UNIVERZA V LJUBLJANI
BIOTEHNIŠKA FAKULTETA

Marko DEVETAK

SEZONSKA DINAMIKA DVEH VRST SOVK IZ RODU *Mamestra* (Lepidoptera: Noctuidae) TER POVEZAVE MED OBSEGOM POŠKODB IN VSEBNOSTJO GLUKOZINOLATOV V ZELJU (*Brassica oleracea* var. *capitata* L.)

DOKTORSKA DISERTACIJA

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DOCTORAL DISSERTATION

Ljubljana, 2014

Doktorska disertacija predstavlja zaključek podiplomskega študija bioloških in biotehniških znanosti na znanstvenem področju agronomije. Poljski poskus je potekal na Laboratorijskem polju Biotehniške fakultete v Ljubljani in na Goriškem. Priprava vzorcev zelja za določevanje vsebnosti glukozinolatov je bila opravljena v Laboratoriju za entomologijo na Katedri za fitomedicino, kmetijsko tehniko, poljedelstvo, pašništvo in travništvo Oddelka za agronomijo Biotehniške fakultete Univerze v Ljubljani, vsebnost glukozinolatov pa smo določevali v laboratoriju Oddelka za agrokemijo in pivovarstvo Inštituta za hmeljarstvo in pivovarstvo Slovenije v Žalcu.

Na podlagi Statuta Univerze v Ljubljani ter po sklepu Senata Biotehniške fakultete in sklepa 7. seje Komisije za doktorski študij dne 10. 6. 2010 je bilo potrjeno, da kandidat izpolnjuje pogoje za neposreden prehod na doktorski Podiplomski študij bioloških in biotehniških znanosti ter opravljanje doktorata znanosti iz področja agronomije. Za mentorja je bil imenovan prof. dr. Stanislav Trdan in za somentorja doc. dr. Iztok Jože Košir.

Komisija za oceno in zagovor:

Predsednik: doc. dr. Dragan ŽNIDARČIČ
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Doktorska disertacija je rezultat lastnega raziskovalnega dela. Podpisani se strinjam z objavo svojega dela na spletni strani Digitalne knjižnice. Izjavljam, da je delo, ki sem ga oddal v elektronski obliki, identično tiskani verziji.

Marko DEVETAK

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ŠD Dd
DK UDK 632.78:595.786:635.34:591.5(043.3)
KG sezonska dinamika/sovke/*Mamestra*/*Mamestra brassicae*/*Mamestra oleracea*/glukozinolati/zelje/glukonapin/glukobrasicin/progoitrin/sinalbin/glukoiberin/sinigrin
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KZ SI-1111 Ljubljana, Jamnikarjeva 101
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IN SEZONSKA DINAMIKA DVEH VRST SOVK IZ RODU *Mamestra* (Lepidoptera: Noctuidae) TER POVEZAVE MED OBSEGOM POŠKODB IN VSEBNOSTJO GLUKOZINOLATOV V ZELJU (*Brassica oleracea* var. *capitata* L.)
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OP VI, 57 str., 11 pril., 42 vir.
IJ sl
JI sl/en
AI Med leti 2008 in 2010 smo izvajali poljske poskuse, da bi preučili sezonsko dinamiko kapusove sovke (*Mamestra brassicae* [L.]) in zelenjadne sovke (*Mamestra*/*Lacanobia oleracea* [L.]) v Ljubljani in na Goriškem. Poleg preučevanja sezonske dinamike z uporabo feromonskih vab tipa VARL+ smo v naši raziskavi ugotavljali še obseg poškodb na desetih različnih genotipih zelja, s čimer smo ugotavljali naravno odpornost rastlin petih sort in petih hibridov zelja, ki so glede na dolžino rastne dobe pripadali zgodnjim, srednje zgodnjim in srednje poznim genotipom. Leta 2011 smo v listih omenjenih genotipov zelja določali vsebnost glukozinolatov glukonapina, glukobrasicina, progoitrina, sinalbina, glukoiberina in sinigrina v listih, da bi preučili njihovo povezavo z obsegom poškodb zaradi gosenic omenjenih sovk. Glede na rezultate ulova samcev obeh vrst škodljivcev iz rodu *Mamestra* v feromonske vabe ugotavljamo, da imata oba do dva rodova letno, pri čemer je zelenjadna sovka manjštevilčna od kapusove sovke, na Goriškem pa zastopanosti prve celo nismo potrdili. V poljskem poskusu, ki je potekal v Ljubljani smo še ugotovili, da je bila povprečna dnevna temperatura v obdobju vrha prvega rodu kapusove sovke med 16 in 19 °C (vsota efektivnih temperatur [VET] od 250 do 375 °C). Ob pojavu vrha drugega rodu pa 20 °C (VET med 986 in 1290°C). Ugotavljamo, da gosenice vrst iz rodu *Mamestra* na zelju najmanj poškodb povzročajo do začetka junija, za poškodbe najbolj dovzetni pa so genotipi z dolgo rastno dobo. Kemična analiza vzorcev zelja je potrdila, da se vsebnost glukozinolatov v listih zelja spreminja glede na razvojni stadij rastlin, koncentracija glukozinolatov pa je bila najvišja pri srednje zgodnjih in srednje poznih genotipih. Med vsebnostjo glukobrasicina in obsegom poškodb na srednje poznih genotipih zelja smo ugotovili rahlo korelacijo, zmerno korelacijo pa smo potrdili tudi med obsegom poškodb in vsebnostjo progoitrina. Kljub temu ugotavljamo, da glukozinolati, analizirani v naši raziskavi, nimajo zadovoljivega antiksenotičnega vpliva na gosenice kapusove sovke.

KEY WORDS DOCUMENTATION

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CX	seasonal dynamics/*moths*/*Mamestra*/*Mamestra brassicae*/*Mamestra oleracea*/glucosinolates/cabbage/gluconapin/glucobrassicin/progoitrin/sinalbin/glucoiberin/sinigrin
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PI	SEASONAL DYNAMICS OF TWO PEST SPECIES OF THE GENUS *Mamestra* (Lepidoptera: Noctuidae) AND THE INTERACTIONS BETWEEN THE LEVEL OF INJURIES AND THE GLUCOSINOLATE CONTENT IN CABBAGE (*Brassica oleracea* var. *capitata* L.)
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AB Between 2008 and 2010 we carried out field experiments in order to study the seasonal dynamics of the cabbage moth (*Mamestra brassicae* [L.]) and the bright-line brown-eye moth (*Mamestra*/*Lacanobia oleracea* [L.]) in Ljubljana and in the Nova Gorica region. Besides studying the seasonal dynamics by using pheromone lures of VARL+ type, our research recorded the extent of damage on ten different cabbage genotypes, thus establishing natural resilience of the five cultivars and the five hybrids of cabbage, which in regard to the growth period length belonged to early, mid-early and mid-late genotypes. In 2011 we determined the content of the glucosinolates gluconapin, glucobrassicin, progoitrin, sinalbin, glucoiberin and sinigrin in the leaves of the said cabbage genotypes in order to study their relation to the extent of damage done by the said caterpillars. Judging from the male harmful organisms of the both species of the genus *Mamestra* which were caught by the pheromone traps, the species produce up to two generations per year, yet the bright-line brown-eye is not as numerous as the cabbage moth, and in the Nova Gorica region we did not confirm its presence. In the field trial that was performed in Ljubljana we realised that the average daily temperature in the period of the first generation peak of the cabbage armyworm was between 16 and 19 °C (sum of effective temperatures [SET] from 250 to 375 °C). On the second generation peak the average daily temperature was 20 °C (SET from 986 to 1290°C). We found out that caterpillars of the genus *Mamestra* cause the least damage on cabbage until the beginning of June and that the genotypes with prolonged growth period are most susceptible to damage. The chemical analysis of cabbage samples confirmed that glucosinolates content in leaves changes with plants' developmental stages, while glucosinolates concentration was highest in mid-early and mid-late genotypes. A slight correlation was established between the glucobrassicin content and the extent of damage in the mid-late cabbage genotypes, a moderate correlation was confirmed also between the extent of damage and the progoitrin content. We can nevertheless say that the glucosinolates analysed in our study do not have satisfactory antixenotic effects on the cabbage moth caterpillars.

KAZALO VSEBINE

KAZALO PRILOG

1 UVOD

Zahteve trga po zdravem pridelku in čistem okolju narekujejo smotrno rabo fitofarmacevtskih sredstev in pridelavo hrane s tehnologijami, ki so okolju prijazne. Zaradi tega je danes uveljavljena zlasti integrirana pridelava rastlin, kjer zasedajo pomembno mesto sredstva za varstvo rastlin, ki manj obremenjujejo okolje. Poleg omenjenih sredstev so za uspešno integrirano pridelavo vrtnin potrebni še drugi agrotehnični ukrepi, med katere spada tudi izbor sort z izraženo naravno odpornostjo proti škodljivim organizmom. Zlasti pretirana uporaba sintetičnih insekticidov širokega spektra lahko privede do zmanjšanja številčnosti domorodnih naravnih sovražnikov, kar je lahko vzrok za prerazmnožitev določenih rastlinskih škodljivcev (Rusch in sod., 2010).

Med pogoste škodljivce zelja in ostalih kapusnic, ki se pridelujejo pri nas in v drugih evropskih državah, spadata kapusova sovka (*Mamestra brassicae* [L.]) in zelenjadna sovka (*Mamestra*/*Lacanobia oleracea* [L.]). Škodljivi vrsti uvrščamo v družino sovk (Noctuidae), v red metuljev (Lepidoptera). Za kapusovo sovko je značilno, da je polifagna, saj se poleg kapusnic njene gosenice hranijo tudi z rastlinskimi vrstami iz drugih botaničnih družin. Kapusova sovka sodi med najpomembnejše škodljivce kapusnic in nekaterih metlikovk, čeprav se gosenice prehranjujejo z več kot 70 vrstami rastlin iz 22 različnih družin. Za gosenice je značilno, da na listih zelja povzročajo izjede, hkrati pa glave onesnažijo z iztrebki. Podobno ima tudi zelenjadna sovka širok spekter gostiteljev, najbolj pogosto pa napada predvsem paradižnik in solato. Slednjo uvrščamo med pomembne škodljivce v zavarovanih prostorih (Pollini, 2006).

