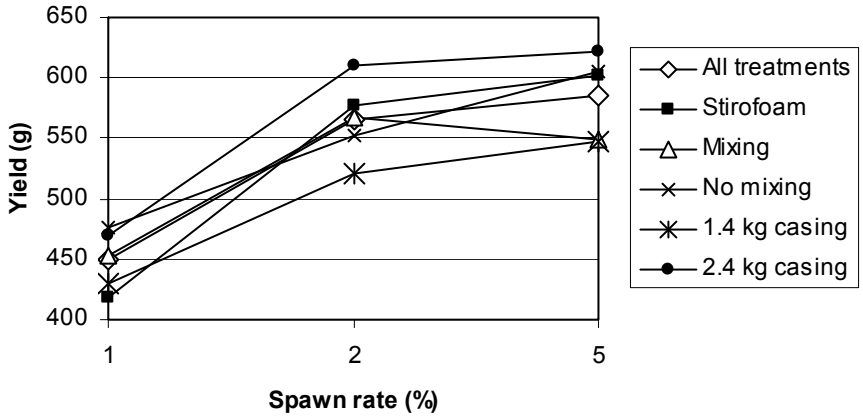

Figure 4: Average fruiting bodies yield at different treatments (Average yield at two different casing soil weights was calculated.)

4 CONCLUSIONS

Compost composed of poultry manure and wheat straw which is used for commercial *A. bisporus* cultivation, showed to be appropriate for *A. blazei* fruiting bodies production. Out of the parameters tested in our experiments, casing soil depth and inoculum rate had the principal positive effect on fruiting bodies production. We can conclude that for *A. blazei* fruiting bodies production higher rates of inoculum and at least 8.5 kg of casing soil per square meter of compost surface should be used. Higher carbon dioxide concentrations during mycelium overgrowth also shoved to be beneficial for attaining higher *A. blazei* fruiting bodies yields.

Also other fungal strains should be tested to determine weather the effects of parameters researched in our study are strain dependent. From economical point of view the optimal cultivation process length should be determined, although the process can last for a long time.

Although compost composed of chicken manure and wheat straw can be successfully used for *A. blazei* cultivation it can be implemented into other activities conducted by big poultry producers, solving their problems with manure disposal and representing other possibilities of fruiting bodies usage (additives to food and feed products).

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Attitudes towards private labels – example of a consumer sensory evaluation of food in Slovenia

Aleš KUHAR[1] and Tanja TIČ[2]

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ABSTRACT

The study aims to extend the understanding of consumers' perception of private labelled food products in Slovenia. Consumer sensory test of sour gherkins was conducted in two experimental conditions where the effect of brand information on hedonic judgment was examined. The difference between private label and producer label products was especially scrutinized. Results show that consumers in Slovenia perceive private labels as a lower price alternative of comparable quality to producer brands. Disposable income and family size proved to have significant effect on propensity to buy private label food. Study confirms that the information about brand significantly affect consumer sensory judgment. The effect of assimilation has been confirmed also in the case of private label.

Key words: Private labels; Food; Consumer sensory evaluation

IZVLEČEK

ODNOS DO TRGOVSKIH BLAGOVNIH ZNAMK – PRIMER SENZORIČNEGA VREDNOTENJA HRANE PRI POTROŠNIKIH V SLOVENIJI

Raziskava poskuša poglobiti razumevanje percepcije trgovskih blagovnih znamk hrane pri slovenskih potrošnikih. Izvedeno je bilo senzorično vrednotenje vzorcev kislih kumaric pri dveh različnih vrstah eksperimentalnih razmer, kjer je bil ocenjevan učinek informacije o blagovni znamki na hedonično vrednotenje. Test je bil osredotočen na razlikovanje trgovskih blagovnih znamk in proizvajalčevih blagovnih znamk. Rezultati so pokazali, da slovenski potrošniki trgovske blagovne znamke vrednotijo kot cenovno ugodno alternativno izbiro primerljive kakovosti v primerjavi s proizvajalčevimi blagovnimi znamkami. Statistično značilni učinki nagnjenosti k izbiri trgovskih blagovnih znamk so bili potrjeni za dejavnike: razpoložljivi dohodek in velikost družine. Raziskava potrjuje hipotezo, da informacija o blagovni znamki statistično značilno vpliva na senzorično vrednotenje vzorcev pri potrošnikih. Učinek asimilacije je bil potrjen tudi pri trgovskih blagovnih znamkah.

[1] University of Ljubljana, Biotechnical Faculty, Zootechnical Department, Groblje 3, SI-1230 Domžale, Slovenia, PhD., email: ales.kuhar@bfro.uni-lj.si.

[2] Wageningen University, Food Technology Programme PO Box 8129 6700 EV, Wageningen, the Netherlands

Ključne besede: trgovske blagovne znamke, hrana, senzorično ocenjevanje pri potrošnikih

INTRODUCTION

A food product is defined as an aggregation of attributes at different levels. According to Grunert et al. (2000) these are: search attributes (e.g. price, colour), experience attributes (e.g. taste and flavour) and credence attributes (e.g. health and safety). Notion of attributes itself, however, cannot explain all complexities of consumer choice, because they are considered as evaluative criteria. The latter are transposed to consumer perception through a process of interaction of product characteristics and personal socio-demographic, economic, psychographic, behavioural and cognitive determinants (Mowen, 1993; Alvensleben, 1997). Food selection and consumption are therefore a complex phenomenon influenced by a multitude of factors.

Individual socio-demographic and economic characteristics are commonly included when consumers are making a purchasing decision and they have to form quality expectations based on quality cues (Tuorila et al., 1998). Sensory properties of food, which have long been regarded as the main determinant of food selection, have a rather limited influence in that stage of process. Consumers therefore form their quality expectation for most of the food categories on extrinsic cues such as price, brand name, brand familiarity, advertisements, etc. The effects of extrinsic cues on consumer behaviour have been widely studied (for a review see Deliza and MacFie, 1996 or Schifferstein, 2001) and important effect on consumer expectations and hedonics sensory ratings has been confirmed. Price has been considered as a very important cue and received a great part of the research attention. However, in the literature (Jacoby et al., 1971) the theory that price is an objective cue, contrary to other factors being defined as subjective was established. In addition, for the regularity of brand's usage the most frequently read information about the foodstuff selected is important (Chernatony, 1991). Keller (2002) identified the following key functions of the brand for consumers: identification of origin; definition of responsibility of producer; risk reduction; search cost reduction and a virtual contract with producer (promise, guarantee). While Deliza and MacFie (1996) put the main focus of brand on informational cue. Consumers combine actual information from shopping environment with past experiences and use them to make purchase decision, but they strive for a "cognitive efficiency" and try to use minimum of information. As a result, they use a brand as a simplifier of a decision making process and hence the foundation of brand power.

According to the ownership, two types of brands are distinguished. Manufacturer brand (also producer brand, national brand), which is owned and coordinated by a producer and private label (also retailer's brand, own label) being owned and coordinated by a retailer or a buying group, as well as produced by a contracted manufacturer (Berthon et al., 1999). The presence of private labels nowadays is increasing rapidly and they are becoming one of the major factors in the developed food market from one side, and from the other are being considered as a significant

threat to producers' brands and manufacturers' profitability (Baltas, 1997; Guerrero et al., 2000).

There is clear evidence from research work that non-sensory attributes of food (extrinsic cues) affect the sensory acceptability of a food product (Di Monaco et al., 2003). However, external attributes mainly affect purchase decision, while sensory attributes confirm liking of a product and therefore determine repeat purchase and loyalty.

Rather large research attention has been devoted to the effect of brand on overall liking and sensory evaluation of food (Deliza and MacFie, 1996; Cardello, 1994).

Schifferstein (2001) pointed out that the effect of a brand in the food choice is also largely dependant on individual characteristics of consumers and it is possible to distinguish them regarding to their sensitivity to brand. The effect of brand on consumer is well represented in scientific literature, however there are much less studies regarding the private labels. DelVecchio (2001) prepared a research focusing on the role of product category characteristics on private label perception and acceptability. He found that the consumer perception and penetration success of private label is driven by the segment complexity, quality variance, price and inter-purchase time. The other relevant study aimed at determining what makes consumers more responsive to private label products (Baltas, 1997). The private label shopper has been identified as price sensitive but not promotion sensitive. High importance has been found regarding the familiarity with the product. Guerrero et al. (2000) have studied consumer attitude towards private labels. They founded that the Spanish consumers perceive private labelled products as reliable, different from producer brands and are good value for money. Cardello (1997) reports about negative stereotypes that affect private label purchase, however this might be dependent on the country and related to the retailer.

The present paper aims to extend the research area focusing on the direct comparison of the two brand types; namely private label and producer label. The main objective is to examine to which extent an extrinsic factor (information on brand) affects hedonic sensory judgment and whether there is a difference in respect to the type of brand.

The research focuses on food consumers in Slovenia. Food retailers have successfully acquired the strategy of private label and the concept is present in Slovenia for a decade with a particularly rapid growth during the last five years (Kuhar, 2005). Than at the beginning the leading retail chain intensively started introducing private label products as a mechanism to increase profitability. As their market share on the Slovenian grocery market was increasing (mainly through mergers and acquisitions), the national level of private label penetration has been accordingly risen. On the other hand, other players at the retail market started to introduce private label products, too. Meanwhile Slovenian food retail sector has become one of the most concentrated in Europe since the largest four retailers hold about 80% of the sector's turnover. Likely the most important factor for penetration growth of private label products in Slovenia is the level of retail sector

concentration. At the same time promotion strategies have been also effectively conducted. As a result, the majority of domestic food processors now produce private label goods, but generally without the adequate sustenance strategies. Vertical dominance of retailers has consequently increased and is being considered as one of the main factors for radical reduction of food industry business performance.

THE SURVEY METHODOLOGY

The study was conducted in two consecutive stages. First, three focus groups were performed (24 participants), discussing food purchasing behaviour with special attention to private labelled products and to sour gherkins. Focus groups were composed from participants (fourteen females and ten males) of various age groups. At the final stage of each focus group a preliminary consumer sensory evaluation test was performed. The latter was intended to determine more precisely the survey protocol for the consumer sensory evaluation. Pickled gherkins were selected to serve as a research object since they offer a rather limited possibility for product differentiation. Furthermore, pickled gherkins are widely used in Slovenia and they were among the first sold food product under a private label.

Wording of consumers relating to the private labels was carefully studied from the focus groups discussions and applied when questionnaire was prepared as suggested by Malholtra and Birks (1999). In addition, the sensory evaluation protocol was fine-tuned following the propositions from Cardello and Shutz (2006).

The second part of the research was a consumer study with attitude questionnaire and sensory evaluation test involving 155 participants. Sampling of the participants was stratified according to the Slovenian population structure regarding gender and age (SORS, 2006).

Table 1. Basic demographic details of the sample
Tabela 1. Osnovni demografski podatki o vzorcu

Age group	*Gender*		*Total*
	Male	Female	
16-27	12.2 %	14.1 %	26.3 %
28-40	15.4 %	14.1 %	29.5 %
41-55	10.9 %	12.8 %	23.7 %
above 56	10.3 %	10.3 %	20.5 %
Total	48.7 %	51.3 %	100.0 %
Minimum	Maximum	Average	Std. variation
17	81	41.37	15.67

Survey was conducted in three locations (two shopping malls and a public library) in equal proportions. The experiments were done in purposely prepared sites with minimally required conditions for consumer sensory evaluations. First, the participants were given the questionnaire, which contained four parts: general food purchasing and eating behaviour; brands; sour gherkins and socio-demography. Each of them was let to fill-in the last part of it. Afterwards, they were asked to express their opinion about five samples of pickled gherkins on a seven-point hedonic scale. For the purposes of this experiment it was sufficient to ask consumers for simple judgment on general acceptability (level of likeness) of the product without indicating specific sensory characteristic

Table 2. Experimental design
Tabela 2. Raziskovalni pristop

Experimental conditions	*No. of subjects*	*Identification of samples*
B - blind	155	3-digit code
I - informed	155	brand name

It is believed that consumers make hedonic judgment considering the product as a whole and are generally not able to concentrate on singular sensory characteristics. Five brands of sour gherkins widely available on Slovenian market were included among which there were two private label products. In the first session samples were served in neutral plastic containers labelled with a random three digit sample code - so called "blind tasting". In the second session participants were serving themselves from the original packaging of sour gherkins and hence they were informed about the brand ("informed tasting"). Between the two tasting sessions consumers completed the remaining three parts of the questionnaire. The break between the sensory evaluation sessions was done to prevent "quiz" effect.

Results from the consumer questionnaire were processed using general descriptive statistics methods. In order to evaluate the effect of the tasting conditions on the hedonic ratings of pickled gherkins the difference between informed and blind ratings was calculated (I-B). Paired *t*-test was used to evaluate the statistical significance of the rating difference.

RESULTS AND DISCUSSION

Results from the consumer questionnaire mainly confirmed the evident trend of increasing private label food market shares in Slovenia. As much as 45 % of the respondents classified into the "frequent buyer" of private label food (16.7% very frequently and 29.5% rather frequently). Only about one fifth of consumers claims "no buy" or "very rare buy" of private labels and the remaining one third buy it occasionally.

Figure 1 shows mean responses for private label product purchase frequency with the corresponding standard deviations (CI=95%). It is interesting for this research that processed vegetable comes as third following dairy products and salt, moreover the standard deviation of answers is the lowest. According to the results, for dairy products and salt around 20 % of respondents always select private labelled product, whereas for processed vegetable almost half of the respondents claim occasional purchase and 30% often purchase. It is therefore possible to conclude that processed vegetable is a product group with high potentials for private label penetration. This is particularly true for the Slovenian market where the leading retailer is efficiently conducting the strategy of "differentiation prevention". Most of the processed vegetable (sour gherkins, red beetroot and sauerkraut) under the private label for this retailer is produced by the market leader and there is actually no difference to the products sold under the producer label. Beside limited quality difference, also other characteristics of the segment are stimulative: segment complexity is low and the inter-purchase time is short to medium. Beer has the lowest frequency with almost two thirds of the respondents claim no private label purchase, which has been expected.

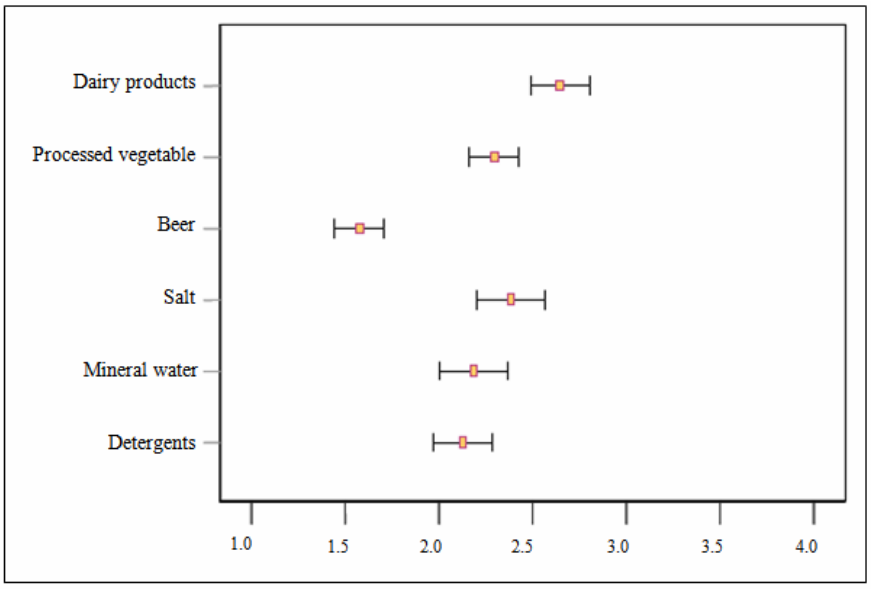

Figure 1. Private label product purchase frequency by product group

Slika 1. Pogostost nakupa trgovinske blagovne znamke po proizvodnih skupinah

The most obvious benefit to consumers afforded by private label is lower price. More than 90% of the respondents believe that the private label products are cheaper (Figure 2). When they were asked to compare overall product quality under producer label and equivalent private label the answer was not that uniform. As much as 49% of respondents stated that the quality of products is the same, but 45% believe the quality is lower. Therefore consumers strongly perceive private label products as a low-price alternative to producer label, however not all believe that they do not scarify on product quality. It seems that despite the lower perceived quality, Slovenian consumers accept the price-quality ratio of private label products. Assortment of private label products is shown to be inferior in comparison to the producer label since 61% of respondents stated the selection is worse. This is particularly true for the Slovenian market since retailers mainly offer simple substitutes to national brands also referred as first generation private labels. There is almost no private label differentiation; however this passive strategy still seems to be sufficient for exerting vertical chain domination and market power of Slovenian retailers. This is also to a great extent conditional with ineffective defensive strategies of Slovenian food processors.

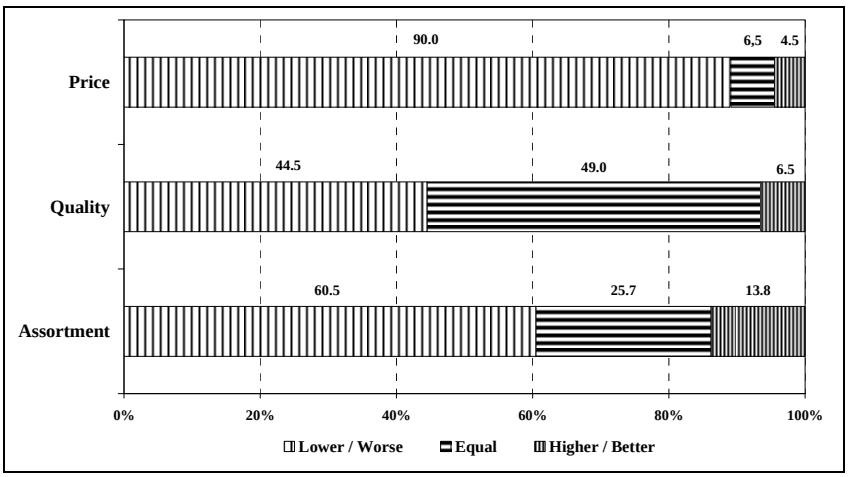

Figure 2. Comparisons of key product characteristics valuation for private label product vs. producer labelled products by respondents

Slika 2. Primerjava vrednotenja ključnih elementov proizvoda za trgovske blagovne znamke in proizvajalčeve blagovne znamke pri anketirancih

We have also attempted to discover whether the propensity to buy private labels is associated with demographic or socio-economic characteristics of consumers.

We found out that the gender, age and education are not significantly related to the reported frequency of private label purchase. This is in accordance with previous researches which also find rather weak association of propensity to buy private label and demographic characteristics of consumers (for review see: Baltas, 1997). Self-reported household disposable income has shown statistically significant effect on private label purchase frequency (p=0.01) with evident negative dependency (Gamma – 0.215). Respondents in lower income groups are more frequent buyers of private label food products.

Table 3. Impact of the disposable household income on the frequency of private label purchase

Tabela 3. Vpliv razpoložljivega dohodka gospodinjstva na pogostost nakupa TBZ

Income group	Frequency of private label purchase				Total
	Very really	Occasionally	Frequently	Very frequently	
< 650	0.0 %	46.2 %	19.2 %	34.6 %	100.0 %
650–1.500	29.2 %	18.8 %	37.5 %	14.6 %	100.0 %
>1.500 – 2.330	14.9 %	46.8 %	27.7 %	10.6 %	100.0 %
>2.330	36.0 %	20.0 %	36.0 %	8.0 %	100.0 %
Total	20.5 %	32.9 %	30.8 %	15.8 %	100.0 %

(p = 0.01; n = 146; Gamma - 0.241)

Also the size of a household is found to be significantly related to private label product purchase frequency (p=0.04), however the frequency density is U-shaped. The smallest and the largest households are very likely among the most frequent buyers of private label products.

Table 4. Impact of the household size on the frequency of private label purchase
Tabela 4. Vpliv velikosti gospodinjstva na pogostost nakupa TBZ

Income group	Frequency of private label purchase				Total
	Very really	Occasionally	Frequently	Very frequently	
< 650	16.0 %	28.0 %	24.0 %	32.0 %	100.0 %
650–1,500	21.4 %	37.5 %	33.9 %	7.1 %	100.0 %
>1,500 – 2,330	24.6 %	33.8 %	27.7 %	13.8 %	100.0 %
>2,330	10.0 %	10.0 %	30.0 %	50.0 %	100.0 %
Total	21.2 %	32.7 %	29.5 %	16.7 %	100.0 %

(p = 0.039; n = 156)

Furthermore preferred retail chain has a significant relation to the frequency of private label purchase. The consumers, who stated to do most of their shopping in the largest retail chain, show the largest propensity to buy private label. However, the chain does not have above the average share of private label in their offer. High penetration of this chain private label is rather a result of efficient marketing strategies and selection of private label producers.

Confirmative results regarding the private label perception of Slovenian consumers comes also from the aggregated descriptor named “Food attitude profile” where consumers were asked to choose the ultimate food purchasing determinant. The highest private label purchase frequency was found for the consumers that stated “Slovenian origin” as the most important factor when making food selection. More than half of them buy private label very frequently. This corresponds with the profile of leading retail chain which builds its position firmly on the ethnocentric strategies. The second most frequent buyers of private labels are, rather controversially, the respondents who stated that the producer is the most important determinant of product selection decision. This might be interpreted in two ways. Respondents either equalize private label with the producer (label), or another specificity of Slovenian market has effect here. Literally all products under the private label have full declaration of the producer, which might reduce risk related to private label selection. Negative relation is discovered for the consumer stating quality and health characteristics of food to be the main food selection determinants. They tend to buy private label “rarely” or “very rarely”, whereas the distribution of respondents that prioritized price and taste in food selection is inconclusive-equally among categories of purchase frequency.

The results from the consumer evaluation are presented in the Tab. 5 which shows mean liking scores for five samples in two experimental conditions. The highest liking mean score in both experimental conditions has been given to the sample N2 which is the high quality product of the national market leader positioned in the

gourmet segment. The liking score for this sample was significantly higher (p=0.010) when the respondents knew the brand of the sample (informed tasting). In this case we can confirm an assimilation effect due to a positive image of the brand.

Table 5. Mean liking scores of hedonic sensory evaluation and effect of information on brand
Tabela 5. Srednje vrednosti hedoničnega senzoričnega vrednotenja in vpliv informacije o blagovni znamki

Sample code	Mean liking score		Standard deviation		Mean Difference	Significance (2-tailed)
	Blind	Informed	Blind	Informed		
N1	4.56	5.08	1.627	1.557	.526	.001
M pl	4.46	5.02	1.703	1.483	.561	.000
S pl	4.08	3.80	1.852	1.709	-.282	.088
D	3.17	3.12	1.914	1.829	-.045	.753
N2	5.07	5.42	1.533	1.455	.346	.010

The second ranked sample in blind testing was N1 and similarly the information about brand resulted in significantly higher mean ranking (p=0.001). Very close mean ranking has been revealed for the sample M-pl which is the private label "version" of the sample N1. There is virtually no other difference except the label design. This is also confirmed by almost negligible difference in mean scores under blind conditions. Respondents in the study therefore attested as rather reliable sensory evaluators. It is interesting, that also in the M-pl sample respondents show positive assimilation with statistically significant difference in mean liking (p=0.000). Actually, the informed-blind mean ranking difference was the largest for that sample. Obviously here consumers are aware of no difference between the producer brand and the private labelled product version. Another possible assimilation determinant might be the fact that the owner of the private label M-pl is the leading retail chain in Slovenia with aggressive private label marketing strategy and explicit ethnocentric positioning. It is rather different for the retail chain which is marketing the product under the sample code S-pl. Hedonic rating under informed conditions gave lower average liking score than blind tasting; however, the difference is not significant. The retailer chain is a subsidiary of a Global buying group and has only recently intensified the promotion strategy for private label segment. It has also rather different strategy regarding private label category composition than the leading retailer in Slovenia. Prevailing part of the private label products is sourced from the common supply chains of the corporation and are therefore not of Slovenian origin. We might therefore speculate that the perception of private label products in this retailer chain is characterized with some uncertainty having in mind expressed high preference of Slovenian consumers to domestic origin of food.

Information on the brand has no significant effect in the case of the D sample; however both average liking scores were lowest. The quality of this product

obviously does not correspond to the expectations of Slovenian consumers. The brand has also lost image of reliable quality in the segment of processed vegetable.

CONCLUSIONS

Our study confirms that the information about brand can significantly affect consumers' hedonic sensory judgment of food. Consumer sensory judgment is therefore influenced by past experiences, familiarity, advertising etc. and preference is therefore influenced by more than the taste of food itself. When comparing the impact of experimental condition with respect to the type of brand, we observed the effect of assimilation also in the case of private label products which might be explained by responses from the attitudinal questions and actual market conditions in Slovenia. It has been noticed that consumers have a set of expectation related to a certain private label which is furthermore influenced by the perceived image of the retailer. In case where the retailer has a reputation on offering private labels produced by domestic leading manufacturers assimilation revealed has been positive. Opposite was discovered in the case of an international retailer where the assimilation has been negative, however not significant. It might be therefore inhered that consumers when making sensory evaluation are influenced similarly by the private label and producer label e.g. there is no difference regarding the type of label. These findings contribute to complex matter and have important implications for strategic brand management. Consumers do not perceive private labels as a "second class" label also in the case when the segment is non-diversified and only first generation private labels exist. Slovenian private label shoppers might be identified as a price-cautious but quality-sensitive. This highlights the necessity of permanent low price strategy for private label food and preventing differentiation from the producer brands in respect of perceived quality. On the other hand the food enterprises should strengthen the extrinsic cues of their products. This situation means that product and brand managers must begin to understand what drives the growing share given to store brands. And the acceptance of such brands means that the traditional view of store brands as a riskier purchase must merit re-evaluation. The concept of efficient consumer response where producer brand owners undertake to eschew price promotions in favor of consistent low prices in Slovenia seems an attractive proposition. Certainly, the retail chains, as the main customers of national brands, are inclined on securing a more consistent approach from manufacturers. However, as we have noticed seen in recent years, the power of supermarket buyers affects brand strategies very considerably. Consideration of the retailer bargaining power can jeopardise the decision to introduce a private label. When retailer bargaining power is high enough, it gives the distributor incentives to maintain its reputation by making the losses. As confirmed in our study, if the good is characterised by a low purchase frequency, significant bargaining power is not sufficient to ensure producer brand dominance. There is indeed a threshold under which a reputable brand is not viable, whatever the market condition. The consumer benefits, as the availability of a low-price product increases alternative choices. More importantly, consumers may prefer the guarantee offered by a familiar retail chain store on a cheaper product than the uncertainty and the risk of an unfamiliar

brand. It has been the minor brands that have disappeared from the market at the expense of private label products.

Potentials for competitive advantage for producer brands therefore relies on superior quality and highly differentiated images via advertising, effective and continuous product innovation and creative design. National brand producers need to put the emphasis on strategies that sustain and justify the price premium over private labeled goods.

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Morphological and agronomic evaluation of tissue culture derived Indian soybean plants

R. RADHAKRISHNAN[1], B.D.RANJITHA KUMARI[2]

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ABSTRACT

Somaclonal variation has become common for many plant species including soybean (*Glycine max* (L.) Merr). The present study was aimed to compare the morphological and yield characters of tissue culture derived and field grown soybean cultivar CO-3 (Coimbatore-3). With respect to the plants derived from tissue culture, the morphological characters such as length of roots, shoots, petioles, internodal region, number of leaf nodes, leaf area, fresh and dry weight of leaves and roots and yield contributing characters length of pods, number of flowers/ node, number of pods/ node, number of pods/ plant, number of seed aborted fruits and number of seeds/ pod were significantly ($p>0.05$) varied from parent or field grown plants, except seed yield. Even the variation was observed in both the type of plants, since the difference was not too large. We conclude that tissue culture technique is not detrimental for plant growth and performance and which is widely used in many genetic engineering techniques.

Key words: soybean, morphological and yield character, somaclonal variation, tissue culture

IZVLEČEK

MORFOLOŠKE IN AGRONOMSKE LASTNOSTI RASTLIN INDIJSKE SOJE, REGENERIRANIH IZ TKIVNIH KULTUR

Somaklonska variabilnost je pri soji (Glycine max (L.) Merr) in mnogih drugih rastlinah med uporabljanimi viri genske variabilnosti. Namen te raziskave je bil preveriti pojavljanje variabilnosti med rastlinami dobljenimi iz tkivnih kultur pri soji cv. CO3 (Coimbatore 3). Avtorji so primerjali regenerirane rastline s kontrolnimi rastlinami. Ugotovili so vrsto značilnih razlik pri morfoloških lastnostih, nas primer glede na dolžino korenin, poganjkov, petiol, internodijev in strokov. Poleg teh lastnosti so bile tudi razlike glede na število olistanih nodijev, število cvetov na nodij, strokov na nodij, strokov na rastlino, stevilo semen na strok, svežo in suho teža listov in korenin značilne ($p>0.05$), razlike pa niso bile značilne glede na pridelek rastlin. Ker razlike niso bile velike, avtorji

[1] Ph.D. Student, Dept. of Plant Science, Bharathidasan University, Trichirappalli-620024, Tamil Nadu, India.

[2] Reader, Dept. of Plant Science, Bharathidasan University, Trichirappalli-620024, Tamil Nadu, India. Corresponding author email: ranjithakumari2004@yahoo.co.in, Phone: 00-91-431-2407061, Fax: 00- 91-431 - 2407045.

ugotavljajo, da spremembe zaradi somaklonske variabilnosti niso nujno škodljive za rastline.To je pomembno, saj se tehniko tkivnih kultur široko uporablja pri uporabi metod genskega inženiringa.

Ključne besede: soja, morfološke lastnosti, pridelek, somaklonska variabilnost, tkivne kulture

1. INTRODUCTION

Genetic variation is an essential component of any conventional crop breeding programme. Conventionally, plant breeders recombine the desired genes from crop varieties and related species by sexual hybridization and develop new cultivars with the desirable traits such as high yielding and resistance to disease, insect and pests and drought. They are now faced with an even greater challenge to sustain food production for the ever-growing human population. The adoption of new technologies such as plant tissue culture and recombinant DNA may help in achieving some of the goals to increase food production. There is a great potential of cell and tissue culture techniques in plant improvement provided plants can be readily regenerated in large numbers (Jain, 1998).

Soybean is an economically important plant and their regeneration from tissue culture has been difficult and recently it became routine. Plants regenerated from tissue culture have exhibited various morphological and biochemical variation due to mutations which is termed as somaclonal variation (Larkin and Scowcroft, 1981). Chromosomal aberrations ranging from changes in ploidy to whole chromosome loss have been demonstrated for tissue culture derived plants. Mutations at different stages like single gene, multigene, and cytoplasmic mutation have also been described previously by Lee and Phillips, 1988; Dahleen et al., 1991. Ranch and Palmer (1987) found 80 chromosomes in regenerated soybean progeny. Barwale and Widholm (1989) reported mixaploidy with chromosome counts ranging from 10 to 60. Freytag et al. (1989) described changes in leaf morphology and growth habit from indeterminate to determinate in organogenically regenerated soybean plants. Where as, three soybean genotypes were regenerated with the organogenic cultures which showed significant variability for plant height and yield, while differences in lodging and maturity were not significant (Graybosch et al., 1987; Wright et al., 1986) and the significance of yield differences between regenerated and control plants were low. Barwale and Widholm (1987) studied the morphology of 212 SC_3 families and 789 SC_4 families from nine soybean genotypes regenerated through both the embryogenic and organogenic culture. The variant phenotypes included chlorophyll deficiency, sterility, abnormal leaf morphology, abnormal leaf number and dwarf growth habit. Interestingly one variant phenotype with wrinkled leaf trait was found to be maternally inherited (Stephens et al., 1991a). However, the regenerated plants were not extensively evaluated for agronomic traits. The objective of this study was to test the presence of tissue culture derived variation in morphological and agronomic traits under field conditions in the plants regenerated by organogenesis.

2. MATERIALS AND METHODS

2.1. Plant material

The certified seeds of Soybean cv. CO3 were obtained from Tamilnadu Agricultural University, Coimbatore, India and used as an initial explant for plant source.

2.2. Seed sterilization and seed pretreatment

The seeds were surface sterilized with 0.1% $HgCl_2$ solution for 5 min and 70% alcohol for 1 min and again washed thoroughly with distilled water for 5 times. The seeds were cultured in B5 medium (Gamborg et al., 1968) Supplemented with 1.0 mg/L Thidiazuron (TDZ) in aseptic condition and the pH of the medium was adjusted in to 5.8 by adding 0.1 N NaOH or 0.1 N HCl and 16 h light and 8 h dark photoperiod was maintained by cool fluorescent lamp.

2.3. Tissue culture and plant regeneration

The cotyledonary node with axillary buds were excised from seven days old seedlings and transferred in to 1.0 mg/L TDZ treated B5 medium. After three weeks, the regenerated plants were hardened in the mud cub and maintained in the growth chamber. The hardened plants were transferred in to the field after one week. At the same time, the healthy seeds were propagated in ten mud pots. The experiment was repeated thrice.

2.4. Analysis of morphological and yield variation between somaclonal line and parent plants:

Both somaclonal line and parent plants, morphological and yield characters like length of roots, shoots, petioles, internodal region and pods and then number of leaf nodes, number of flowers/ node, number of pods/ node, number of pods/ plant, number of seed aborted fruits, number of seeds/ pod, leaf area, fresh and dry weight of leaves and roots and seed weight were measured at over the seed maturation in the pod.

2.5. Statistical analysis

Data from the experiment were analyzed by SPSS software, in which statistical significance was determined at the 0.05 probability level.

3. RESULTS AND DISCUSSION

Comparison of somaclonal lines (SC) with the parental cultivar CO3 showed significant variation ($p < 0.05$) for length of roots, shoots, petioles, internodal region and pods and then number of leaf nodes, number of flowers/ node, number of pods/ node, number of pods/ plant, number of seed aborted fruits, number of seeds/ pod, leaf area, fresh and dry weight of leaves and roots, but not in seed weight.