Uspešno zatiranje škodljivcev ni mogoče brez poznavanja njihove sezonske dinamike. Zato smo med leti 2008 in 2010 z uporabo feromonskih vab opravili načrtno spremljanje populacij kapusove sovke in zelenjadne sovke na dveh območjih v Sloveniji, na Laboratorijskem polju Biotehniške fakultete Univerze v Ljubljani in na dveh lokacijah na Goriškem. Z ugotavljanjem sezonske dinamike obeh vrst sovk smo želeli ugotoviti število rodov, ki jih razvijeta na leto, ter čas pojavljanja odraslih osebkov, saj se omenjene informacije med različnimi državami precej razlikujejo. Tako Johansen in sod. (1996) navajajo, da kapusova sovka na Norveškem razvije le en rod, medtem ko Cartea in sod. (2009a) za Španijo navajajo dva rodova tega škodljivca na leto.

Hkrati smo v poljskem poskusu v Ljubljani ocenjevali poškodbe zaradi hranjenja gosenic na vehah in zunanjih listih desetih genotipov zelja z uporabo standardne lestvice EPPO z indeksi poškodb od 1 do 6. V omenjenih rastlinah - petih sortah in petih hibridih zelja (*Brassica oleracea* var. *capitata* L.) - smo določali tudi sestavo in razmerja med sekundarnimi metaboliti glukozinolati. Določevanje glukozinolatov smo izvedli v letu 2011 z uporabo HPLC z DAD detektorjem na Inštitutu za hmeljarstvo in pivovarstvo Slovenije v Žalcu. Na podlagi rezultatov analize smo ugotavljali pomen glukozinolatov v zelju pri naravni odpornosti preučevanih genotipov na napad gosenic sovk iz rodu *Mamestra*.

Glukozinolati so sekundarni metaboliti, ki so značilni za rastline iz družine križnic (Brassicaceae). Gre za skupino glukozidov, ki vsebujejo žveplove ione in z delovanjem encima mirozinaza razpadejo v različne spojine, kot so izocianati, nitrili, tiocianati, epitionitrili in oksazolidini (Bones in Rossiter, 2006). Vsebnost glukozinolatov se v različnih tkivih razlikuje (Bohinc in sod., 2013), prav tako prihaja do razlik v vsebnosti teh sekundarnih metabolitov med različnimi razvojnimi stadiji rastlin. Na njihovo vsebnost v rastlinah vplivajo tudi podnebni dejavniki in gnojenje (Kushad in sod., 2003; Bohinc in Trdan, 2012). Pomemben vpliv na vsebnost glukozinolatov ima še čas sajenja zelja (Radovich in sod., 2005). Za omenjene spojine je značilen toksičen vpliv na nekatere škodljivce (Rosa in sod., 1996). Poleg tega van Leur in sod. (2008) navajajo vpliv glukozinolatov na ovipozicijo nekaterih škodljivcev, ki so značilni za kapusnice. Podobno tudi Newton in sod. (2009) poročajo o vplivu glikozinolatov in njihovih razgradnih produktov na zaviranje razvoja nekaterih škodljivcev in repelentno delovanje pri njihovi ovipoziciji. Za zelje in ostale kapusnice je še značilno, da koncentracija glukozinolatov v tkivih narašča ob napadu škodljivcev (Ahuja in sod., 2010).

Sestava glukozinolatov je glede na rastlinsko vrsto različna. Kushad in sod. (2003) navajajo, da v brokoliju (*Brassica oleracea* L. var. *italica*) prevladujejo glukorapanin (4-methilsulfinilbutil-glukozinolat), glukonapin (3-butenil-glukosinolat) in glukobrasicin (3-indolilmetil-glukosinolat), medtem ko v zelju (*Brassica oleracea* var. *capitata* L.), cvetači (*Brassica oleracea* var. *botrytis* L.) in ohrovtu (*Brassica oleracea* var. *sabauda* L.) prevladujejo sinigrin, glukobrasicin in progoitrin (2-hidroksibut-3-enil-glukozinolat). Za razliko od brokolija zelje ne vsebuje glukorapanina.

Dejstvo, da imajo določene vrste rastlin različno razmerje v sestavi glukozinolatov, pojasnjuje, zakaj posamezni škodljivci odlagajo jajčeca ali pa se prehranjujejo le z določenimi vrtninami (Müller in Sieling, 2006). Nekatere žuželke zaradi vpliva metabolitov odlagajo jajčeca samo na izbrane vrste rastlin (Li in sod., 2000). Spencer in sod. (1999) navajajo, da samica kapusovega molja odlaga jajčeca na rastlino le, če je zadoščeno določenim pogojem kot je prisotnost sinigrina. V poskusu, kjer so substratu dodajali sinigrin, so samice hitreje odlagale jajčeca.

Kapusova sovka in zelenjadna sovka sta pomembna škodljivca zelja in drugih vrst kapusnic, zato je zatiranje obeh vrst metuljev nujno za pridelavo kakovostnega pridelka. K manjši porabi insekticidov pa pripomore tudi izbira ustreznega genotipa zelja in poznavanje časa pojavljanja škodljivcev. Glukozinolati kot sekundarni metaboliti, ki jih tvorijo kapusnice, pomembno vplivajo na prehranjevanje in ovipozicijo žuželk.

Pred našo raziskavo smo postavili naslednje hipoteze:

- različne koncentracije in razmerja med glukozinolati v zelju vplivajo na različno aktivnost gosenic sovk na rastlinah. Zaradi navedenega pričakujemo razlike v obsegu poškodb med posameznimi genotipi zelja in s tem njihovo različno ustreznost za pridelavo v Sloveniji.

- ker gre za domači sorti predvidevamo, da bo pri 'Kranjsko okroglo' in 'Varaždinsko' manj poškodb na listih kot pri ostalih genotipih.

- zaradi različne dolžine rastne dobe preučevanih genotipov bo obseg poškodb med posameznimi genotipi različen.

- obseg poškodb, ki jih povzročajo gosenice sovk, je odvisen od številčnosti škodljivcev med rastno dobo, ki jo v precejšnji meri določajo vremenske razmere in razvojni stadij rastlin. Pričakujemo razlike v sezonski dinamiki posameznega škodljivca na različnih lokacijah.

- pričakujemo, da bosta oba škodljivca razvila do dva rodova na leto.

Glavni cilj doktorske disertacije je bil preučiti bionomijo kapusove sovke in zelenjadne sovke na dveh območjih in določiti povezavo med obsegom poškodb in vsebnostjo glukozinolatov v desetih genotipih zelja. Na ta način bi lažje opredelili, kateri glukozinolati posamezno ali v kombinaciji ključno vplivajo na naravno odpornost zelja proti gosenicam sovk iz rodu *Mamestra*.

2 ZNANSTVENI ČLANKI

2.1 SEZONSKA DINAMIKA KAPUSOVE SOVKE (*Mamestra brassicae* [L.]) IN ZELENJADNE SOVKE (*Mamestra oleracea* [L.]) V SLOVENIJI

DEVETAK, Marko, BOHINC, Tanja, KAČ Milica in TRDAN, Stanislav
Seasonal dynamics of the cabbage armyworm (*Mamestra brassicae* [L.]) and the bright line brown-eyes moth (*Mamestra oleracea* [L.]) in Slovenia
Horticultural Science (Prague), 2014, 2: 80-88
Prejeto 19.9. 2013; sprejeto 21.3. 2014

Kapusova sovka (*Mamestra brassicaa* [L.]) in zelenjadna sovka (*Mamestra oleracea* [L.]) sta polifagni žuželčji vrsti. V obdobju 2008-2010 smo spremljali sezonsko dinamiko obeh vrst škodljivcev na dveh lokacijah v Sloveniji, v Ljubljani in na Goriškem. S feromonskimi vabami tipa VARL+ smo želeli natančneje določiti pojavljanje odraslih osebkov obeh žuželčjih vrst, zlasti začetek in zaključek pojavljanja populacije ter vrh naleta. Na ta način smo lahko določili povezave med številčnostjo škodljivcev, povprečno dnevno temperaturo in povprečno dnevno množino padavin. Iz rezultatov ulova samcev je razvidno, da se je škodljivec *Mamestra brassicae* na obeh lokacijah pojavljal v dveh rodovih na leto. Sezonska dinamika vrste *Mamestra oleracea* ni tako jasna zaradi majhnega ulova osebkov. Med leti 2008 in 2010 je bila v Ljubljani povprečna dnevna temperatura v obdobju vrha prvega rodu kapusove sovke od 16 do 19 °C (vsota efektivnih temperatur [VET] od 250 do 375 °C), v obdobju vrha drugega rodu pa 20 °C (VET med 986 in 1290°C). Temperaturni prag nad katerim smo računali vsoto povprečnih dnevnih temperatur je bil 10 °C. Med povprečnim številom samcev kapusove sovke v času vrhov obeh rodov in povprečno temperaturo zraka 35 in 70 dni pred pojavom vrhov nismo ugotovili nobene povezave.

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Seasonal dynamics of the cabbage armyworm (*Mamestra brassicae* [L.]) and the bright-line brown-eyes moth (*Mamestra oleracea* [L.]) in Slovenia

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Abstract

Devetak M., Bohinc T., Kač M., Trdan S., 2014. **Seasonal dynamics of the cabbage armyworm (*Mamestra brassicae* [L.]) and the bright-line brown-eyes moth (*Mamestra oleracea* [L.]) in Slovenia**. Hort. Sci. (Prague), *41*: 80–88.

The cabbage armyworm (*Mamestra brassicae* L.) and the bright-line brown-eyes moth (*Mamestra oleracea* L.) are polyphagous insect species. From 2008 to 2010, we monitored the seasonal dynamics of both pests in two locations in Slovenia, Ljubljana and the Nova Gorica region. Pheromone traps (VARL + type) were used to precisely determine the occurrence of adults, i.e., the beginning and end of generations and the peaks of the populations. This allowed us to examine the relationship between the quantity of pests, average daily air temperature and average daily precipitation. Our results established that there were two generations of *Mamestra brassicae* per year in both locations; however, the seasonal dynamics of *Mamestra oleracea* was not as clear due to low trap catch. During 2008–2010 in Ljubljana, the average temperature during the peaks of the first generation of *M. brassicae* ranged from 16–19°C (sum of effective temperatures (SET) from 250°C to 375°C) and 20°C (SET from 986°C to 1,290°C) during the peaks of the second generation. We found no correlation between the average number of cabbage armyworm adults during the peaks of both generations and the mean air temperature 35 and 70 days prior to the peaks.