The results presented in our study revealed that some morphological variations exhibited between somaclonal lines (SC) and parental cultivar CO3 (table 1). The length of roots, shoots, internodal regions, petioles and root fresh weight were highly reduced (above 50%) in somaclonal lines than that of parent plants. In somaclonal plants, fresh and dry weight of leaf, leaf area and number of leaf node were reduced (< 25%) when compared with parent plants. The root dry weight was also reduced into 35% compared with parent plants. The changes in plant height and leaf size among micropropagated plants have been reported to be the effect of somaclonal variation in some plant species (Ravindra et al., 2004). The high

variability observed in micropropagated rhubarb PC49 might be triggered by the cytokinin during micropropagation (Yipeng et al., 2005). Due to the hormonal concentrations in the tissue culture medium, the somaclonal variations occured caused in soybean.

Table 1. Comparison of morphological characters of somaclonal lines and parent plants

S. No	Morphological characters	Parent plants	Somaclonal line
1.	Root length (cm)	38.03±0.15	14.32±0.17
2.	Shoot length (cm)	123.43±0.21	53.82±0.25
3.	No. of leaf nodes	10.13±0.25	7.92±0.23
4.	Length of internodal region(cm)	8.81±0.24	4.27±0.23
5.	Length of petiole (cm)	12.18±0.17	6.2±0.18
6.	Leaf area (cm)	1681.58±25.1	1264.61±45.7
7.	Leaf fresh weight (g)	1.22±0.14	0.88±0.14
8.	Leaf dry weight (g)	0.260±0.02	0.21±0.16
9.	Root fresh weight (g)	0.274±0.03	0.112±0.01
10.	Root dry weight (g)	0.028±0.06	0.018±0.00

The yield characters, number of flowers/ nodal region, number of pods/ nodal region, length of pods and number of seeds (table 2) were less significant variations between somaclonal lines and parent plants. The number of pods/ plants and percentage of seed aborted fruits were increased 30% in somaclonal lines than that of parent plants. The number of pods in somaclonal lines were more than parent plants, which had equalized the yield reduction. In oil palm, woody tropical crop species, field evaluation of tissue culture derived plants revealed the occurrence of variant palms which show an abnormal flower development preventing fruit set (Duval et al., 1995).

Table 2. Comparison of yield contributing characters of somaclonal lines and parent plants

S. No	Yield characters	Parent plants	Somaclonal line
1.	No. of flowers/ nodal region	3.43±0.07	2.47±0.10
2.	No. of pods / nodal region	2.19±0.13	1.25±0.16
3.	No. of pods / plants	6.86±0.10	8.85±0.16
4.	Length of pod (cm)	4.06±0.15	3.32±0.12
5.	No. of seeds / pod	2.27±0.10	1.78±0.09
6.	Seed weight (g)	0.101±0.01	0.092±0.05
7.	Seed aborted fruits (%)	61.98	73.42

The seed weight was slightly reduced (less than 10%) in somaclonal lines when compared to that of parent plants. Stephens et al., (1991b) also showed same results in soybean cultivar A3127, which is in consistence to the results of Graybosch et al.

(1987), who showed a less variation in yield for some of the regenerated soybean lines. The normal appearance and small differences in the variants suggest that several genes or a minor gene may have been altered. If chromosome aberrations were present or if genes responsible for qualitative traits had been altered, we would expect to see abnormal plants and greater variation (Stephens et al., 1991b). The frequency of somaclonal variation would depend on the culture protocol applied during the *in vitro* process, particularly on the hormone composition of the medium and the number of subcultures. (Ducos et al., 2003).

The results presented here showed that soybean plants cultured through an organogenic regeneration procedure would not necessarily have detrimental mutations resulting from the tissue culturing process and would retain the yield potential of the parental cultivar. The results showed that somaclonal variation did cause significant beneficial variation.

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Indigenous arbuscular mycorrhiza is more important for early growth period of groundnut (*Arachis hypogea L.*) for P influx in an Oxisol

Amitava RAKSHIT[1] and P.B.S BHADORIA[2]

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ABSTRACT

The contribution of indigenous arbuscular mycorrhiza (AM) on phosphorus (P) uptake by groundnut was examined in a low P field soil. The fungicide benomyl was applied to eradicate mycorrhizal infection. The treatments consisted of three P levels viz. 0, 50 and 400 mg P kg^{-1} soil, with and without benomyl application. Groundnut as test crop was sown two weeks after the application of benomyl and was harvested four times covering the whole growth period. At each harvest, the shoot yield, shoot P concentration, root length, soil solution P (C_{Li}) and per cent root infection by AM was determined for benomyl treated and untreated soil at all P levels. Benomyl showed no effect on soil solution P concentration. When P was limiting, application of benomyl did reduce early groundnut growth by 40-50% at P-0, and by 25-30% at P-50. At high P supply (P-400), benomyl had little or no effect on dry matter production. Thus, indicate that the effect of benomyl on plant growth was by its influence on P uptake from soil. Phosphorus supply affected percentage of root infected by AM which was 40% of the roots at P-0, and decreased to around 30% and 10% at P-50 and P-400. In the early growing season, the P influx of maize was dependent on P in soil solution and the effect of AM was rather large. At high P supply, the contribution of AM to P influx showed a decrease. Without or low AM infection and at low P level, the P influx was 62% of that with AM. During early growth period groundnut showed a similar behaviour as maize at middle growth stage and without AM reduction of P influx, which was to an extent of 67%. In absolute terms AM is more important at maximum growth in the early growth season for groundnut. It is evident from the present investigation that AM may make an significant contribution by about 35 % to the P nutrition of groundnut, but other factors, like P solubilization by root exudates, may be even more important.

Key words: Oxisol, benomyl, arbuscular mycorrhiza, groundnut, solution concentration, P uptake, root length.

[1] Department of Soil Science and Agril Chemistry, Institute of Agricultural Science, BHU, Varanasi,221005, UP, India E-mail: amitavabhu@gmail.com

[2] Department of Agricultural and Food Engineering, Indian Institute of Technology Kharagpur 721 302, India

IZVLEČEK

SPONTANA ARBUSKULARNA MIKORIZA JE POMEMBNA ZA OSKRBO RASTLIN ARAŠIDA (*Arachis hypogea* L.) S FOSFORJEM

Proučevan je bil vpliv samonikle arbuskularna mikorize (AM) na sprejem fosforja (P) pri rastlinah arašida. Fungicid benomyl je bil uporabljen za zagotovitev kontrolnih rastlin brez mikorize. Gnojenje s P je potekalo na treh nivojih in sicer 0, 50 in 400 mg P na kg tal, z oziroma brez uporabe benomyla. Arašidi so bili posajeni dva tedna po tretiranju tal s fungicidom, vzorce so jemali štirikrat tekom obdobja rasti. Pri vsakem jemanju vzorcev je bila določena teža poganjkov, koncentracija P v poganjkih, dolžina korenin, topen P v tleh in odstotek okužbe z mikorizno glivo, na obeh nivojih tretiranja s fungicidom in na vseh nivojih dodatka P. Fungicid ni vplival na vsebnost topnega P v tleh. Ko je bil P omejujoč dejavnik je fungicid zmanjšal zgodnjo rast arašidov za 40 do 50% pri P-0 in za 25 do 30% pri P-50. Pri visokem dodatku P (P-400) je imel fungicid majhen vpliv ali sploh ni imel vpliva na pridelek sušine. Tako kaže, da je fungicid vplival na rast rastlin z vplivom na sprejem P iz tal. Oskrba s P je vplivala na AM, ki je bila 40% pri koreninah skupine rastlin P-0 in se je znižala na okoli 30% in 10% pri P-50 in P-400. Pri visokih odmerkih P se je zmanjšal pomen AM za oskrbo rastlin s P. Brez AM in pri nizkem nivoju P je bil dotok P v rastline samo 62% tistega, ki je bil pri rastlinah z AM. AM je najpomembnejša za zagotovitev maksimalne rasti v začetku rastne sezone arašidov. Raziskava je pokazala da je AM značilno prispevala z okoli 35% deležem oskrbe rastlin arašidov s P, da pa so lahko celo bolj pomembni tudi drugi vplivi, kot na primer, da izločki korenin prispevajo k povečanju topnega P v tleh.

Ključne besede: Oxisol, benomyl, arbuskularna mikoriza, arašidi, koncentracija topnega P, privzem P, dolžina korenin.

1 INTRODUCTION

In the tropics and subtropics (Oxislos and Alfisols) strong weathering is associated with an increase in the amount of sesquioxides, which exhibit high P sorption properties (Torrent, 1997). When P fertilizers are applied to replenish soil fertility major portion of is bound in oxisols by Fe/Al oxides as P compounds of variable adsorption strength, reducing the effectiveness of P fertilization and results in low P soil. Due to these reasons, phosphorus is often limiting crop growth in these soils of low P supplying capacity. Crop species differ in their ability to grow well in low phosphorus supplying soils (Föhse *et al.,* 1988). A persistently low level of available phosphorus in the soil solution has led to numerous morphological, physiological, and biochemical adaptations by plants to survive in the nature. The results of field experiment on wheat, maize and groundnut (Bhadoria *et al*., 2001) carried out on a low P soil have shown that maize had an increased P influx during the middle growing season even though influx was very low in the early stage, groundnut showed a high P influx right from the beginning and wheat had an average to low P influx during the whole growing season. Possible reasons for this large variation of influx among the crops during the growing season at limiting P supply may have been due to the contribution of arbuscular mycorrhizae (AM) (Marschner, 1995), phosphatase activity near root (Elliott and Lauchli, 1986) and rate of root exudation (Gerke *et al.,* 1994). The present investigation was undertaken to study the significance of AM on P influx of groundnut under field conditions.

2 MATERIALS AND METHODS

Field experiments were carried out on a P fixing soil of eastern India at the Agricultural and Food Engineering Department experimental farm of Indian Institute of Technology Kharagpur, India. The soil with $pH_{(H2O)}$ 5.3, organic C 3.5g kg^{-1}, contained 16% clay, 24% silt and 6.2 ppm P (Bray.1). Treatments consisted of three P levels, P-0 (unfertilised, without P), P-50 (50 mg P kg^{-1} soil) and P-400 (400 mg P kg^{-1} soil) as single superphosphate and treatment with and without benomyl Treatments were arranged in a factorial randomised block design with four replication. Commercial formulated grades of the fungicides, benomyl was mixed thoroughly to 15 cm soil depth at 500 kg ha^{-1}. Nitrogen was applied at the rate of 20 kg ha^{-1} and potassium at the rate of 50 kg ha^{-1}. Besides that Ca and Mg and micronutrients including Zn, Fe, Cu, B, Mn and Mo were applied at the recommended doses for this soil. After levelling the field plots, seeds of groundnut (*cv. A K 12/24*) were sown in rows keeping row to row spacing of 30cm and plant to plant distance was 20cm.

The crop was harvested four times to obtain shoot yield, root length shoot P concentration, Soil solution P concentration (Adams, 1974) and per cent root infection by mycorrhizae during the growing season. Dry mass of shoots were recorded after drying in a hot air oven at 60°C to a constant weight and grinding to a fine powder. The P content was determined after tri-acid digestion, using the vanado-molybdophosphoric yellow color method
Phosphorus influx is calculated as follows:

$$In = 2(U_2-U_1) / ((t_2-t_1) (RL_2+RL_1)$$

where,
In = P influx (mol $cm^{-1}s^{-1}$),
U = P uptake (mol m^{-2}),
RL = root length (cm m^{-2}),
t = time (seconds)
subscripts 1 and 2 refers to current and previous harvests

Percentage root infection:
Root infection was assessed on a representative root sample taken from each plot in fixed positions evenly distributed at each harvest to a depth of 15 cm were taken. The roots from each plot sample were separated, washed free of soil, cut into 1-1.5 cm lengths. Root samples were stained with tryptan blue (Philips and Hayman, 1970). AM infection of each plant was determined by estimating the percent root colonization as described by Bierman and Linderman (1981).

Per cent root infection was obtained as follows:

$$\%\,\text{Root infection} = \frac{(100 \times \text{Number of intersections with arbuscular infections})}{\text{Total number of intersections counted}}$$

3 RESULTS

Soil solution concentration

Table 1 shows the average soil solution concentration (C_{Li}) during the growing season at different P fertilization both in benomyl treated and untreated plots. It may be seen that C_{Li} increases exponentially with P fertilization. Application of fertilizer at the rate of 50 mg P kg^{-1} soil had negligible effect on C_{Li} which become significant only at P-400 level. Effect of benomyl on C_{Li} was non significant (Table 1) at all harvests. In general, there was decrease in C_{Li} in benomyl treated plots as compared to untreated plots and this was more at P-0 than at P-50 or P-400 levels .The results clearly show that benomyl had no major effect on P concentration in the soil solution, and consequently on the P availability in soil (Fitter and Nicholas, 1988).

Bentivenga and Hetrick (1991) also found that benomyl application could not measurably change P availability in a silty clay loam soil.

Table 1. Effect of benomyl on soil solution concentration (μM) of phosphorus of groundnut at no P (P-0), 50 mg P kg^{-1} (P-50) and 400 mg P kg^{-1} (P-400) application to the soil.

P levels (mg kg^{-1} soil)	30 DAS		50 DAS		68 DAS		112 DAS	
	Benomyl							
	-	+	-	+	-	+	-	+
0	0.90	0.62	0.85	0.52	0.73	0.45	0.71	0.45
50	2.95	2.23	2.50	2.10	2.50	2.10	2.45	2.05
400	6.39	6.25	6.30	6.20	6.25	6.20	6.05	6.00
	SEm±	LSD(0.05)						
P	1.21	3.73	1.18	3.49	1.13		1.08	3.26
B	1.06	NS	1.03	NS	3.41		0.78	NS
PxB	1.37	NS	1.33	NS	1.01	NS	1.18	NS
					1.25	NS		

(P: Phosphorus levels; B: Benomyl application; DAS: Days after sowing; SEm: Standard error of mean; LSD: Least square difference)

Root infection

The root infection by AM as effected by benomyl and P supply is shown in Table 2. In general the extent of mycorrhizal infection decreased, with increased application phosphate to the soil but the extent of this effect did not vary much between the crop species. It can be seen P supply affected percent root infected by AM, being 40% of the roots at P-0 and decreasing to around 30% and 10% at P-50 and P-400 respectively. This agrees with the results of earlier workers who have found that supply of phosphate to the plant by soil (Smith, 1982, Thompson et al., 1991) had an inhibitory effect on infection. High P application to the soil depressed AM formation and this effect has been attributed to the increase of P in the plant (Jasper, 1979, Amijee et al., 1989). There have been other experiment Mirinda et al., (1989) where it has been demonstrated that soil P levels have direct effect on AM particularly during the early stages of root colonization when the AM fungus is first developing in the soil. Benomyl was effective to suppress AM infection up to day 30. Thereafter some infection occurred, but was still less than in the untreated plot. Khaliq and Sanders (1997) found that inoculation of maize plants was effective during the early stages but response gradually disappeared during the later stages of growth. They also concluded that the inoculation response was reversed after the second harvest was because of higher root densities which might have been higher to render mycorrhizal fungus superfluous. Jakobsen (1987) and Thingstrup et al., (1998) reported that fumigation with Dazomet strongly decreased mycorrhiza formation and the effect persisted at least for 60 days after sowing.

Table 2. Effect of benomyl on root infection (%) of groundnut at no P (P-0), 50 mg P kg^{-1} (P-50) and 400 mg P kg^{-1} (P-400) application to the soil.

P levels (mg kg^{-1} soil)	30 DAS		50 DAS		68 DAS		112 DAS	
	Benomyl							
	-	+	-	+	-	+	-	+
0	60	0	32	8	28	10	25	12
50	48	0	26	10	22	12	20	14
400	0	0	6	2	12	2	14	4
	SEm	LSD(0.05)						
P	1.46	4.42	1.30	3.91	1.48	4.47	1.30	3.91
B	1.90	5.73	1.06	3.20	1.20	3.61	1.06	3.20
PxB	2.07	6.24	1.84	5.65	2.09	6.28	1.84	5.64

(P: Phosphorus levels; B:Benomyl application; DAS: Days after sowing; SEm: Standard error of mean; LSD: Least square difference)

Shoot and root growth

Table 3 gives the shoot growth as affected by P supply and Benomyl application. Phosphorus supply affected groundnut growth mainly in the later stages, early growth reduction was much smaller. Dry matter yield recorded following benomyl treatment was significantly lower over untreated plot. At high P supply (P-400), benomyl had little or no effect on dry matter production. This result indicates that benomyl has no direct effect on growth. This is in conformity with the findings of Carey et al. (1992) who concluded that Benomyl had no direct effect on the growth of wide range of plants. When P was limiting, the application of Benomyl did reduce early groundnut growth by 25 % at P-0 and by 10 % at P-50. In general, variation in dry matter production due to influence of both P levels and benomyl application has been small in the initial stage of crop growth but gradually increased up to third harvest. However the growth reduction during second harvest showed drastic decrease in benomyl treated P-0 plot than untreated plot. Groundnut had small growth rates when young, the rates increased strongly by 5-7 times in the middle for both benomyl treated and untreated plots. Reduction of growth following benomyl application is mainly attributed to eradication of AM and that might have influenced the P uptake from soil. Similarly Thingstrup et al., (1998) reported that the growth and P content of flux was lower in fumigated than in untreated plots and this effect decreases with increasing level of P application.

Table 3. Effect of benomyl on shoot growth (g m^{-2}) of groundnut at no P (P-0), 50 mg P kg^{-1} (P-50) and 400 mg P kg^{-1} (P-400) application to the soil.

P levels (mg kg^{-1} soil)	30 DAS		50 DAS		68 DAS		112 DAS	
	Benomyl							
	-	+	-	+	-	+	-	+
0	9.14	3.78	62.7	48.3	211	201	385	365
50	11.16	5.73	73.5	66.2	268	260	433	403
400	10.93	9.81	69.6	69.3	244	241	492	463
	SEm	LSD(0.05)						
P	0.31	0.92	1.93	5.82	4.73	14.3	11.9	36
B	0.25	0.78	1.57	4.73	3.89	NS	10.9	NS
PxB	0.44	1.35	2.73	NS	6.68	NS	20.1	NS

(P: Phosphorus levels; B: Benomyl application; DAS: Days after sowing; SEm: Standard error of mean; LSD: Least square difference)

Table 4. Effect of benomyl on root length (km m^{-2}) of groundnut at no P (P-0), 50 mg P kg^{-1} (P-50) and 400 mg P kg^{-1} (P-400) application to the soil.

P levels (mg kg^{-1} soil)	30 DAS		50 DAS		68 DAS		112 DAS	
	Benomyl							
	-	+	-	+	-	+	-	+
0	0.12	0.21	0.57	0.62	1.92	2.08	1.28	1.32
50	0.16	0.23	0.72	0.74	2.38	2.46	1.35	1.37
400	0.16	0.24	0.68	0.70	2.31	2.36	1.40	1.52
	SEm	LSD(0.05)						
P	0.02	0.06	0.017	0.051	0.06	0.18	0.06	0.18
B	0.02	NS	0.013	NS	0.05	NS	0.05	NS
PxB	0.03	NS	0.023	NS	0.08	NS	0.09	NS

(P: Phosphorus levels; B: Benomyl application; DAS: Days after sowing; SEm: Standard error of mean; LSD: Least square difference)

P Influx

Benomyl application had almost no effect on P concentration in the shoot and so P uptake was closely related to dry matter production. The central question of this section is the effect of mycorrhiza on P uptake. If mycorrhizal hyphae absorb P and transport it to the root than the uptake expressed per unit of root and unit time, the influx, should be increased due to mycorrhiza. Figure 1 depict the relationship between the P influx as a function of the P concentration in soil solution. The P influx is shown for plants with full mycorrhizal infection or with no or reduced infection due to benomyl application. Furthermore is shown the P influx as calculated by the model which does not include mycorrhizal action nor the effect of root exudates on P solubility in soil, i.e., without chemical mobilization.

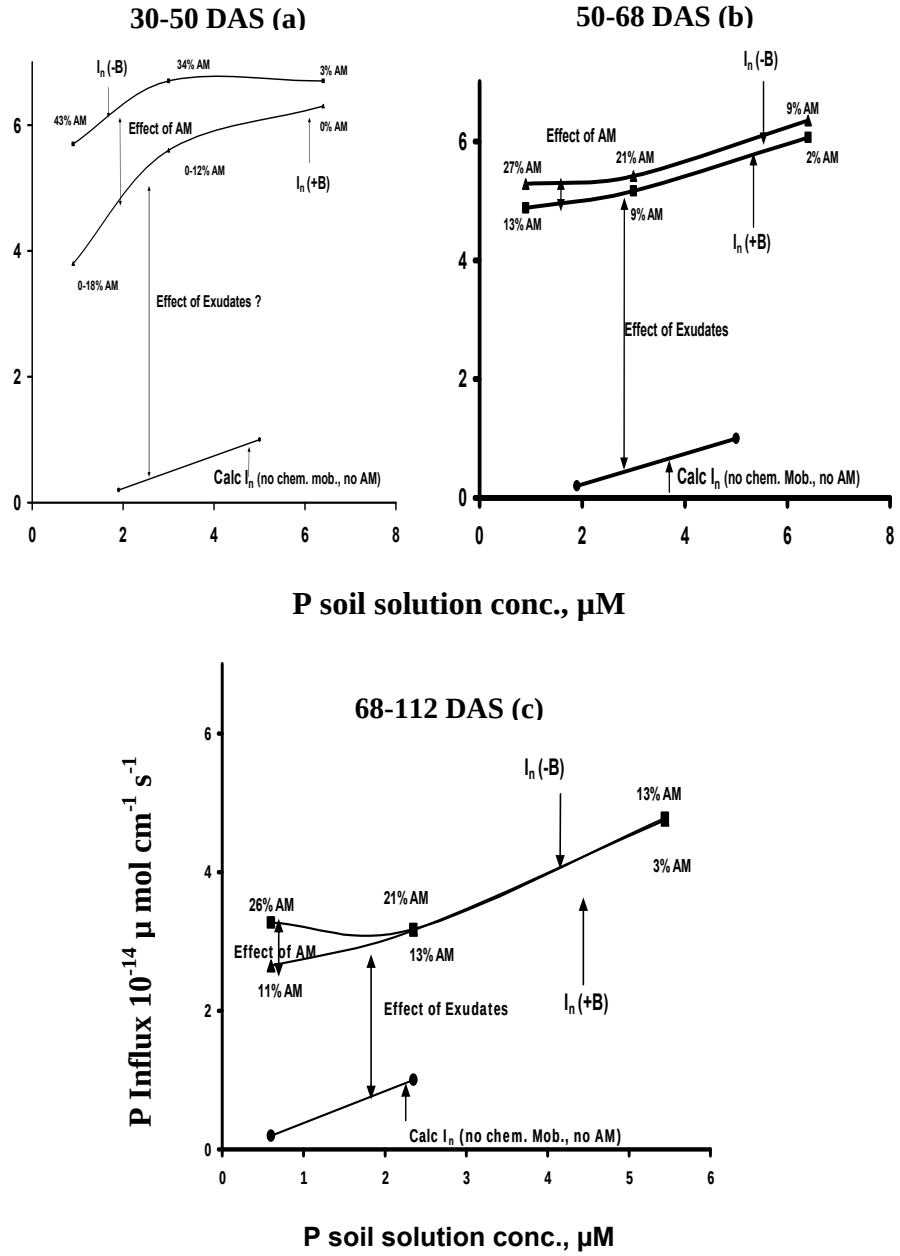

Figure 1: Phosphorus influx, (I_n), of groundnut roots as a function of P concentration in soil solution of roots not treated (-B) or treated with benomyl (+B) in early (a) and middle (b) growing season. Furthermore the mycorrhizal infection (% AM) of the roots is given and the P influx as calculated by a model without the action of arbuscular mycorrhiza nor of root exudates (DAS).

The P influx in groundnut with full mycorrhizal infection or with no or reduced infection due to benomyl application shows that in the early growing season (Figure 1) the P influx of groundnut was increased sharply and was not dependent on P supply, being around $6x10^{-14}$ mol $cm^{-1}s^{-1}$ at C_{Li} = 0.8 (P-0) as well as at C_{Li} = 6.3 µM (P-400). At this growth stage the effect of AM was largest at low P supply. Without AM infection and at low level the P influx was 67% of that with AM infection (Fig.1). In middle and end of the growth cycle, P influx was found to be related to P supply, where the degree of AM infection had no influence. Jakobsen (1986) and Smith (1982) reported two to three times increase in influx of P in to the roots of pea and clover plants respectively where mycorrhiza was not controlled. Influx of P in roots colonized by mycorrhizal fungi could be several times higher than in non-mycorrhizal roots (Smith and Read, 1997) in different crops.

4 DISCUSSION

Comparing the P influx of the plots treated with and without benomyl (Figure 1) it was observed that at full AM infection, P influx could increase by factor of 3 to 4. However, without AM infection, the influx was still higher as calculated by simulation model. It is speculated that the reasons for measured influx being higher than calculated influx could be the solubilizing action of the root exudates.

According to the theory of diffusion P (Barber, 1995) transports to the root and therefore P influx should be about proportional to P concentration in soil solution, C_{Li}. This was evident in case of maize during early growing season, when influx was low, but at a later stage when P influx was high, soil solution concentration showed no effect on P influx and this could be the reason for different behavior of P influx in early and middle growing season. AM could not explain fully the variation in the measured P influx. A possible explanation, could be that in early growing season, the root functions mainly as an absorbing organ i.e., as sink for P, and in that case transport to the root is determined by the concentration in soil solution. Later, the root actively participates in P dynamics in the rhizosphere by excreting root extudates that influenced P solubility in soil.

Since in our experiments we assessed the effect of AM on the P influx we can now estimate the effect of root exudates that solubilize strongly bound soil P on P influx by knowing the difference between measured P influx without AM and calculated influx simulated by the nutrient uptake model. One has to keep in mind that the estimate of the effect of root exudates is a residual of all other determinations and calculation and all errors if committed will accumulate here. With this caution, it can be seen that chemical mobilization (action of root exudates) for groundnut was almost 50-60% of P influx in early and middle of the season and becoming less in the later part of the growth stages. The remaining 50 to 40 % of P influx not accounted for by model calculation or by AM, could be due to root exudates and other factors that solubilize strongly bound soil P. Root exudates, often as a reaction to phosphorus deficiency (Ae *et al*., 1990; Gerke *et al*., 1994;) could have made an important contribution towards P uptake, because of their influence on P solubility in soil.

The results show that AM can make an significant contribution towards P nutrition as observed in groundnut, but other factors, like P solubilization by root exudates, can be even more important.

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Agrovoc descriptors: drought; precipitation; precipitation deficit; data collection; soil water; soil water deficit; groundwater; statistical data

Agris category code: P40; P10

COBISS code 1.01

Obravnava meteorološke suše z različnimi indikatorji

Andrej CEGLAR[1], Lučka KAJFEŽ-BOGATAJ[2]

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IZVLEČEK

Meteorološko sušo pogosto označimo s sušnimi indeksi, ki so preprosti za uporabo, hkrati pa absorbirajo ogromne količine podatkov o količini padavin, temperaturi, vodnemu režimu v tleh, … Za študijo meteorološke suše v Sloveniji smo uporabili dva tovrstna indeksa: standardiziran padavinski indeks – SPI ter Palmerjev indeks sušnosti – PDSI. SPI lahko izračunamo na različnih časovnih skalah, zaradi česar lahko bolje opredelimo začetek, trajanje ter intenziteto suše. Prilagodljiva časovna skala pri SPI nam lahko pomaga nadzirati sušo tudi v kmetijstvu in hidrološkem sistemu. Primerjava obeh indeksov na primeru izračuna za Ljubljano nam je pokazala, da se PDSI najbolje ujema z SPI na devet- ter dvanajst-mesečni časovni skali. Oba indeksa kažeta, da je bilo v Ljubljani po letu 1900 najbolj sušno leto 1946. S pomočjo SPI smo ugotovili tudi statistično značilno (α=0,05) upadanje količine poletnih padavin v Ljubljani, Murski Soboti ter Biljah v obdobju 1971 – 2006 (postaje se nahajajo na klimatsko različnih območjih v Sloveniji). Analiza meteorološke suše v letu 2003 nam je pokazala, da je bil v vegetacijskem obdobju ekstremen primankljaj padavin prisoten na širšem območju Slovenije z izjemo skrajnega severozahodnega dela, kjer je bila količina padavin nadpovprečna. Leto 2003 je bilo pri nas eno izmed najbolj sušnih po letu 1950.

Ključne besede: meteorološka suša, standardiziran padavinski indeks, Palmerjev sušni indeks, padavine, Slovenija

ABSTRACT

ANALYSIS OF METEOROLOGICAL DROUGHT WITH DIFFERENT INDICATORS

Meteorological drought is often described in terms of drought indices, which are simple to use and simultaneously absorb great amount of precipitation data, temperature data, ground water content data, etc. Two of them were used in analysis of meteorological drought in Slovenia: standardised precipitation index – SPI and Palmer drought severity index – PDSI. SPI can be calculated on different time scales, which is better for determining drought onset, duration and intensity. SPI with its adjustable time scale can be useful tool to determine the effects of precipitation shortages to ground water level, river discharges and soil water content. The comparison of two indices in Ljubljana showed us good agreement between the PDSI and SPI

[1] univ. dipl. meteor., Biotehniška fakulteta, p.p. 2995, 1001 Ljubljana, andrej.ceglar@bf.uni-lj.si

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

on nine-month and twelve-month time scale. Both indices showed us that after 1900 Ljubljana experienced worst drought conditions in 1946. SPI on three months time scale showed us significant (α=0,05) negative trend for summer precipitation (period 1961 - 2006) for stations Ljubljana, Murska Sobota and Bilje (they are located in three different climatic regions within Slovenia). Six months SPI for September 2003 indicated extreme precipitation deficiency in greater part of Slovenia (except northwest, where above average precipitation was measured). In 2003 Slovenia recorded its most severe drought conditions after 1950 in all agricultural parts.

Key words: meteorological drought, standardised precipitation index, Palmer drought severity index, precipitation, Slovenia

1 UVOD

Suša velja za enega izmed kompleksnejših naravnih pojavov; je normalna ter ponavljajoča značilnost v vseh podnebnih tipih, vendar je pri njenih lastnostih in vplivih zaznati precejšnjo regionalno variabilnost (Wilhite, 1999). Širok nabor področij, na katere vpliva suša, geografska raznolikost pojavljanja suše ter zahteve po zalogah vode, ki jih določamo sami, otežujejo oblikovanje ene same definicije suše. V splošnem zato obstajata dve vrsti definiranja suše; prva je pojmovna, druga pa operativna. Pojmovne definicije pomagajo ljudem razumeti pojem suše, operativne definicije suše pa pomagajo ljudem prepoznati začetek, konec, pogostost pojavljanja ter intenziteto suše. Slednje temeljijo predvsem na odstopanju količine padavin od dolgoletnega povprečja. V kmetijstvu pomagajo primerjati dnevno količino padavin z evapotranspiracijo, kar omogoča določevanje razmerja zmanjševanja vlažnosti v tleh, iz česar se nato sklepa na vpliv suše na samo rastlinje v različnih fazah razvoja.

Suša se v nekaterih pogledih razlikuje od drugih naravnih nevarnosti. Težko je ugotoviti začetek in konec, saj se posledice akumulirajo počasi skozi precejšnje časovno obdobje, vztraja pa lahko več let. V splošnem poznamo štiri vrste suš: meteorološka, kmetijska, hidrološka ter socialno-ekonomska suša. Meteorološka suša je odvisna izključno od stopnje suhosti (manj padavin od povprečja) ter trajanja obdobja brez padavin. Ponavadi je definirana s stopnjo primankljaja padavin (v primerjavi z neko normalno oz. povprečno vrednostjo) in trajanjem sušnega obdobja. Nekatere definicije identificirajo sušo glede na število dni, ko je količina padavin manjša od vnaprej določenega nivoja. V območjih, ki jih karakterizirajo sezonske padavine, je daljše obdobje brez padavin povsem nekaj normalnega, zato tam določevanje suše glede na število dni brez padavin nima smisla. Definicije kmetijske suše se nanašajo na situacije, ko je v tleh premalo vlage, da bi ta zadostila potrebam rastlin v rastnem obdobju. Poleg padavin je v tem primeru potrebno upoštevati še zaloge vode v tleh ter razliko med dejansko in potencialno evapotranspiracijo. Količina vode, ki jo rastlina potrebuje, je odvisna od vremenskih razmer (temperatura, relativna vlažnost), biološke sestave ter razvojne faze rastline ter od sestave tal, na katerih se ta rastlina nahaja. Ob pomanjkanju talnih (reke, jezera) in podtalnih vodnih zalog (podtalnica), govorimo o hidrološki suši, ki jo povzroči manjko padavin skozi daljše časovno obdobje. Pojavlja se na nekoliko daljši časovni skali, kot meteorološka ter kmetijska suša. Socialno-ekonomska suša se nanaša na stanje, ki nastane, ko pomanjkanje vode začne vplivati na ljudi in

njihov način življenja. Ta povezuje ekonomske standarde z elementi meteorološke, kmetijske in hidrološke suše. V večini primerov se zahteve po vodi večajo z naraščajočim številom prebivalstva in večjo potrošnjo. Pri ekonomsko socialni suši še posebej velja poudariti dejstvo: če se zahteve po vodi na določenem območju večajo hitreje, kot vodne zaloge to dopuščajo, bo sušni »udarec« toliko bolj značilen.