Keywords: abiotic factors; bionomics; monitoring; noctuids; pheromone traps

Pheromone traps are considered to be one of the most effective methods to monitor and study the seasonal dynamics of adult male insects (Vanparys 1994; Giron-Perez et al. 2009; Cohnstaedt et al. 2012). The selectiveness of sex pheromones is widely known and makes these traps ideal for the determination of the abundance of a single species. They can also be used for mass trapping of pests (Oltean et al. 2009). Pheromone traps were successfully used to determine the first occurrence of adult males and to consequently estimate the timing of damage to plants caused by pests (Lima, McNeil 2009; Devetak et al. 2010; Cruz et al. 2012).

In addition to monitoring the occurrence and quantity of pests, the use of pheromone traps can assist in the determination of the most advanta-

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geous time to apply insecticides. Thus, pheromone traps contribute to an effective and economical pest control program. Nevertheless, the number of adults found in pheromone traps is not a direct indicator of the number of larvae present, which is the life stage that damages cabbage plants (Cartea et al. 2009; 2010). Pheromones can also be used to prevent the mating of insects (Călin et al. 2009).

The cabbage armyworm predominately feeds on cabbage, sugar beet, tobacco, sunflower and grain crops. In addition, it can cause damage to spinach, tomato, potato, mangold, lettuce and pepper. The bright-line brown-eyes moth feeds on tomato, lettuce, cabbage, celery and mangold. In addition, this moth can also feed on soybeans, tobacco, and sugar beet. This pest can be attracted to fruit trees, primarily apple and peach (Pollini 2006).

The owlet moth caterpillars develop well during wet summers, which have been quite frequent during the last decade. Harmful lepidopteran species, appearing in increasing numbers throughout Europe due to favourable climatic conditions, include cabbage armyworms (*Mamestra* spp.) and other pests (Legarrea et al. 2012). In Slovenia, the populations of these species have not been monitored systematically, but the cabbage armyworm and bright-line brown-eyes moth are known to be the most numerous and most frequently observed pests of this group. For the cabbage armyworm, it was established that, in central Europe, it has two generations per year (Čamprag, Jovanić 2005). Some authors claim that this pest can have up to three generations per year (Oku, Kobayashi 1974). In northern Europe, it was reported that the cabbage armyworm is a univoltine species (Johansen 1997; Metspalu et al. 2004). In central Europe, the bright-line brown-eyes moth also has two generations (Čamprag, Jovanić 2005).

During this three-year experiment, we studied the seasonal dynamics of the cabbage armyworm and the bright-line brown-eyes moth adults with a special emphasis on correlating the number of adult specimens of the pests with the average air temperatures and average precipitation in the regions of Ljubljana and Nova Gorica.

MATERIAL AND METHODS

Field monitoring using pheromone traps. The field trial to monitor the seasonal dynamics of cabbage armyworm (*Mamestra brassicae* L.) and bright-line brown-eyes moth (*Mamestra oleracea* L.) males was performed in two locations. These locations were the Laboratory Field of the Biotechnical Faculty in Ljubljana (296.4 m a.s.l., 46°2'58''N, 14°28'28''E) during 2008–2010 and the Nova Gorica region during 2008–2009. In 2008, monitoring was conducted in a field near the town of Miren (50.3 m a.s.l., 45°53'28''N, 13°35'42''E), while in the year 2009 (due to the flood of the river Vipava in Miren), monitoring was performed at two locations. Trapping started near Orehovlje (48.1 m a.s.l., 45°53'18''N, 13°36'51''E), then on May 31, the traps were moved to the previous location near Miren, where they were maintained until September 12, 2009. After the crops were harvested, the traps were moved to a location near Orehovlje, where some cultivars of late cabbage were grown. At the Laboratory Field of the Biotechnical Faculty, the pheromone traps were placed in an area where different vegetable crops were grown from April until November; cabbage and lettuce were the main crops. In the region of Nova Gorica, in addition to cabbage and Savoy cabbage, other vegetables were grown, including lettuce and potato. Near the site of the trial field in Orehovlje, there was a peach orchard and a vineyard. To monitor the seasonal dynamics of the pests as accurately as possible, meteorological data (average daily temperatures and average daily precipitation) were included in the study. The data for the 2008–2010 period were recorded at the meteorological station in Ljubljana-Bežigrad (299 m a.s.l. , 46°04'N, 14°31'E), and those in Bilje at Nova Gorica (55 m a.s.l., 45°54'N, 13°38'E) were taken into consideration.

VARL + Csalomon® (Plant Protection Institute, Budapest, Hungary) pheromone traps were used in this experiment. The traps were fixed on wooden sticks, approximately 1.5 m above the ground, and the distance between traps was approximately 10 m. They were located on the outer borders of the fields planted with cabbage. Traps designed to catch cabbage armyworm males were alternated with those designed to catch bright-line brown-eyes moth (i.e., a trap containing bright-line brown-eyes moth female pheromones). In total, eight pheromone traps were placed on both fields under investigation, four for each insect species. To catch the max. number of specimens, the pheromone dispensers were changed at four to six week intervals as recommended by the manufacturer.

The traps were inspected every seven to thirteen days. Occasionally, the traps had to be replaced due to damage by inclement weather, especially wind. The pheromone dispensers were kept in a refrigerator prior to the use (–17°C).

Data evaluation. The results from monitoring the moths in the selected intervals are shown as the average numbers of males caught per trap per day (± standard error) related to the average temperatures (°C) and average precipitation (mm). The latter two values were divided by 100 to make the graphs more readable. The beginning of the occurrence of both species is shown in relation to the sum of the effective temperatures (SET). The SET was calculated as the average daily temperature minus 10; the hypothetical lower temperature threshold for both pests is considered to be 10°C. The calculation began with January 1 (the days when the average daily temperature was below 10°C were ignored) and ended with the date when the first adult males appeared. In addition to the occurrence of the males of the first generation, the peak and end of the occurrence were also determined. Additionally, we determined the beginning, peak and end of the occurrence of the second generation of males.

The SET was calculated as follows:

$$EFT_{daily} = T_{daily} - 10$$

where:

EFT_{daily} – effective temperature of each day from January 1 of the year of observation until the last day of the experiment (pheromone traps at the location)

T_{daily} – average daily temperature of air

$$SET = \Sigma EFT_{daily}$$

where:

SET – sum of the effective temperatures

ΣEFT_{daily} – sum of the effective daily temperatures

Correlations between the mean number of cabbage armyworm adults per trap during the peaks of both generations and the mean air temperature and mean precipitation in the last 5 and 10 time intervals before both peaks in Ljubljana (in the period 2009–2010) were examined using linear regression analysis ($y = kx + n$) with the Statgraphics Plus For Windows 4.0 (Statistical Graphics Corp., Manugistics, Inc., Warrenton, USA) computer program.

The trap catch of cabbage armyworm and bright-line brown-eyes moth males is presented in association with the SET values, according to the methods of Dochkova (1972), Devetak and Trdan (2011).

RESULTS AND DISCUSSION

Monitoring of cabbage armyworm males in Ljubljana during 2008–2010

The population of cabbage armyworm in the Ljubljana region was monitored from 2008 to 2010. The SET results related to the beginning, peak and end of the distinct generations are presented in Table 1.

In 2008, the number of cabbage armyworm males caught in Ljubljana was extremely low. The first specimen appeared between June 2–9 (0.75 ± 0.60 males/trap/day), which was also the time of the highest peak of the first generation. There were three records of catching adult specimens of cabbage armyworm males during the periods June 16–23 (0.25 ± 0.20 males/trap/day), July 7–14 (0.22 ± 0.21 males/trap/day) and July 14–21 (0.22 ± 0.20). Because of the small number of specimens caught, the potential bivoltinism of the population could not be confirmed. The first speci-

Table 1. Occurrence of cabbage armyworm in Ljubljana in 2008–2010

Year		First generation			Second generation		
		occurrence	peak	end	occurrence	peak	end
2008	date	June 2–9	–	June 16–23	July 7–14	–	July 14–21
	SET (°C)	336.9	–	461	734.6	–	806.7
2009	date	April 16–22	May 26–June 3	June 17–24	July 9–17	August 12–24	September 10–18
	SET (°C)	85	374.6	655.2	807.9	1,289	1,500.3
2010	date	April 28–May 5	May 26–June 7	June 24–July 7	July 7–16	July 26–August 4	September 1–9
	SET (°C)	104.3	298.7	637.5	782.6	986.1	1,312.3