Meteorološko, kmetijsko ter hidrološko sušo pogosto opišemo s sušnimi indeksi, ki so zelo pripravni in preprosti za uporabo, hkrati pa absorbirajo ogromne količine podatkov o količini padavin, snežni odeji, vodnemu režimu v tleh itd. Obstaja mnogo različnih indeksov, ki merijo odstopanja padavin v določenem časovnem obdobju od povprečne vrednosti, ki pripada daljšemu obdobju v preteklosti. Najpogosteje uporabljen indeks na tem področju je standardiziran padavinski indeks - SPI (Mckee s sod., 1993). SPI nam predstavlja, kaj določena količina padavin skozi neko časovno obdobje pomeni glede na normalno oz. pričakovano količino padavin za to obdobje. Edini vhodni podatek za njegov izračun predstavljajo padavine. Glavni prednosti tega indeksa sta njegova standardizirana narava in možnost izračuna na različnih časovnih skalah. To nam omogoča, da so frekvence sušnih dogodkov na katerikoli lokaciji ter na kakršnikoli časovni skali med seboj primerljive. SPI so uporabili za določevanje sušnih obdobij že na Madžarskem (Szalai in Szinnel, 2000), kjer so ugotovili, da je indeks na različnih časovnih skalah sposoben identificirati vse vrste suš. Saunders in Hughes (2002) sta v svoji analizi ugotovila, da SPI prispeva k boljši prostorski standardizaciji, kot Palmerjev indeks sušnosti (Palmer, 1968). SPI na nacionalnem nivoju uporablja tudi NMDC (National Drought Mitigation Centre), v projektinih raziskavah pa so ga uspešno uporabili v Mehiki, Kostariki, Argentini, Čilu, Turčiji, na Madžarskem, Južni Afriki ter Keniji (NMDC, 2007). Splošna ugotovitev študije o sušah v Evropi (Lloyd-Hughes in Saunders, 2002) obsega dejstvo, da je SPI preprosto in učinkovito sredstvo za ugotavljanje suše v Evropi. Vogt in sod. (2000) ugotavlja, da je SPI vse bolj uporabljeno orodje v znanstvenih krogih.

Namen študije je uporabiti SPI za analizo meteorološke suše v Sloveniji. Za Ljubljano, ki ima nekoliko daljši niz meteoroloških podatkov, smo poleg SPI izračunali tudi Palmerjev indeks sušnosti (PDSI) ter ju med seboj primerjali. Analizirali smo meteorološko sušo v letu 2003 ter časovno vrsto SPI za poletne mesece na treh meteoroloških postajah v Sloveniji (Murska Sobota, Ljubljana ter Bilje). Tovrstna študija je tudi osnova za bolj obširno raziskavo o sušnem nadzoru nad območjem Slovenije ter jugovzhodne Evrope.

2 MATERIAL

Meteorološko sušo v Sloveniji smo analizirali z SPI, za Ljubljano pa smo izračunali še PDSI. Za izračun prvega potrebujemo čim daljši padavinski niz za določeno meteorološko postajo, pri drugem pa poleg padavin potrebujemo še temperaturo ter podatek o kapaciteti tal za zadrževanje rastlinam dostopne vode. Pri prostorski interpolaciji SPI smo uporabili 161 meteoroloških postaj v Sloveniji z zveznimi padavinskimi nizi za obdobje 1961 – 2006 (slika 1).

Slika 1: Lokacije meteoroloških postaj v Sloveniji, ki so bile izbrane za izračun SPI
Figure 1: Locations of meteorological stations in Slovenia, that were chosen for the calculation of SPI

Vse podatke in metapodatke smo dobili iz arhivov Urada za meteorologijo Agencije Republike Slovenije za okolje (ARSO). Za prostorsko interpolacijo SPI smo uporabili metodo splošnega kriginga z upoštevanjem nadmorske višine (Cressie, 1993), ki je implementirana v geostatističnem programskem paketu GSTAT. Nekoliko podrobnejšo analizo SPI ter PDSI smo naredili za Ljubljano, kjer so meritve padavin ter temperature prisotne od leta 1866 naprej.

3 METODE

Pri določevanju začetka, trajanja ter intenzitete suše si pomagamo s sušnimi indeksi. Sušni indeksi so ponavadi zvezna funkcija količine padavin, temperature ter vsebnosti vode v tleh. Največkrat so za izračun najbolj uporabni tisti indeksi, katerih vhodni podatki predstavljajo le padavine, saj imamo za te ponavadi dostopen dolg niz meritev. Samo podatki o količini padavin sami po sebi ne odražajo sušnih razmer najbolje, služijo pa kot strokovna rešitev na območjih, kjer drugih podatkov ni (Tate in Gustard, 2000).

3.1 STANDARDIZIRAN PADAVINSKI INDEKS (SPI)

SPI nam omogoča določevanje pogostosti ekstremno suših oz. ekstremno mokrih dogodkov na določeni časovni skali za katerokoli lokacijo, ki ima arhiviran padavinski niz podatkov. SPI je bil izpeljan z namenom, da bi lahko izmerili presežke oz. primankljaje padavin na različnih časovnih skalah. Različne časovne skale nam omogočajo določiti vpliv padavinskega primankljaja oz. presežka na razpoložljivost vodnih zalog pri različnih vodnih virih.

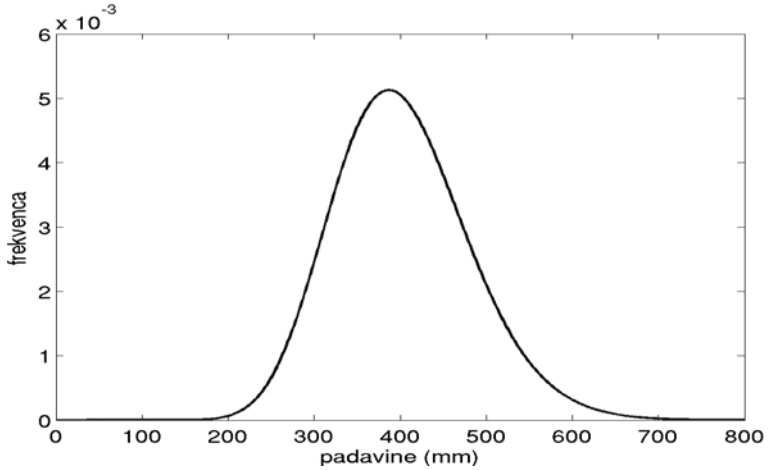
Thom (1966) je ugotovil, da se gama porazdelitev (1) dobro ujema s porazdelitvijo padavin v kalibracijskem obdobju. Porazdelitev gama definiramo s pomočjo frekvence oz. verjetnostne porazdelitvene funkcije kot:

$$g(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta} \Rightarrow x > 0\,, \tag{1}$$

kjer parameter α predstavlja obliko porazdelitve, parameter β definira časovno skalo, x nam predstavlja količino padavin, $\Gamma(\alpha)$ pa je funkcija gama:

$$\Gamma(\alpha) = \int_0^{\infty} y^{\alpha-1} e^{-y} dy\,. \tag{2}$$

Najprej je potrbno poiskati ustrezne parametre α in β tako, da se bo verjetnostna porazdelitvena funkcija (1) najbolje ujemala z porazdelitvijo padavin. Postopek iskanja parametrov α in β je podrobno opisan v članku »Some Methods of Climatological Analysis« (Thom, 1966). Slika 2 kaže primer frekvenčne poradelitve poletnih padavin (enačba 1) za Ljubljano, s parametri $\alpha = 26$ ter $\beta = 16$. Maksimum porazdelitve se nahaja nekoliko pod 400 mm.



Slika 2: Porazdelitev količine poletnih padavin za Ljubljano, kalibracijsko obdobje 1961 - 2000
Figure 2: Frequency distribution of summer precipitation for Ljubljana, calibration period 1961 – 2000

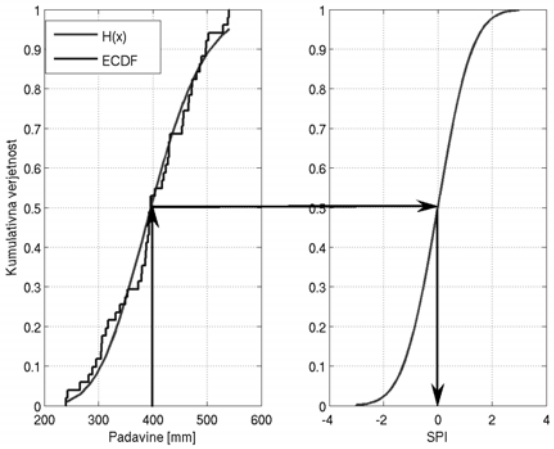
Z izračunanimi parametri določimo kumulativno verjetnost za opazovan padavinski dogodek (s količino padavin x) za določeno časovno skalo ter mesec v letu. Kumulativno verjetnost izračunamo kot:

$$G(x) = \int_0^x g(x)dx = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} \int_0^x x^{\alpha-1} e^{-x/\beta} dx\,. \tag{3}$$

Ker gama porazdelitev ni definirana pri x=0 (v izbranem mesecu ni bilo padavin), kumulativno verjetnost zapišemo kot:

$$H(x) = q + (1-q)G(x)\,, \tag{4}$$

kjer je q verjetnost, da ni padavin (x=0). Kumulativno verjetnost H(x) je nato potrebno pretvoriti v standardizirano normalno naključno spremenljivko Z s povprečjem 0 ter varianco 1, kar je nato kar vrednost indeksa SPI. Pojmovno tako SPI predstavlja število standardnih odklonov padavinskega dogodka pod oz. nad povprečjem, kjer je SPI enak 0 (Panofsky in Brier, 1958). Uporaba metode je ilustrirana na sliki 3, kjer je prikazana transformacija padavinske porazdelitve s slike 2 (poletne padavine v Ljubljani, obdobje 1961 - 2000).



Slika 3: Pretvorba vsote poletnih padavin (v našem primeru 400 milimetrov) v vrednost indeksa SPI. Gladka krivulja na levem grafu H(x) predstavlja izračunano kumulativno porazdelitev padavin, lomljena črta (ECDF) pa nam predstavlja empirično kumulativno porazdelitev.

Figure 3: Transformation of summer precipitation cumulative (400 milimeters in our case) into SPI. Smooth curve H(x) on left graph represents derived cumulative precipitation distribution, graded line ECDF represents empirical cumulative distribution.

Na tej sliki torej vidimo transformacijo trimesečne vsote padavin (junij, julij, avgust) v vrednost SPI (s povprečjem 0 ter varianco 1). Lomljena črta na levem grafu predstavlja empirično kumulativno verjetnostno porazdelitev za omenjeno vsoto padavin za obdobje 1961 – 2000. Gladka krivulja na levem grafu predstavlja kumulativno verjetnostno porazdelitev G(x), krivulja na desnem grafu pa kumulativno verjetnostno porazdelitev standardizirane normalne naključne spremenljivke Z. Vrednost SPI odčitamo na x osi na desnem grafu, kot kaže vrisana puščica (če npr. v poletnih mesecih skupno izmerimo 400 mm padavin, potem tej vrednosti po transformaciji pripada vrednost SPI okrog 0). Računski posotopek pretvorbe kumulativne verjetnostne porazdelitve G(x) v statndardizirano normalno spremenljivko Z je podrobneje opisan v članku »Accepting the standardised precipitation index: A calculation algorithm« (Guttman, 1999).

Že Tannehil (1947) je ugotovil, da majhna količina dežja v najbolj sušnem obdobju na določeni lokaciji lahko pomeni padavinsko obilje za drugo lokacijo. Akinremi s sod. (1996) je ugotovil, da glavni problem pri razvijanju primernega sušnega indeksa predstavljajo časovne in prostorske dimenzije suše; ne samo, da morajo biti padavinska odstopanja normalizirana glede na lokacijo, temveč morajo ta biti normalizirana tudi v času. Samo v tem primeru lahko indeks dobro opiše sušo. SPI izpolnjuje oboje; normaliziran je glede na lokacijo postaje, ker razloži frekvenčno porazdelitev padavin, ravno tako pa tudi spremljajočo variabilnost na sami postaji. Normaliziran pa je tudi v času, ker ga lahko izračunamo v kakršnem koli številu časovnih skal. Ne glede na lokacijo ter časovno skalo izračuna, SPI predstavlja kumulativno verjetnost glede na izbrano kalibracijsko obdobje, na osnovi katerega sta bila določena parametra gama porazdelitve. Preglednica 1 predstavlja vrednosti indeksa SPI ter pripadajočo sušno klasifikacijo s kumulativno verjetnostjo (ta je podana v procentih).

Hayes s sod. (1999) je ugotovil prednosti in slabosti uporabe SPI. SPI tri prednostne lastnosti:

1. Prva in glavna prednost je enostavnost uporabe tega indeksa. SPI temelji le na padavinskih nizih ter zahteva izračun samo dveh parametrov (PDSI npr. zahteva izračun 68 parametrov). Ker SPI ni odvisen od parametrov vlažnosti v tleh, ga lahko uporabimo za izračun v zimskem in poletnem času. Nanj ravno tako ne vpliva topografija.
2. Druga prednost je variabilna časovna skala izračuna; tako lahko opišemo sušne razmere v smislu meteorološke, kmetijske ter hidrološke uporabe. Tovrstni časovni značaj indeksa nam omogoča analizo sušne dinamike (določitev začetka ter konca suše).

3. Tretja prednost SPI izhaja iz njegove standardizirane narave. Ta nam omogoča, da so frekvence ekstremnih sušnih dogodkov na katerikoli lokaciji ter katerikoli časovni skali med seboj primerljive.

Po drugi strani pa ima SPI tri pomankljivosti:

1. Prva pomankljivost izhaja iz predpostavke, da obstaja primerna teoretična verjetnostna porazdelitev, s katero opišemo gole padavinske podatke; to seveda zahteva določeno količino kvalitetnih podatkov. McKee et al. (1993) predlagajo vsaj 30 letni padavinski niz za določitev parametrov gama porazdelitve.
2. Druga omejitev izhaja iz standardizirane narave indeksa; ekstremne suše (smatrano čez daljše obdobje) se bodo pojavljale z isto frekvenco na vseh lokacijah. SPI zato ni zmožen identificirati področij, ki so bolj »naklonjena« ekstremnim sušam od drugih.
3. Tretji problem se pojavi, ko uporabimo SPI na krajših časovnih skalah (1 mesec, 2 meseca) na območjih, kjer je sezonska količina padavin majhna. V tem primeru se lahko pojavijo zavajujoče visoke pozitivne ali negativne vrednosti indeksa SPI.

S standardiziranim padavinskim indeksom kot indikatorjem je določena operativna definicija suše. Posamezen sušni dogodek se začne, ko je vrednost SPI neprekinjeno negativna ter pade pod -1 in traja toliko časa, dokler se vrednost SPI v časovni vrsti zopet ne dvigne nad 0 (Wilhite, 1999). Intenziteta sušnega dogodka je določena z najnižjo doseženo vrednostjo indeksa v tem obdobju. Obseg suše pa je enolično določen kot vsota absolutnih vrednosti indeksa med trajajočim sušnim dogodkom (Mckee s sod., 1993):

$$DM = -\left(\sum_{j=1}^{x} SPI_{ij} \right), \tag{5}$$

kjer se j začne s prvim sušnim mesecem ter konča ob koncu sušnega dogodka (x).

Preglednica 1: Klasifikacija suše ter pripadajoča verjetnost za pojav sušnega dogodka pri SPI
Table 1: Drought classification by SPI value and corresponding event probabilities

SPI	Klasifikacija	Verjetnost (%)
2,00 ali več	ekstremno mokro	2,3
1,50 do 1,99	zelo mokro	4,4
1,00 do 1,49	zmerno mokro	9,2
0 do 0,99	normalno	34,1
0 do -0,99	normalno	34,1
-1 do -1,49	zmerna suša	9,2
-1,50 do -1,99	huda suša	4,4
-2,00 ali manj	ekstremna suša	2,3

4.1 PALMERJEV INDEKS SUŠNOSTI (PDSI)

Izračun PDSI temelji na določeni zbirki empiričnih enačb, ki jih je izpeljal Palmer (1965). Indeks je bil vse od izpeljave eden najbolj uporabljenih sušnih indikatorjev v ZDA. PDSI predstavlja uteženo vsoto indikatorja trenutnega stanja vlažnosti ter vrednosti indeksa v prejšnjem časovnem koraku. Indikator trenutnega stanja vlažnosti zapišemo kot:

$$d = P - \hat{P}, \tag{6}$$

kjer P predstavlja mesečno vsoto padavin, $\hat{P}$ pa je klimatsko utežena vsota mesečnih padavin (Palmer, 1965). S pomočjo $\hat{P}$ zapišemo vodno bilančno enačbo:

$$\hat{P} = \overline{ET} + \overline{R} + \overline{RO} - \overline{L}, \tag{7}$$

kjer členi po vrsti predstavljajo povprečne vresdnosti (za kalibracijsko periodo) evapotranspiracije ($\overline{ET}$), višine talnega vodnega rezervoarja $\overline{R}$, površinskega odtoka

($\overline{RO}$) ter izgube vode iz tal ($\overline{L}$). V nadaljevanju postopka je treba najprej izračunati Palmerjev indeks stanja vlažnosti Z :

$$Z = K \cdot d \,, \tag{8}$$

kjer parameter K igra vlogo klimatske uteži in je uporabljen z namenom primerljivosti indeksa v prostoru in času. PDSI za i-ti mesec je potem definiran kot:

$$PDSI_i = 0.897 \cdot PDSI_{i-1} + Z_i / 3 \,. \tag{9}$$

Tako dobljeno vrednost PDSI potem primerjamo z intervali, kot so prikazani v preglednici 2, in določimo primerno sušno klasifikacijo.

Osnovna prednost PDSI je njegova standardizirana narava (Lloyd-Hughes B. in Saunders M. A., 2002), ki nam olajša kvantitativno primerjavo nastopa suše na različnih krajih ter časih.

Pri izračunu smo uporabili kalibrirano verzijo PDSI, ki izračuna klimatske uteži za vsako lokacijo posebej. V prvotni verziji (Palmer, 1965) so bili ti koeficienti zaradi računske zahtevnosti ter nerazvite računalniške tehnologije, določeni za omejeno območje v ZDA, zato so bili rezultati izračuna vprašljivi za ostale predele sveta (Alley, 1984).

Preglednica 2: Klasifikacija suše pri PDSI
Table 2: Drought classification by PDSI value and corresponding event probabilities

PDSI	Klasifikacija
4,00 ali več	ekstremno mokro
3,00 do 3,99	zelo mokro
2,00 do 2,99	zmerno mokro
1,00 do 1,99	neznatno mokro
0,50 do 0,99	začetek mokrega obdobja
0,49 do -0,49	normalno
-0,50 do -0,99	začetek suhega obdobja
-1,00 do -1,99	mila suša
-2,00 do -2,99	zmerna suša
-3,00 do -3,99	huda suša
-4,00 ali manj	ekstremna suša

4 REZULTATI Z RAZPRAVO

4.1 Meteorološka suša v Ljubljani

Pri izračunu indeksov za Ljubljano smo uporabili niza padavinskih ter temperaturnih podatkov, ki se začneta leta z letom 1900. Za izračun parametrov gama porazdelitve (enačba 1) smo uporabili kalibracijsko obdobje od leta 1901 do 2000. SPI smo izračunali na štirih časovnih skalah (tri-, šest-, devet- ter dvanajstmesečno), vrednosti pa so skupaj s PDSI prikazane na sliki 7. Ekstremno sušni ter mokri dogodki so pri obeh indeksih osenčeni.

SPI na tri- ter šest-mesečni časovni skali kaže nekoliko večjo variabilnost, kot na daljših časovnih skalah. Na sliki 7 vidimo, da na daljših časovnih skalah postanejo suše manj pogoste, vendar te trajajo dlje. SPI je precej močno koreliran z PDSI, predvsem na daljših časovnih skalah (preglednica 3); korelacija je največja med SPI na devet- ter dvanajst-mesečni časovni skali (r=0,76), kar se dobro ujema z rezultati,

ki jih je objavil Bussay s sod. (1998) za Madžarsko. SPI na trimesečni časovni skali pojasni preko 50 % variabilnosti SPI na šestmesečni časovni skali ter okrog 45 % variabilnosti PDSI. SPI na letni časovni skali pojasni okrog 56 % variabilnosti SPI na dvoletni časovni skali ter 58 % variabilnosti PDSI. Največja korelacija med SPI na devet- oz. dvanajst-mesečni skali s Palmerjevim indeksom je vidna tudi na sliki 7.

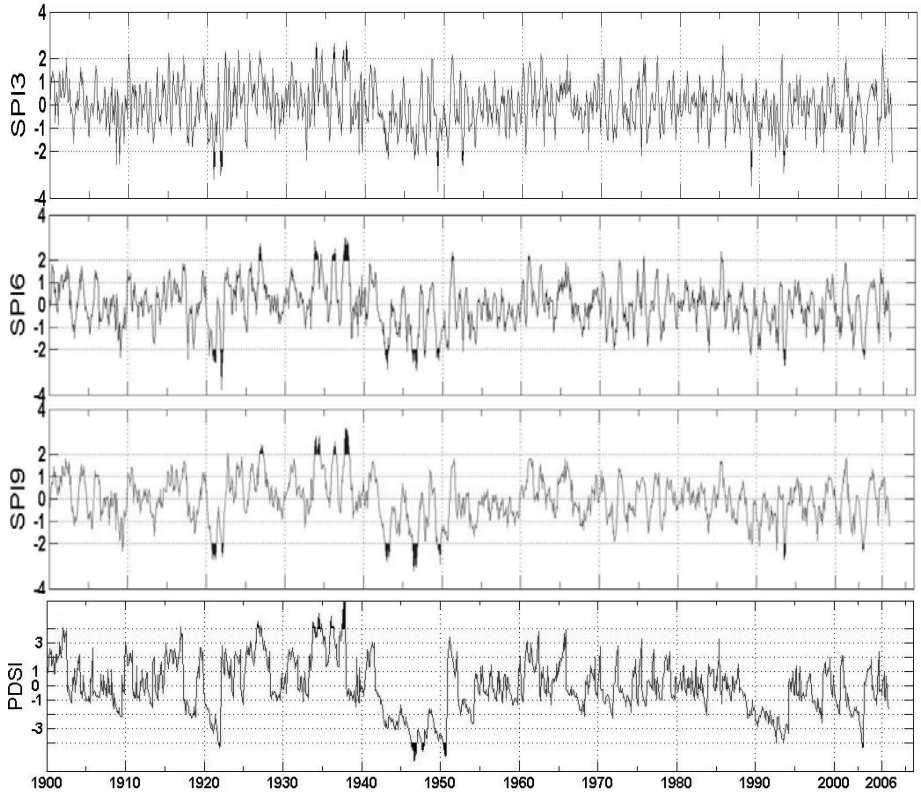
Preglednica 3: Korelacijski koeficienti med SPI3 – SPI 24 ter PDSI za Ljubljano
Table 3: Cross-Correlation between SPI3 – SPI24 and PDSI for Ljubljana

	SPI1	SPI3	SPI6	SPI9	SPI12	SPI24	PDSI
SPI1	1	0,55	0,39	0,32	0,30	0,22	0,47
SPI3		1	0,71	0,58	0,53	0,40	0,67
SPI6			1	0,82	0,72	0,56	0,75
SPI9				1	0,88	0,66	0,76
SPI12					1	0,75	0,76
SPI24						1	0,70
PDSI							1

Pri PDSI v splošnem ni zaznati tako velike variabilnosti, kot pri SPI (na krajših časovnih skalah). Na posameznih sušnih dogodkih, ki so opisani v nadaljevanju, lahko vidimo, da ima PDSI večji »spomin«, torej bolje opiše dogodke na daljši, kot na krajši časovni skali (to smo videli že pri korelacijskih koeficientih). PDSI ima »vgrajen« časovni korak devetih mesecev (Trnka, 2003), zato lahko razliko med SPI na devetmesečni časovni skali ter PDSI razložimo z upoštevanjem tal ter vodne bilance v izračunu PDSI. To je tudi razlog za manjšo variabilnost PDSI, saj lahko zaloga vode v tleh odloži začetek suše, ravno tako pa lahko tudi ublaži sam padavinski primankljaj, če ta ni prevelik in ne traja predolgo. Po daljšem padavinskem primankljaju PDSI ponavadi nekoliko kasneje konča sušno obdobje, saj izsušena tla potrebujejo nekaj časa za vzpostavitev vodnih zalog v talnem vodnem rezervoarju. Med sušnim obdobjem manjši padavinski skoki, ki jih zaznamo pri SPI na krajših časovnih skalah, ne pomenijo nujno bistvenega izboljšanja sušne situacije na daljši časovni skali. Tipičen primer te vrste vidimo ob koncu osemdesetih ter začetku devetdesetih let. V začetku leta 1989 je zelo ekstremen padavinski primankljaj povzročil začetek suše na daljši časovni skali. Padavinski primankljaj se je v naslednjih nekaj letih večal (SPI9 ter SPI12 sta bila večino časa negativna), zato je stalno upadal tudi PDSI. Tudi po ekstremnih padavinah ob koncu leta 1992 se je PDSI le malo povečal; znatno povečanje je videti šele v aprilu leta 1994.

Pred letom 1950 nam SPI na letni časovni skali kaže na 4 ekstremno sušne ter 4 ekstremno mokre dogodke. Ekstremna suša se je najprej začela konec leta 1920 ter se nadaljevala do septembra 1922 (SPI12 postane pozitiven). Podobno nam na ekstremno sušo kaže Palmerjev indeks, ki se marca v letu 1922 strmo dvigne, kar naznanja konec suše nekoliko prej kot SPI12. Ravno v tem obdobju je suša vztrajala na širšem območju Slovenije (Trontelj, 1997), v Ljubljani je padlo samo 850 milimetrov padavin. Sušam je sledilo nekoliko bolj mokro obdobje, kjer nam SPI12 kaže na ekstremno mokre dogodke v letih 1927, 1933 ter 1937. V letu 1933 je v

Ljubljani padlo kar 2003 milimetrov, v letu 1937 pa 2379 milimetrov padavin. V letu 1933 so na Barju imeli poplavo (v septembru), ravno tako pa je poplavljala tudi Ljubljanica (Trontelj, 1997). Sledilo je obdobje suš; ekstremni primankljaj padavin na letni časovni skali (SPI12) smo zabeležili v letih 1943, 1947 ter 1949, suša pa je vztrajala kar od leta 1942 do konca leta 1950. Podobno nam kaže tudi PDSI, kjer se dobro vidi, da je v tem obdobju suša vztrajala najdlje v zadnjih 100 letih. O sušah v letih 1942, 1943, 1946 ter 1949 poroča tudi Trontelj (1997). Kobold (2002) pravi, da je za Ljubljanico (meritev gladine v Mostah) v neprekinjenem obdobju opazovanj najbolj suho bilo leto 1947 (SPI12 ter PDSI sta v tem obdobju dosegla najmanjšo vrednost v prejšnjem stoletju).



Slika 7: Vrednosti SPI na tri-, šest-, devet- ter dvanajstmesečni časovni skali ter PDSI za Ljubljano (obdobje 1900 – 2006)

Figure 7: Drought severity index values representative of Ljubljana for the period 1900 to 2006

Po letu 1950 nam SPI12 ne kaže več ekstremnih sušnih dogodkov v Ljubljani, opaziti pa je nekoliko pogostejše pojavljanje ekstremne suše na krajših časovnih skalah (SPI3, SPI6). Najnižjo vrednost indeksa opazimo pri SPI na trimesečni skali v januarju 1989, ko je od novembra v prejšnjem letu do januarja padlo le 60 mm padavin. O suhi, topli in izredno sončni zimi 1989/90 piše tudi Trontelj (1997). Sušni dogodki so bili pogostejši po letu 1990, predvsem na krajših časovnih skalah. Padec PDSI je zaznati v začetku devetdesetih let, z najintenzivnejšo sušo v letu

1993. Takrat je dosegel ekstremno vrednost tudi SPI na eno-, tro-, -šest ter devet-mesečni skali. V zimi 1992/93 poročajo o ekstremni suši, ki se je nadaljevala do konca poletja (Trontelj, 1997). Oba indeksa (SPI na vseh časovnih skalah ter PDSI) kažeta na ekstremno sušo tudi v letu 2003; ta je bila v kmetijskem pogledu ena izmed najhujših v zadnjih 50 letih (Kajfež-Bogataj, 2005).

Preglednica 4 predstavlja najnižje vrednosti SPI na vseh časovnih skalah. Na mesečni časovni skali je dosegel najnižjo vrednost novembra 1924, ko je v Ljubljani padel le 1 milimeter padavin. Trimesečna vsota padavin za april (vsota februarskih, marčevskih ter aprilskih) je bila najmanjša v letu 1949, ko je od marca do aprila padlo le 28 milimetrov padavin. Dvanajstmesečna vsota padavin za september je bila najmanjša leta 1946, ko je od oktobra 1945 do septembra naslednje leto padlo le 615 milimetrov padavin.

Preglednica 4: Najnižje dosežene vrednosti SPI na različnih časovnih skalah v obdobju 1900 – 2006 (kalibracijsko obdobje za izračun SPI je 1901 – 2000). Poleg indeksa so še ustrezne vsote padavin za pripadajočo časovno skalo.

Table 4: Lowest values of SPI on different time scales for a period 1900 – 2006 (calibration period for SPI calculation is 1901 – 2000). Beside index values there are precipitation sums, belonging to time scale of SPI.

	Datum	Vrednost	Vsota padavin (mm)
SPI1	1924, november	-4,24	1
SPI3	1949, april	-3,73	28
SPI6	1921, december	-3,76	277
SPI9	1946, junij	-3,21	508
SPI12	1946, september	-3,49	615
SPI24	1921, december	-3,19	1781

4.3 Analiza količine poletnih padavin z SPI

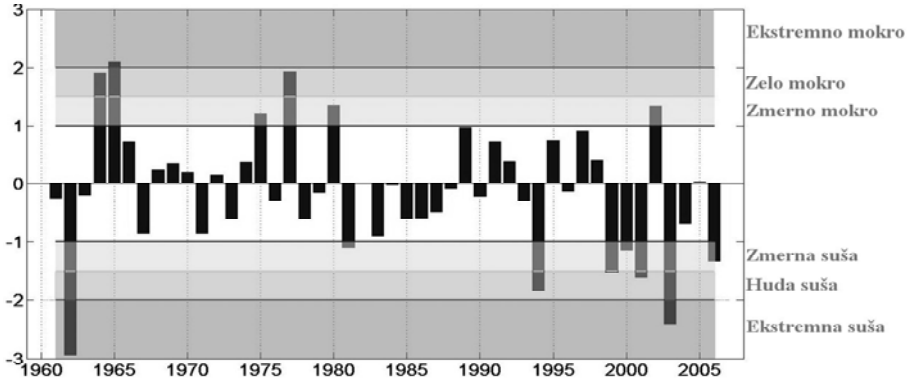
Trimesečni SPI za avgust primerja padavinsko vsoto za mesece junij, julij ter avgust v posameznih letih z isto trimesečno vsoto za vsa leta v kalibracijski periodi. Lahko bi rekli, da nam avgustovski trimesečni SPI govori o primankljaju oz. presežku poletnih padavin. Analizo tega parametra smo naredili za postaje Bilje, Ljubljano in Mursko Soboto.

Na sliki 8 je prikazana časovna vrsta tri-mesečnega SPI za mesec avgust za postajo Bilje. V Biljah smo imeli največji primankljaj padavin v poletju 1962, ko je vrednost indeksa padla kar krepko pod -2. V tem letu je padlo v poletju le 131 milimetrov padavin (v avgustu padavin ni bilo). Ekstremno sušno je bilo tudi poletje 2003, ko je padlo 162 mm padavin, medtem ko povprečna količina poletnih padavin v kalibracijskem obdobju znaša 360 milimetrov. Od leta 1998 naprej je z izjemo leta 2002 opaziti občutno bolj sušna poletja.

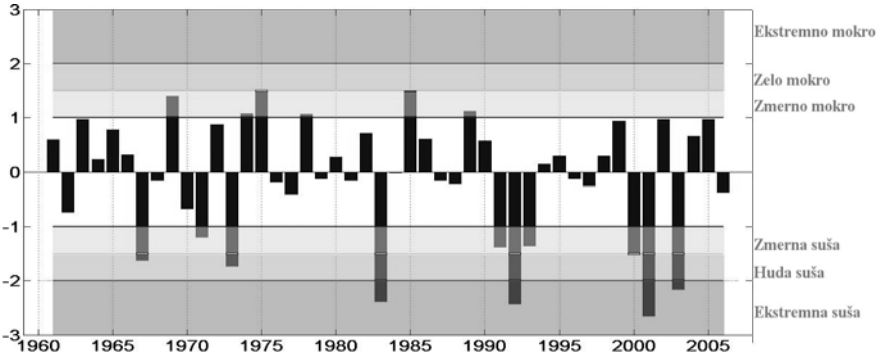
V Ljubljani so bila v obdobju od 1961 do 2006 kar štiri poletja ekstremno sušna (slika 9). Največji primankljaj padavin smo imeli v letu 2001, ko je poleti padlo le 228 milimetrov padavin, medtem ko povprečna količina padavin v kalibracijskem obdobju znaša 409 milimetrov. Ekstremno sušno je bilo tudi poletje 1992, ko je padlo 240 milimetrov padavin. Ekstremne primankljaje smo zabeležili še v letih 1983 ter 2003.

Tudi v Murski Soboti so poletja v zadnjih 15 letih v povprečju bolj sušna (slika 10). Izstopajo poletja v letih 1992, 2000 ter 2003. Največji primankljaj padavin je opaziti v poletju 1992, ko je padlo le 137 milimetrov padavin (povprečna količina poletnih padavin za Mursko Soboto znaša 296 milimetrov).

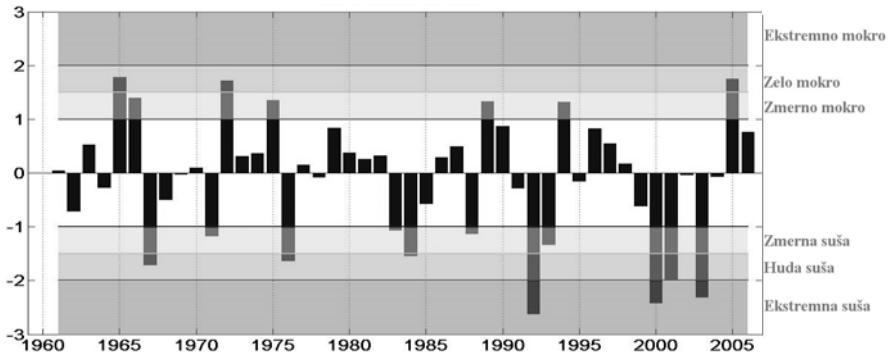
Na vseh treh postajah je opaziti statistično značilen upad količine poletnih padavin v obdobju 1971 – 2006 (ARSO, 2007). Pri stopnji tveganja 5 % lahko trdimo, da smo na vseh treh postajah opazili tudi statistično značilen upad trimesečnega SPI za avgust. Trend je najbolj negativen v Ljubljani.



Slika 8: Trimesečni SPI za mesec avgust ter postajo Bilje.
Figure 8: Three month august SPI for station Bilje.



Slika 9: Trimesečni SPI za mesec avgust ter postajo Ljubljana.
Figure 9: Three month august SPI for station Ljubljana.

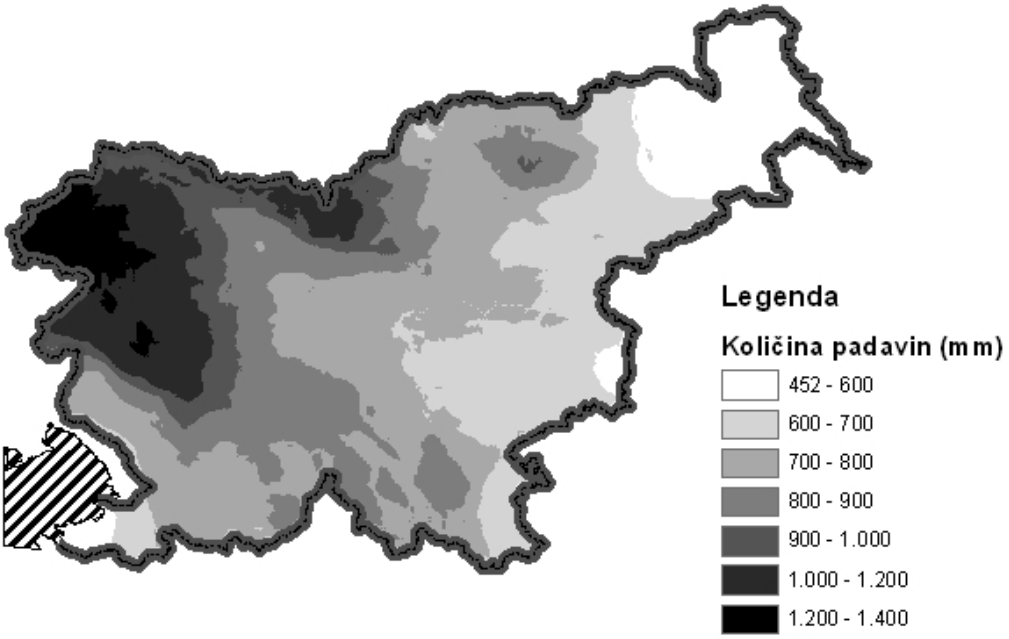


Slika 10: Trimesečni SPI za mesec avgust ter postajo Murska Sobota.
Figure 10: Three month august SPI for station Murska.

4.4 Meteorološka suša v Sloveniji v letu 2003

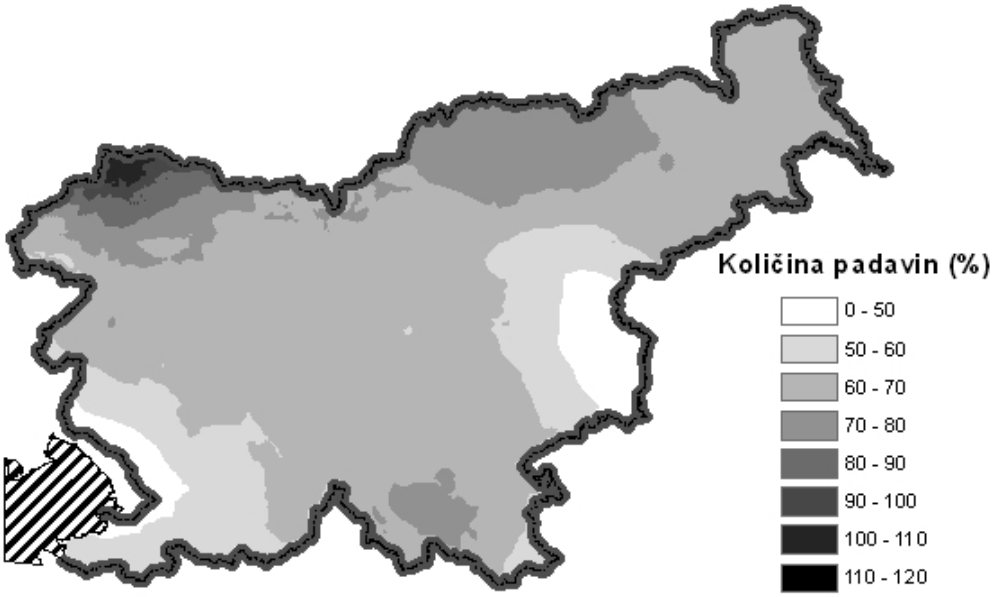
Prostorska porazdelitev vrednosti indeksa SPI je močno povezana s količino padlih padavin v določenem časovnem obdobju. Sama prostorska porazdelitev padavin v Sloveniji je povezana z njenim razgibanim reliefom. Orografski učinek povzroči povečanje količine padavin, ko gremo z morja proti notranjosti Slovenije, maksimalna pa je količina padavin ob Dinarsko-Alpski pregradi. Tako se ob obali letna količina padavin giblje med 1100 ter 1200 milimetri, v Julijskih Alpah pa pade letno tudi do 3200 milimetrov padavin. Letna količina padavin se močno zniža proti severovzhodu države, kjer ta ponavadi ne preseže 900 milimetrov. Primankljaj padavin na severovzhodu države tako pomeni povsem nekaj drugega kot enak primankljaj v goratih predelih zahodne Slovenije. Zaradi majhne količine padavin v severovzhodnem delu Slovenije ter na Primorskem se suše tam pojavljajo pogosteje. SPI je v tem pogledu dobro orodje za oceno meteorološke suše, saj nam opiše primankljaj oz. presežek padavin glede na povprečno vrednost na določenem območju. V smislu sušne intenzitete lahko zato primerjamo padavinski primankljaj na dveh območjih, ki imata povsem drugačne padavinske lastnosti. Koncept SPI je podoben sliki razlike med dejansko količino padavin ter povprečno količino padavin, njegova informacija pa podaja tudi statistično velikost odstopanja od povprečnih padavin in tako bolje prikaže resnost padavinskega primankljaja.

Analiza meteorološke suše v letu 2003 nam je pokazala ekstremne padavinske razmere v večjem delu Slovenije. Sliki 11 in 12 nam kažeta povprečno količino padavin v vegetacijski dobi (april - september) za obdobje 1961 – 2000 ter odstopanje količine padavin od povprečja v letu 2003. Tedaj je bila količina padavin v širšem območju Slovenije precej pod povprečjem, razen v skrajnem severozahodnem delu, kjer so namerili nadpovprečno količino padavin. Najbolj očitno odstopanje od povprečja je vidno v vzhodnem delu Slovenije (tam je padlo le nekaj nad 200 milimetri padavin), velik padavinski primankljaj pa je opazen tudi v severovzhodnem delu ter na Primorskem.



Slika 11: Povprečna količina padavin (v milimetrih) v vegetacijski dobi (april – september) za obdobje 1961 – 2000.

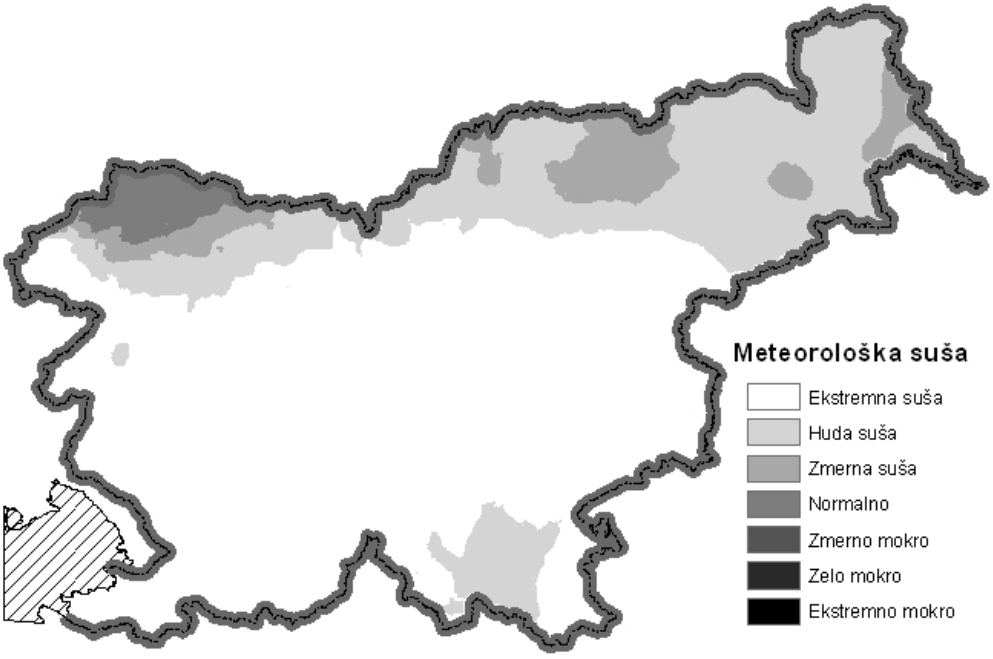
Figure 11: Average precipitation (in milimeters) in vegetation period (april – september) for calibration period 1961 – 2000.



Slika 12: Količina padavin v vegetacijski dobi leta 2003 v primerjavi s povprečjem obdobja 1961 – 2000.

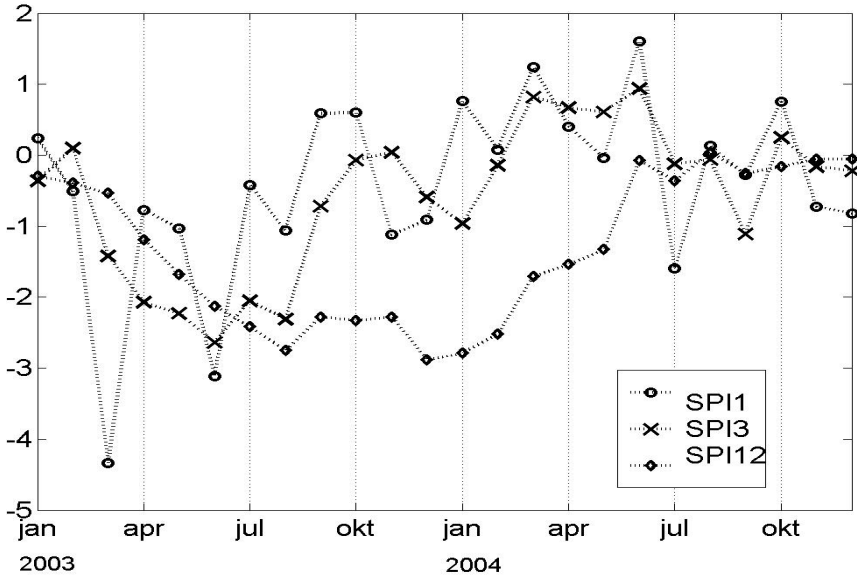
Figure 12: Precipitation amount in vegetation period 2003 compared with 1961 – 2000 normals.

Sliki odstopanja padavin je zelo podobna prostorka interpolacija šestmesečnega SPI (slika 13) za september v letu 2003. Z izjemo Zgornjesavske doline in nekaterih predelov Koroške ter severovzhodne Slovenije, je vegetacijsko obdobje v večjem delu države zaznamovala ekstremna meteorološka suša (ekstremni padavinski primankljaj).



Slika 13: Šestmesečni SPI za september 2003, kalibracijsko obdobje 1961 - 2000
Figure 13: Six month SPI for september 2003, calibration period 1961 – 2000

Razvoj meteorološke suše na različnih časovnih skalah v Murski Soboti je prikazan na sliki 14. Suša se je začela že v marcu 2003, ko je SPI na mesečni skali dosegel ekstremno negativno vrednost. V marcu je padlo padlo le 1,5 milimetra padavin (najbolj suh marec po letu 1961). Suša se je na mesečni skali nadaljevala vse do oktobra, ko je indeks dosegel pozitivno vrednost. Poleg marca je bil ekstremno sušen še junij. Na trimesečni skali je suša vztrajala vse od marca do novembra, ekstremen primankljaj pa je viden od aprila do septembra. Na letni časovni skali (SPI12) je indeks postal negativen že novembra v letu 2001; ta suša trajala vse do avgusta v letu 2004, z ekstremnimi primankljaji od junija 2003 do aprila 2004; dolgoročno je torej meteorološka suša vztrajala več let, kar je v veliki meri vplivalo tudi na kmetijski pridelek v regiji. Vodni primankljaj je močno prizadel ozimna žita, koruzo ter travno rušo, ravno tako pa je škodoval tudi sadnemu drevju (ARSO, 2007).



Slika 14: SPI na mesečni, trimesečni ter letni časovni skali za Mursko Soboto
Figure 14: SPI on different time scales for Murska Sobota

6 SKLEPI

V delu smo predstavili dva sušna indeksa (SPI ter PDSI) za določevanje začetka, trajanja ter intenzitete suše. SPI lahko izračunamo na različnih časovnih skalah, kar nam omogoča boljši nadzor nad sušo, natančnejšo določitev začetka ter trajanja suše. Poleg tega pri SPI kot vhodni podatek potrebujemo le padavinski niz, pri PDSI pa poleg padavin potrebujemo še temperaturni niz ter podatek o kapaciteti tal za zadrževanje rastlinam dostopne vode.

Primerjava SPI na različnih časovnih skalah ter PDSI za Ljubljano je pokazala, da se slednji najbolje ujema z SPI na devet- ter dvanajst-mesečni časovni skali. PDSI ima v primerjavi z SPI krajši odziv na padavinska odstopanja in se v splošnem obnaša bolj stabilno, kar se ujema tudi z rezultati madžarske študije (Szalai, Szinell, 2000). Počasnejši odziv bi lahko povzročil težave pri določevanju začetka ter konca sušnega dogodka. SPI je z možnostjo izračuna na večih časovnih skalah boljše orodje za karakterizacijo sušnega dogodka. Prilagodljiva časovna skala pri SPI bi nam lahko pomagala nadzirati sušo tudi v kmetijstvu in hidrološkem sistemu (kmetijske rastline se odzovejo že na krajše, hidrološki sistem pa na daljše pomanjkanje padavin). V splošnem smo videli, da je odziv SPI na padavinske razmere na daljši časovni skali počasnejši.

Analiza kolilične poletnih padavin z SPI nam je pokazala, da je količina poletnih padavin v Ljubljani, Biljah ter Murski Soboti v upadanju. Opaziti je vse več

ekstremno sušnih poletij, predvsem v Ljubljani, kjer je upad poletnega SPI za avgust tudi najbolj izrazit. Po letu 1990 so bila na vseh omenjenih postajah najbolj izrazito sušna poletja 1993, 2000, 2001 ter 2003.

Analiza meteorološke suše v letu 2003 nam je pokazala ekstremni primankljaj padavin v vegetacijskem obdobju v večjem delu Slovenije z izjemo severozahodnega dela; v večjem delu Slovenije je padlo le med 40 % ter 70 % dolgoletne povprečne količine padavin. Poleg ekstremne meteorološke suše je bila tudi kmetijska suša v letu 2003 ena izmed najhujših v zadnjih 50 letih (Kajfež-Bogataj, 2005). K kmetijski suši so prispevale tudi ekstremno visoke temperature, ki so povzročile intenzivnejše izhlapevanje. Za nadziranje kmetijske suše bi bilo zato potrebno med seboj primerjati več sušnih indeksov, ki poleg padavin upoštevajo tudi evapotranspiracijo.

Oba indeksa bo potrebno primerjati z merjenimi pretoki rek, globino podtalnice, vlažnostjo tal ter kmetijskim pridelkom. S tem bomo lahko ugotovili, na kateri časovni skali se SPI najbolje ujema s posameznimi parametri, poleg tega pa tudi morebitno ujemanje PDSI z naštetimi parametri.

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Agrovoc descriptors: climatic change; water balance; soil water balance; soil water deficit; models; drought

Agris category code: P40; P10

COBISS koda 1.02

Možni vplivi podnebnih sprememb na vodno bilanco tal v Sloveniji

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

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IZVLEČEK

Novejše projekcije podnebnih sprememb v vedno večji meri kažejo na spreminjanje vodne bilance tal, ki ima tudi povraten učinek nanje. Obravnavali smo časovno dinamiko vode v tleh za Ljubljano in Mursko Soboto za zadnjih 46 let in preko podnebnih scenarijev do konca stoletja. Za osnovo smo izbrali tridesetletno obdobje 1961-1990, s tem smo nato primerjali obdobje 1991-2006 in projekcije po treh različnih scenarijih podnebnih sprememb, ki smo jih pripravili v obliki inkrementalnih sprememb temperature in padavin kot kombinacijo različnih projekcij za Slovenijo. Z modelom SIMPEL smo določili spremembe potencialne evapotranspiracije (metoda EPIC Penman-Monteith), vodnega primanjkljaja (razlika med količino padavin in potencialno evapotranspiracijo) in števila sušnih dni. Pri vseh treh spremenljivkah se kažejo naraščajoči trendi že za obdobje 1961-2006. Opazovali smo tudi spreminjanje variabilnosti, ki je izrazito predvsem pri številu sušnih dni in nam prinaša dodatno povečevanje tveganja suš. Glavne rezultate smo predstavili z izračuni verjetnosti za pojav določenega števila sušnih dni. Pri tem verjetnosti za več kot 35 sušnih dni v vegetacijskem obdobju (od aprila do septembra) v drugem obravnavanem obdobju ter pri projekcijah po srednjem in še toliko bolj po visokem scenariju podnebnih sprememb bistveno presegajo verjetnosti v prvem obdobju in pri projekcijah po blagem scenariju.

Ključne besede: vodna bilanca tal, podnebne spremembe, suša, vodnobilančni model SIMPEL, vodni primanjkljaj

POTENTIAL CLIMATE CHANGE IMPACTS ON WATER BALANCE IN SLOVENIA

ABSTRACT

The latest climate change projections increasingly indicate the changing of soil water balance, which is then reflected back in climate change. This paper examines soil moisture availability time dynamics in Ljubljana and Murska Sobota in the last 46 years and under climate change scenarios for these locations through the end of the century. The basis was a thirty-year period 1961-1990 serving as a comparison with the period 1991-2006 and with projections of climate changes under three scenarios, presented in the form of incremental temperature and precipitation changes as a combination of alternative projections for Slovenia. Using the SIMPEL model, we determined variability of potential evapotranspiration (the EPIC Penman-Monteith method), water deficit (difference between the volume of precipitation and potential evapotranspiration) and the number of dry days. The analysis showed growing trends for all

[1] univ. dipl. meteor.

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

three variables in the period 1961-2006. Another subject of observation was variability change which is evident above all in the number of dry days and increases the risk of drought. The main results are presented by means of calculations of probability for the occurrence of a certain number of dry days. The probability of over 35 dry days in the vegetation period (April-September) of the second analysed period, under the medium and increasingly so high climate change scenario is much higher than such a probability in the first analysed period and under the low scenario.

Key words: soil water balance, climate change, drought, water-balance model SIMPEL, water deficit

1 UVOD

Podnebne spremembe so že nekaj časa precej aktualna tema, z njo pa se v ospredje prebijajo tudi sorodne raziskave. Opaznih sprememb v klimatskem sistemu je vedno več, med drugim tudi v naših krajih vse pogosteje srečujemo vremensko pogojene težave v kmetijstvu. Z raziskavami na temo spreminjanja vodne bilance tal se med drugim ukvarja Agencija Republike Slovenije za okolje (ARSO). Pri obravnavanju vodne bilance tal uporabljajo vodnobilančni model IRRFIB, s katerim napovedujejo predvsem potrebne količine namakanja, uporablja pa se tudi za preučevanje suš. V želji po alternativi si bomo pogledali izračune vodne bilance tal z nemškim modelom SIMPEL.

Zaradi vedno izrazitejših težav s sušami so po svetu, predvsem v ZDA, že ustanovili sušne centre, po katerih se bo zgledoval tudi novonastali slovenski na ARSO, namenjen celotni JV Evropi. Ukvarjal se bo z raziskovanjem in napovedovanjem suš, pri čemer je potrebno poenotiti modele in pri tem upoštevati veliko pomanjkanje podatkov sploh pred letom 1990, ponekod pa tudi še sedaj. V Sloveniji v to smer še ni veliko storjenega, zato so pomembne vse raziskave, povezane z ekstremnimi pojavi v vodnem ciklu, kar je bila dodatna spodbuda za usmeritev tega dela.

V delu je glavni namen predstaviti pričakovano sušnost v drugi polovici tega stoletja na podlagi izračunov vode v tleh z modelom SIMPEL. Za osnovo so uporabljeni izračuni v letih 1961-1990, za primerjavo oz. oceno že opazovanih sprememb izračuni v letih 1991-2006, za napoved do konca stoletja pa projekcije treh različnih scenarijev podnebnih sprememb temperature in padavin glede na leta 1961-1990. Postavili smo hipotezo, da se bo vodna bilanca tal v Sloveniji spreminjala. Pri tem pričakujemo povečanje števila sušnih dni in primanjkljaja vode v tleh, kakor tudi povečano variabilnost sušnosti.

Poleg sprememb temperature in padavin, ki so precej dobro znane, je za nas pomembno tudi opaženo spreminjanje evapotranspiracije in vodne bilance tal. Povprečna letna količina vode v tleh se opazno znižuje v subtropskem pasu, Sredozemlju in višjih geografskih širinah, kjer se zmanjšuje snežna odeja, povečuje pa se v vzhodni Afriki, centralni Aziji in ponekod drugod, kjer narašča količina padavin (IPCC, 2007). V Anatoliji je študija pokazala, da se v prvih mesecih rasti dejanska evapotranspiracija zaradi podnebnih sprememb poveča, nato pa začne hitro

upadati, ko postane količina vode v tleh zelo omejena (Komuscu in sod., 1998). Raziskave v Indiji pa zanimivo kažejo, da se je kljub splošnemu zvišanju temperature v zadnjih desetletjih evapotranspiracija zmanjšala, kar so povezali z naraščanjem relativne vlažnosti in zmanjševanjem obsevanja. Za večje območje (ZDA in Rusija) in daljše časovno obdobje so prav tako opazili zmanjševanje evapotranspiracije, ki so jo pripisali povečanju oblačnosti, ki zmanjšuje direktno obsevanje (Chattopadhyay in Hulme, 1997).

Pomemben del raziskav evropskega projekta PRUDENCE opozarja na dejstvo, da moramo poleg višjih temperatur pričakovati tudi izrazito povečano poletno variabilnost, ki zaenkrat še ni bila opažena. Pri projekcijah sprememb padavin nastopajo veliko večje negotovosti kot pri projekcijah sprememb temperatur. Upoštevati moramo različne scenarije podnebnih sprememb, poleg tega pa še dejstvo, da imajo različni robni pogoji za regionalne modele učinek na projekcije podnebnih ekstremov, ki je povsem primerljiv z učinkom različnih emisijskih scenarijev.

Globalne spremembe evapotranspiracije naj bi uravnotežile globalne spremembe padavin, vendar se to lokalno zaradi sprememb v atmosferskem prenosu vodne pare ne bo povsod odražalo (IPCC, 2007). Izračuni za Afriko kažejo, da je izrednega pomena povezava med temperaturo in evapotranspiracijo, ki je eksponentna in še dodatno utežena z učinki vetra in relativne vlažnosti. Tako bo v srednjih geografskih širinah, kjer so bazne temperature nižje, enak dvig temperature povzročil bistveno manjše povečanje evapotranspiracije kot v toplejših tropskih predelih. Poleg tega poveča razliko še dejstvo, da je v srednjih geografskih širinah ogrevanje napovedano predvsem pozimi, ko je evapotranspiracija skoraj zanemarljiva. Tako bodo tropski predeli z manjšim ogrevanjem izkusili večje naraščanje potreb po vodi (Feddema, 1992 in 1999). V Indiji trendi za prihodnost kažejo naraščanje evapotranspiracije, česar ni lahko razložiti, saj se je v zadnjem obdobju evapotranspiracija zmanjševala. Morda bodo precej višje temperature kljub običajnemu višanju relativne vlažnosti učinkovale nasprotno in jo nižale, kar bi povzročilo izrazito naraščanje evapotranspiracije (Chattopadhyay in Hulme, 1997). Relativno majhne spremembe temperature in padavin, skupaj z nelinearnim vplivom na evapotranspiracijo in površinski odtok vode, imajo lahko velik vpliv na zemeljski ekosistem preko sprememb količine vode v tleh, ki se bo verjetno najbolj kazal v sušnih in polsušnih pokrajinah (Sakura in Tang, 2003; Komuscu in sod., 1998).

Herbst in Hörmann (1998) sta pokazala, da lahko globalno zvišanje temperature za 2 °C, čeprav se evapotranspiracija pri tem ne spremeni bistveno, resno vpliva na ravnovesje vode v tleh med vegetacijskim obdobjem.

Verjetno je, da se bo največji učinek podnebnih sprememb na tla pokazal preko sprememb uporabe tal zaradi podnebnih sprememb (Rounsevell in sod., 1999). Feddema (1999) omenja precej poročil (Walker in Rowntree, 1977; Shukla in Mintz, 1982; Manabe in Wetherald, 1987; Xue in Shukla, 1993), ki potrjujejo, da modeli napovedujejo velik vpliv sprememb vode v tleh na lokalno cirkulacijo in vzorce razporeditve padavin.

Indijska raziskava poudarja, da bodo zelo verjetno imele spremembe relativne vlažnosti nad celinskimi tropskimi predeli večji vpliv na vodno ravnotežje kot le na temperature. Najbolj občutljivi sta predmonsunsko in zimsko obdobje, med katerima so že sedaj največji vodni primanjkljaji, medtem ko se v monsunskem obdobju količina vode v tleh ne bo bistveno spremenila (Mehrotra, 1999). Vse spremembe bodo prizadele vodne vire in s tem kmetijski sektor, ki je v Indiji eden glavnih prispevkov k državnemu gospodarstvu (Chattopadhyay in Hulme, 1997).

Upoštevajoč globalne napovedi bodo v Afriki vrednosti potencialne evapotranspiraci-je narasle precej bolj kot količina padavin, kar seveda pomeni zmanjšanje presežka vode v tleh. Tako naj bi se v povprečju po celem kontinentu vodni presežek zmanjšal za 10 mm. Spremembe so v povprečju majhne, a postanejo na posameznih lokacijah zelo pomembne. Projekcije vodnih presežkov in primanjkljajev kažejo največje sušenje južno od ekvatorja v južno-centralni Afriki, v Ugandi, in v mokrem delu zahodnoafriške obale. Nekoliko milejše sušenje se obeta na mnogih drugih predelih, kot sta območje Sahela in južna Afrika. Pomembno je razumeti, da ima v teh marginalnih podnebnih lokacijah že majhna sprememba vodne bilance lahko zelo velik vpliv na ekosisteme in človeške aktivnosti. Ogrožena bo dobrobit ljudi, poleg tega pa so pomembni tudi povratni podnebni učinki, ki jih je težko predvideti. Na mnogih območjih bodo zaloge vode v tleh porabljene v prezgodnjem delu sušnega obdobja. Dodatno bo še poslabšanje kakovosti tal, ki bo prineslo manjšo možnost zadrževanja vode v tleh (Feddema, 1999).

Raziskave za ameriški srednji zahod pa kažejo nekoliko drugačno sliko, saj pravijo, da bodo, ne glede na to, v katero smer se bodo razvile, spremembe količine vode v tleh zelo majhne (1 do 2 %). Sušenje naj bi torej bilo manjše od predhodno napovedanega (Senevirante in sod., 2002). Za Anatolijo v Turčiji so izračuni pokazali, da se bodo vodni primanjkljaji poleti po vseh scenarijih povečali. Poskus je pokazal, da ima še 20 % povečanje količine padavin zelo majhen pozitiven učinek na hitro naraščanje primanjkljajev vode v tleh (Komuscu in sod., 1998). Projekcije za Veliko Britanijo pa kažejo le majhne spremembe vode v tleh z ustaljenim vzorcem rahlega presežka vode pozimi in rahlega primanjkljaja poleti (Naden in Watts, 2001).

Za Slovenijo naj bi se po izračunih v okviru projekta PRUDENCE spomladi primanjkljaj povečal za 50 do 100 mm, poleti pa za 230 do 280 mm. Obširno analizo vodnih primanjkljajev v Sloveniji lahko preberemo v magistrskem delu Andreje Sušnik (2005).

Na splošno je suša stanje primanjkljaja vode take stopnje, da ima neugoden vpliv na rastline, živali in ljudi na obsežnem območju (Warrick, 1975).

Evropska agencija za okolje definira sušo kot rezultat združevanja meteoroloških, fizičnih in človeških dejavnikov. Pri tem je osnovni vzrok pomanjkanje padavin in čas, porazdelitev ter jakost primanjkljaja v povezavi z obstoječo zalogo in porabo vode. Glavni meteorološki dejavniki, ki vplivajo na pojav suše, so vzorec atmosferske cirkulacije zraka, pomanjkanje padavin, temperatura in evapotranspiracija. Dodatni fizični in človeški dejavniki pa so obseg naravne zaloge

vode ter socioekonomski dejavniki, ki kontrolirajo porabo vode, kot npr. spreminjanje števila prebivalstva, življenjski standard (Sušnik, 2005).

Van Lanen in Peters (2000) sta pripravila zelo praktično razvrstitev suš v tri glavne skupine: meteorološka, agrometeorološka (kmetijska) in hidrološka suša (suša na vodnih virih - v podzemnih in površinskih vodah). V to delitev je že vključeno stopnjevanje pogostosti, jakosti in trajanja suše.

Meteorološka suša (imenovana tudi klimatološka) je po definiciji Evropske agencije za okolje posledica primanjkljaja padavin v daljšem časovnem obdobju, ki ga lahko izrazimo z odklonom od povprečne klimatske vrednosti in trajanja suhega obdobja. Značilna pri tem je povezava z visokimi temperaturami zraka, vetrom in nizko relativno vlago, ki povzročajo večje izhlapevanje, manjšo infiltracijo ipd.

Pri definiranju agrometeorološke suše poleg primanjkljaja padavin upoštevamo še fizikalne in biološke lastnosti rastlin v povezavi s sistemom tla - rastlina - atmosfera in razmerjem med porabo vode pri rastlinah in njihovo dejansko oskrbo. Agrometeorološka suša povzroča zmanjšanje pridelka ali poslabšanje njegove kvalitete. Njeno napovedovanje je povezano z namakanjem in s tem z ekonomičnostjo kmetovanja.

Hidrološka suša za meteorološko in agrometeorološko časovno zaostaja, saj traja dlje, da se pomanjkanje padavin pokaže v pretokih vode, pri vlagi v tleh, gladini podzemne vode ipd. Poleg podnebja vplivajo na hidrološko sušo tudi spremembe rabe tal, poslabšanje lastnosti tal, gradnja jezov in drugo. V nekaterih primerih lahko ti dejavniki spremenijo pogostost primanjkljaja vode tudi, če ni meteorološke suše, ker lahko poraba vode za npr. namakanje, rekreacijo, hidroenergijo in ostalo predstavlja še dodatno obremenitev za vodne vire.

Obstaja nekaj različnih metod za opredelitev suše. Najenostavnejši so sušni indeksi, ki jih delimo na indekse, ki potrebujejo meteorološke in agrometeorološke podatke, ter indekse, ki potrebujejo tudi podatke o rastlini in tleh. Najbolj splošni se lahko uporabljajo za velika območja. Sem sodijo standardizirani indeks padavin SPI, Palmerjev indeks jakosti suše PDSI in vlažnostni indeks poljščin CMI. Poleg indeksov poznamo še modelne ocene vodne bilance. Najbolj učinkovito je združevanje meritev na terenu in matematičnega modeliranja.

Preglednica 1 predstavlja delitev let od 1961 do 2004 po sušnosti, ki jo je pripravila Sušnikova (2005) za vse regije, glede na sušni indeks, ki združuje tedensko povprečje primankljaja vode in njegovo trajanje. Prikazani so le rezultati za Ljubljano in Mursko Soboto, s katerima se bomo še ukvarjali. Že za ti dve lokaciji se rezultati precej razlikujejo, kot vidimo, pa sta v obe smeri najbolj ekstremni zadnji vključeni leti, kar ne preseneča, saj smo že omenili, da podnebne spremembe prinašajo predvsem več ekstremov.

Preglednica 1: Ljubljana in Murska Sobota: leta 1961-2004, razporejena glede na sušni indeks (Sušnik, 2005)
Table 1: Ljubljana and Murska Sobota: years 1961-2004, arranged by the drought index (Sušnik, 2005)

ekstremno mokra (extremly wet)	zelo mokra (very wet)	mokra (wet)	normalna (normal)	suha (dry)	zelo suha (very dry)	ekstremno suha (extremly dry)
Ljubljana						
2004		1961, 1962, 1965, 1966, 1968, 1972, 1974, 1975, 1978, 1989, 1996	1963, 1964, 1967, 1969, 1970, 1976, 1977, 1979, 1980, 1981, 1983, 1984, 1985, 1986, 1987, 1991, 1994, 1995, 1999, 2002	1971, 1982, 1988, 1990, 1993, 2000	1992, 1997, 1998, 2001	2003
Murska Sobota						
2004		1964, 1965, 1966, 1970, 1972, 1974, 1978, 1979, 1989, 1996	1961, 1962, 1963, 1967, 1968, 1969, 1973, 1975, 1976, 1980, 1981, 1982, 1984, 1985, 1987, 1990, 1991, 1995, 1997, 1998, 1999, 2002	1977, 1983, 1986, 1988, 1993, 1994	1971, 1992, 2000, 2001	2003

V Sloveniji je potrebno proučiti različne možnosti pri preprečevanju posledic suše: gojenje kultur, odpornejših na sušo, zmanjševanje denarne pomoči pri gojenju slabo odpornih kultur, vpis namakalnih sistemov v zemljiško knjigo, analiziranje stanja razpoložljivih in dejansko izkoriščanih kapacitet vseh vodnih virov, ki so potencialno primerni za namakanje, in med drugim analiziranje učinkovitosti zgodnjega napovedovanja suše, izvajanja specifičnih agrometeoroloških aplikacij ter monitoringa kmetijske suše z indikatorji (Računsko sodišče Republike Slovenije, 2007).