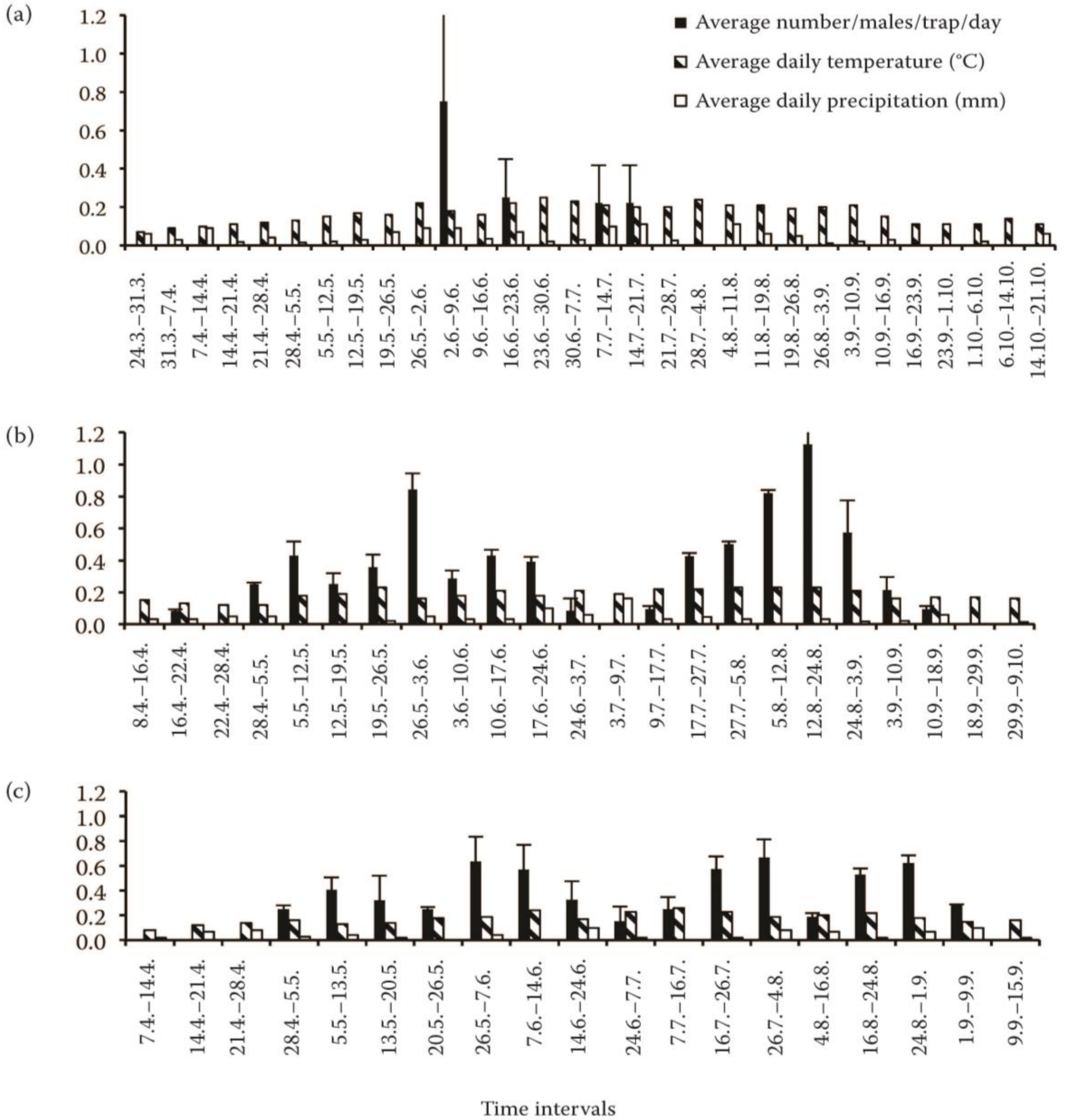

Fig. 1. Seasonal dynamics of cabbage armyworm males in Ljubljana during (a) 2008, (b) 2009 and (c) 2010 values for average daily temperature (°C) and average daily precipitation (mm) were divided by 100 for clarity

men was caught at the average temperature of 18°C (SET = 336.9°C) and the last one at the average temperature of 20°C (SET = 806.7°C) (Table 1). The highest number of males was trapped during the period June 2–9 (0.75 ± 0.60 males/trap/day) (Fig. 1a). The average precipitation in the period from June 7 to 21, when males were detected, was greater than 10 mm.

During 2009, the number of cabbage moth males exceeded that of the previous year. Six cabbage armyworm males were caught in 2008, and 246 were caught in 2009. The data indicated two distinctly separated generations. The highest number trapped in 2009 occurred between August 12 and 24 (1.13 ± 0.03 males/trap/day) (Fig. 1b) at an average temperature of 23°C (SET = 1,289°C) (Table 1). After this pe-

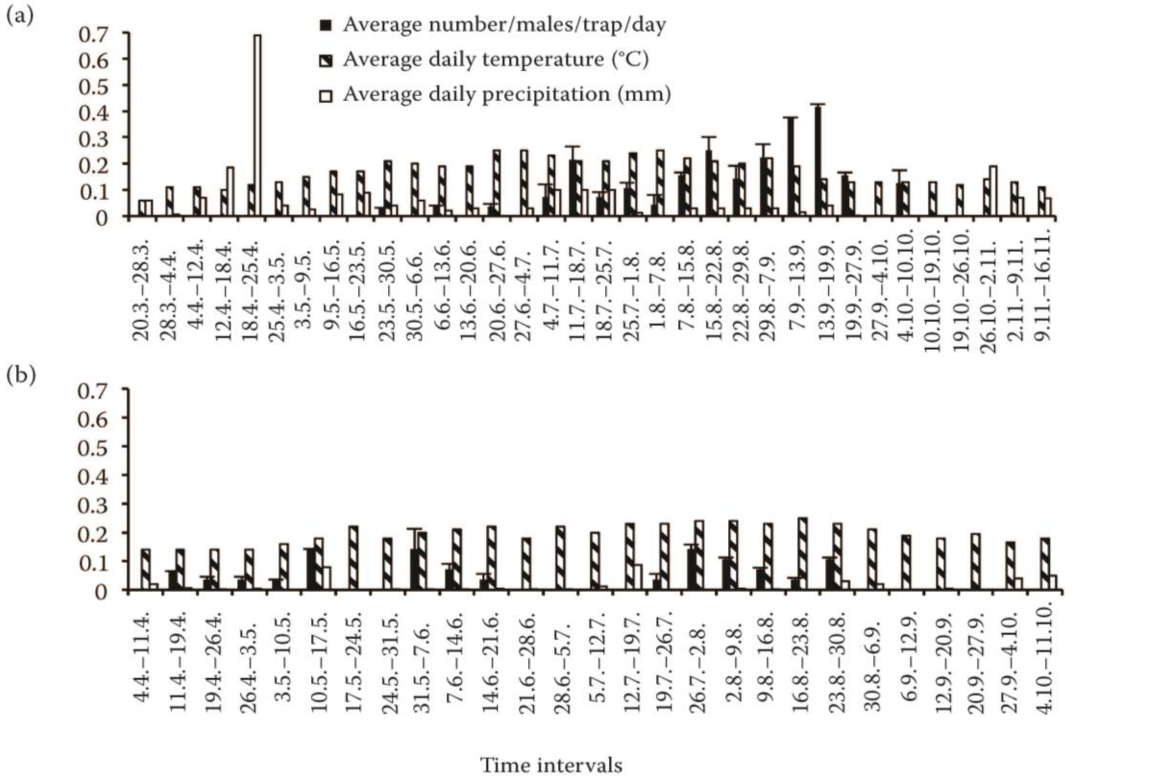

Fig. 2. Seasonal dynamics of cabbage armyworm males in the Nova Gorica region during (a) 2008 and (b) 2009 values for average daily temperature (°C) and average daily precipitation (mm) were divided by 100 for clarity

riod, the number of the specimens caught was lower. The average temperature at the occurrence of the first male moth was considerably lower compared with 2008 (year 2008: 18°C; year 2009: 13°C) (Fig. 1a,b). Additionally, the specimens appeared earlier in the second year of monitoring, with the first catch being recorded at the end of April. The peak of the first generation was determined to be between May 26 and June 3 (0.84 ± 0.01 males/trap/day) at an average temperature of 16°C (SET = 374.6°C). In the period that followed, the number of specimens decreased, and the first generation ended on June 17 (0.39 ± 0.03 males/trap/day) (Fig. 2) at an average temperature of 18°C (SET = 655.2°C) (Table 1). During the period of flying of the first and second generations of males, precipitation was scarce, with the largest amount (16 mm daily) being recorded between the flying periods (June 3 to 9).

In 2010, two population peaks were confirmed in the third year of studying the seasonal dynamics of the pest (Fig. 1c). These two peaks strongly confirmed the bivoltinism of the cabbage armyworm in the Ljubljana region. The first generation began between April 28 and May 5 (0.25 ± 0.03 males/trap/day) (Fig. 1c) at an average temperature of 16°C (SET = 104.3°C) (Table 1). The max. number (the peak of the generation) (0.64 ± 0.02 males/trap/day) was recorded at the average temperature of 19°C (SET = 298.7°C). The end of the occurrence of the first and the beginning of the second generation were influenced by abundant precipitation (more than 10 mm daily for the period between June 14–24) (Fig. 1c). The second generation showed two maxima for the numbers of the adult cabbage armyworm males. The absolute maximum was the first peak between July 26 and August 4 (0.67 ± 0.15 males/trap/day), while the second increase was recorded between August 24 and September 1 (0.63 ± 0.06 males/trap/day). The last specimens were caught in the period September 1–9 (0.28 ± 0.01 males/trap/day) with the average temperature of 15°C (SET = 1,312.3°C). Again, the end of flying was influenced by precipitation (average of more than 10 mm daily for this period).

Monitoring of bright-line brown-eyes moth males in Ljubljana during 2008–2010

During 2008, only two specimens were trapped: the first in the period May 26 to June 2 and the second between August 4–11. More bright-line brown-eyes moth males were trapped in 2009 compared with 2008. The first specimen was caught on the pheromone trap in the period between April 28 and May 5. The second generation began between July 27 and August 5 (0.03 ± 0.01 males/trap/day). The last male moths, the peak of the second generation, were caught during the period August 5–12 (0.04 ± 0.005 males/trap/day).

During the last year of the field trial (2010), the first generation appeared at the end of May (0.13 ± 0.02 males/trap/day) and the second generation in the second half of July (0.03 ± 0.01 males/trap/day). Similar to 2009, the specimens of the second generation were caught until September 9. During the period of the second generation, the max. catch of the pest occurred in the period from August 16–24 (0.16 ± 0.09 males/trap/day). The abundant precipitation during this summer postponed the occurrence of the second generation; the end of flying of this generation also had an influence on the interruption of their flying period.

Monitoring of cabbage armyworm and the bright-line brown-eyes moth in the Nova Gorica region

In the Nova Gorica region, no adult bright-line brown-eyes moth specimens were recorded in the 2008 and 2009 periods. The results for the cabbage armyworm monitoring (SET for the occurrence, peak and ending of the generations) are given in Table 2.

In 2008, the results of males caught in the Nova Gorica region were significantly different from those obtained in the Ljubljana region (on the trial field of the Biotechnical Faculty). The first specimens appeared in the period between May 23–30, their number increased with the increase in average daily temperatures. The peak of the population occurred between July 11 and 18 at an average temperature of 21°C (SET = 1,033°C). The peak of the second generation was observed during the period September 13–19 (the average temperature was 14°C) (SET = 1,564.8°C). After the period October 4–10 (0.13 ± 0.02 males/trap/day), no male moths were found in the pheromone traps (Fig. 2a).

The precipitation was less abundant during the period of the occurrence of the second generation (no period had more than 5 mm average daily rainfall) compared with the occurrence of the first generation; the rain had no influence on the time when the flying of the males ended.