2 MATERIAL IN METODE

Na vodni cikel predvsem regionalno resno vplivajo podnebne spremembe, prav tako pa ima sam pomemben vpliv na podnebne spremembe. Spremembe zemeljskega sevalnega ravnovesja vplivajo na vetrove, temperature, vodni transport, dinamiko oblakov in drugo. Spremembe temperature vplivajo na jakost evapotranspiracije, količino oblačnosti, vodo v tleh, obliko in količino snežnih padavin. Spremembe padavin vplivajo na trajanje, časovno razporeditev in obsežnost poplav in suš ter določajo površinski odtok vode. Podnebne spremembe preko vodnega cikla vplivajo na vodne vire in kmetijstvo, kar postaja zaskrbljujoč problem po celem svetu (Tao in sod., 2003; Mehrotra, 1999).

Za razumevanje morebitnih sprememb v rasti rastlin je v vodnem ciklu bistvenega pomena voda v tleh, pri čemer pa se moramo zavedati, da bodo tudi spremembe v produktivnosti vplivale nazaj na vodo v tleh.

Za določanje sušnih obdobij največkrat uporabljamo izračune vodne bilance. Razliko med potencialno evapotranspiracijo (ETp) in količino padavin (RR) imenujemo vodni primanjkljaj (RR-ETp), poleg le-tega računajo vodnobilančni modeli tudi dejansko količino vode v tleh. Te izračune lahko preverimo z meritvami, ki pa se le redko kje izvajajo.

Na količino vode v tleh najbolj vplivajo infiltracija, pronicanje, kapilarni dvig, površinski odtok in izsuševanje (Rounsevell in sod., 1999). Celoten volumen zadržane vode na enoto površine predstavlja zadrževalno sposobnost površine, ki je odvisna od nepravilnosti površine in nagiba. Ko je zadrževalna sposobnost površine presežena, se začneta površinski odtok in globinsko pronicanje. Infiltracija oz. vstop vode v tla preko površine je ključni člen v vodnem ciklu. Odvisna je od lastnosti tal, dežja, profila ... Natančnejši opis pojavov med drugim lahko preberemo v doktorskem delu Zupančeve (2003).

V literaturi zasledimo širok izbor modelov za sistem tla - rastlina, ki večinoma računajo glavne procese, a ima vsak svoje prednosti in slabosti. Modeli, ki vsebujejo funkcionalno reprezentacijo strukture tal in vodnega ravnovesja, so relativno eno-stavni za parametrizacijo in so primerni za ocenjevanje vplivov vremena, dostopnosti vode v tleh in erozije na pridelek. Modeli z mehanično reprezentacijo strukture tal in vodnega ravnovesja pa nudijo podrobnejšo reprezentacijo vode v tleh, a zahtevajo zapletenejšo parametrizacijo. Za slednje pa vseeno lažje določimo natančnejše vrednosti parametrov iz izmerjenih podatkov. Obstoječi modeli so precej kompleksni, a kljub temu ostaja še veliko dela z razvijanjem boljših metod za večjo uporabnost modelov, boljše določanje parametrov in reševanje problemov za večje skale. Modeli bodo bolje sprejeti, ko bodo enostavnejši za uporabo, sploh ker postajajo vedno bolj podrobni (Connolly, 1998).

V Evropski skupnosti se uporablja kar nekaj namakalnih modelov. Izmed teh je mo-dele SWAP, AMBAV, IRRFIB in CROPWAT priporočila COST akcija 718 Evropske skupnosti za meteorološke aplikacije za kmetijstvo. Model IRRFIB uporabljajo na ARSO za določanje in napovedovanje sušnosti ter napovedi potrebnega namakanja. Služil nam je za osnovo, s katero smo primerjali vodnobilančni model SIMPEL, ki smo ga želeli preizkusiti.

Model SIMPEL, ki je nemškega izvora in prosto dostopen na internetu, lahko uspešno uporabljamo pri okoli 95 % vseh vrst zemljin. Napisan je v programu Microsoft Excel in obstaja v več različnih verzijah. Ločeno ima vhodno datoteko, datoteko za računanje evapotranspiracije in datoteko z modelom vodne bilance. Zaradi neupoštevanja stranskega pritoka in, v primeru prekoračenja infiltracijske kapacitete, površinskega odtoka so rezultati nezanesljivi pri nagnjenih površinah, težko prepustnih zemljinah ter pri visokih dnevnih temperaturnih nihanjih.

Izmed meteoroloških podatkov potrebujemo dnevne vrednosti naslednjih meteoroloških spremenljivk: povprečna dnevna temperatura zraka, dnevna količina padavin, trajanje sončnega obsevanja ali energija globalnega obsevanja, povprečna dnevna relativna vlaga, povprečna dnevna hitrost vetra. Model zahteva še povprečno letno vrednost pritiska.

Glavni ekofizioloških podatki so višina rastlin, spreminjanje indeksa listne površine skozi leto, debelina koreninskega sistema, albedo rastlin, prevodnost listov. Pedološki podatki pa so poljska kapaciteta (PK), točka venenja (TV), začetek redukcije, faktor sušenja, albedo tal. Poleg tega potrebujemo še geografsko širino in nadmorsko višino.

Pri modelu SIMPEL lahko izbiramo med uporabo različnih metod za izračun potencialne evapotranspiracije: Haude, Thornthawaite, Blaney-Criddle, Turc, Penman-Wendling, Makkink, Wendling (obala), Penman-Monteith (iglasti gozd) in EPIC Penman-Monteith. Potek ETp po mesecih je pri vseh metodah približno enak, vendar se vrednosti nekoliko razlikujejo. Najbolj kompleksen je izračun po metodi Penman-Monteith, povzet po modelu EPIC, ki ga bomo tudi uporabljali. Pri tem potrebujemo konstante, povezane z metodo.
Model izračuna in upošteva poleg dejanske evapotranspiracije, kjer upošteva intercepcijo padavin v višjih plasteh (listje in površinska plast), še infiltracijo, površinski odtok vode in tok vode iz zemlje v podtalnico. Za nas najpomembnejša rezultata sta količina vode v tleh in vodni primanjkljaj.

Ne glede na to, kako računamo količino vode v tleh, moramo določiti kriterij, ki bo definiral sušen dan. Pri modelu SIMPEL ta kriterij v osnovi ni določen. Brez dodatnega zapletanja izračunov smo določili, da so sušni dnevi vsi, pri katerih je količina vode v tleh pod 1,01TV. Vrednosti TV za mejo smo se izognili, saj pod to mejo količina vode praktično ne pade.

Za vrednotenje in analizo podatkov je bil uporabljen statističen programski paket SPSS (Statistical Package for the Social Sciences) za Microsoft Windows. Uporabili smo ANOVA

primerjavo povprečij in varianc dveh vzorcev. Za sledenje in tendenco sprememb uporabljamo analizo trenda s pomočjo linearne regresije, o katerem pa lahko govorimo le, če imamo na voljo dovolj dolg niz podatkov (vsaj 30 let pri klimatoloških analizah). Za ocenjevanje, kako dobro izbrani vzorec opisuje celotno dogajanje, uporabimo objektivne izračune statistične zanesljivosti. Glede na statistične karakteristike trenda mora biti koeficient determinacije r^2 vsaj 0,097 za 40-letni niz in 0,088 za 44-letni niz z upoštevanjem 95 % zanesljivosti (Sušnik, 2005). Verjetnosti, da se zgodi določen dogodek, smo izračunali s pomočjo prehoda na standardizirano normalno porazdelitev. Več o uporabljenih statističnih metodah lahko preberemo v delovnem gradivu Košmeljeve (2000).

Za analizo smo izbrali iz osrednje Slovenije Ljubljano, iz Pomurja Mursko Soboto in iz Primorske Bilje. A za kakovostno analizo potrebujemo polne in čim bolj homogenizirane nize podatkov, zato smo se morali postaji Bilje zaradi pomanjkanja podatkov odpovedati, saj v obdobju 1961-1990 na tej lokaciji nimamo meritev energije sončnega obsevanja in prav tako ne meritev trajanja sončnega obsevanja. V Ljubljani je izbrana postaja Bežigrad (46, 07°; 14, 52°; 299 m), v Murski Soboti pa Rakičan (46, 65°; 16, 18°; 188 m).

Meteorološke podatke smo pridobili na Uradu za meteorologijo na ARSO. Za Ljubljano ni podatkov o energiji globalnega obsevanja (RG [Jcm^{-2}]) pred letom 1964, za Mursko Soboto pa pred letom 1993. Model SIMPEL v takih primerih potrebuje vsaj podatke o trajanju sončnega obsevanja (S [h]), iz katerega po Angstromovi enačbi določi energijo.

Lastnost tal, ki močno vpliva na vodnobilančne razmere, je vodno zadrževalna sposobnost oziroma vezava rastlini razpoložljive vode. ARSO ima v bazo vodnobilančnih izračunov vključene hipotetične tipe tal, v katere so razvrščena tla meteoroloških postaj (Sušnik, 2005). Podatke so pripravili na Centru za pedologijo Biotehniške fakultete. V Ljubljani imamo tip tal s slabo zadrževalno sposobnostjo, ki so globoka do 30 cm, v Murski Soboti pa tip tal s srednjo zadrževalno sposobnostjo, ki so globoka 30 do 60 cm. Pri tem je v Ljubljani razpoložljiva voda v 10 cm sloju 9,6 mm, v Murski Soboti pa 14,4 mm. Poljska kapaciteta v 10 cm sloju je v Ljubljani 22,9 mm in v Murski Soboti 33 mm. Točka venenja prav tako v 10 cm sloju je v Ljubljani 13,3 mm, v Murski Soboti pa 18,6 mm.

Vse izračune smo opravili za travo, ki jo smatramo kot referenčno rastlino, ki je visoka 0,12 m, z albedom 0,23. Indeks listne površine določimo za vsak dan posebej, kot se spreminja z rastjo. V našem primeru, ko gre za travo, smo letno spreminjanje določili od 1,5 do 2,5, pri čemer so vmesne vrednosti določene z linearno interpolacijo.

Za osnovno, bazno - primerjalno obdobje, smo izbrali tridesetletje 1961-1990, ki se največkrat uporablja za izhodišče. Preučevali smo le vpliv spremenjene temperature in količine padavin, vsi ostali vhodni podatki so ostali nespremenjeni. Tako smo iz podatkov za leta 1961-1990 pripravili nova tridesetletja, recimo 2061-2090, po treh različnih scenarijih podnebnih sprememb.

Spremembe so predstavljene le za vegetacijsko obdobje, v katerem smo računali, torej od aprila (A) do septembra (S). Za primerjavo smo analizirali obdobje 1991-2006. Zanimalo nas je, kako se že opaženo višanje temperatur in nižanje količine padavin kaže pri količini vode v tleh in številu sušnih dni. Tako smo preučevali tudi spremembe, ki so že nastopile v obdobju zadnjih 16-ih let, in z njimi primerjali projekcije sprememb za konec stoletja. Tu moramo upoštevati dejstvo, da imamo za analizirano obdobje realne podatke, kjer se spreminjata na primer tudi sončno obsevanje in relativna vlažnost, medtem ko pri projekcijah sprememb upoštevamo le spremembe temperature in padavin.

Preglednica 2 prikazuje uporabljene inkrementalne spremembe temperature in padavin, ki smo jih nanesli na dnevne vrednosti padavin in povprečnih temperatur baznega tridesetletja, torej spremembe smo dodali podatkom za vsak dan v tem tridesetletju posebej. Vrednosti sprememb smo pripravili kot kombinacijo različnih sezonskih projekcij za Slovenijo.

Spremembe so predstavljene le za vegetacijsko obdobje, v katerem smo računali, torej od aprila (A) do septembra (S). Za primerjavo smo analizirali obdobje 1991-2006. Zanimalo nas je, kako se že opaženo višanje temperatur in nižanje količine padavin kaže pri količini vode v tleh in številu sušnih dni. Tako smo preučevali tudi spremembe, ki so že nastopile v obdobju zadnjih

16-ih let, in z njimi primerjali projekcije sprememb za konec stoletja. Tu moramo upoštevati dejstvo, da imamo za analizirano obdobje realne podatke, kjer se spreminjata na primer tudi sončno obsevanje in relativna vlažnost, medtem ko pri projekcijah sprememb upoštevamo le spremembe temperature in padavin.

Preglednica 2: Inkrementalne spremembe temperature in padavin po treh različnih scenarijih podnebnih sprememb
Table 2: Incremental temperature and precipitation changes according to three different scenarios

Scenarij (Scenario)	**Blagi (Low)**			**Srednji (Medium)**			**Visoki (High)**		
Meseci (Months)	AM	JJA	S	AM	JJA	S	AM	JJA	S
Sprememba povprečne dnevne temperature (Average daily temperature change) [°C]	+1	+3	+2	+3	+3	+3	+4	+7	+5
Sprememba dnevnih padavin (Average precipitation change) [°C]	0	0	0	-20	-20	-20	-30	-45	-15

3 REZULTATI IN DISKUSIJA

Statistično smo obdelali rezultate potencialne evapotranspiracije, vodnega primanjkljaja in števila sušnih dni.

Spreminjanje povprečja in variabilnosti vegetacijske (april – september) ali sezonske (junij – avgust) vsote potencialne evapotranspiracije je bilo v našem primeru odvisno le od sprememb temperature zraka. To je verjetno tudi vzrok, da presežejo vrednosti v obdobju 1991-2006, ko so bile temperature večinoma zelo visoke, tudi tiste, izračunane po visokem scenariju.

Za Mursko Soboto se sezonska povprečja, izračunana po vseh treh scenarijih in za obdobje 1991-2006, pri 95 % stopnji zanesljivosti statistično značilno razlikujejo od povprečja za obdobje 1961-1990. Povprečji, izračunani za vegetacijsko obdobje, pa se pri blagem in srednjem scenariju ne razlikujeta od povprečja za obdobje 1961-1990.

Z linearno regresijo smo ugotovili, da za obdobje 1961-1990 za sezono ni statistično značilnega naraščanja, v obdobju 1961-2006 pa povprečna potencialna evapotranspiracija narašča s koeficientom linearnega trenda k = 1,9 mm/leto (r^2 = 0,45), kar pomeni spreminjanje povprečja za 5 % na 10 let. V vegetacijskem obdobju imamo že v obdobju 1961-1990 naraščanje s k = 2,8 mm/leto (r^2 = 0,15), kar je 4 % na 10 let, v obdobju 1961-2006 pa s k = 3,1 mm/leto (r^2 = 0,31), kar je 4,3 % na 10 let.

Za Ljubljano velja podobno, le da se od povprečja v obdobju 1961-1990 pri 95 % stopnji zaupanja statistično značilno ne razlikuje le povprečje, izračunano za blagi scenarij v vegetacijskem obdobju. Linearna regresija kaže na naraščanje povprečij. V obdobju 1961-1990 s koeficientom linearnega trenda k=1,2 mm/leto (r^2 = 0,15) v sezoni in s k = 2,0 mm/leto (r^2 = 0,16) ter v obdobju 1961-2006 s k = 1,7 mm/leto (r^2 = 0,41) v sezoni in s k = 2,4 mm/leto (r^2 = 0,37) v vegetacijskem obdobju. Pri vseh

trendih je to spreminjanje povprečja za 3 % na 10 let, le pri obdobju 1961-2006 v sezoni gre za 4 % na 10 let.

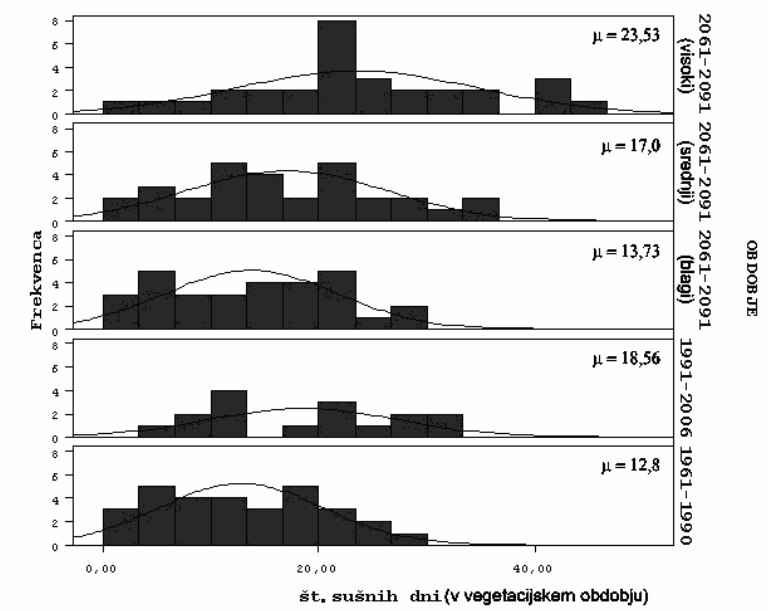
Pri vodnem primanjkljaju (RR-ETp) so rezultati nekoliko drugačni. Izračunana povprečja za blagi scenarij se v nobenem primeru ne razlikujejo statistično značilno od povprečij v obdobju 1961-1990. Prav tako z linearno regresijo nismo za obdobje 1961-1990 v nobenem primeru dobili statistično značilnega naraščajočega trenda. Za obdobje 1961-2006 naraščajo povprečne vrednosti primanjkljaja (postajajo vedno bolj negativne) za Mursko Soboto s k = -2,7 mm/leto (r^2 = 0,12) v sezoni, kar pomeni spreminjanje povprečja za 25 % na 10 let, in s k = -3,7 mm/leto (r^2 = 0,11) v vegetacijskem obdobju (18 % na 10 let) ter za Ljubljano prav tako s k = -2,7 mm/leto (r^2 = 0,12) v sezoni in s k = -3,8 mm/leto (r^2 = 0,11) v vegetacijskem obdobju, pri čemer gre zaradi nizkih povprečij (-10 mm v sezoni in 42 mm v vegetacijskem obdobju) za velike spremembe: v sezoni spreminjanje povprečja za 269 % na 10 let in v vegetacijskem obdobju za 91 % na 10 let.

Pri analiziranju vodnega primanjkljaja so povprečja obdobja 1991-2006 najbolj podobna povprečjem po srednjem scenariju. Gre za obdobje, ko spremembe podnebja že opažamo. Tako vidimo, da projekcije niso neko govorjenje v prazno, ampak so te spremembe že prisotne v zadnjih letih, le da bo verjetnost za taka in sušnejša leta konec stoletja še večja. Za vegetacijsko obdobje za Mursko Soboto pa se povprečje obdobja 1991-2006 pri 95 % stopnji zaupanja ne razlikuje statistično od povprečja obdobja 1961-1990. V Ljubljani smo imeli v obdobju 1961-1990 pozitivno povprečje RR-ETp, torej presežek, tako ostane še po blagem scenariju, v vseh ostalih primerih pa imamo primanjkljaj.

Variabilnost se z različnimi scenariji niti ne spremeni bistveno, le za obdobje 1991-2006 imamo izrazito povečano variabilnost. Pri potencialni evapotranspiraciji se tudi povprečje ne spreminja dosti, medtem ko se pri vodnem primanjkljaju povprečja precej razmaknejo. Tak rezultat lahko pripišemo že omenjenemu vplivu le sprememb temperature na spremembe potencialne evapotranspiracije in vplivoma tako sprememb temperature kot tudi padavin na spremembe primanjkljaja.

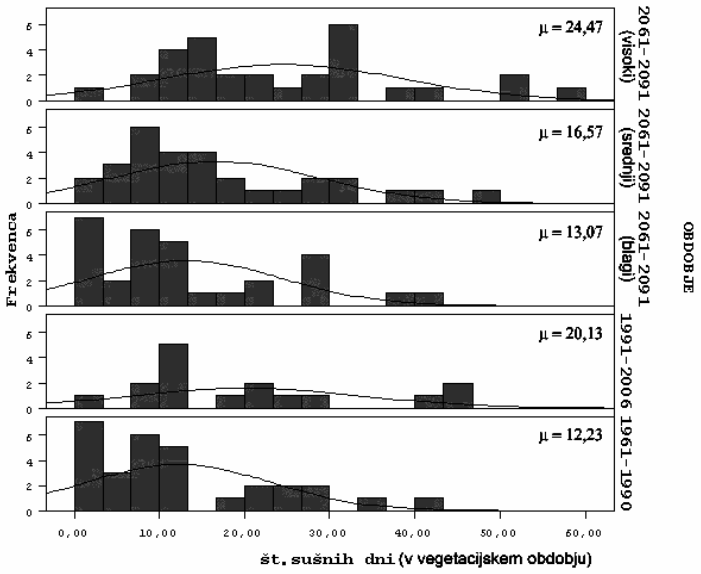
Pri izračunih števila sušnih dni se povprečja v vegetacijskem obdobju pri 95 % stopnji zanesljivosti statistično značilno razlikujejo od povprečja v obdobju 1961-1990 le v obdobju 1991-2006 in pri visokem scenariju podnebnih sprememb. V sezoni se za Mursko Soboto le povprečje pri blagem scenariju ne razlikuje statistično značilno od povprečja v obdobju 1961-1990, za Ljubljano pa se povsem drugače le povprečje pri visokem scenariju razlikuje od povprečja v obdobju 1961-1990.
Linearna regresija kaže naraščajoč trend le za obdobje 1961-2006, ne pa za 1961-1990. Za Mursko Soboto imamo v sezoni naraščanje števila sušnih dni s k=0,3 dan/leto (r^2 = 0,28), kar je 33 % na 10 let, prav tako v vegetacijskem obdobju (r^2 = 0,10), kar je 19 % na 10 let. Za Ljubljano pa imamo v sezoni manjše naraščanje s k = 0,2 dan/leto (r^2 = 0,09), kar pomeni 10 % na 10 let, in prav tako v vegetacijskem obdobju (r^2 = 0,14), kar je 15 % na 10 let.

Grafa na slikah (Slika 1 in Slika 2) nas opozarjata na izrazito večanje variabilnosti števila sušnih dni.



Slika 1: Pogostostna porazdelitev števila sušnih dni. Spremembe povprečja in variabilnosti za Ljubljano.

Figure 1: Frequency distribution of the number of dry days. Changes in average and variability values for Ljubjana.



Slika 2: Pogostnostna porazdelitev števila sušnih dni. Spremembe povprečja in variabilnosti za Mursko Soboto.

Figure 2: Frequency distribution of the number of dry days. Changes in average and variability values for Murska Sobota.

Izračunali smo še verjetnosti za pojav določenega števila sušnih dni. Iz preglednic preprosto razberemo, da se predvsem za Ljubljano obdobje 1991-2006 precej ujema s srednjim scenarijem, za Mursko Soboto pa že skoraj z visokim. Upoštevati moramo, da v tem obdobju obravnavamo le 16 let in imamo manjši vzorec in zato že v osnovi večjo variabilnost.

Preglednica 3: Verjetnost za pojav sušnih dni v vegetacijskem obdobju (april – september) v Ljubljani , pri čemer so v oklepajih predstavljene kumulativne verjetnosti

Table 3: Probability of the dry days appearance in the vegetation period (April – September) in Murska Sobota with cumulative values in brackets

	1961-1990	**1991-2006**	**blagi scenarij (low)**	**srednji scenarij (medium)**	**visoki scenarij (high)**
povprečno št. sušnih dni (average number of dry days)	12,8	18,56 (+45 %)	13,73 (+7 %)	17,0 (+33 %)	23,53 (+84 %)
standardni odklon (standard deviation) [dni (days)]	7,56	8,66	7,92	9,19	11,0
št. sušnih dni (number of dry days)	**verjetnost [%] za pojav sušnih dni (probability of the dry days appearance)**				
<5	15	6	14	10	5
5-10 (>5)	21 (85)	10 (94)	18 (86)	12 (90)	6 (95)
10-15 (>10)	25 (64)	18 (84)	24 (68)	19 (78)	11 (89)
15-20 (>15)	22 (39)	23 (66)	23 (44)	22 (59)	15 (78)
20-25 (>20)	12 (17)	20 (43)	13 (21)	18 (37)	18 (63)
25-30 (>25)	4 (5)	14 (23)	6 (8)	11 (19)	17 (45)
30-35 (>30)	1 (1)	6 (9)	2 (2)	5 (8)	13 (28)
>35	0	3	0	3	15

Preglednica 4: Verjetnost za pojav sušnih dni v vegetacijskem obdobju (april – september) v Murski Soboti , pri čemer so v oklepajih predstavljene kumulativne verjetnosti

Table 4: Probability of the dry days appearance in the vegetation period (April – September) in Murska Sobota with cumulative values in brackets

	1961-1990	**1991-2006**	**blagi scenarij (low)**	**srednji scenarij (medium)**	**visoki scenarij (high)**
povprečno št. sušnih dni (average number of dry days)	12,23	20,13 (+65 %)	13,07 (+7 %)	16,57 (+35 %)	24,47 (+100 %)
standardni odklon (standard deviation) [dni (days)]	10,95	13,77	11,22	12,10	14,07
št. sušnih dni (number of dry days)	**verjetnost [%] za pojav sušnih dni (probability of the dry days appearance)**				
<5	25	14	24	17	8
5-10 (>5)	17 (75)	9 (86)	15 (76)	12 (83)	7 (92)
10-15 (>10)	18 (58)	13 (77)	18 (61)	16 (71)	10 (85)
15-20 (>15)	16 (40)	14 (64)	16 (43)	16 (55)	12 (75)
20-25 (>20)	12 (24)	14 (50)	13 (27)	15 (39)	15 (63)
25-30 (>25)	7 (12)	12 (36)	7 (14)	11 (24)	13 (48)
30-35 (>30)	3 (5)	10 (24)	4 (7)	7 (13)	12 (35)
>35	2	14	3	6	23

4 SKLEPI

Izbrana tema in njej podobne, povezane z vodo v tleh, sušnostjo ipd., so nekje na meji večih znanstvenih področij, kot so meteorologija, agronomija, pedologija in druge, zato dostikrat ostanejo zapostavljene.

Pri pripravi scenarijev podnebnih sprememb je pomembno, da upoštevamo več različnih projekcij za obravnavani del sveta, saj so učinki zelo regionalno značilni.

Potencialna evapotranspiracija se po scenarijih sprememb ne spreminja tako opazno kot vodni primanjkljaj in število sušnih dni, ker nanjo spremembe padavin ne vplivajo. Vsi izračuni kažejo povečevanje vodnega primanjkljaja in s tem tudi števila sušnih dni v vegetacijskem obdobju. Še večji problem od sprememb povprečij pa predstavlja spreminjanje variabilnosti pojava sušnih dni. To lahko prinese veliko večje izzive pri soočanju s problemi, povezanimi z vodo, ne le v kmetijstvu, pač pa tudi pri hidroelektrarnah, vodnih virih in njihovi uporabi, morda celo zdravju ljudi.

Obdobje 1991-2006 že odraža spremembe, kar daje večjo veljavo projekcijam za konec stoletja. Variabilnost je zaradi manjšega obravnavanega vzorca sicer že v osnovi večja, glede na obdobje 1961-1990 pa imamo pri vseh spremenljivkah naraščanje, ki je pri potencialni evapotranspiraciji celo višje od vrednosti pri visokem scenariju, saj smo imeli v obdobju 1991-2006 visoko temperaturno

povprečje. V obdobju 1961-1990 večinoma ni statistično značilnega naraščajočega trenda pri obravnavanih spremenljivkah, medtem ko je za obdobje 1961-2006 trend vedno statistično značilno naraščajoč.

Verjetnost za pojav več kot 35 sušnih dni se je v Murski Soboti iz 2 % v obdobju 1961-1990 spremenila na 14 % v obdobju 1991-2006. Po blagem scenariju naj bi bila ta verjetnost 3 %, po srednjem 6 % in po visokem kar 23 %. Visoki scenarij opozarja, da bodo morda zadnja leta, ki so se nam sedaj zdela ekstremna, postala nekaj običajnega. V Ljubljani v obdobju 1961-1990 sploh ni bilo verjetnosti za pojav več kot 35 sušnih dni, kot ostaja tudi po blagem scenariju, imamo pa v obdobju 1991-2006 3 % verjetnost za več kot 35 sušnih dni, prav tako tudi po srednjem scenariju, po visokem pa že kar 15 %.

V tej smeri je vsekakor potrebno še veliko raziskovalnega dela. Podobne raziskave bi morali pripraviti za čim več krajev po Sloveniji, se soočiti z manjkajočimi podatki in uporabiti različne vodnobilančne modele. Z boljšim spremljanjem in napovedovanjem suš bi se jim lahko tudi uspešneje prilagodili, kar pa spet zahteva preizkušanje različnih metod, obširnejše meritve in umerjanje modelov.

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Agrovoc descriptors: small farms; family farms; progeny; sons; age; highlands; inheritance (economics); property transfers; models; socioeconomic environment

Agris category code: E50; E90

COBISS koda 1.01

Vpliv dejavnikov socialnoekonomske strukture hribovskih kmetij v Sloveniji na časovno opredelitev prenosa teh kmetij na naslednike

Boštjan KERBLER – KEFO[1]

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IZVLEČEK

V članku je predstavljeno, kako dejavniki socialnoekonomske strukture vplivajo na časovno opredelitev prenosa hribovskih kmetij na naslednike. Podrobneje je opisana metodologija dela, zlasti modeli z omejeno odvisno spremenljivko – tobit modeli –, s katerimi smo ugotavljali vplive, spoznanja o vplivih pa so povezana z ugotovitvami drugih raziskovalcev. Rezultati kažejo, da se čas predaje kmetij naslednikom podaljša z večanjem števila otrok v gospodarjevi družini, zlasti števila otrok moškega spola, in s povečevanjem starosti gospodarja, podaljša pa se tudi, če so kmetije večje in ekonomsko močnejše, kar je v nasprotju s pričakovanji.

Ključne besede: kmetijstvo, tobit modeli, hribovske kmetije, nasledstvo, čas predaje kmetij naslednikom

ABSTRACT

THE INFLUENCE OF FACTORS OF THE SOCIO-ECONOMIC STRUCTURE OF MOUNTAIN FARMS IN SLOVENIA ON THE TIMING OF SUCCESSION ON THESE FARMS

The paper presents how factors of the socio-economic structure of mountain farms influence the timing of succession. The methodology is described in detail, especially the limited dependent variable models (tobit models) by which influences were assessed. The results were linked with findings of other researchers and show that the timing of succession increases with an increase in the number of children – especially male children – in a householder's family, and with an increase in the householder's age, as well as with an increase in the size and economic power of a farm, which is contrary to our expectations.

[1] Urbanistični inštitut Republike Slovenije, Trnovski pristan 2, SI-1000 Ljubljana, Slovenija, dr., e-pošta: bostjan.kerbler@guest.arnes.si

V prispevku je povzet del rezultatov iz avtorjeve doktorske disertacije, z naslovom »Povezanost nasledstva na hribovskih kmetijah v Sloveniji z njihovo socialnogeografsko strukturo«; mentor prof. dr. Marijan M. Klemenčič in somentor prof. dr. v pokoju Matija Kovačič.

The paper presents part of the results from the doctoral thesis, 'The Relationship Between Succession on Mountain Farms in Slovenia and their Socio-Geographical Structure' carried out by the author under the supervision of Prof. Marijan M. Klemenčič PhD and the co-supervision of Prof. Matija Kovačič PhD.

Key words: agriculture, tobit models, mountain farms, farm succession, timing of succession

1 UVOD

Časovna opredelitev prenosa kmetij na naslednike – trenutek, v katerem gospodar formalno preda kmetijo nasledniku (angl. *timing of succession* – izraz prevajamo tudi kot »čas predaje kmetije nasledniku«) – ima za nadaljnji razvoj kmetij velik pomen. Upadanje nasleditev na slovenskih kmetijah je po mnenju Ane Barbič (1991) vse večje tudi zaradi nepripravljenosti starejše generacije, da bi kmetije pravočasno predala. Če namreč gospodarji s predajo kmetij zavlačujejo, tvegajo, da jih sploh ne bodo mogli predati, saj si bodo v tem času določeni ali predvideni nasledniki uredili življenje po svoje in morda ne bodo več imeli namena kmetovati, če pa jih predajo pravočasno, ko so prevzemniki[i] še mladi, lahko pričakujejo, da se bo na kmetijah dvignila produktivnost dela, s tem pa tudi njihova finančna sposobnost.

V raziskavi, ki smo jo opravili v okviru doktorske disertacije, smo med drugim proučili, kateri »notranji« dejavniki, ki so značilni za kmetijo oziroma »izvirajo z nje«, vplivajo na čas predaje hribovskih kmetij naslednikom in kakšen je njihov obseg. Pri tem smo se osredotočili na dejavnike socialnoekonomske strukture kmetije, med njimi pa na dejavnike posestne, demografske, proizvodne (ekonomske) in razvojno-inovativne strukture. V prispevku predstavljamo, kako ti dejavniki vplivajo na časovno opredelitev prenosa hribovskih kmetij na naslednike posamično, torej neodvisno drug od drugega, in kakšen je vpliv več dejavnikov hkrati.

2 RAZISKAVE O ČASOVNI OPREDELITVI PRENOSA KMETIJ NA NASLEDNIKE

Doslej so se v Sloveniji o času predaje kmetij naslednikom ukvarjali predvsem ruralni sociologi (npr. Barbič, 1993; Černič Istenič, 2003), kvantitativne empirične analize o vplivih dejavnikov na čas predaje kmetij na naslednike pa še niso bile opravljene. Med tujimi raziskavami smo našli le tri, ki se ukvarjajo s to problematiko, vendar pa se nobena posebej ne ukvarja s hribovskimi kmetijami. Raziskave se med seboj ločijo po pristopih proučevanja:

- dve raziskavi temeljita na pristopu *ex-ante* – pri katerem je čas predaje kmetije nasledniku predviden oziroma načrtovan (angl. *planned timing of succession*);
- ena raziskava pa temelji na pristopu *ex-post* – pri katerem gre za dejanski čas predaje kmetije na naslednika (angl. *actual timing of succession*).

2.1 Raziskavi o predvidenem času predaje kmetije nasledniku

Kot eno od treh razsežnosti ravnanja v zvezi z nasledstvom (angl. *dimensions of succession behaviour*) so v prvi raziskavi Glauben, Tietje in Weiss (2002) za kmetije Zgornje Avstrije proučili, kako posebne značilnosti družine in kmetije (angl.

specific family and farm characteristics) vplivajo na čas, v katerem bo gospodar formalno predal kmetijo (angl. *expected time until the proposed transfer of the farm*).

V drugi raziskavi je Tietje (2004) na severnonemških kmetijah, na katerih so gospodarji izjavili, da je nasleditev na kmetiji verjetna (angl. *farm succession is likely*), skupaj z Glaubenom in Weissom (2004) proučil, kako poleg omenjenih značilnosti vplivajo na predvideno časovno opredelitev prenosa kmetije na naslednika še nekatera osebna prepričanja gospodarjev do procesa nasledstva (angl. *some subjective attitudes to the succession process*). Ugotavljali so še, kakšen je vpliv naštetih dejavnikov na predvideno časovno opredelitev opustitve kmetije (angl. *timing of exit from farming*).

Pri obeh raziskavah so kot časovno opredelitev predaje kmetije nasledniku upoštevali število let do načrtovane predaje, pri časovni opredelitvi opustitve kmetije pa število let do načrtovane opustitve.

2.2 Raziskava o dejanskem času predaje kmetije nasledniku

Kimhi (1994) je zato, da bi ugotovil, kdaj je optimalni trenutek za gospodarjevo predajo kmetije potomcu (angl. *optimal timing for transferring the family farm from parent to child*), pri izraelskih kmetijah proučil, kako na to, kdaj gospodar preda kmetijo nasledniku, vplivajo gospodarjeva starost in izkušnje, naslednikova stopnja izobrazbe, socioekonomske značilnosti in značilnosti kmetije (angl. *parents' age and experiences, successor's educational level, socioeconomic characteristics, and farm attributes*). Pri tem je v raziskavo vključil kmetije, ki so jih gospodarji v desetletnem obdobju proučevanja predali naslednikom, kot čas predaje kmetije nasledniku pa je upošteval starost naslednika, pri kateri je ta prevzel kmetijo.

3 HIPOTEZE

V raziskavi smo kot vplivne opredelili le tiste dejavnike socialnoekonomske strukture kmetij, za katere so avtorji opisanih raziskav dokazali, da vplivajo na čas predaje kmetije nasledniku. Zaradi preglednosti in sistematičnosti so ti dejavniki in predvidene smeri njihovih vplivov predstavljeni v preglednici 1.

Preglednica 1: Dejavniki socialnoekonomske strukture kmetij, za katere je predvideno, da vplivajo na čas prenosa hribovskih kmetij v Sloveniji na naslednike, in predvidene smeri njihovih vplivov.[ii]

Table 1: Factors of socio-economic structure of farms that we foresee will influence the timing of succession on mountain farms in Slovenia and expected directions of their influences.

Dejavniki socialnoekonomske strukture kmetije **Factors of socio-economic structure of farm**	**Smer vpliva** **Direction of influence**
Dejavniki demografske strukture kmetije / Factors of demographical structure of farm	
Število otrok v gospodarjevi družini / Number of children in householder's family	Pozitivna / Positive
Število otrok moškega spola v gospodarjevi družini / Number of male children in householder's family	Pozitivna / Positive
Starost gospodarja / Householder's age	Pozitivna / Positive
Zaposlitev gospodarja in/ali njegovega partnerja zunaj kmetije / Householder's off-farm employment and/or off-farm employment of his/her partner	Negativna / Negative
Dejavniki posestne strukture kmetije / Factors of farm estate structure	
Velikost kmetije[iii] / Farm size	Negativna / Negative
Dejavniki proizvodne (ekonomske) strukture kmetije / Factors of production (economic) structure of farm	
Višina letnega prihodka, ki izhaja iz virov na kmetiji[iv] / Annual gross income derived from farm sources	Negativna / Negative
Dejavniki razvojno-inovativne strukture kmetije / Factors of developmental-innovative structure of farm	
Finančna sposobnost kmetije za vlaganje v nadaljnji razvoj / Financial capability of farm for investment in further development	Negativna / Negative

4 MATERIALI IN METODE

4.1 Pristop k proučevanju in podatkovni viri

Raziskava o vplivu dejavnikov socialnoekonomske strukture hribovskih kmetij v Sloveniji na časovno opredelitev prenosa teh kmetij na naslednike temelji na **pristopu *ex-ante,*** kar pomeni, da je čas predaje hribovskih kmetij naslednikom predviden, načrtovan vnaprej (angl. *beforehand*). Ta pristop smo izbrali, ker na podlagi podatkov dosedanjih popisov v Sloveniji ne bi bilo mogoče ugotoviti, kdaj v proučevanem (popisnem) obdobju je gospodar kmetijo predal nasledniku oziroma koliko sta bila takrat stara gospodar in naslednik. Podatke za raziskavo smo zato pridobili z **anketiranjem,** ki smo ga izvedli po pošti junija 2005. S to tehniko bi sicer lahko za določeno (izbrano) obdobje proučevanja pridobili tudi informacije o dejanskem času predaje kmetij naslednikom – torej bi lahko raziskava temeljila na pristopu *ex-post* –, vendar pa se morajo pri tem pristopu podatki o dejavnikih socialnoekonomske strukture kmetij nanašati na stanje na začetku proučevanega obdobja. Le tako je namreč mogoče v empirično analizo vključiti vse kmetije – ne glede na to, ali je v proučevanem obdobju gospodar kmetijo predal nasledniku ali ne, oziroma ne glede na to, ali je bila kmetija v tem času opuščena – v nasprotnem primeru namreč vplivov ni mogoče določiti. Da bi bili rezultati čim relevantnejši, bi moralo biti proučevano obdobje tudi ustrezno dolgo, navezujoč se na Kimhija (1994) vsaj desetletno, zato pa bi lahko bili podatki, ki bi jih izpraševanci navedli v anketah, premalo natančni, nepravilni ali pa se jih sploh ne bi spomnili, še zlasti težko pa bi pridobili želene podatke za kmetije, ki bi bile v tem času opuščene.

4.2 Metoda dela

Glede na predstavljene empirične raziskave smo vplive dejavnikov socialnoekonomske strukture na čas predaje hribovskih kmetij naslednikom ugotavljali s pomočjo **modelov z omejeno odvisno spremenljivko** (angl. *censored[v] regression models/limited dependent variable models*), ki jih nekateri avtorji, kot npr. Pindyck in Rubinfeld (1991) ter Gujarati (1995), uvrščajo med modele diskretne izbire (angl. *discrete choice models*). Modeli z omejeno odvisno spremenljivko so podobni konvencionalnim regresijskim modelom, vendar vsebujejo le podatke tistih opazovanih enot, pri katerih se dogodek (angl. *event*) zgodi – kar pri naši raziskavi pomeni, da bo gospodar kmetijo nasledniku predal. V takih primerih zavzema odvisna spremenljivka (Y_i) zvezne vrednosti, vendar enote v analizo vključimo le, če so zvezne vrednosti odvisnih spremenljivk pozitivne. Opazovanih enot, za katere nimamo podatkov o vrednostih, ki jih zavzemajo odvisne spremenljivke (gre za opazovane enote, pri katerih se dogodek ne zgodi), imamo pa vrednosti, ki jih zavzemajo pojasnjevalne spremenljivke (X_1, ..., X_k) – v naši raziskavi so to dejavniki socialnoekonomske strukture hribovskih kmetij –, ne izključimo iz analize, ampak jih omejimo, najpogosteje z vrednostjo 0 ($Y_i = 0$), ki pa je diskretna in ne zvezna (Pindyck in Rubinfeld, 1991; Gujarati, 1995; Greene, 2003). Modele z omejeno odvisno spremenljivko po Gujaratiju (1995) imenujemo tudi tobit modeli[vi], saj je ta metodološki pristop pri izvedbi modelov te vrste najpogostejši. Tobit model predpostavlja, da mora opazovana odvisna spremenljivka Y_i za $i = 1, ..., N$ opazovanih enot zadostiti kriteriju

$$Y_i = \max (Y_i^*, 0)$$

Pri tem je Y_i^* latentna spremenljivka, ki ni opazovana in je izpeljana iz klasičnega linearnega regresijskega modela, ki ga zapišemo

$$Y_i^* = \alpha + \beta X_i + \varepsilon_i$$

Pri tem modelu predpostavljamo, da je konstanta $\alpha = 1$, slučajna napaka ε_i pa je neodvisno in normalno porazdeljena s povprečno vrednostjo 0 in varianco σ^2 – $N(0, \sigma^2)$ ter pogojena z neodvisnimi spremenljivkami X_i (Bierens, 2004; Oladele, 2005; Internet 1).

Odnos med opazovano odvisno spremenljivko Y_i in latentno spremenljivko Y_i^* matematično zapišemo v obliki enačbe

$$Y_i = \begin{cases} Y_i^* & \text{če je } Y_i^* > 0 \\ 0 & \text{če je } Y_i^* \leq 0 \end{cases}$$

Tobit modele smo izvedli z računalniškim programom LIMDEP 7.0, ki je bil izdelan posebej za izračunavanje linearnih in nelinearnih regresijskih modelov.

4.3 Opredelitev odvisne spremenljivke

V nasprotju z drugimi raziskavami smo časovno opredelitev prenosa kmetije (predvideni čas predaje hribovske kmetije nasledniku) opredelili na dva načina:

- s starostjo gospodarja, pri kateri bo ta kmetijo predal nasledniku in
- s starostjo naslednika, pri kateri bo ta kmetijo prevzel.

Menimo namreč, da je čas do trenutka, v katerem bo gospodar predal kmetijo nasledniku, preveč relativna časovna določitev. Kot pojasnilo navajamo primer: gospodar, ki je star 45 let, in gospodar, ki je star 80 let, načrtujeta, da bosta kmetiji predala naslednikoma v petih letih. Čas do trenutka, v katerem bosta kmetijo predala nasledniku, bi bil torej pri obeh kmetijah enak (5 let) in vključen v analizo kot izid odvisne spremenljivke Y_i, čeprav se lahko zgodi, da so zaradi starosti gospodarjev in njunih odnosov z naslednikoma ter drugih razlogov, socialnoekonomska struktura kmetij in perspektive za nadaljnji razvoj bistveno drugačni. V takšnih primerih rezultati analize in s tem tudi model časovne opredelitve prenosa kmetije nasledniku ne bi bili pravilni.

Izid odvisne spremenljivke Y_i, ki smo ga omejili, je za oba modela enak, in sicer:

$Y_i = 0$ na kmetiji še ni natančno določen naslednik in nihče še ni predviden za to, gospodar pa meni, da zagotovo ne bodo našli in določili naslednika, ki bo prevzel kmetijo in na njej tudi nadaljeval s kmetovanjem.

Izida odvisne spremenljivke Y_i, ki zavzema v modelih zvezne vrednosti, pa smo opredelili kot:

$Y_{i1} = Y_{i1}^*$ starost gospodarja, pri kateri bo ta kmetijo predal nasledniku;
$Y_{i2} = Y_{i2}^*$ starost naslednika, pri kateri bo ta kmetijo prevzel.

Izida $Y_{i1} = Y_{i1}^*$ in $Y_{i2} = Y_{i2}^*$ smo pripisali le tistim kmetijam, ki so zadostile naslednjim kriterijem:

- nasledniki na kmetijah so že natančno določeni oziroma so predvideni;
- gospodarji menijo, da bodo kmetije zagotovo predali naslednikom;
- nasledniki so se o tem, da bodo kmetije zagotovo prevzeli, že sami odločili;
- po prevzemu bodo nasledniki nadaljevali s kmetovanjem.

4.4 Opredelitev pojasnjevalnih spremenljivk

Dejavnike socialnoekonomske strukture hribovskih kmetij, za katere smo predvideli, da vplivajo na časovno opredelitev prenosa kmetij, smo izrazili na en način ali na več različnih načinov. Načine, s katerimi prikazujemo dejavnike socialnoekonomske strukture kmetij, smo v tobit modelu opredelili kot pojasnjevalne spremenljivke. Vsako pojasnjevalno spremenljivko smo šifrirali z ustrezno oznako oziroma s simbolom in predstavili ustrezna merila (preglednica 4 v prilogi).

Ker so pojasnjevalne spremenljivke kvalitativne ali pa kvantitativne in so zato podatki merjeni v različnih enotah, smo jih po zgledu drugih empiričnih analiz oziroma izračunov modelov diskretne izbire poskušali med seboj (in znotraj njih samih) čim bolj umeriti ter zato ustrezno modificirati ali transformirati. S tem smo izpolnili eno od zahtev pri izvedbi regresijske analize – zahteva po homoskedastičnosti, kar po Košmelj in sod. (2001) pomeni, da mora biti v regresijskem modelu varianca slučajnih napak oziroma vplivov konstantna za vse opazovane vrednosti pojasnjevalnih spremenljivk, ki so vnaprej določene.

4.5 Opredelitev ciljne skupine in raziskovalnega vzorca

Da bi se prilagodili podatkom Statističnega registra kmetijskih gospodarstev v Sloveniji leta 2005, na podlagi katerih smo določili ciljno skupino in izbrali naslovnike za anketiranje, smo **hribovske kmetije** opredelili na podlagi Robičeve (1988, 1990) členitve območij z omejenimi dejavniki za kmetovanje, in sicer kot kmetije, ki ležijo v gorsko-višinskem območju, na več kot 600 metrih nadmorske višine, in tudi kot kmetije, ki ležijo pod 600 metri nadmorske višine, vendar imajo več kot 60 odstotkov kmetijskih zemljišč v nagibu nad 35 odstotkov – po Robičevi tipologiji t. i. strme kmetije.

Da bi bila socialnoekonomska struktura posameznih hribovskih kmetij med seboj čim primerljivejša, smo za raziskavo oblikovali homogeno **ciljno skupino** hribovskih kmetij, ki smo jih izbrali na podlagi naslednjih kriterijev:

- kmetija se je nahajala v alpski ali predalpski Sloveniji, pri čemer smo območje teh pokrajin določili na podlagi Ilešičeve naravnogeografske regionalizacije iz leta 1972;
- glavna proizvodna usmeritev na kmetiji je bila živinoreja – reja pašne živine ali mešana živinoreja (uporabili smo podatke o razvrstitvi kmetij glede na tip kmetijske pridelave, in sicer po tipologiji, ki je opredeljena v Popisu kmetijskih gospodarstev leta 2000);
- starost gospodarja na kmetiji je bila 45 let ali več – pri tej starosti postajajo namreč vprašanja glede nasleditve na kmetiji vedno bolj aktualna in upoštevana pri gospodarjevih načrtih, sklepamo pa lahko tudi, da je večina gospodarjevih potomcev, ki so najverjetneje potencialni nasledniki, že stara toliko, da se lahko opredeli do gospodarjevih načrtov in predvidevanj glede nasleditve na kmetiji in v zvezi s tem sama sprejema odločitve.

Na podlagi vseh treh kriterijev in po izločitvi nekaterih kmetij brez podatkov o starosti gospodarjev smo za ciljno skupino opredelili 6801 hribovsko kmetijo. Za anketiranje je bilo med temi kmetijami naključno izbranih 3000 gospodarjev. Pri določitvi raziskovalnega vzorca smo med vrnjenimi anketnimi vprašalniki upoštevali le tiste, ki so bili izpolnjeni v celoti, izbrane kmetije pa so morale povsem ustrezati kriterijem za določitev odvisne spremenljivke Y_i. Takšnih je bilo 605 hribovskih kmetij oziroma 8,9 odstotka vseh hribovskih kmetij, ki so predstavljale ciljno skupino. Opredelili smo jih kot **raziskovalni vzorec.** Izida $Y_{i1} = Y_{i1}^*$ in $Y_{i2} = Y_{i2}^*$ smo pripisali 380 kmetijam (62,8 odstotka kmetij raziskovalnega vzorca) – na tolikih kmetijah so namreč izpraševanci odgovorili na vprašanje, čez koliko let bo gospodar kmetijo predal nasledniku, ki se je za prevzem tudi že sam odločil in bo s tem prevzel vse ali večino poslov na kmetiji, po prevzemu pa bo tudi nadaljeval s kmetovanjem[vii] –, izid $Y_i = 0$ pa smo dodelili 225 kmetijam (37,2 odstotka kmetij raziskovalnega vzorca).

5 REZULTATI

Povprečna starost gospodarjev, pri kateri naj bi predali kmetije naslednikom, je 63,8 leta – najmlajši naj bi jo predal, ko bo star 48 let, najstarejši pa v starosti 85 let (če ne upoštevamo gospodarjev, ki so glede časovne predaje kmetije navedli, da bodo gospodarili do smrti). Povprečna starost naslednikov, pri kateri bodo prevzeli kmetije, je 32,9 leta, najmlajši naslednik naj bi kmetijo prevzel pri 18-ih, najstarejši pa pri 60-ih letih.

Oceno vplivov dejavnikov socialnoekonomske strukture hribovskih kmetij v Sloveniji na časovno opredelitev predaje kmetije nasledniku smo ugotavljali na dva načina, in sicer:

- kako vplivajo posamezni dejavniki socialnoekonomske strukture hribovskih kmetij;
- kako vpliva več dejavnikov socialnoekonomske strukture hribovskih kmetij hkrati.

Z izvedbo parcialnih tobit modelov, s katerimi smo ugotavljali vplive posameznih dejavnikov socialnoekonomske strukture hribovskih kmetij, smo oblikovali parcialne modele časovne opredelitve prenosa hribovskih kmetij na naslednike. Modela, ki smo ju poimenovali sintezna modela časovne opredelitve prenosa hribovskih kmetij na naslednike (za $Y_{i1} = Y_{i1}^*$ in $Y_{i2} = Y_{i2}^*$), pa smo oblikovali na podlagi ugotavljanja vplivov več dejavnikov socialnoekonomske strukture hkrati.[viii] Za večino parcialnih tobit modelov je značilno, da imajo zelo nizko napovedno moč. Vrednosti McFaddnovih psevdo-R^2 (R^2_{MF}) oziroma indeksov razmerja verjetij (LRI) kot kazalnikov skladnosti so namreč zelo nizke – pod 0,150 –, kar pomeni, da je s temi modeli pojasnjenih manj kot 15 odstotkov celotne variance odvisne spremenljivke Y_i. Ker se pri modelih diskretne izbire vrednosti psevdo-R^2 večinoma gibljejo med 0,2 in 0,6, rezultati izračunanih parcialnih modelov niso natančni in zanesljivi. Sintezna tobit modela, s katerima smo ugotavljali vplive več dejavnikov socialnoekonomske strukture hkrati, imata sicer višje pojasnjevalne vrednosti, vendar pa sta vrednosti še vedno nizki. Pojasnil in mogočih rešitev za to nismo našli niti v raziskavah, ki se ukvarjajo z enako tematiko, niti v teoriji o modelih z omejeno odvisno spremenljivko.

Avtorji, ki so raziskovali vplive na časovno opredelitev prenosa kmetije na naslednika, in teoretiki, ki se ukvarjajo z modeli z omejeno odvisno spremenljivko

(npr. Gujarati, 1995) ugotavljajo, da je rezultate tobit modelov zelo težko interpretirati in tudi grafično predstavljati, saj so v empirično analizo vključene enote, pri katerih odvisna spremenljivka Y_i zavzema zvezne vrednosti, in tudi enote z omejeno odvisno spremenljivko Y_i, ki pomeni diskretno vrednost. Kljub temu in kljub redkim zgledom smo izračunane modele v nadaljevanju predstavili. Menimo, da lahko kljub svojim pomanjkljivostim služijo kot izhodišča za nadaljnje raziskave.

5.1 Vplivi posameznih dejavnikov socialnoekonomske strukture na časovno opredelitev predaje kmetij naslednikom

Rezultati izvedbe parcialnih tobit modelov – tako modelov, v katerih pomeni zvezna vrednost Y_i^* starost gospodarja, pri kateri bo predal kmetijo nasledniku (PRENEH_S), kakor tudi modelov, v katerih je zvezna vrednost Y_i^* starost naslednika, pri kateri bo kmetijo prevzel (PREVZ_S) – so podrobneje predstavljeni v preglednicah 5 in 6 v prilogi. Ne glede na to, kako je bila v modelih izražena odvisna spremenljivka Y_i, pa razlik v jakosti in smeri vplivov posameznih dejavnikov skoraj ni.

Med vsemi tremi demografskimi dejavniki, za katere smo predpostavili, da vplivajo na čas prenosa kmetije na naslednike, ne vpliva na čas predaje le **zaposlitev gospodarja in partnerja zunaj kmetije,** vendar je v skladu s pričakovanji smer vpliva tega dejavnika negativna – to pomeni, da predajo gospodarji kmetijo nasledniku prej, če so zaposleni zunaj kmetije oziroma če so zaposleni zunaj kmetije tudi njihovi partnerji.

Število otrok v gospodarjevi družini, zlasti **število otrok moškega spola,** kot drugi od predpostavljenih demografskih dejavnikov, ima izrazit vpliv na to, kdaj bo gospodar predal kmetijo nasledniku. S povečevanjem števila otrok v gospodarjevi družini, zlasti števila otrok moškega spola, se namreč čas predaje kmetije nasledniku podaljšuje. Med vsemi izračunanimi parcialnimi tobit modeli se modeli, v katerih sta posamično vključeni pojasnjevalni spremenljivki, s katerimi smo izrazili število otrok moškega spola v gospodarjevi družini (OTR in OTRM_OTR), najbolj približajo dejanskim vrednostim – pojasnijo celo več kot 15 odstotkov vse variance odvisne spremenljivke Y_i. Vendar pa je pri parcialnem tobit modelu s pojasnjevalno spremenljivko OTRM_OTR izkazalo, da konstanta α pri obeh različicah modelov glede na zvezno vrednost Y_i^* statistično ni značilna, zato tega modela kljub višji vrednosti McFaddnovega R^2 oziroma LRI ne moremo interpretirati kot zanesljivega.

Na čas predaje kmetije vpliva tudi **starost gospodarja,** vendar je v primerjavi s številom otrok (moškega spola) v gospodarjevi družini vpliv tega dejavnika precej manjši, izračunani koeficienti β pa so statistično značilni pri 90- ali 95-odstotnem intervalu zaupanja. Smer vpliva je pozitivna, kar pomeni, da starejši gospodarji predajo kmetije naslednikom kasneje kot mlajši.

Za ugotavljanje vpliva **ekonomske moči kmetije** na časovno opredelitev prenosa kmetije naslednikom smo izbrali tri kazalnike ekonomske moči, in sicer število živine (GVZ), oceno višine letnega prihodka na kmetiji, ki izhaja iz virov na kmetiji (PR_EVR), in mnenje gospodarja o finančni sposobnosti kmetije za vlaganje v

nadaljnji razvoj (KAPIT). Za vse tri pojasnjevalne spremenljivke, ki smo jih posamično vključili v modele, se je ne glede na to, kako je bila opredeljena zvezna vrednost Y_i^*, pokazalo, da močno vplivajo na čas predaje kmetije nasledniku. S povečevanjem ekonomske moči se podaljšuje čas predaje kmetije nasledniku – ekonomsko močnejše kmetije prevzemajo nasledniki kasneje, predajajo pa jim jih starejši gospodarji –, kar je v nasprotju s tem, kar smo predpostavljali.

5.2 Vplivi več dejavnikov socialnoekonomske strukture hribovskih kmetij hkrati na časovno opredelitev predaje kmetij naslednikom

Glede na dvojno opredelitev zvezne vrednost Y_i^* smo izračunali tudi dva sintezna tobit modela, vendar se je pokazalo, da so si smeri in jakosti vplivov dejavnikov socialnoekonomske strukture pri obeh modelih zelo podobne. Za vsak dejavnik socialnoekonomske strukture hribovskih kmetij, za katerega smo predpostavili, da vpliva na časovno opredelitev prenosa kmetij na naslednike, smo v sintezni tobit model vključili po eno pojasnjevalno spremenljivko X_i, in sicer tisto, za katero se je izkazalo, da najbolj vpliva na čas predaje kmetije nasledniku, parcialni tobit model z izbrano pojasnjevalno spremenljivko X_i pa je moral biti (v danih okvirih) čim natančnejši. Ker se je že pri izračunih parcialnih tobit modelov potrdil podoben vpliv dejavnikov na čas predaje kmetije – ne glede na to, kako je bila opredeljena zvezna vrednost Y_i^* –, smo v oba sintezna tobit modela vključili enake pojasnjevalne spremenljivke X_i. Pogoj je bil tudi, da so dejavniki med seboj čim manj povezani – v model smo vključili tiste pojasnjevalne spremenljivke, ki so izkazovale čim manj kolinearnosti z ostalimi (gre za pojav, pri katerem so pojasnjevalne spremenljivke med seboj tesno povezane – dejavniki med seboj namreč ne delujejo izolirano, ampak se bolj ali manj spreminjajo skupno, na medsebojno povezan način (Pfajfar, 1998)). Sintezna modela časovne opredelitve prenosa hribovskih kmetij na naslednike sta predstavljena v preglednicah 2 in 3.

Vplivi dejavnikov oziroma pojasnjevalnih spremenljivk so zelo podobni tudi pri obeh sinteznih modelih časovne opredelitve prenosa hribovskih kmetij na naslednike, to pomeni, da dobimo enake rezultate ne glede na to, ali izrazimo zvezne vrednost Y_i^* kot starost gospodarja, pri kateri bo ta predal kmetijo nasledniku, ali kot starost naslednika, pri kateri bo ta kmetijo prevzel. Jakosti vplivov posameznih dejavnikov oziroma pojasnjevalnih spremenljivk so v primerjavi s parcialnimi tobit modeli nižje, kar je posledica povezanosti med dejavniki. Kljub temu so se razmerja med jakostmi in smermi vplivov v primerjavi s parcialnimi tobit modeli ohranila.

Preglednica 2: Sintezni model časovne opredelitve prenosa hribovskih kmetij na naslednike – zvezna vrednost Y_i^* pomeni starost gospodarja, pri kateri bo predal kmetijo nasledniku (PRENEH_S).[ix]

Table 2: Synthesised model of the timing of mountain farm succession – the continuous value Y_i^* represents the age of the householder on the transfer of the farm to a successor (PRENEH_S)

Pojasnjevalna spremenljivka **Explanatory variable**	**Koeficient** **Coefficient**	***T*-vrednost** ***T*-value**	**Stopnja značilnosti** **Significance level**
Konstanta / Constant	–0,241	–1,830	0,067
OTRM_OTR	0,396	7,307	0,000
G_STAR	0,312	1,587	0,102
PR_EVR	0,069	6,370	0,000
Število kmetij – N / Number of farms – N: 605			
Log-funkcija verjetja – log *L* / Log-likelihood function – log *L*: –381,92			
Sigma – σ (*t*-vrednost) / Sigma – σ (*t*-value): 0,217 (24,824)			
McFaddnov psevdo-R^2 – R^2_{MF} – oziroma indeks razmerja verjetij – LRI / McFadden's pseudo-R^2 – R^2_{MF} – or likelihood ratio index – LRI: 0,230			
Prilagojen McFaddnov psevdo-R^2 – $\overline{R}^2_{MF}$ / Adjusted McFadden's pseudo-R^2 – $\overline{R}^2_{MF}$: 0,226			
Akaikov informacijski kriterij – AIC / Akaike information criterion – AIC: 0,273			
Model je statistično značilen pri manj kot enoodstotnem tveganju / Model is statistically significant at less than 1 per cent level.			

Preglednica 3: Sintezni model časovne opredelitve prenosa hribovskih kmetij na naslednike[x] – zvezna vrednost Y_i^* pomeni starost naslednika, pri kateri bo ta prevzel kmetijo (PREVZ_S)

Table 3: Synthesised model of timing of mountain farm succession – the continuous value Y_i^* represents the age of the householder on the transfer of the farm to a successor (PREVZ_S)

Pojasnjevalna spremenljivka **Explanatory variable**	**Koeficient** **Coefficient**	***T*-vrednost** ***T*-value**	**Stopnja značilnosti** **Significance level**
Konstanta / Constant	–0,142	–2,003	0,045
OTRM_OTR	0,211	7,235	0,000
G_STAR	0,183	1,737	0,082
PR_EVR	0,353	6,075	0,000
Število kmetij – N / Number of farms – N: 605			
Log-funkcija verjetja – log *L* / Log-likelihood function – log *L*:–141,68			
Sigma – σ (*t*-vrednost) / Sigma – σ (*t*-value): 0,405 (24,699)			
McFaddnov psevdo-R^2 – R^2_{MF} – oziroma indeks razmerja verjetij – LRI / McFadden's pseudo-R^2 – R^2_{MF} – or likelihood ratio index – LRI: 0,211			
Prilagojen McFaddnov psevdo-R^2 – $\overline{R}^2_{MF}$ / Adjusted McFadden's pseudo-R^2 – $\overline{R}^2_{MF}$: 0,207			
Akaikov informacijski kriterij – AIC / Akaike information criterion – AIC: –0,937			
Model je statistično značilen pri manj kot enoodstotnem tveganju / Model is statistically significant at less than 1 per cent level.			

6 RAZPRAVA

6.1 Zaposlitev gospodarja in/ali njegovega partnerja zunaj kmetije

Ugotovitev, da so kmetije, na katerih sta zunaj kmetij zaposlena gospodar in/ali partner, predane naslednikom prej kot kmetije, na katerih gospodar in/ali partner nista zaposlena zunaj njih, se ujema s Kimhijevimi (1994) rezultati empirične analize, vendar pa se obe interpretaciji rezultatov (naša in njegova) le delno ujemata. Kimhi sklepa, da je to posledica višjih skupnih dohodkov na kmetijah, katerih gospodar in partner sta zaposlena zunaj njih, kar naj bi vzpodbudilo gospodarje k čimprejšnji predaji kmetije naslednikom, to pa za proučevane hribovske kmetije ne drži – kot namreč kažejo rezultati empirične analize, predajo gospodarji večjih kmetij te naslednikom kasneje, kar je podrobneje razloženo v nadaljevanju. Mogoč vzrok za zgodnejšo predajo kmetij, katerih gospodar in partner sta zaposlena zunaj kmetije, navaja Kimhi tudi, da na teh kmetijah zaradi zaposlitve zunaj njih ne izkoriščajo vseh njihovih potencialov, kar naslednike vzpodbudi k zgodnejšemu prevzemu. Ta razlaga je za proučene hribovske kmetije bolj smiselna – za osebe, ki živijo na kmetiji, zlasti za gospodarja in njegovega partnerja, namreč predstavlja zaposlitev zunaj kmetije fizično in psihično obremenitev. Zaposleni utegnejo sproti opravljati le tista dela na kmetiji, ki so nujna, druga pa pogosto zaostajajo za zastavljenimi načrti.[xi] Zaradi konkurence na trgu dela, zlasti v sekundarnem sektorju, se vse pogosteje tudi dogaja, da se delavci zaradi strahu pred izgubo zaposlitve podrejajo zahtevam delodajalcev, ki so zaradi tržnega gospodarstva zelo visoke (npr. nadurno delo, nočne izmene). Delo zunaj kmetije tako zahteva vedno več časa in energije. Sklepamo, da gospodarji kmetij prenašajo vedno več zadolžitev na določene ali predvidene naslednike in jim sčasoma kmetije tudi v celoti predajo.

6.2 Velikost in ekonomska moč kmetije

Ker so kmetije, katerih gospodar in/ali njegov partner sta zaposlena zunaj njih, manjše od kmetij, katerih gospodar in/ali njegov partner nista zaposlena zunaj njih, lahko sklepamo, da je vpliv zaposlitve gospodarja in/ali njegovega partnerja zunaj kmetije na časovno opredelitev prenosa kmetij na naslednike le posreden, prek njega se namreč kaže vpliv velikosti kmetije oziroma vpliv ekonomske moči kmetije (glede na vire, ki iz nje izhajajo). Rezultati o vplivu tega dejavnika na čas predaje kmetije nasledniku to potrjujejo – gospodarji manjših kmetij predajo te naslednikom prej kot gospodarji velikih, kar je v nasprotju z ugotovitvami Kimhija (1994) ter Glaubena in sod. (2002, 2004)[xii] in v nasprotju s pričakovanji. Pričakovali smo namreč, da so gospodarji na manjših kmetijah nanje bolj čustveno navezani in jih zato predajajo naslednikom kasneje. Vendar pa imajo rezultati kljub temu smiselno razlago: ker so manjše kmetije v tržnem gospodarstvu ranljivejše, morajo biti, če se želijo obdržati, dovolj prožne in prilagodljive.[xiii] Mladi prevzemniki so razvojno naravnani, inovativni v spreminjajočih tržnih razmerah pa se učinkoviteje prilagajajo tehnološkim spremembam in razmeram na trgu kot starejši gospodarji – to je tudi pogoj za dvig produktivnosti dela in s tem konkurenčnosti kmetijstva (Program ..., 2007) –, deležni pa so tudi vzpodbud in pomoči s strani države.[xiv]

Podrobnejša empirična analiza je tudi pokazala, da se na večjih kmetijah potencialni nasledniki po večini sicer odločajo, da bodo za gospodarji kmetije prevzeli in na njih tudi nadaljevali s kmetovanjem, vendar pa se dogaja, da gospodarji po tem, ko začnejo nasledniki usmerjati svojo energijo v delo na kmetijah, s predajo kmetij zavlačujejo. Po Pinterič in sod. (2006) daje namreč gospodarju vodenje kmetije moč, pravice, vrednost in s tem poslušnost družine ter tistih, ki delajo na kmetiji. Gospodarji velikih kmetij se torej premalo zavedajo, da če s predajo zavlačujejo, se pri naslednikih zmanjša interes za prevzem, sami pa postajajo vse manj kreativni in nedovzetni za tržne novosti itd., zato se začne rast in finančna trdnost kmetije postopoma zmanjševati, kar lahko še dodatno vzpodbudi potencialne naslednike, da se ne odločijo za prevzem kmetij. Hribernik (1995, 210) meni, da je »ponovna vrnitev na kmetijo, potem ko si je 'pregnani' potomec že uredil lastno življenje drugod, vsekakor manj pogosta«.