In 2009, due to the flooded field in Miren, the trial was carried out in two locations: the first and third part near Orehovlje, and the second part near Miren. Compared with the previous year (2008), the specimens appeared earlier. The beginning of the first generation was observed in the period from April 11–19 (0.06 ± 0.00 males/trap/day) at an average temperature of 14°C (SET = 86.6°C). The peak of the first generation occurred at an average temperature of 18°C (SET = 249.1°C) in the period from May 10–17 (0.14 ± 0.00 males/trap/day). At the end of May, the crop of the early cabbage hybrid varieties in Orehovlje was collected; therefore, the traps were moved to the location near Miren where the seasonal dynamics of the pest were studied in 2008. In 2009, the first generation ended between June 14–21 (0.04 ± 0.02 males/trap/day) with an average temperature of 22°C. The first males of the second generation were detected between July 19–26 (0.04 ± 0.02 males/trap/day) at the average temperature of 23°C (SET = 1,031.7°C). The peak of the second generation was recorded during the next period (from July 26 until August 2) (0.14 ± 0.01 males/

Table 2. Occurrence of cabbage armyworm in the Nova Gorica region (Miren and Orehovlje) in 2008–2009

Year		First generation			Second generation		
		occurrence	peak	end	occurrence	peak	end
2008	date	May 23–30	July 11–18	July 25–August 1	August 1–7	September 13–19	October 4–10
	SET (°C)	285.4	856.5	1,033	1,126.3	1,564.8	1,633.9
2009	date	April 11–19	May 10–17	June 14–21	July 19–26	July 26–August 2	August 23–30
	SET (°C)	86.6	249.1	628.6	1,031.7	1,136.4	1,526.4

Table 3. Regression equations, Pearson's coefficients (r) and significance levels (P) for the correlation of the mean number of cabbage armyworm adults per trap during the peaks of both generations in Ljubljana during the period 2009–2010

Intervals before adult peaks (days)	Regression equation (Y)	Mean temperature		Mean precipitation	
		r	P	r	P
5	$Y = -26.79 + 1.55x$ (temperature) $Y = 7.24 - 1.16x$ (precipitation)	0.5996	0.4003	−0.24	0.7591
10	$Y = -32.17 \pm 1.89x$ (temperature) $Y = 9.42 - 0.98x$ (precipitation)	0.6013	0.2131	−0.15	0.1265

mean air temperature and mean precipitation in the last 5 and 10 time intervals prior to both peaks

trap/day) with an average temperature of 25°C. After that date, the number of the male moths caught declined until the end of August when the last specimens were detected in the traps (Fig. 2b). After the collection of the cabbage crops in Miren in the beginning of September, the traps were moved to Orehovlje (on September 12) where some late cultivars of cabbage were grown, but no males of cabbage armyworm were caught at this location. The intense precipitation (14 mm/day) in the period July 5–12 may have influenced the later occurrence of the first males of the second generation; both peaks were recorded in periods with little rain.

We attempted to identify the relationships between the mean number of cabbage armyworm adults during the peaks of both generations, the mean air temperature and mean precipitation in the last 5 of the 7-day time intervals before both peaks in Ljubljana in the period 2009–2010; however, we did not confirm the significance of the correlations either between the number of adults and temperature (P = 0.4003) nor between the number of adults and precipitation (P = 0.7591). The same statistically confirmed result was found for the relationships in the last 10 of the 7-day intervals: the levels of the correlations between the adults and temperature were 0.2131 and between the adults and precipitation it was 0.1265 (Table 3). Correlations were not calculated for the bright-line brown-eyes moth because their numbers were very low in both years and at both locations.

In the field experiments, which were conducted from 2008 to 2010 in the regions of Ljubljana and Nova Gorica, the seasonal dynamics of cabbage armyworm and bright-line brown-eyes moth were studied. In the region of Ljubljana, the pheromone traps were placed at the same location during the entire experiment, while in the region of Nova Gorica, they were temporarily moved from the field near Miren to a field near Orehovlje at the beginning of 2009 due to the flooding of the Vipava river. The average daily temperatures and the quantities of rainfall influenced the seasonal dynamics of both pests. Temperature was identified as an important factor for the development of other Noctuidae species. Dochkova (1975) and Mironidis and Savopoulou-Soultani (2012) report that the temperature threshold for eggs of the bright-line brown-eyes moth is 9.7°C and the sum of effective daily temperatures (SET) is 65°C, for larvae 12.2°C (SET = 358.5°C) and for pupae 11.4°C (SET = 287.8°C). For the cabbage armyworm, Kwon et al. (2005) reported the following values: for eggs, 7.9°C (SET = 69.4°C); for larvae, 4.8°C (SET = 434.8°C); and for pupae, 6.7°C (SET = 344.8°C). For the cabbage armyworm in particular, the number of specimens caught in the pheromone traps was significantly lower in the periods with considerable rainfall. The influence of precipitation on the seasonal dynamics was also studied by Vajgand et al. (2008).

For cabbage armyworm, two generations per year were determined for both locations, which is consistent with the results of other studies on the seasonal dynamics of this pest in the region of central Europe (Čamprag, Jovanić 2005). The same conclusion was drawn in Spain (Cartea et al. 2009). In contrast, in Norway, Johansen (1996) reports only one generation per year. The correlation between the number of generations and temperature was also observed by Oku and Kobayashi (1974), who showed that this pest can have up to three generations in Japan. Three generations per year were also found by Setokuchi and Tanaka (1980). Our study did not observe a correlation between the number of males caught and temperatures.

Monitoring of the bright-line brown-eyes moth confirmed that it is found in lower numbers compared with the cabbage armyworm. The same result was obtained by Cartea et al. (2009), who observed that cabbage armyworm constitutes approximately 48.5% of insects of the order Lepidoptera caught in field experiments in Spain.

In the region of Nova Gorica, not a single specimen of the bright-line brown-eyes moth was trapped in the pheromone traps during the two-year period.

The first specimen of adult males of cabbage armyworm appeared in Ljubljana at the end of April (from April 16–22 in 2009 and from April 28–May 5 in 2010). In 2009, the adult males of this pest were less numerous compared with 2010. In 2008, in the Nova Gorica region, the first specimens of cabbage armyworm were observed later (May 23–30, SET = 285.4°C) compared with the Ljubljana region. In 2009, the first generation appeared nearly a month earlier (April 11–19, SET = 86.6°C). Additionally, in 2008, the adults of the second generation appeared later, with the peak occurring between September 13 and 19, while the peak of the second generation in 2009 was observed between July 26 and August 2. Saninno and Espinosa (1999) reported that in the South of Italy, the population of this pest exhibited two peaks (in May and in September). In 2008, our field trial lasted until October at SET = 1,633.9°C, which was the highest SET value during the three-year period for both locations. In 2008 and in 2009, the second generation in the Nova Gorica region appeared at the end of July or in the beginning of August, which is consistent with the data of Vanparys (1994) for Belgium.

Our study demonstrates that, compared with the bright-line brown-eyes moth, the cabbage armyworm is a much more abundant insect pest in Slovenia and that both moth species develop two generations.

There was no correlation detected between the mean number of cabbage armyworm adults during the peaks of both generations and the mean air temperature 35 and 70 days before both peaks or between the mean number of cabbage armyworm adults during the peaks of both generations and the mean precipitation 35 and 70 days before both peaks.

In years of high occurrence, the peak of the first generation of cabbage armyworm occurs between the SET of 250°C to 375°C, while the peak of the second generation occurs between the SET of 986°C to 1,290°C.

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2.2 NARAVNA ODPORNOST DESETIH GENOTIPOV ZELJA NA NAPAD KAPUSOVE SOVKE (*Mamestra brassicae* [L.]) V POLJSKIH RAZMERAH

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Natural resistance of ten cabbage genotypes to cabbage moth (*Mamestra brassicae* [L.]) attack under field conditions
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V poljskem poskusu v obdobju 2010-2011 smo v Ljubljani na petih sortah in petih hibridih zelja preučevali obseg poškodb gosenic prvega rodu kapusove sovke (*Mamestra brassicae* [L.]) na listih (izjede) in glavah (izvrtine) ter pridelek preučevanih genotipov, z namenom, da bi določili genotip(e), ki izkazujejo največjo naravno odpornost na škodljivca in so zato najustreznejši za uporabo v okoljsko sprejemljivih sistemih pridelave te vrtnine. V vsakem od štirih blokov je bila polovica rastlin v obeh letih poskusa (7 krat v letu 2010 in 5 krat v letu 2011) tretirana z insekticidnimi pripravki, medtem ko se ostalo polovico rastlin ni škropilo. Pri ocenjevanju poškodb na listih zelja v istih terminih med tremi zgodnjimi (dolžina rastne dobe od 55 do 70 dni), tremi srednje zgodnjimi (80-90 dni) in tremi srednje poznimi (110-140 dni) genotipi nismo ugotovili večjih razlik, večjo povprečno poškodovanost listov sort (upoštevajoč vse termine ocenjevanja poškodb) pa pripisujemo njihovi daljši rastni dobi, s čimer so bile dlje izpostavljene večjim in škodljivejšim gosenicam prvega rodu. Glave z insekticidi tretiranih rastlin so bile od gosenic v obeh letih precej manj poškodovane kot glave netretiranih rastlin, največ lukenj v glavah pa smo ugotovili pri zgodnjih in srednje zgodnjih genotipih. Z uporabo insekticidov smo uspeli število lukenj v prvem letu zmanjšati pod še sprejemljivo eno luknjo na glavo, v drugem letu pa pri večini na manj kot dve luknji. Majhna poškodovanost glav srednje poznih genotipov je bila posledica formiranja glav v obdobju, ko se na lokaciji raziskave še niso pojavljale gosenice drugega rodu. Glave z insekticidi tretiranih rastlin zelja so bile v večini primerov težje od netretiranih rastlin, največji izpad pridelka (30-40 %) pa smo v obeh letih ugotovili na dveh genotipih, katerih glave niso bile močno napadene od preučevanih gosenic, zato pa sta imela močneje poškodovane liste. V prispevku predstavljeni rezultati so lahko verodostojen temelj za prihodnje raziskave dejavnikov odpornosti zelja na napad gosenic kapusove sovke, ki so v vlažnih letih vse pomembnejši biotični dejavnik oteževanja pridelave zelja.

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Natural resistance of ten cabbage genotypes to cabbage moth (*Mamestra brassicae* [L.]) attack under field conditions

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Abstract

The field test in the period 2010 - 2011 in Ljubljana (Slovenia) studied the extent of injuries in five cabbage cultivars and five hybrids which were caused by the first-generation caterpillars of the cabbage moth (*Mamestra brassicae*) on leaves (feeding tracks) and on heads (mining holes), as well as the yield of the studied genotypes, in order to determine genotype(s) which display the greatest natural resilience to the harmful pest and are for this reason most appropriate for use in environmentally acceptable systems of this vegetable production. In each of the four blocks, one-half of the plants was in both years intensively (7 times in 2010 and 5 times in 2011) treated with insecticides, while the other half of the plants was not sprayed. When assessing the injuries on the cabbage leaves at the same intervals among the three early (the growth period between 55 and 70 days), the three mid-early (80 - 90 days) and the three mid-late (110 - 140 days) genotypes, we detected no major differences, while higher average injuries on the cultivars' leaves (when all assessments were considered) was attributed to their longer growth period - the plants were exposed to larger and more damaging first-generation caterpillars for a longer period of time. The heads of the plants treated with insecticides were considerably less damaged by the caterpillars in both years than the heads of the plants which had been not been treated, while the highest number of holes in the heads were detected in the early and mid-early genotypes. By applying insecticides, we in the first year managed to reduce the number of holes below the acceptable, which is one hole per head, while in the second year, it was reduced to less than two holes per head in the majority of the plants. The little injuries in the heads of the mid-late genotypes were the result of the way the heads were forming during the period, when the second-generation caterpillars had not yet appeared at the research location. The heads of the cabbage plants treated with insecticides were in most cases heavier than the untreated plants, while the most extensive crop failure (30 - 40%) was in both years observed in two genotypes whose heads were not heavily attacked by the studied caterpillars, yet their leaves were more injured. The results presented in this paper can present a reliable foundation for future research into the factors affecting the plant's resilience to attacks of the cabbage moth caterpillars, which are in precipitous years an increasingly significant biotic factor hindering cabbage production.