Čeprav bi bilo treba za podrobnejše poznavanje te problematike v slovenskem okolju izvesti intervjuje, menimo, da predstavljajo kmetije mnogim slovenskim gospodarjem še vedno način in smisel življenja – življenjski projekt –, ne pa (še) kapitala, ki ga je treba nenehno oplajati, pri čemer je eden od zelo učinkovitih načinov za to prenos kmetij na mlade gospodarje.

6.3 Starost gospodarja

Kot smo pričakovali, obstajajo razlike glede časovne opredelitve prenosa kmetij tudi med mlajšimi in starejšimi gospodarji, kar kaže na razlike med njimi v odnosu do kmetij in kmetovanja. Mlajši gospodarji bolje poznajo zakonitosti tržne ekonomije, zlasti mehanizme za učinkovitejšo akumulacijo kapitala, kakor starejši, zato predajo kmetije naslednikom prej kakor starejši gospodarji – po Kimhiju (1994) običajno preden začne produktivnost kmetij upadati oziroma kmalu po tem. Podrobnejša analiza podatkov proučenih hribovskih kmetij kaže, da namerava skoraj 95 odstotkov gospodarjev, ki so stari med 45 in 54 let, do svojega 65. leta predati kmetije naslednikom, ki so se že odločili, da jih bodo prevzeli in bodo na njih tudi nadaljevali s kmetovanjem.[xv] V enem od intervjujev, ki smo jih izvedli v raziskavi, je 52-letni gospodar, ki je nameraval kmetijo predati nasledniku čez 4 leta, ko naj bi ta dopolnil 24 let, svojo namero pojasnil z besedami: »/.../ Sina, ki me bo nasledil, smo vzgojil v poštenega in pridnega človeka. Veliko mi pomaga, o marsičem že odloča in takoj, ko bo končal s študijem agronomije, mu bom kmetijo predal. Čeprav sem še mlad, smo taki za našo mladino že stari. Na mladih svet stoji, pravijo /.../ Ne pa tako, kot na mnogih naših kmetijah, ko držijo gospodarji kmetije v svojih rokah do svoje smrti, mladi pa do takrat že obupajo /.../«

V zvezi s starostjo gospodarjev in časovno opredelitvijo prenosa kmetij naslednikom govorijo Glauben in sod. (2002) tudi o pojavu, ki ga imenujejo časovna pot za prenose kmetij (angl. *time path for farm transfers*). Po njihovem mnenju se s daljšanjem načrtovanega časa predaje kmetije nasledniku podaljšuje dejanski čas prenosa kmetij na naslednike, in sicer ugotavljajo, da gospodarji, ki načrtujejo, da bodo kmetije predali naslednikom v petih letih, to tudi dejansko storijo, če pa načrtujejo, da jih bodo predali po več kot petih letih, jih dejansko predajo kasneje, kot so načrtovali. Glede na ugotovitve lahko sklepamo, da bo več kot 56 odstotkov gospodarjev proučenih hribovskih kmetij, ki so navedli, da nameravajo kmetije predati naslednikom v petih letih, svoje namere tudi uresničilo. Več kot 40

odstotkov med njimi jih je bilo starih od 50 do 60 let. Zaskrbljujoče pa je, da namerava tretjina gospodarjev, starejših od 60 let, naslednikom predati kmetije čez več kot pet let – v povprečju čez 10,5 leta.

6.4 Število otrok (moškega spola) v gospodarjevi družini

Ugotovitev, da število otrok v gospodarjevi družini, zlasti število otrok moškega spola, podaljša čas predaje kmetije nasledniku, podpirajo rezultati empiričnih raziskav Kimhija (1994) ter Kimhija in Nachlielija (2001). Vzrok za to naj bi bilo večje število potencialnih naslednikov v družinah z več otroki, zlasti z moškimi potomci, saj imajo, kot ugotavljata Kimhi in Nachlieli (2001) pri nasleditvi gospodarjevi sinovi že po tradiciji prednost pred hčerami, tako da si gospodar pri odločitvi za naslednika običajno vzame več časa (Nerlov in sod., 1987, navedeno v Kimhi, 1994). Glede na to, da se na kmetijah, na katerih so nasledniki že določeni oziroma predvideni in naj bi kmetije zagotovo prevzeli ter na njih nadaljevali s kmetovanjem, čas predaje kmetij podaljšuje s povečevanjem števila otrok, zlasti otrok moškega spola, lahko sklepamo, da gre v teh primerih običajno za kmetije, na katerih so nasledniki le predvideni, takšnih kmetij pa je 44 odstotkov oziroma skoraj četrtina vseh proučenih kmetij. To pa pomeni, da ni izključeno, da zaradi zavlačevanja gospodarjev z natančno določitvijo naslednikov in predaje kmetij nanje do nasleditve sploh ne bo prišlo.

Čeprav v model časovne opredelitve prenosa hribovskih kmetij niso bile vključene kmetije, na katerih naslednikov še niso določili ali predvideli, vendar menijo, da jih bodo pravočasno določili ter da bodo ti kmetije zagotovo prevzeli in na njih tudi nadaljevali s kmetovanjem, sklepamo, da so to kmetije, na katerih gospodarji naslednika med otroki še niso izbrali, ker je potencialnih naslednikov več. Najprimerneje bi bilo, če bi domnevo preverili z vprašanjem v anketi ali z intervjuji, vendar nudijo tudi zbrani podatki dokaj zanesljive rezultate: na skoraj 80 odstotkih teh kmetij je v gospodarjevi družini več kot en otrok in na slabi polovici več kot dva otroka. Med kmetijami z otroki je skoraj tri četrtine kmetij takšnih, na katerih je vsaj polovica otrok moških potomcev, pri tretjini kmetij pa so moški potomci vsi otroci v gospodarjevi družini. Če bodo gospodarji z določitvijo primernega naslednika in s predajo teh kmetije odlašali, ni nujno, da bo na njih dejansko prišlo do nasleditve, čeprav so gospodarji o nasleditvi prepričani.

7 SKLEPI

Na čas prenosa hribovskih kmetij na naslednike vplivajo skoraj vsi predvideni dejavniki socialnoekonomske strukture teh kmetij, razen dejavnika, ki smo ga opredelili kot zaposlitev gospodarja in/ali njegovega partnerja zunaj kmetije. V součinkovanju dejavnikov imata najizrazitejši vpliv število otrok moškega spola v gospodarjevi družini in višina letnega prihodka, ki izhaja iz virov na kmetiji. V nasprotju s pričakovanji se na večjih in ekonomsko močnejših kmetijah podaljša njihov čas predaj naslednikom, smeri drugih izračunanih vplivov pa se ujemajo s predvidenimi – z večanjem števila otrok v gospodarjevi družini, zlasti števila otrok

moškega spola, in s staranjem gospodarja se torej podaljšuje čas predaje kmetije nasledniku.

Izsledki raziskave kažejo, da so na slovenskih hribovskih kmetijah, zlasti pri starejših gospodarjih, še vedno zelo zakoreninjeni tradicionalni vzorci razmišljanja in ravnanj, ki ogrožajo nadaljnji razvoj in obstoj hribovskih kmetij. Če bi jih gospodarji prepoznali in presegli, bi se zavedali, da morajo naslednikom kmetije predati pravočasno, ko so ti na višku svojih delovnih moči ter imajo za delo na kmetiji voljo in veselje, pri čemer spol naslednika sploh ne bi smel biti pomemben.

8 SUMMARY

The timing of mountain farm succession is influenced by all of the foreseen factors of the socio-economic structure of these farms, except for the factor that we defined as the householder's off-farm employment and/or the off-farm employment of his/her partner. Regarding the influence of multiple factors at the same time, the timing of succession is most affected by the number of male children in a householder's family and the annual gross income derived from farm sources. Contrary to our expectations, the timing of succession is extended on larger and more economically powerful farms. Directions of influence of other factors are, however, in accordance with our predictions: the timing of succession is extended with an increase in the number of children – especially male children – in the householder's family, and with an increase in the householder's age.

The results of the research show that on Slovene mountain farms traditional patterns of thinking and behaviour are still deeply rooted, especially among older householders. For this reason, the existence and development of mountain farms is threatened. If householders recognised and surpassed these patterns they would realise that farms must be handed over in a timely fashion, when the successors' ability and will to work is at its highest point, and when they find pleasure in such work. In this regard, however, the gender of the successor should not be significant at all.

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10 PRILOGE

Preglednica 4: Oznake in opisi dejavnikov socialnoekonomske strukture kmetije kot pojasnjevalnih spremenljivk tobit modela

Table 4: Signs and descriptions of factors of socio-economic structure of farm as explanatory variables of tobit model

Simbol **Symbol**	**Opis** **Description**
Pojasnjevalne spremenljivke dejavnikov demografske strukture kmetije / Explanatory variables of factors of demographical structure of farm	
OTR	Število otrok v gospodarjevi družini / Number of children in householder's family
OTR_M	Število otrok moškega spola v gospodarjevi družini / Number of male children in householder's family
OTRM_OTR	Razmerje med številom otrok moškega spola in skupnim številom otrok v gospodarjevi družini (koeficient) / Ratio of number of male children and total number of children in householder's family (coefficient)
G_STAR	Starost gospodarja (modificirana vrednost – 1 = 100 let) / Householder's age (modified value – 1 = 100 years)
G_STAR2	Transformacija spremenljivke G_STAR (kvadrat vrednosti) / Transformation of variable G_STAR (square of value)
G_ZAP	Zaposlitev gospodarja zunaj kmetije[xvi] (slamnata spremenljivka[xvii] – 1 = da, 0 = ne) / Householder's off-farm employment (dummy variable – 1 = yes, 0 = no)
G_P_ZAP	Zaposlitev gospodarja ali/in partnerja zunaj kmetije (slamnata spremenljivka – 1 = da, 0 = ne) / Householder's off-farm employment and/or off-farm employment of his/her partner (dummy variable – 1 = yes, 0 = no)
Pojasnjevalni spremenljivki dejavnikov ekonomske strukture kmetije / Explanatory variables of factors of economic structure of farm	
GVZ	Število živine[xviii] (modificirana vrednost – 1 = 10 GVŽ) / Number of livestock (modified value – 1 = 100 LSU)
PR_EVR[xix]	Ocena višine letnega prihodka na kmetiji, ki izhaja iz virov na kmetiji (nominalna spremenljivka – v 1000 EUR) (0 = do 2,086; 1 = nad 2,086 do 4,172; 2 = nad 4,172 do 12,518; 3 = nad 12,518 do 20,864; 4 = nad 20,864 do 29,210; 5 = nad 29,210 do 41,729; 6 = nad 41,729) Estimate of annual gross income derived from farm sources (nominal variable – in 1000 EUR) (0 = up to 2.086; 1 = above 2.086 up to 4.172; 2 = above 4.172 up to 12.518; 3 = above 12.518 up to 20.864; 4 = above 20.864 up to 29.210; 5 = above 29.210 up to 41.729; 6 = above 41.729)
Pojasnjevalne spremenljivke dejavnikov razvojno-inovativne strukture kmetije / Explanatory variables of developmental-innovative structure of farm	
KAPIT	Mnenje gospodarja o finančni sposobnosti kmetije za vlaganje v nadaljnji razvoj (slamnata spremenljivka – 1 = finančno sposobna, 0 = finančno nesposobna) Householder's opinion of financial capability of farm for further investment in development (dummy variable – 1 = financially capable, 0 = not financially capable)

Preglednica 5: Rezultati izvedbe parcialnih tobit modelov za ugotavljanje vplivov dejavnikov socialnoekonomske strukture kmetij na časovno opredelitev prenosa kmetij na naslednike[xx] – zvezna vrednost Y_i^* pomeni starost gospodarja, pri kateri bo predal kmetijo nasledniku (PRENEH_S).

Table 5: Results of the realisation of partial tobit models for determining the influence of factors of socio-economic structure of farms on the timing of succession – the continuous value Y_i^* represents the age of the householder on the transfer of the farm to a successor (PREVZ_S)

Pojasnjevalna spremenljivka **Explanatory variable**	**α**	**Koeficient (*t*-vrednost)** **Coefficient (*t*-value)**	**Stopnja značilnosti** **Significance level**	**R^2_{MF} (LRI)**	**σ (*t*-vrednost) (*t*-value)**
OTR	0,078*	0,083 (5,796)	0,000	0,057	0,453 (24,540)
OTR_M	0,065**	0,161 (9,949)	0,000	0,152	0,427 (24,626)
OTRM_OTR	0,019	0,551 (10,838)	0,000	0,173	0,421 (24,611)
G_STAR	0,568***	0,445 (2,089)	0,037	0,003	0,467 (24,490)
G_STAR2	0,444***	0,387 (2,270)	0,023	0,003	0,467 (24,492)
G_ZAP	0,316***	–0, 029 (–0,733)	0,464	0,001	0,468 (24,495)
G_P_ZAP	0,311***	–0, 018 (–0,402)	0,687	0,000	0,468 (24,494)
GVZ	0,129***	0, 198 (8,230)	0,000	0,104	0,441 (25,581)
PR_EVR	0, 079**	0, 101 (10,180)	0,000	0,155	0,427 (24,635)
KAPIT	0,142***	0, 356 (9,436)	0,000	0,136	0,432 (24,608)

*, **, *** Konstanta α je statistično značilna pri manj kot 10- (*), manj kot 5- (**) in manj kot 1-odstotnem (***) tveganju.

*, **, *** Constant α is statistically significant at less than 10 per cent (*), 5 per cent (**) and 1 per cent (***) level.

Preglednica 6: Rezultati izvedbe parcialnih tobit modelov za ugotavljanje vplivov dejavnikov socialnoekonomske strukture kmetij na časovno opredelitev prenosa kmetij na naslednike[xxi] – zvezna vrednost Y_i^* pomeni starost naslednika, pri kateri bo kmetijo prevzel (PREVZ_S).

Table 6: Results of realisation of partial tobit models for determining the influence of factors of socio-economic structure of farms on the timing of succession – the continuous value Y_i^* represents the age of the householder on the transfer of the farm to a successor (PREVZ_S)

Pojasnjevalna spremenljivka **Explanatory variable**	**α**	**Koeficient (*t*-vrednost)** **Coefficient (*t*-value)**	**Stopnja značilnosti** **Significance level**	**R^2_{MF} (LRI)**	**σ (*t*-vrednost) (*t*-value)**
OTR	0,485**	0,393 (5,147)	0,000	0,040	0,242 (24,647)
OTR_M	0, 034**	0, 082 (9,130)	0,000	0,130	0,229 (24,742)
OTRM_OTR	0,007	0,288 (10,680)	0,000	0,161	0,245 (24,785)
G_STAR	0,280***	0,208 (1,844)	0,065	0,001	0,248 (24,592)
G_STAR2	0,223***	0,184 (2,032)	0,042	0,002	0,248 (24,596)
G_ZAP	0,016***	–0,148 (–0,683)	0,495	0,001	0,248 (24,604)
G_P_ZAP	0,158***	–0,006 (–0,239)	0,881	0,000	0,248 (24,603)
GVZ	0,065***	0,103 (8,049)	0,000	0,096	0,235 (24,699)
PR_EVR	0,398**	0,052 (9,778)	0,000	0,137	0,229 (24,753)
KAPIT	0,072***	0,185 (9,155)	0,000	0,124	0,231 (24,727)

*, **, *** Konstanta α je statistično značilna pri manj kot 10- (*), manj kot 5- (**) in manj kot 1-odstotnem (***) tveganju.

*, **, *** Constant α is statistically significant at less than 10 per cent (*), 5 per cent (**) and 1 per cent (***) level.

OPOMBE

[i] V raziskavi smo enačili termin prevzemništvo (prevzem) s terminom nasledstvo, čeprav pomeni po Kladniku (1999) prevzemništvo predajo kmetije v upravljanje, pri tem pa v primerjavi z nasledstvom ni nujno, da pride tudi do spremembe lastništva.

[ii] Smer vpliva se ne nanaša na zgodnejši prenos kmetije na naslednika, kar bi bilo logično in smiselno, ampak na podaljšanje časa predaje kmetije nasledniku, npr. za velikost kmetije predvidevamo negativno smer vpliva – to pomeni, da predvidevamo, da so naslednikom manjše kmetije predane kasneje, večje pa prej. Smeri vplivov posameznih dejavnikov smo zaradi konsistentnosti morali poenotiti z modelnim izračunom. Smer vpliva je določena glede na povečanje vrednosti dejavnika, če je dejavnik kvantitativne narave, oziroma s pritrditvijo, če gre za dejavnik kvalitativne narave in sta mogoča odgovora da in ne.

The direction of influence does not refer to an earlier transfer of the farm to a successor, which would be logical and reasonable, but refers to an extension of the timing of succession, e.g., for farm size we foresee a negative direction of influence, i.e., we foresee that smaller farms will be handed over to the successor later, while larger farms will be transferred sooner. For the sake of consistency, we have had to unify the directions of influence of several factors with the model calculation. The direction of influence is determined with regard to an increase in the factor value if the factor is quantitative, or with confirmation if the factor is qualitative and the possible answers are 'yes' or 'no'.

[iii] Velikost kmetije lahko obravnavamo kot dejavnik posestne ali ekonomske strukture kmetije, odvisno kako jo izrazimo (npr. s površino kmetijskih zemljišč v uporabi ali številom živine).

We can treat farm size either as a factor of farm estate structure or of the economic structure of the farm, depending on how it is expressed (e.g., by utilised agricultural area or by number of livestock).

[iv] Ker na nobeni testni kmetiji niso vodili evidence spremenljivih in stalnih stroškov, smo se odločili, da bomo z anketiranjem namesto podatkov o dohodkih zbirali podatke o prihodkih. Zanimali so nas prihodki iz virov na kmetiji, h katerim smo prišteli prihodke od kmetijske proizvodnje, gozdarstva in tudi morebitnih dopolnilnih dejavnosti. Subvencije sicer niso vir, ki izhaja s kmetije, vendar so z dejavnostmi na kmetiji tesno povezane in so vključene v prihodke teh dejavnosti, zlasti kmetijske proizvodnje.

As none of the farms tested kept records of variable and fixed costs, we decided to collect survey data on gross income instead of net income. We were interested in gross income arising from farm sources, including gross income from agricultural production, forestry and any possible supplementary activities. Subsidies are not a source arising from the farm, but are closely connected with activities on the farm and are incorporated in income from these activities, especially from agricultural production.

[v] Juvančič (2002) izraz »censored« prevaja kot okrnjen, čeprav je angleška ustreznica tega izraza »truncated«.

[vi] Ime modela je skovanka med priimkom avtorja tega modela Tobinom in poimenovanjem probit model, modelom, na katerem temelji tobit model (Bierens, 2004).

[vii] Če gospodarji časovne predaje kmetije niso navedli v letih, ampak opisno – pri tem je šlo za odgovore kot »gospodar bom do smrti«, »kmetije ne bom predal vse do svoje smrti« –, smo upoštevali, da bo gospodar kmetijo predal pri starosti 90 let, in kmetijo vključili v empirično analizo.

[viii] Čeprav Košmelj (2001) ter Košmelj in Vadnal (2003) v takih primerih govorita o univariatnem oziroma multivariatnem modelu, smo modela poimenovali parcialni in sintezni model. Želeli smo se namreč izogniti mogočim zamenjavam s pojmoma univaritni in multivariatni model, ki ju opredeljuje Greene (2003) in imata drug pomen.

[ix] Smer vpliva se ne nanaša na zgodnejši prenos kmetije na naslednika, kar bi bilo logično in smiselno, ampak na podaljšanje časa predaje kmetije nasledniku.

The direction of influence does not refer to an earlier transfer of the farm to a successor, which would be logical and reasonable, but refers to an extension of the timing of succession.

[x] Smer vpliva se ne nanaša na zgodnejši prenos kmetije na naslednika, kar bi bilo logično in smiselno, ampak na podaljšanje časa predaje kmetije nasledniku.

The direction of influence does not refer to an earlier transfer of the farm to a successor, which would be logical and reasonable, but refers to an extension of the timing of succession.

[xi] Kljub obremenitvam gospodarji in/ali njihovi partnerji pri zaposlitvah zunaj kmetije po večini vztrajajo. To je posledica pridobljenega vzorca obnašanja, mišljenja in eksistencialnega strahu, ki izvirajo iz izkušenj z družbenim sistemom v Jugoslaviji in iz časa tranzicije v devetdesetih letih 20. stoletja, predvsem pa želje po povečanju gospodarske moči kmetije in blaginje v družini ter zato, da bi omogočili boljše življenje otrokom, med njimi tudi tistim, ki jih imajo določene ali predvidene za naslednike. Hribovske kmetije so namreč običajno premajhne, da bi dosegale paritetni dohodek, zato je zaposlitev zunaj kmetije nujna za zagotavljanje ekonomske in socialne varnosti.

[xii] Glauben in sod. (2004) za velike in finančno sposobne nemške kmetije ugotavljajo, da jih želijo določeni ali predvideni nasledniki čim prej prevzeti ter s svojim znanjem in z idejami oplemenititi kapital na njih ter izboljšati svoj življenjski standard.

[xiii] Z anketiranjem bi bilo smiselno preveriti tudi, katere kmetije so vključene v ukrep zgodnjega upokojevanja. Z rento, ki se izplača prenosnikom, se namreč izboljša tudi ekonomski položaj kmetij, ki so vključene v ta ukrep, za kar sklepamo, da bi lahko vzpodbudno vplivalo predvsem na manjše kmetije, še zlasti ker je del rente, ki se izplača, omejen z velikostjo prenesenih kmetijskih zemljišč.

[xiv] Mladi prevzemniki lahko npr. zaprosijo za nepovratna sredstva iz naslova pomoči mladim kmetom za prevzem kmetije. Pomoč je namenjena za delno pokrivanje stroškov, ki izhajajo iz naslova generacijskega lastniškega prevzema kmetije s strani mladega kmeta na podlagi izročilne oziroma darilne pogodbe (Internet 2). Vlogo lahko oddajo le majhne in srednje velike kmetije, s čimer se potrjujejo ugotovljene težnje gospodarjev manjših kmetij glede časovne opredelitve prenosa na naslednike.

[xv] Za nekatere kmetije sklepamo, da je to povezano z namenom gospodarjev, da se vključijo v ukrep zgodnjega upokojevanja, saj se lahko vanj vključijo gospodarji, ki so dopolnili 57 let, renta pa se izplačuje največ 10 let (Program ..., 2007).

[xvi] Gospodar nima statusa kmeta ali kmetijskega podjetnika. Med gospodarje z zaposlitvijo zunaj kmetije sodijo tudi brezposelne osebe in osebe, ki so upokojene, vendar so bile pred upokojitvijo zaposlene zunaj kmetije in niso imele statusa kmeta ali kmetijskega podjetnika.

The householder's (official) occupational status is not that of a farmer or agricultural entrepreneur. Amongst householders with off-farm employment we have also included unemployed persons and persons who are retired but before retiring were employed off-farm and their status was not that of a farmer or agricultural entrepreneur.

[xvii] Spremenljivko, ki je prirejena vsaki vrednosti nominalne spremenljivke in dobi vrednost 1, če ima enota izbrano vrednost nominalne spremenljivke, in vrednost 0, če enota nima izbrane vrednosti nominalne spremenljivke, imenujemo slamnata (umetna) spremenljivka (angl. *dummy variable*) (Košmelj in sod., 2001).

As a dummy variable we denominate a variable that is adapted to each value of the nominal variable and receives a value of 1 if the unit has the selected value of the nominal variable, and a value of 0 if the unit does not have the selected value of the nominal variable (Košmelj et al., 2001).

[xviii] V koeficientih glav velike živine – GVŽ / In coefficients of livestock units – LSU.

[xix] Ker smo anketiranje izvajali pred uvedbo nove valute – evra –, so razredi z ocenami višine letnega prihodka zaokrožene v nekdanji nacionalni valuti – tolarjih (SIT). Informativno navajamo še vrednosti preračunane v tolarje, po centralnem paritetnem tečaju Banke Slovenije – 1 EUR = 239,64 SIT. 500000 sit = 2086,46 eur, 1 milijon sit = 4172,93 eur, 3 milijone sit = 12518,78 eur, 5 milijonov sit = 20864,63 eur, 7 milijonov sit = 29210,48, 10 milijonov sit = 41729,26 eur.

As the survey was carried out before the euro became the new currency in Slovenia, the ranks with estimates of annual gross income are rounded up in the former national currency – tolars (SIT). For the reader's information, we state the values converted into tolars, according to the parity exchange rate of the Bank of Slovenia: 1 EUR = 239.64 SIT.

500,000 sit = 2,086.46 euro, 1 million sit = 4,172.93 euro, 3 million sit = 12,518.78 euro, 5 million sit = 20,864.63 euro, 7 million sit = 29,210.48, 10 million sit = 41,729.26 euro.

[xx] Smer vpliva se ne nanaša na zgodnejši prenos kmetije na naslednika, kar bi bilo logično in smiselno, ampak na podaljšanje časa predaje kmetije nasledniku.

The direction of influence does not refer to an earlier transfer of the farm to a successor, which would be logical and reasonable, but refers to an extension of the timing of succession.

[xxi] Smer vpliva se ne nanaša na zgodnejši prenos kmetije na naslednika, kar bi bilo logično in smiselno, ampak na podaljšanje časa predaje kmetije nasledniku.

The direction of influence does not refer to an earlier transfer of the farm to a successor, which would be logical and reasonable, but refers to an extension of the timing of succession.

Agrovoc descriptors: mitosis; cell division; biological development; tracheophyta

Agris category code: F63

COBISS koda 1.02

Mitoza in celični cikel pri višjih rastlinah

Tomaž SINKOVIČ[1]

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IZVLEČEK

Prikazane so značilnosti celične delitve (mitoze) in njihovih faz. Mitozi sledi precej daljša interfaza ali obdobje med dvema delitvama. Po končani delitvi jedra (kariokineza) nastopi še delitev citoplazme (citokineza). Izmenjavo mitoze in interfaze imenujemo celični cikel. Čeprav je bila mitoza odkrita pred več kot sto leti so procesi mitoze, njej sledeče interfaze in predvsem regulacija celičnega cikla še do danes precej nejasni. Predstavljeni so osnovni mehanizmi regulacije celičnega cikla. V evkariontskih organizmih celični cikel regulirajo beljakovinske kinaze. Kompleks kinaz (CDKs) in ciklina se imenuje MPF (mitozni promocijski faktor), ki sproži delitve. Predstavljene so motnje regulacijskega mehanizma celičnega cikla. Celični cikel je skrbno nadzorovan. Usklajenost dogajanj, kot so celična rast, podvojevanje DNK in razporejanje podvojenih kromosomov, zagotavlja celično potomstvo in nespremenjen genom. Napake v regulaciji celičnega cikla vodijo v nenormalno delitev in lahko tudi v nastanek rakastih celic, zato je regulacija delovanja celičnega cikla predmet intenzivnih raziskav.

Ključne besede: višje rastline, mitoza, interfaza, regulacija celičnega cikla, motnje delovanja celičnega cikla

MITOSIS AND CELL CYCLE IN HIGHER PLANTS

ABSTRACT

Characteristics of cell division (mitosis) and their phases are represented. Mitosis is followed by interphase or the period beetween two divisions. After the division of the nucleus (caryokinesis) the division of cytoplasma (cytokinesis) takes place. Although mitosis was discovered more than hundred years ago its processes, the following interphase and the regulation of the cell cycle are up to now still unclear. The basic mechanisms of the regulation of the cell cycle are presented. In eucaryotic organisms the cell cycle is regulated by protein kinases. The complex of kinases (CDKs) and cyclins is called MPF (mitosis promoting factor), which is the trigger for mitosis. Some disturbances of cell cycle regulation typical for higher plants are presented. The cell cycle is carefully regulated. Cell proliferation, duplication of DNA and the arrengement of duplicated chromosomes to daughter cells ensures future cell generations and unvaried genome. Errors in cell regulation cycle lead to abnormal divisions including also to cancers cells, therefore the regulation of the cell cycle is the subject of intense investigations.

Key words: higher plants, mitosis, interphase, regulation of the cell cycle, disturbances of the cell cycle

[1] viš. pred. mag. Univerza v Ljubljani, Biotehniška fakulteta, Jamnikarjeva 101, SI-1111 Ljubljana.

1. UVOD

Vsaka rastlina prične razvoj z celico, ki se deli in raste. Ko se rastlina razvije imajo samo nekatere celice sposobnost neprestanih delitev in rasti predvsem v rastnih vršičkih in kambijih (meristemi). Ostale celice se večinoma specializirajo za določeno nalogo kot je spravilo hranil, fotosintezo, oporo, prevajanje hranil, pokrivanje in zaščita rastlinskega telesa (Sitte in sod., 1991; Moore in sod., 1995).

Delitev celice obsega dva procesa: delitev jedra ali kariokinezo in delitev citoplazme ali citokinezo, čeprav se izraz celična delitev pogosto uporablja kot sinonim za mitozo. Izraz mitoza izvira iz grške besede "mitos" - nit. Ime je po nitasti zgradbi kromosomov, ki so jih opazovali prvi raziskovalci pri celičnih delitvah.

Pri telesnih ali somatskih celicah višjih rastlin, ki imajo ponavadi diploidno število kromosomov (2n) ločimo dva osnovna tipa delitev jedra:

1. Amitoza ali direktna delitev jedra, pri kateri se jedro enostavno razdeli na dvoje, brez vidnih faz. S svetlobnim mikroskopom je ne opazimo.
2. Mitoza ali indirektna delitev jedra, ki poteka indirektno preko 4 faz. Obdobje med dvema delitvama pa imenujemo interfaza.

Delitev celic je tesno povezana z zgradbo jedra in kromosomov.

2. Indirektna delitev celic (mitoza)

Mitoza in njej sledeča interfaza, kjer se vrši celična rast sestavljata celični cikel, ki traja pri rastlinah povprečno od 20 do 30 ur, od tega traja mitoza krajši del od 1 do 2 uri. Po končani mitozi lahko celice preidejo v nov celični cikel (embrionalna tkiva) ali pa preidejo v trajno stanje (trajna tkiva). Potek mitoze je poznan že približno sto let. Prva sta mitoze opazovala raziskovalca Eduard Strasburger in Walther Fleming pri rastlinah in živalih s posebej velikimi kromosomi. Pri mitozi se genetski material razdeli na dve novi identični hčerinski jedri. Vse celice pridobljene z mitozo so kloni - genetsko enake celice. Mitozo lahko pri rastlinah opazujemo v zarodnih tkivih - meristemih, največkrat v koreninskih rastnih vršičkih, ki so za opazovanje najprimernejši. Pri celicah zarodnih tkiv zavzema jedro 50% prostornine celice. Jedra diferenciranih celic trajnih tkiv, ki zgube sposobnost delitev, ponavadi zavzemajo samo 10% prostornine celice.

Mitozo delimo na štiri štadije: profazo, metafazo, anafazo in telofazo, čeprav je v živih celicah teh štadijev več, ker faze prehajajo spontano iz ene v drugo (Denffer in Ziegler, 1979; Dubravec, 1993; Krajnčič, 2001; Nultsch, 1991).

2.1 Značilnosti faz mitoze

Profaza (pro = prej)

V začetku profaze je kromatin v obliki tankih, dolgih odvitih niti. Kromatin je kemično sestavljen iz DNK, RNK in beljakovin. Proti koncu profaze se kromatinske niti zgostijo kar pomeni zavijanje in krajšanje in tvorbo pod svetlobnim mikroskopom dobro vidnih kromosomov. Lahko bi to fazo opisali tudi kot prehod

dednega materiala iz delovne v prenosno obliko. Prične se vzdolžna delitev profaznih kromosomov na dve sestrski kromatidi, ki sta tesno druga ob drugi. Pod optičnim mikroskopom so vidne majhne razpoke med kromatidama, ki kažeta na delitev kromosoma v dve sestrski kromatidi. Kromatidi ostaneta spojeni na mestu na kromosomu imenovanem primarna zožitev ali centromera. Ob koncu profaze se prične tvoriti ovoj kromosomov. Jedrce izgine prav tako kot jedrna ovojnica. Oblikujejo se niti delitvenega vretena, ki ga sestavljajo mikrotubuli.

Metafaza (meta = vmes; srednja)

V metafazi se delitveno vreteno dokončno izoblikuje. V tej fazi se tvorijo polni in kinetohorni mikrotubuli. Kinetohorni mikrotubuli se pritrjajo na centromero ali primarno zožitev kromosomov preko kinetohorjev. Kromosomi so v metafazi najkrajši, najbolj zgoščeni, ugodni za opazovanje, štetje in za analize kariotipa rastlinske vrste. Metafazni kromosomi so dokončno razdeljeni v dve sestrski kromatidi, ki sta spojeni le še v centromeri. Kromosomi so v idealnem primeru razporejeni v ekvatorijalni ravnini celice. Pri pripravi mikroskopskih preparatov - mečkancev korenin so metafazni kromosomi pogosto razporejeni po celotni celici, ker jedrna ovojnica na koncu profaze razpade.

Anafaza (ana = vzdolž)

Sestrski kromatidi se v tej fazi dokončno ločita z nitmi delitvenega vretena. Kinetohorni mikrotubuli se krčijo in vlečejo kromatidi proti poloma celice in enakomerno razdelijo dedno snov na hčerinski celici. S potovanjem na celična pola se konča anafaza. Ob koncu anafaze se prično zbirati v ekvatorijalni ravnini celice Golgijevi vezikli, ki tvorijo celično ploščo (Van Damme in sod., 2007). Po trajanju je anafaza najkrajša.