Key words: Cabbage moth, *Mamestra brassicae*, injuries, yield loss, cabbage, genotypes, varieties, hybrids, insecticides, natural resistance.

Introduction

The production of Brassicas is an important agricultural branch in Europe. Due to favourable climatic conditions, the production of Brassicas on the Old Continent is jeopardised by many harmful organisms. The more important among them are several species of harmful insects, for example cabbage flea beetles (*Phyllotreta* spp.) and cabbage stink bugs (*Eurydema* spp.) [1], onion thrips (*Thrips tabaci* Lindeman) [25], Swede midge (*Contarinia nasturtii* [Keiffer]), diamondback moth (*Plutella xyllostella* [L.]) [14, 26], large white (*Pieris brassicae)* [L.] [5], cabbage fly (*Delia radicum)* [L.] [15], as well as some other species. Cabbage moth (*Mamestra brassicae* [L.] [7] has in Europe recently, as a harmful pest, caused some concerns; it is a typical polyphagous insect; it can complete its developmental cycle on more than 70 plant species from 22 families, among which it favours Brassicaceae and Chenopodiaceae [17]. In the middle and southern Europe, this harmful pest comprises from two to three genera. The first-generation caterpillars damage leaves and heads of early and mid-early genotypes of cabbage, while the second-generation caterpillars drill cabbage heads of late genotypes. They can thus render them unsuitable for marketing [9]. They also intensively feed on leaves of the sugar beet and some other plant species [21].

Since the number of synthetic insecticides for suppressing harmful pests on cabbage and other cultivated and self-seeding plant species is dramatically decreasing, the need to find alternative methods of plant protection comes to the fore [4, 12, 22]. Besides using trap crops and other non-crop plants to reduce injuries caused by harmful insects on cabbage [1, 3, 8, 24], and biotic protection of cabbage [29], there is also the possibility of using natural resilience of plants to attacks of harmful insects, which often considerably vary in different genotypes within the same plant species [2, 5, 6]. The natural resilience of cabbage to attack harmful pests has been already studied for the onion thrips, and the genotypes with a larger content of epicuticular wax were less susceptible to attacks by this harmful insect [23]. Similarly, susceptibility to attacks by the cabbage moth has been confirmed to vary in different genotypes of kale (*Brassica oleracea* var. *acephala*) [5, 6, 16, 19] and cabbage [7], but since cabbage is in Europe one of the economically most important vegetables, whose pool of genotypes is also due to production in different environments, exceptionally broad, the research into the genotypic resilience should be continued. The use of more resilient cultivars and hybrids reduces the application of insecticides, consequently a more economical and environmentally acceptable production.

The aim of our research was to study the natural resilience of ten cabbage genotypes to attacks by cabbage moth caterpillars in order to identify those which are the least susceptible to attacks by this harmful pest. Such genotypes can be included into environmentally acceptable systems of cabbage production.

Materials and Methods

Study site and material: The field experiment was carried out in 2010 and 2011 at the Laboratory Field of the Biotechnical Faculty in Ljubljana (altitude 296.4 m, 46° 2' 58" N, 14° 28' 28" E). The transplants were grown in a greenhouse in plant trays with commercial compost and fed and irrigated according to the standard practices [25]. The cabbage seedlings were planted on April 25th 2010 and May 4th 2011 in 4 blocks; one half of the seedlings in the block was sprayed with insecticides, while the other half of seedlings was not treated. Both the treated and the untreated seedlings belonged to the 10 genotypes, and each genotype represented a separate treatment in the test. The seedlings were planted in a grid of 0.40 m × 0.30 m; each block consisted of two beds (breadth 1 m, length 25 m); the seedlings in one bed were sprayed, while the seedlings on the other were not. The experiment included the following genotypes, namely 5 hybrids and 5 cultivars: 'Pandion F1' (the growth period from 55 to 70 days) (the supplier: Seminis, Ltd., Holland), 'Early Erfurt' (form 55 to 70 days) (the supplier: Semenarna Ljubljana, Ltd., Ljubljana), 'Cheers F1' (from 80 to 90 days) (the supplier: Takii Seed, Ltd.), 'Holland Late' (from 110 to 140 days) (the supplier: Semenarna Ljubljana, Ltd., Ljubljana), 'Candisa F1' (from 55 to 70 days) (the supplier: Takii Seed, Ltd.), 'Grandslam F1' (from 80 to 90 days) (the supplier: Semenarna Ljubljana, Ltd., Ljubljana), 'Varaždin cabbage' (from 110 to 140 days) (the supplier: Semenarna Ljubljana, Ltd., Ljubljana), 'Hinova F1' (from 110 to 140 days) (the supplier:), 'Kranjsko okroglo' (from 110 to 140 days) (the supplier: Semenarna Ljubljana, Ltd., Ljubljana) and 'Futog' (the supplier: Semenarna Ljubljana, Ltd., Ljubljana) (from 80 to 90 days). The genotypes with the shortest growth period are early; those with medium growth period are mid-early, while genotypes with the longest growth period are mid-late. Beds were covered with black polyethylene. Under the polyethylene, two parallel taps (T-tape system) were placed for drip irrigation.

The plants which were treated with insecticides were on May 4th 2010 treated with the preparation Karate Zeon 5 CS (5% lambda-cyhalothrin; the producer: Syngenta Crop Protection AG, Basel; the supplier: Syngenta Agro d.o.o.) in the dosage 0.2 l/ha. On May 18th the preparation Decis 2.5 EC (2.5% deltametrin; producer and supplier: Bayer CS; Bayer CropScience) followed in the dosage 0.5 l/ha. On May 25th the cabbage was treated also with the preparation Confidor SL 200 in the dosage 0.75 l/ha (20% imidacloprid; the producer: Bayer CS; Bayer CropScience). On June 7th the caterpillars were suppressed by the insecticidal preparationom Actara 25 WG (25% thiamethoxam; the producer: Syngenta Crop Protection AG, Basel; the supplier: Syngenta Agro d.o.o.) in the dosage 200 g/ha. The spraying with the same preparations was repeated also in July in the following order: Karate Zeon 5 CS (Jul 1st), Actara 25 WG (Jul 9th) and Decis 2.5 EC (Jul 15th).

The same preparations were used also in the second year of the field test, though the treatments began in June. The first preparation, which was used on June 3rd, was Karate Zeon 5 CS. On June 16th it was followed by Confidor SL 200. At the end of June (28. 6.) cabbage moth were suppressed by 2.5 EC in the dosage 0.5 l/ha. The suppression with the same agent was repeated on July 12th, while on July 27th 2011, we applied Actara 25 WG in the dosage 200 g/ha.

Field observations and evaluations: Injuries by cabbage moth caterpillars (*Mamestra brassicae* [L.]) on cabbage leaves were in 2010 and 2011 assessed with a 6-grade scale, which represented a slightly modified EPPO scale for assessing the extent of injuries (feeding tracks) by cabbage flea beetles on Brassicas [19]. The value 1 meant an undamaged leaf, as follows (2) up to 1% damaged leaf surface, (3) between 2 and 10%, (4) between 11 to 25%, (5) between 26 and 50% of injured leaf surface, and 6 meant more than 50% injured leaf surface. Besides indices of injuries on leaves were also determined, in all genotypes, the mass of heads and the numbers of holes which were caused by cabbage moth caterpillars in cabbage heads (± SE). The data on the heads' mass and the number of holes were in both years obtained on bringing the harvest home. Storing of produce was carried out in technological ripeness of individual genotypes, while the survey of injuries on leaves was performed in weekly and three-week intervals.

In 2010 the injuries done by caterpillars on leaves were assessed in 6 different intervals, always until the harvest of the studied genotypes was brought home. The injuries on 'Pandion F1' and 'Candisa F1' were assessed three times (14. 5., 4. 6., 17. 6.), on 'Cheers F1', 'Grandslam F1', 'Early Erfurt' five times (14. 5., 4. 6., 17. 6., 7. 7., 22. 7.), on 'Futog', 'Hinova F1', 'Holland Late', 'Kranjsko okroglo', 'Varaždin cabbage' six times (14. 5., 4. 6., 17. 6., 7. 7., 22. 7., 5. 8). In 2011 injuries were assessed at 9 different intervals. The injuries on 'Pandion F1' and 'Candisa F1' were assessed seven times (23. 5., 31. 5., 6. 6., 15. 6., 27. 6., 5. 7., 15. 7.), while the injuries on 'Cheers F1', 'Futog', 'Grandslam F1', 'Hinova F1', 'Holland Late', 'Kranjsko okroglo', 'Early Erfurt', 'Varaždin cabbage' were assessed nine times (23. 5., 31. 5., 6. 6., 15. 6., 15. 7., 27. 7. and 10. 8. 2011).

Before each assessment of injuries we determined ste growth stages of the studied genotypes. The growth stages of the cabbage were identified using the BBCH scale for leafy vegetables that form heads [10, 13] (Tables 1 and 2).

Table 1. Growth stages of individual cabbage genotypes on the assessment dates for 2010.

Cultivar	The assessment date in 2010					
	14. 5.	4.6.	17.6.	7. 7.	22. 7.	5. 8.
'Candisa F1'	18-19	41-45	47-49	-	-	-
'Cheers F1'	17-18	19	19	44-45	46-48	-
'Futog'	16-18	19	19	43-44	47	47-49
'Grandslam F1'	18-19	19-45	19-45	44-46	48	-
'Hinova F1'	18-19	19	19	42-43	45	47-48
'Holland Late'	17-18	19	19	41-42	42-43	47-48
'Kranjsko okroglo'	12-15	19	19	41-42	46	46-47
'Pandion F1'	16-19	43-45	45-49	-	-	-
'Early Erfurt'	16-19	19	19	43-45	47	-
'Varaždin cabbage'	12-15	19	19	41-42	46	46-47

The statistical analysis of the data: The differences in injuries due to feeding of the larvae on the leaves and in the heads of cabbage as well as the differences in the mass of the cabbage heads were analysed using a general ANOVA. Related to analysis, each variable was tested for homogeneity of the variance (Bartlett's test), and the data found to be non-homogenous were

Table 2. Growth stages of individual cabbage genotypes on the assessment dates for 2011.

Cultivar	The assessment date in 2011								
	23. 5.	31. 5.	6. 6.	15. 6.	27. 6.	5. 7.	15. 7.	27. 7.	10. 8.
'Candisa F1'	15-19	17-41	17-41	17-41	19-42	19-46	19-46	-	-
'Cheers F1'	16-19	17-19	17-41	17-41	17-42	18-42	18-42	41-46	44-46
'Futog'	14-18	18-19	18-41	18-41	18-41	18-43	18-44	42-46	42-49
'Grandslam F1'	15-17	17-19	17-41	17-41	17-42	17-42	18-42	41-45	-
'Hinova F1'	15-18	17-19	17-19	17-19	17-19	17-41	17-41	18-44	18-47
'Holland Late'	15-18	16-18	16-18	16-18	16-41	16-41	16-41	16-45	16-45
'Kranjsko okroglo'	13-17	17-19	17-19	17-19	17-19	17-41	17-44	18-44	18-46
'Pandion F1'	18-41	41	41-42	41-42	41-46	41-47	45-48	-	-
'Early Erfurt'	15-18	16-19	17-19	17-19	17-42	17-42	17-42	18-44	42-45
'Varaždin cabbage'	12-17	17-19	17-19	17-19	17-19	17-41	17-44	41-49	41-49

transformed to log (Y) prior to the ANOVA. Kruskal-Wallis tests were also used to analyse the impact of different variables on injuries extent. The differences between the average values were identified using the Student-Newman-Keuls multiple range test. All the statistical analyses were calculated using Statgraphics Centurion XVI [20]. The data are presented as untranformed means ± SE.

Results and Discussion

The general statistical analysis established that in 2010 the extent of injuries caused by cabbage moth caterpillars on cabbage leaves was significantly affected by the date of assessment (ANOVA, F = 51.32; Df = 5; P < 0.05; Kruskal-Wallis test, H = 264.33; Df = 5; P < 0.05), the growth stage of the plants (ANOVA, F = 14.41; Df = 15; P < 0.05; Kruskal-Wallis test, H = 219.32; Df = 15; P < 0.05) and the manner of suppression (ANOVA, F = 49.83, Df = 1; P < 0.05; Kruskal-Wallis test, H = 50.91; Df = 1; P < 0.05), while the cabbage genotype did not significantly affect the extent of injuries on leaves (ANOVA, F = 0.64; Df = 9; P = 0.7605; Kruskal-Wallis test, H = 6.27; Df = 9; P = 0.7122).

In 2011 the same statistical method confirmed significant influence of all four factors on the extent of injuries caused by caterpillars on leaves; the date of assessment (ANOVA, F = 2.96; Df = 8; P < 0.05; Kruskal-Wallis test, H = 31.79; Df = 8; P < 0.05), cabbage genotype (ANOVA, F = 11.50; Df = 9; P < 0.05; KW test, H = 106.14; Df = 9; P < 0.05), the manner of suppression (ANOVA, F = 5.56; Df = 1; P < 0.05; Kruskal-Wallis test, H = 14.62; Df = 1; P < 0.05) and the plants' growth stage (ANOVA, F = 8.93; Df = 16; P < 0.05; Kruskal-Wallis test, H = 191.75; Df = 16; P < 0.05).

The average indexes of injuries on leaves of sprayed cabbage in 2010: We established that the extent of injuries caused on cabbage leaves by caterpillars was affected by the date of assessment (ANOVA, F = 14.03; Df = 5; P < 0.05; KW test, H = 80.67; Df = 5; P < 0.05) and the plants' growth stage (ANOVA, F = 6.45; Df = 10; P < 0.05; KW test, H = 67.45, Df = 10; P < 0.05), while the genotype's influence was not detected (ANOVA, F = 0.46; Df = 9; P = 0.8981; KW test, H = 1.45; Df = 9; P = 0.9974).

Fig. 1 shows that on the first two dates of assessment (14. 5. in 4. 6) none of the ten cabbage genotypes displayed injuries, while on the third date (17. 6.) injuries were present in all genotypes. On subsequent dates of assessment the average indexes of injuries rose ('Cheers F1', 'Futog', 'Grandslam F1', 'Hinova F1', 'Holland Late', 'Varaždin cabbage') or remained the same as on the third assessment ('Kranjsko okroglo', 'Early Erfurt'). The largest extent of injuries was on 22. 7. established in the genotype 'Grandslam F1', namely 1.67 ± 0.22, the least injured cabbage was on bringing the harvest home was the hybrid 'Candisa F1' and the cultivar 'Kranjsko okroglo', with the average index of injuries 1.25± 0.05. Among the arly cultivars, we did not find any important differences in the extent of injuries between the hybrids 'Pandion F1' and 'Candisa F1' which would significantly differ from the earliest cultivar in the test, 'Early Erfurt' (the average index of injuries on the harvest did not exceed 1.5 in none of the cases). No differences in susceptibility to injuries between the mid-early hybrids 'Grandslam F1' (1.28 ± 0.07) and 'Cheers F1' (1.23 ± 0.06) were detected. Among the mid-late genotypes, the greatest susceptibility to attacks by caterpillars was displayed by the cultivar 'Varaždin cabbage' (1.29 ± 0.06). Yet the average value of indices of injuries did not differ from the other three genotypes from this group.

Average indices of injuries on leaves of the untreated cabbage in 2010: We established that the extent of injuries caused on cabbage leaves by the caterpillars was affected by the date of assessment (ANOVA, F = 43.88; Df = 5; P < 0.05; KW test, H = 197.86; Df = 5; P < 0.05) and the plants' growth stage (ANOVA, F = 11.52; Df = 15; P < 0.05; KW test, H = 164.24; Df = 15; P < 0.05), while the genotype's influence was not confirmed

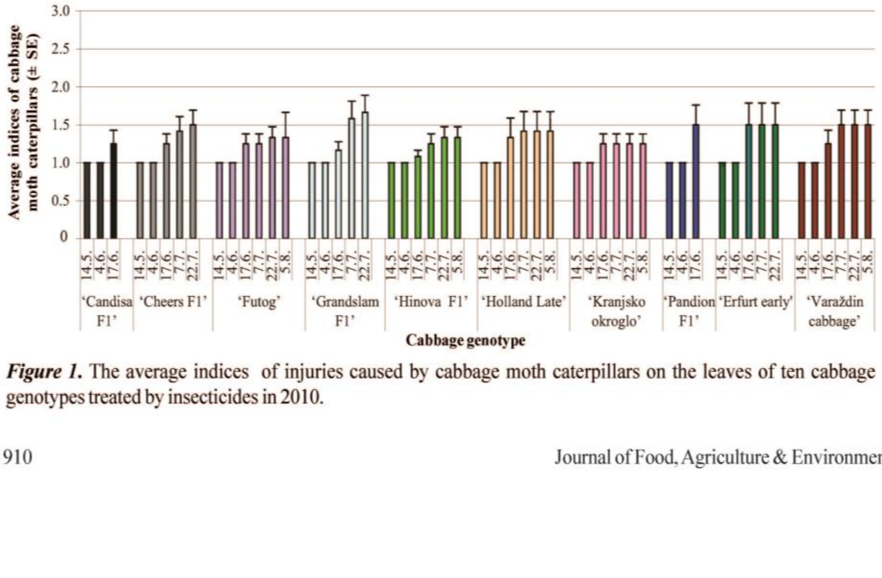

Figure 1. The average indices of injuries caused by cabbage moth caterpillars on the leaves of ten cabbage genotypes treated by insecticides in 2010.

(ANOVA, F = 1.14; Df = 9; P = 0.3328; KW test, H = 9.18; Df = 9; P = 0.4204). The extent of injured leaves on the untreated cabbage was on average larger than that on the sprayed cabbage. On the first two dates of assessment, no genotype displayed injuries, while on the third assessment, injuries were present in all genotypes. The largest extent of injuries was on the 5th of August (2.42 ± 0.29) established in the cultivar 'Kranjsko okroglo', and the cultivar 'Varaždin cabbage' also proved to be among more susceptible cultivars; on the 22. 7. and the 5. 8., it had the average index of injuries 2.08 ± 0.19. Among the early cultivars, the higher average index of injuries on the last date of assessment (17. 6.) was detected also in the hybrid 'Candisa F1', while the most naturally resilient genotype in regard to cabbage moth caterpillars was the hybrid 'Grandslam F1', whose average index of injuries was 1.67 ± 0.19 on the 22. 7. (Fig. 2). Among the early genotypes we detected no differences between 'Pandion F1' (1.27 ± 0.11), 'Candisa F1' (1.36 ± 0.14) and the cultivar 'Early Erfurt' (1.48 ± 0.09). Among the mid-early genotypes, the largest extent was detected in 'Cheers F1' (1.55 ± 0.10), while the extent of injuries in 'Grandslam F1' was lesser (1.30 ± 0.06). Among the late cultivars, we detected the largest extent of injuries in the cultivars 'Varaždin cabbage' (1.64 ± 0.08) and 'Kranjsko okroglo' (1.76 ± 0.11), while the extent of injuries in the cultivar 'Futog' was among the lowest (1.42 ± 0.08).

The average indexes of injuries on leaves of treated and untreated cabbage in 2011: In the second year of the test the sprayed cabbage did not display any significant influence of the date of assessment on the extent of injuries on leaves (ANOVA, F = 0.66; Df = 6; P = 0.6802; KW test, H = 6.11; Df = 6; P = 0.4106), the latter, however, was affected by the genotype (ANOVA, F = 10.45; Df = 9; P < 0.05; KW test, H = 61.04; Df = 9; P < 0.05) and the plants' growth stage (ANOVA, F = 1.93; Df = 10; P < 0.05; KW test, H = 24.76; Df = 10; P < 0.05).