Telofaza (telos = konec)

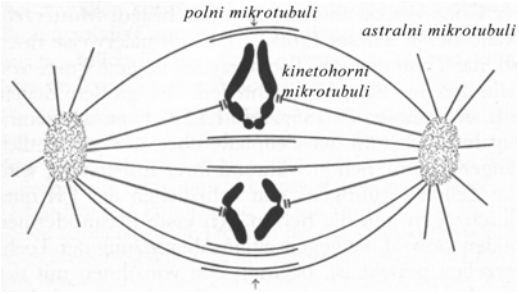
V telofazi se kromosomi despiralizirajo, odvijajo, podajšajo izgubijo ovoj ali matriks in preidejo v kromatin. Kromatin predstavlja odvito omrežje DNK, RNK in beljakovin in ga lahko opazujemo v telofazi in interfazi. Bolj spiraliziran in temneje obarvan del kromatina se imenuje heterokromatin, manj spiraliziran in genetsko aktivnejši del pa je evkromatin. Dedna snov z odvijanjem preide v delovno obliko. Niti delitvenega vretena razpadejo. Iz membran ER se tvori jedrna ovojnica in ponovno se tvori jedrce. Po naštetih dogajanjih v jedru je telofaza nasprotna profazi. V telofazi se iz mehurčkov Golgijevega aparata tvori celična plošča (fragmoplast) in kasneje osrednja lamela in s tem celična stena (Lloyd in Buschmann, 2008), ki predeli novo nastali celici.

Mitoza je pogosto, vendar ne vedno povezana z delitvijo celice na dve hčerinski (citokineza).

2.2 Tvorba niti delitvenega vretena

Mikrotubuli ali niti delitvenega vretena so pomembni pri potovanju kromosomov pri mitozi in mejozi. Pričnejo se razvijati v profazi in se dokončno izoblikujejo v metafazi. Ločimo tri vrste mikrotubulov delitvenega vretena:

- polne mikrotubule
- kinetohorne mikrotubule (kromosomski mikrotubuli)
- žarkaste (astralne) mikrotubule



Slika 1: Niti delitvenega vretena igrajo pomembno vlogo pri potovanju kromatid na pola celice v anafazi mitoze in razdelitvi dednega materiala v novonastali hčerinski celici.

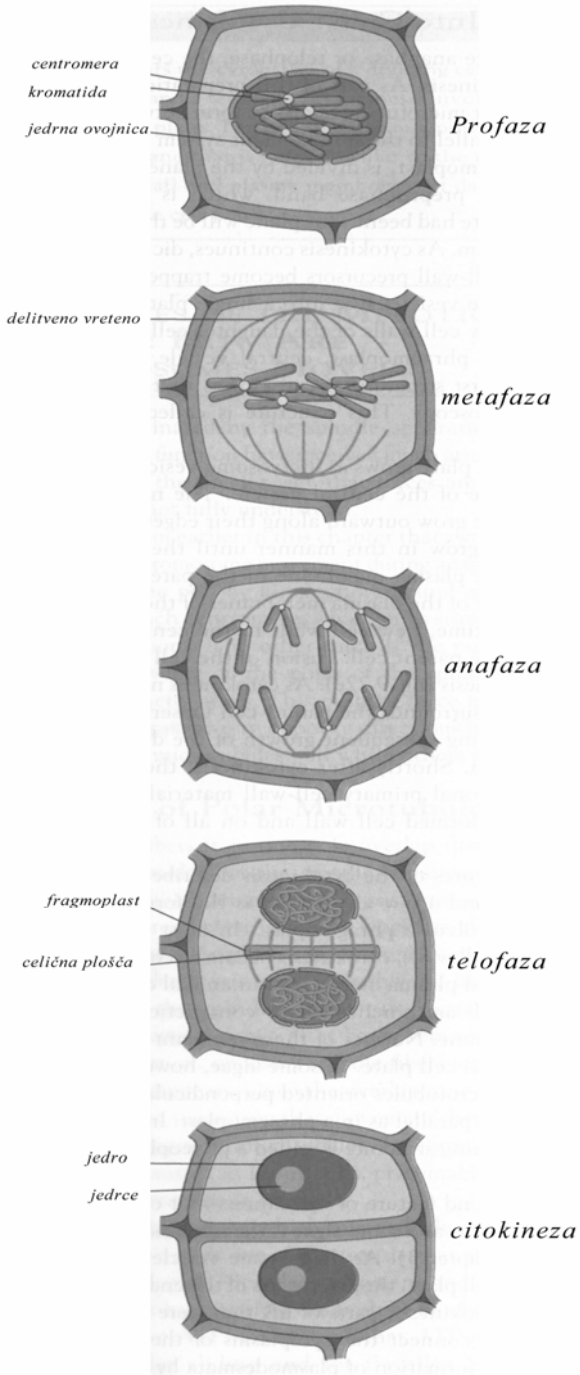
Fig. 1: The spindle apparatus has an important role in migration of the chromatids to cell poles in anaphase of mitosis and dividing the genetic material into new established daughter cells.

Polni mikrotubuli potekajo samo do ekvatorialne ravnine celice, kjer se stekajo in dajejo videz enotnih mikrotubolov.

Kinetohorni mikrotubuli se v anafazi jedrne delitve krčijo ob kinetohorju (primarni zožitvi = centromera) kromosoma in omogočajo potovanje kromatid na pola celic v anafazi.

Iz polov celic se pojavijo tudi žarkasti mikrotubuli v vseh smereh, ki se zato imenujejo žarkasti ali astralni mikrotubuli.

Kinezine imenujemo skupino z mikrotubuli povezanih beljakovin, ki imajo pomembno nalogo pri potovanju kromosomov pri celičnih delitvah in tudi pri tvorbi fragmoplasta. Raziskave pri rastlinskih celičnih kulturah so pokazale, da vsaj 23 različnih kinezinov sodeluje pri procesih mitoze (Vanstraelen in sod., 2006).



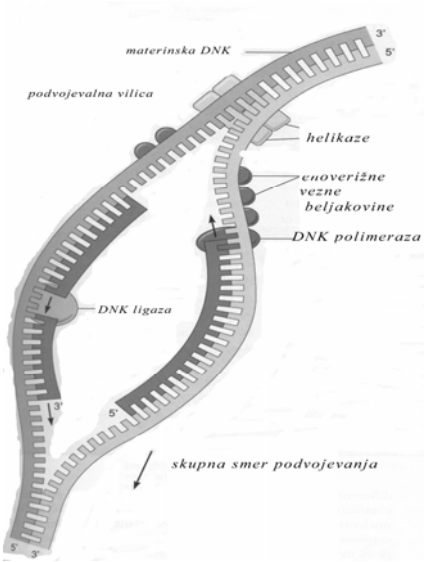
Slika 2. Mitoza obsega štiri faze: profaza, metafaza, anafaza in telofaza. Po delitvi jedra nastopi še delitev citoplazme ali citokineza.

Fig. 2: The four phases of mitosis: prophase, metaphase, anaphase and telophase. The division of the nucleus is followed by the division of cytoplasma (cytokinesis).

2.3 Interfaza (obdobje med dvema delitvama)

Interfaza je časovno najdaljša, traja povprečno 9x dalj, kot sama delitev celice ali M faza. Med različnimi celicami so velike razlike v trajanju celičnega cikla. Včasih so interfazo zmotno imenovali fazo mirovanja, ker z optičnim mikroskopom niso opazili spremembe kot pri sami mitozi. Dejansko je v tej fazi DNK molekula odvita in v delujoči obliki. Interfazo delimo na tri podobdobja:
G_1 = prva rastna faza
S = perioda sinteze DNK (podvojevanje)
G_2 = druga rastna faza

V G_1 se vrši priprava na sintezo DNK, tvori se RNA, lipidi in beljakovine. Molekula DNK je v tej fazi močno odvita in organizirana s pomočjo histonov (bazičnih jedrnih beljakovin) v enote, imenovane nukleosomi (slika 4).



(Slika je predelana po viru: Randy Moore, W. Dennis Clark, Kingsley R. Stern, Darrell Vodopich 1995. Botany. Wm. C. Brown Publishers.)

Slika 3: Krajše fragmente novo sintetizirane DNK povežejo DNK ligaze. Pri podvojevanju DNK sodelujejo številni encimi in beljakovine. Encimi helikaze odvijejo dvojno vijačnico DNK. Vezne beljakovine stabilizirajo enoverižno DNK. DNK polimeraza poveže nukleotide novosintetizirane DNK v krajše odseke.

Fig. 3: During the process of the duplication of DNA many enzymes and proteins cooperate. The enzymes helicases unwind DNA double helices. Binding proteins stabilize the single stranded DNA molecule. The enzymes DNA polymerases bind the nucleotids of new synthetized DNA into short fargments. New synthetized short fragments are bind by DNA ligases.

Sledi perioda podvojevanja DNK ali S faza, v kateri se dvojni vijačnici odvijeta in po vzorcu matrične DNK sintetizirata novi kopiji. Tako nastaneta dve dvoverižni molekuli DNK. Ker podvojevanje poteka po načelu komplementarnosti baz sta nastali molekuli DNK enaki med seboj. Novo nastale molekule DNK nastajajo hitro pri evkariontih se v povprečju poveže 50 nukleotidov na sekundo. Verigi dvojne vijačnice se razkleneta in ob vsaki se sintetizira nova. Tako nastaneta dve dvoverižni molekuli DNK, pri čemer je ena veriga v novo nastali molekuli nespremenjena »materinska« molekula, druga pa je sintetizirana na novo (semikonzervativno podvojevanje).

Podvojevanje in prepis dednih informacij je možen samo v odviti obliki, da imajo do molekule DNK dostop encimi, ki so nujno potrebni za podvojevanje. Encima DNK helikaza in topoizomeraza, cepita dvoverižno DNK. Osrednji encim podvojevanja je DNK polimeraza, ki ob vsaki od obeh razprtih enoverižnih DNK s povezovanjem nukleotidov izgrajuje matrici komplementarno verigo. DNK polimeraza spaja nukleotide v smeri 5' proti 3' glede na potek fosfodiestrskih vezi v dvojni vijačnici. Podvojevanje DNK poteka na več mestih hkrati na molekuli DNK, imenovanih izvori podvojevanja. Hitrost in številni izvori podvojevanja skrajšajo S-fazo celičnega cikla na razmeroma kratko obdobje.

Krajši, nekaj sto do nekaj tisoč nukleotidov dolgi fragmenti novo sintetizirane zaostajajoče verige DNK, so po raziskovalcu Reiju Okazakiju znani kot Okazakijevi fragmenti. Okazakijeve fragmente pa poveže encim DNK ligaza. V S fazi poteka tudi sinteza jedrnih bazičnih beljakovin - histonov.

Po podvojevanju DNK sledi rastna faza ali G_2 faza, v kateri se vrši sinteza beljakovin delitvenega vretena in ATP.

3. Celični cikel

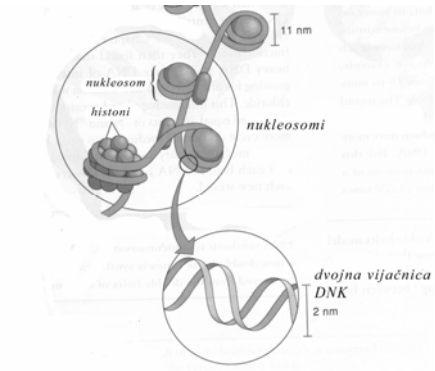
Celični cikel obsega mitozo ali M fazo med katero poteka delitev jedra (kariokineza) in citokinezo, med katero poteka delitev citoplazme in s tem celice. Celični cikel pa obsega tudi sledečo interfazo v kateri preživi celica najdalj. Obdobje med končanjem mitoze in začetka S faze se imenuje G_1 faza (G=gap) V obdobju G_1 faze celica preiskuje svojo okolje in lastno velikost in se odloči po določenem času, da vstopi v S fazo. Celice v G_1 štadiju, ki ne bodo podvajale DNK stopijo v G_0 štadij, ki lahko traja od nekaj dni do nekaj let in je značilna za popolno diferencirane celice. Po S fazi (S= sintetska) in pred mitozo so celice v G_2 fazi.

Celični cikel se lahko ustavi v kontrolnih točkah (restrikcijskih točkah), ki s povratnimi signali preprečujejo nadaljne procese dokler prejšnji niso končani. Dve glavni kontrolni točki sta v G_1 fazi , kratko pred vstopom v S fazo in v G_2 fazi pred mitozo. Obstaja še dodatna kontrolna točka v metafazi imenovana točka brez povratka. Kontrolna točka v G_2 kontrolira nepodvojeno DNK, ki povzroča signal za ustavitev celičnega cikla, če podvojevanje DNK ni končano. Nadaljni razvoj celičnega cikla v G_2 se lahko ustavi tudi zaradi poškodb DNK in s tem omogoča čas za popravilo DNK molekul. Poškodbe DNK lahko ustavijo celični cikel tudi v G_1 fazi. Sproži se posebna beljakovina, ki ustavi celični cikel. V človeškem organizmu obstaja p53 beljakovina, ki blokira celični cikel, če je DNK poškodovana. Če je

poškodba huda ta beljakovina lahko povzroči celično smrt (apoptozo). P27 je beljakovina, ki se veže na ciklin in ustavi cikel pri vstopu v v S fazo. Nižje vsebnosti p27 beljakovine dajejo slabo prognozo bolezni pri nekaterih vrstah raka človeškega organizma.

Pomembno je da se genom podvoji samo enkrat na celični cikel (Eckardt, 2001). Ko je enkrat DNK podvojena obstajajo kontrolni mehanizmi, ki preprečujejo novo S fazo pred mitozo.

Kontrolna točka v metafazi, preiskuje pripenjanje niti delitvenega vretena na kromosome in s tem omogoča pravilno razporeditev kromosomov v hčerinske celice. Če kromosomi niso pravilno razporejeni, hčerinske celice odmrejo ali utrpijo genetske poškodbe in ne morejo delovati pravilno. Molekula DNK je v G_1 fazi interfaze močno odvita (despiralizirana) in organizirana s pomočjo različnih histonov (bazičnih beljakovin) v enote imenovane nukleosomi. Po G_1 fazi se celice lahko diferencirajo v trajna tkiva in zgube sposobnost delitev (G_0) ali nadaljujejo celični cikel (embrionalna tkiva).

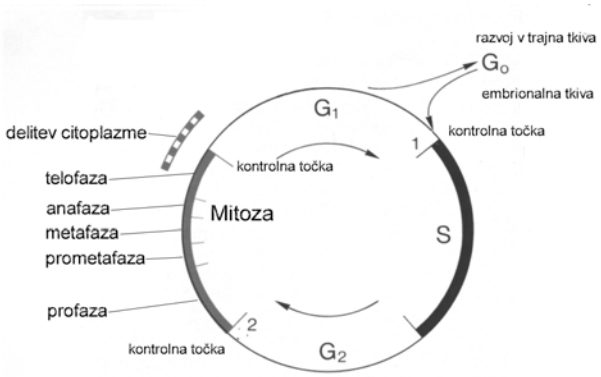


(Slika je predelana po viru: Randy Moore, W. Dennis Clark, Kingsley R. Stern, Darrell Vodopich 1995. Botany. Wm. C. Brown Publishers.)

Slika 4: Tudi v interfazi je DNK molekula z različnimi histoni organizirana v pakete imenovane nukleosomi. Nukleosom je sestavljen iz bazičnih beljakovin ali histonov in ovite DNK.

Fig. 4: Also in interphase the coiled DNA is organized with histon proteins in structures called nucleosomes.

V S obdobju interfaze se dvojna vijačnica DNK razklene in podvaja. V G_2 obdobju pa celice tvorijo beljakovine, ki jih potrebujejo za mitozo.

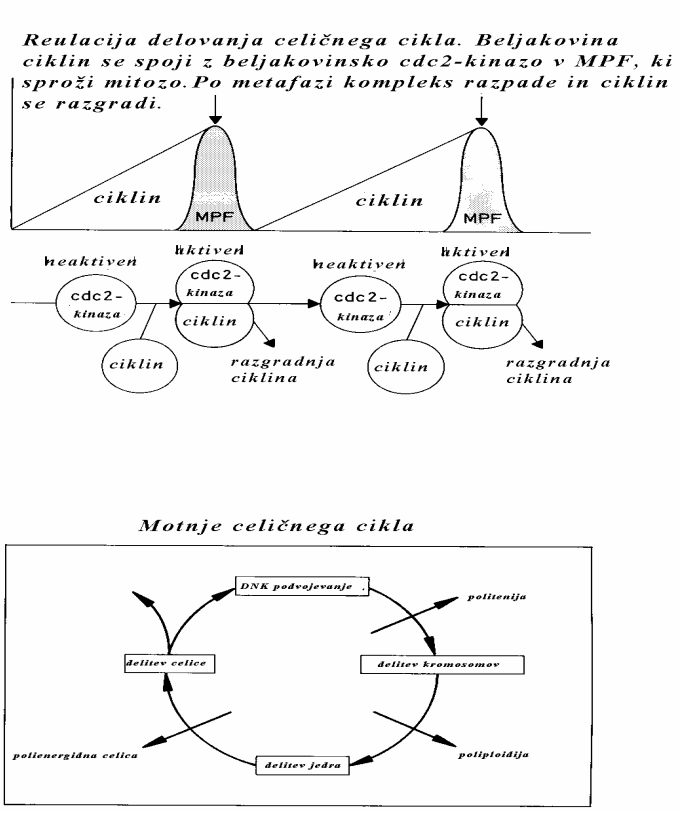


Slika 5: Potek celičnega cikla; menjave mitoze in interfaze in lega kontrolnih točk. Interfaza je razdeljena na tri podobdobja: G_1, S in G_2.

Fig. 5: The cell cycle; the sequence of mitosis and interphase and the position of control points. Interphase is divided in three periods: G_1, S in G_2.

3.1 Regulacija celičnega cikla

Celični cikel je zaporedje dogajanj, ki vključujejo celično delitev in interfazo. Celični cikel vključuje rast celice, podvojevanje DNK in razporejanje podvojenih kromosomov v hčerinski jedri, ki imajo enak genom. Dogajanja v mitozi potekajo podobno pri glivah, rastlinah, živalih in tudi pri človeku. Genetske študije so odkrile nekatere mehanizme kontrole celičnega cikla (Thyson in sod., 2002). Izolirali so mutante pri kvasovkah, kjer se njihove celice bodisi niso normalno delile ali pa so se delile hitreje kot običajno. Mutanti so imeli okvare genov, ki kontrolirajo vstop v S fazo in mitozo. Najvažnejši odkriti gen so poimenovali Cdc2 (Cdc = cell division cycle 2). Kvasovke brez Cdc2 gena niso uspele vstopiti v S fazo in mitozo, vendar so nadaljevale z rastjo v dolžino. Celice, ki so imele bolj aktiven Cdc2 gen kot je normalno so se delile hitreje in tvorile majhne celice (Morgan, 2007). Osnovni mehanizem kontrole celičnega cikla je verjetno enak pri vseh živih organizmih.



Slika 6. Regulacija delovanja celičnega cikla (zgoraj). Kompleks kinaz in ciklina se imenuje mitozni promocijski factor (MPF), ki sproži delitve. Motnje celičega cikla (spodaj).

Fig. 6: Regulation of the cell cycle (top). The complex of kinases and cyclin is called mitosis promoting factor (MPF), which promotes divisions. Disturbances of the cell cycle (bottom)

Pri evkariontskih celicah celični cikel nadzirajo beljakovinske kinaze (Freeman in sod., 2003). Zaradi regulacijske vloge celičnega cikla se imenujejo od ciklina odvisne beljakovinske kinaze (CDKs), ki fosforilirajo izbrane beljakovine. Pri celicah z redno delitvijo je koncentracija kinaze stalna. Druga skupina beljakovin pa spreminja koncentracije v celičnem ciklu in se zato imenuje ciklin.

Koncentracija ciklina se povečuje v interfazi. Ciklin je dobil ime glede na njegovo ciklično tvorbo in degradacijo v celičnem ciklu. Pri večini rastlin je saharoza glavna transportna oblika ogljika in obstajajo mehanizmi za povezavo med nivojem saharoze in kontrolo celičnega cikla. Prisotnost sladkorjev igra pomembno vlogo pri kontroli izražanja ciklina D (CycD) pri navadnem repnjakovcu (*Arabidopsis thaliana*); (Riou-Khamlichi in sod., 2000). Kompleks beljakovinskih kinaz in ciklinov imenujemo MPF (mitozni promocijski faktor). Ta kompleks sproži delitve

(Francis, 2001). Ko se ciklini razgradijo, se MPF inaktivira poteka delitev do konca in se vrši prehod v interfazo.

Pri glivah kvasovkah so doslej odkrili preko 50 genov za regulacijo celičnega cikla (Cdc – geni). Pri glivah kvasovkah je regulacija celičnega cikla precej enostavnejša kot pri sesalcih in višjih rastlinah, zato so raziskave celičnega cikla pri kvasovkah precej razširjene.

3.2 Fiziološki vplivi na mitozo in celični cikel

Od fizioloških vplivov na mitozo rastlin imamo še omejeno znanje. Pri rastlinah potekajo delitve ritmično in kažejo dnevno spreminjanje (koreninski vršički čebule in zoospore pri algah). Pri rastlinah vplivajo na celični cikel številni zunanji in notranji dejavniki - ritem dan noč, pri številnih algah potekajo delitve ponoči. V 24 urah lahko poteče tudi več celičnih ciklov. Kot drugi fiziološki procesi nastopajo delitve pri rastlinah v določenem značilnem temperaturnem območju in imajo svojo optimalno temperaturo. Pri navadnem fižolu potekajo delitve med 0º in 45º C. Temperaturni optimum je med 28-30º C. Pri mladih kalečih rastlinicah potekajo delitve pri nižjih temperaturah kot pri odraslih rastlinah. Vlaga in razpoložljiva hraniva vplivajo na ritem celičnega cikla. Mitoza poteka na podlagi nakopičene energije in ni odvisna od kisika. Na celične delitve in regulacijo celičnega cikla vplivajo tudi rastlinski hormoni predvsem citokinini in avksini pa tudi abcizinska kislina, etilen in jasmonska kislina imajo vpliv na nadaljni potek ali ustavitev celičnega cikla (Ramirez-Parra in sod., 2005). Avksini igrajo pomembno vlogo pri razvoju rastlin, celičnih delitvah in rasti, apikalne dominance, razvoj stranskih korenin in prevajalnega tkiva. Tudi citokinini so pomebni pri rastnih procesih, proženju celičnih delitev, tvorbi in razvoju poganjkov in zaviranju staranja (senescenca).

Tvorba celične stene v telofazi mitoze je pri rastlinskih celicah večkrat povezana z izmenjavo žvepla (aminokislina cistein).

Celični cikel je skrbno nadzorovan. Usklajenost dogajanj, kot so celična rast, podvojevanje DNK in razporejanje podvojenih kromosomov, zagotavlja celično potomstvo in nespremenjen genom. Regulacijska mesta v celičnem ciklu so kontrolne točke. Kontrolne točke so v G1, G2 in M fazi in z njimi se preverja ali so vsi prejšnji dogodki, ki so nujni za nadaljevanje cikla, potekali pravilno. Če celica prekorači kontrolne točke se delitve nadaljujejo, sicer se ustavijo.

3.3 Motnje v celičnem ciklu

Motnje v celičnem ciklu lahko potekajo na več mestih. Podvojevanje DNK vijačnic brez delitve kromosomov vodi do politenije. Podvojevanje kromosomov v celicah brez jedrne delitve privede do poliploidije (Verkest in sod., 2005). Umetno lahko povzročimo poliploidije s citostatiki, ki negativno vplivajo na tvorbo niti delitvenega vretena (De Jager in sod., 2005). Pri večjedrnih (polienergidnih) celicah številnih alg in gliv pride do podvajanja DNK, delitev kromosomov in jeder, vendar nato ne sledi delitev celice ali citokineza.

3.4 Apoptoza (programirana celična smrt)

Večina diferenciranih celic pri rastlinah je v G_0 stanju. Apoptoza je normalen fiziološki življenski proces v celicah. Med apoptozo se kromosomalna DNK razcepi med nukleosomi. Kromatin se zavija in jedro razpade v manjše dele. Končno tudi celica razpade na manjše mešičke ali apoptotska telesa. Telo te dele prepozna in odstrani iz tkiv s fagocitozo sosednjih celic.

4. SKLEPI

Delitev je osnovna značilnost celic in hkrati tudi živih organizmov. Višje rastline imajo razen spolnega načina razmnoževanja tudi nespolen način razmnoževanja, ki temelji na mitozah. Sem prištevamo tudi vse vrste vegetativnega razmnoževanja rastlin, naravnega in umetnega s čebulicami, gomolji, korenikami, koreni, stoloni, koreninskimi, stebelnimi, listnimi podtaknjenci in cepljenjem. K umetnim vegetavnim načinom razmnoževanja prištevamo v novejšem času tudi razmnoževanje z meristemskimi kulturami. K nespolnim načinom razmnoževanja prištevamo tudi razširjanje rastlin s sporami.

Vse telesne celice rastejo se obnavljajo z delitvijo na dve hčerinski celici. Celični cikel obsega dva bistvena dogodka: podvojevanje DNK, vzdolžno delitev kromosomov na dve sestrski kromatidi in razporejanje kromatid v hčerinski celici. Dedni material (molekula DNK) se odvija in zavija in prehaja iz delovne v prenosno obliko. Genom celice lahko v življenju doživi veliko napak in poškodb. Zaradi obsežnih popravljalnih mehanizmov se večina napak in poškodb DNK popravi. Mutacije – napake, ki postanejo stalne in se prenašajo naprej ob celični delitvi so v naravnem okolju sorazmerno redke. Večina teh mutacij je tihih in ne vplivajo na izražanje genov.

Razumevanje delovanja celičnega cikla bo imelo velik praktičen pomen pri povečanju biomase in pridelka pri pomembnih kmetijskih rastlinah. Povečanje števila celic skupaj s povečano rastjo celic bo povečalo rastlinsko biomaso. Pospeševanje hitrosti celičnega cikla bo po iskušnjah skrajšalo življensko dobo kmetijskih rastlin in s tem hitrejšo tvorbo generativnih delov rastlin – semen in plodov (Inze, 2003).

Napake v regulaciji celičnega cikla vodijo v nenormalno delitev in lahko tudi v nastanek rakastih celic, zato je regulacija delovanja celičnega cikla predmet intenzivnih raziskav (Jezernik in Komel, 1998). Geni oz. beljakovine, ki kontrolirajo celični cikel predstavljajo novejši izziv za zdravljenje te bolezni.

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CONTENT ANALYSIS OF THE PAPERS IN THE ACTA AGRICULTURAE SLOVENICA

VSEBINSKA OBDELAVA PRISPEVKOV V ACTA AGRICULTURAE SLOVENICA let. 91 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)

Acta agriculturae Slovenica, 91 - 2, september 2008 str. 483 - 485

Ob 100-letnici rojstva zasl. prof. dr. Franca Janežiča

Pred 100 leti (18. avgusta 1908) se je na Pavlovskem vrhu - Miklavž pri Ormožu - rodil zaslužni profesor dr. Franc Janežič, prvi univerzitetni učitelj, ki je deloval na področju zdravstvenega varstva rastlin v Sloveniji. Po osnovni šoli v domačem kraju, ter klasični gimnaziji v Mariboru, se je po diplomi na Agronomsko gozdarski fakulteti in krajši specializaciji v Zagrebu, vrnil v Slovenijo, kjer je začel pionirsko delo na ožjem področju varstva rastlin, najprej na strokovnem, po doseženem doktoratu iz fitopatološke tematike leta 1947, pa tudi na znanstvenem področju. Dve leti po ustanovitvi Agronomske in gozdarske fakultete (sedaj Biotehniške) v Ljubljani, se je odzval vabilu in začel predavati najprej honorarno, kasneje pa redno vse do upokojitve leta 1978, predmete s področja varstva rastlin. Dolga leta je bil to en predmet, ki se je v začetku imenoval Zaščita kmetijskih rastlin in se kasneje preimenoval v Varstvo rastlin, pridružil pa mu je kasneje še predmet Entomologija. Predmet Gozdna fitopatologija je profesor Janežič predaval od leta 1952 do leta

1974. Z Biotehniško fakulteto, ki mu je leta 1987 podelila naslov zaslužni profesor, je ostal povezan do konca. Umrl je leta 1999 v Ljubljani.

Vseskozi se je zavedal, da je pisana beseda tista, ki za človeka in človekom ostane in prav na ta način se je stalno potrjeval. Precej objav izpod peresa profesorja Janežiča je v Zborniku Biotehniške fakultete (sedaj *Acta agriculturae Slovenica*), kjer je leta 1994 izšel njegov zadnji izvirni članek s področja aplikativne entomologije. Več o življenju in delu je napisano v prispevku, objavljenem v časopisu Research Reports (Milevoj, Maček, 1998).

Obudimo še nekaj spominov na spoštovanega profesorja Janežiča, ki smo mu bili njegovi študentje oziroma sodelavci.

Študentje in študentke, ki so po drugi svetovni vojni študirali agronomijo oziroma gozdarstvo na Biotehniški fakulteti v Ljubljani, se profesorja Janežiča spominjajo kot zahtevnega do sebe in študentov, ki je bil hkrati ugleden in spoštovan ter blag človek. Njegova predavanja so bila zanimiva in dobro obiskana. Posebno skrb je namenjal pisani besedi, študijskim pripomočkom, slikam in zbirki škodljivih organizmov, na katero je bil posebno ponosen. Na vprašanje o nastanku entomološke zbirke, je leta 1992 zadevo pojasnil takole: Zbirka je nastala v letih 1948-1951. Najprej je pripravil profesor Janežič seznam škodljivih metuljev in hroščev in drugih škodljivcev. Na podlagi tega seznama je naredil zbirko metuljev ljubiteljski zbiralec metuljev Rakovec, zbirko hroščev pa Gspan, oba iz Ljubljane. Oba sta predlagano zbirko še dopolnila s svojimi ljubljenci. Tako je nastala zbirka, ki so jo bili vsi veseli, je še povedal profesor. V 90-letih je bila zbirka prenovljena ter tudi občasno dopolnjena z novimi primerki in služi študijskim potrebam in znanstvenim namenom na sedanji Katedri za entomologijo in fitopatologijo, na Oddelku za agronomijo. Posebno skrb je gojil do slovenskega jezika oziroma jezika stroke. Objavil je Indeks rastlinskih bolezni v Sloveniji ter terminološki slovar z njihovimi imeni, s čimer je obogatil tudi slovenski jezik. Njegovi prispevki, znanstveni in strokovni, so napisani razumljivo, kratko in jedrnato. Znanstvena objektivnost in resnicoljubnost je bila njegova odlika. Spominjam se, ko je nekoč dejal: »če nismo o neki zadevi trdno prepričani, tedaj ne smemo napačno niti pomisliti, kaj šele reči ali celo napisati«.

Izpiti so bili pri profesor Janežiču ustni. Da se je treba na izpit dobro pripraviti, je bilo jasno vsakemu študentu in priprava na izpit je trajala tudi nekaj mesecev. Celo dobri študenti so včasih pristopili k izpitu večkrat. Izpiti so bili ustni in so trajali različno dolgo, kar je bilo odvisno tudi od znanja kandidatov. V tistih časih ni bilo možnosti za prehrano na fakulteti. Tako profesorji kakor študenti so bili odvisni od tistega, kar so prinesli s seboj ali pa kupili v bližnji trgovini. Tudi profesor Janežič si je med izpiti vzel čas za malico, ki jo je prinesel s seboj in je trajala kar nekaj časa. Posebno rad je imel v zimskem času jabolka ali pa pomaranče. Bil je visoke, vitke postave in hitre, pokončne hoje. Na delovno mesto se je pripeljal s kolesom, čeprav je imel tudi avto, včasih pa je prišel peš. Po upokojitvi leta 1978, je predaval Entomologijo podiplomskim študentom ter prihajal dokaj redno na fakulteto, kjer je imel svoj kabinet. Material (vzorce obolelih/napadenih rastlin) je sam nabiral, pregledoval, mikroskopiral ali drugače obdeloval. Ko se je bližal 90-letom je nekoč prizadeto potožil: »Z očmi imam težave in težko mikroskopiram«.

Leta 1998 smo v okviru Biotehniške fakultete, Oddelka za agronomijo, takratne Katedre za fitomedicino (sedaj Katedra za entomologijo in fitopatologijo) in Društva za varstvo rastlin Slovenije, praznovali 90-letnico rojstva profesorja Janežiča. Pripravili smo tudi priložnostno razstavo. Profesor Janežič se je prireditve razveselil, vendar se je žal ni mogel udeležiti. Zastopal pa ga je njegov vnuk.

Ponosni smo, da smo lahko gradili ali vsrkavali znanja s področja zdravstvenega varstva rastlin s profesorjem Janežičem, katerega sledi so in bodo ostale trajno zapisane v fitomedicinski stroki.

Sodelavci Katedre za entomologijo in fitopatologijo

Oddelek za agronomijo Biotehniške fakultete

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.

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Acta agriculturae Slovenica

Doslej: Zbornik Biotehniške fakultete Univerze v Ljubljani Kmetijstvo

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Glavni in odgovorni urednik	Prof. dr. Ivan Kreft
Uredniki	Prof. dr. Franc Batič; prof. dr. Lučka Kajfež Bogataj; prof. dr. dr. dr. Jože Maček, dipl. ing. agr., dipl. oec.; prof. dr. Katja Vadnal.
Svetovalni odbor	Doc. dr. Mihaela Černe (Ljubljana), prof. dr. Jürgen Fuhrer (Liebefeld-Bern, Švica), prof. dr. Andrej Hočevar (Ljubljana), akademik prof. dr. James Mac Key (Uppsala, Švedska), dr. Dragica Kralj (Žalec), prof., dr. Julija Smole (Ljubljana), prof. dr. Franc Sunčič (Ljubljana)
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