On average, the most injured leaves were those of the mid-early hybrid 'Grandslam F1' (1.32 ± 0.09), which between the dates of assessment did not display statistically characteristic differences (p ≥ 0.05). In comparison with other genotypes, slightly higher values of average indexes of injuries were confirmed in the hybrids 'Cheers F1' and 'Pandion F1', as well as in the cultivar 'Varaždin cabbage'. In the latter, we recorded the value 1.17 ± 0.11 on the 15. 6. Injuries were also detected on the hybrid 'Cheers F1' (1.03 ± 0.01), while in early hybrids injuries were detected only in the hybrid 'Pandion F1' (1.07 ± 0.09). In mid-late genotypes we detected injuries only in the cultivar 'Varaždin cabbage' (1.02 ± 0.01).

In 2011, the extent of injuries on leaves of the untreated cabbage was significantly affected by the date of assessment (ANOVA, F = 5.73; Df = 8; P < 0.05; KW test, H = 53.27; Df = 8; P < 0.05), the genotype (ANOVA, F = 12.49; Df = 9; P < 0.05; KW test, H = 120.31; Df = 9; P < 0.05) and the plants' growth stage (ANOVA, F = 13.80; Df = 15; P < 0.05; KW test, H = 202.26; Df = 15; P < 0.05). In the hybrids 'Candisa F1', 'Cheers F1', 'Hinova F1' and in the cultivars 'Holland Late' and 'Early Erfurt', we detected no injuries during the growth period, while the extent of injuries was throughout the entire growth period significantly the highest in the cultivar 'Kranjsko okroglo' (1.42 ± 0.15), between the 6th of June and the 10th of August, the same holds true for the cultivar 'Futog' (1.33 ± 0.14). Among the early genotypes, injuries were detected only in the cultivar 'Pandion' (1.14 ± 0.03), among the mid-late hybrids, injuries appeared only in the cultivar 'Grandslam F1' (1.05 ± 0.03); among the mid-late cultivars, the largest extent of injuries was observed in the cultivars 'Kranjsko okroglo' (1.16 ± 0.03) and 'Futog' (1.21 ± 0.03). No injuries were detected in the remaining mid-late genotypes. Due to the low extent of injuries on the leaves of both treated and untreated plants of the studied genotypes, as well as the considerable number of uninjured genotypes; the results are presented only in words and not graphically.

The mass of heads and the number of holes in the heads in 2010: The mass of cabbage heads was significantly influenced by the manner of suppression (ANOVA, F = 6.67; Df = 1; P < 0.05; KW test, H = 4.11; Df = 1; P < 0.05) and the genotype (ANOVA, F = 31.81; Df = 9; P < 0.05; KW test, H = 151.93; Df = 9; P < 0.05), the number of holes in cabbage heads did not significantly influence the average mass of cabbage heads (ANOVA, F = 0.71; Df = 11; P = 0.7273; KW test, H = 11.30; Df = 11; P = 0.4184). In the first year of the experiment, we detected the difference between the harvest of treated and untreated plants (ANOVA, F = 6.67, Df = 1; P = 0.0104; KW test, H = 4.11; Df = 1; P = 0.0426).

Among the cabbage genotypes which were in 2010 treated with insecticides, the significantly highest average mass of heads was observed in the hybrid 'Cheers F1' (2475.83 ± 274.64 g), and the significantly smallest crop was observed in the cultivar

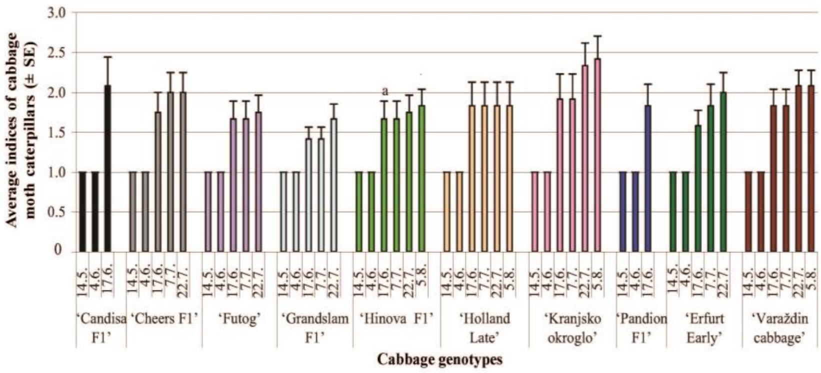

Figure 2. The average indexes of injuries due to cabbage moth caterpillars on leaves of the ten cabbage genotypes which were not treated with insecticides in 2010.

'Kranjsko okroglo' (120.92 ± 17.60 g). The average mass of untreated plants of the hybrid 'Cheers F1' was 1441.90 ± 150.12 g, which did not significantly differ from the harvest of hybrid 'Grandslam F1' (1567.83 ± 146.3). The mentioned genotypes had the significantly highest yield. The lowest yield among the untreated plants was manifested by the cultivar 'Kranjsko okroglo' (211.42 ± 24.52) (Fig. 3).

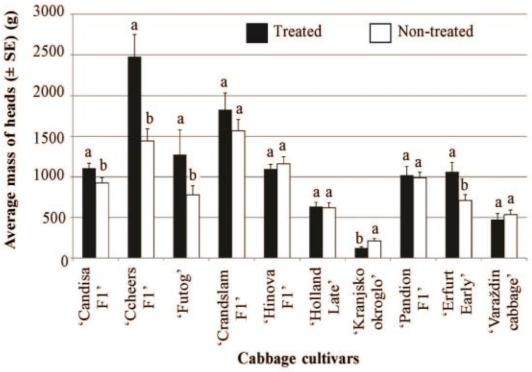

Figure 3. Average mass of heads of the ten cabbage genotypes with different manners of suppression caterpillars in 2010.

No holes, in both treated and untreated plants, were found in four genotypes ('Hinova F1', 'Holland Late', 'Kranjsko okroglo' and 'Varaždin cabbage'), while the five genotypes of treated and untreated plants displayed significant differences in the average number of holes per head, the number of holes was consistently larger in the untreated plants. The largest number of holes (3.17 ± 1.35) was recorded in the untreated plants of the cultivar 'Futog', which was followed by the untreated hybrid 'Grandslam F1' with 3.08 ± 1.24. Slightly less holes were observed in the hybrid 'Candisa F1' (2.58 ± 0.66b), which was followed by the hybrid 'Pandion F1' (2.08 ± 0.49). The average number of holes in the treated plants of all genotypes did not exceed one hole per head, and the most injured hybrids were 'Candisa F1', 'Pandion F1' and 'Grandslam F1' (Fig. 4).

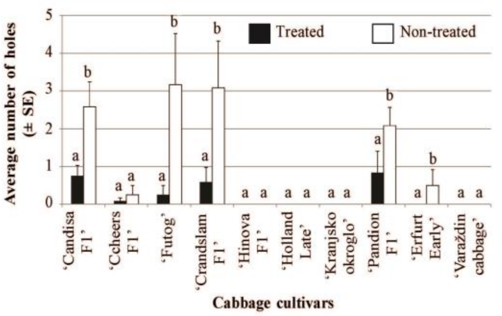

Figure 4. Average number of holes in the heads of ten cabbage genotypes with different manners of suppression of caterpillars in 2010.

The mass of heads and the number of holes in the heads in 2011: The average mass of heads in the first year of the research was significantly influenced by the cabbage genotype (ANOVA, F = 14.30; Df = 9; P < 0.05; KW test, H = 91.24; Df = 9; P < 0.05), while the manner of suppression (ANOVA, F = 1.06; Df = 1; P = 0.3050; KW test, H = 2.86; Df = 1; P = 0.0909) and the number of holes in the cabbage heads (ANOVA, F = 0.84; Df = 14; P = 0.6229; KW test, H = 10.06; Df = 14; P = 0.7576) did not significantly influence the crop. The number of holes in the heads was conditioned by the application of insecticides (ANOVA, F = 10.46; Df = 1, P = 0.0046; KW test, H = 7.41; Df = 1; P = 0.032).

The significantly highest average mass of heads with and without insecticide treatment was observed in the hybrid 'Cheers F1', namely 1917.67 ± 313.63 g and 2385.33g ± 315.81 g. The use of insecticides did not cause any difference in the average mass of heads between the hybrids 'Cheers F1', 'Candisa F1' and 'Hinova F1', while the last two were untreated significantly less productive than the hybrid 'Cheers F1'. The significantly lowest mass of heads in the treated plants was established in the cultivar 'Holland Late' (584.33 ± 69.92 g), while among the untreated plants the least productive cultivars were 'Futog' (540.36 ± 107.91g), 'Holland Late' (471.17 ± 86.37 g) and 'Kranjsko okroglo' (509.33 ± 74.27 g). The application of insecticides proved the most reasonable in the cultivar 'Kranjsko okroglo', since the mass of the treated yield was increased by the factor 2.08 (1058.92 ± 110.44 g) in comparison with the untreated yield (509.33 ± 74.27 g) (Fig. 5).

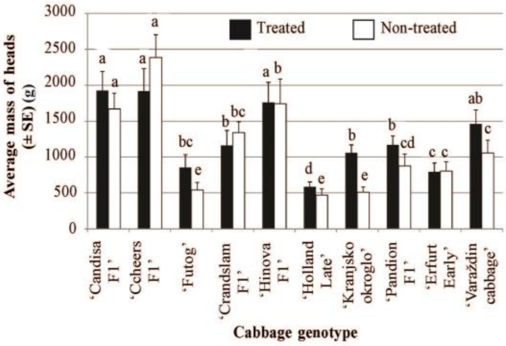

Figure 5. The average mass of the heads in ten cabbage genotypes with different manners of suppression of caterpillars in 2011.

In regard to the number of holes in the heads, the genotypes displayed the greatest differences when they were not treated with insecticides. Significantly the highest number of holes in the untreated plants were observed in the cultivars 'Varaždin cabbage' and 'Futog', as well as in the hybrids 'Cheers F1' and 'Pandion F1' (in the first three genotypes always more than 5 holes per head, slightly less in the last one), significantly the lowest number of holes in the said plants were confirmed in the cultivars 'Holland Late', 'Kranjsko okroglo' and 'Early Erfurt', these had on average one hole per head or even less. The significantly highest number of holes among the treated plants were found in the hybrid 'Pandion F1' (3 per head) and the cultivar 'Futog' (approximately 2 holes per head), significantly the lowest number of holes was on average found in the cultivars Holland Late' and 'Kranjsko okroglo', as well as in the hybrid 'Hinova F1', yet the number of holes in no genotypes exceeded 0.33 per head (Fig. 6).

The results of our research show that the harmfulness of cabbage moth caterpillars on cabbage can be controlled by selecting appropriate, i.e. naturally more resilient cabbage hybrids or cultivars. In regard to cabbage, this has been proved in the case of onion thrips [23, 28], cabbage flea beetles and cabbage

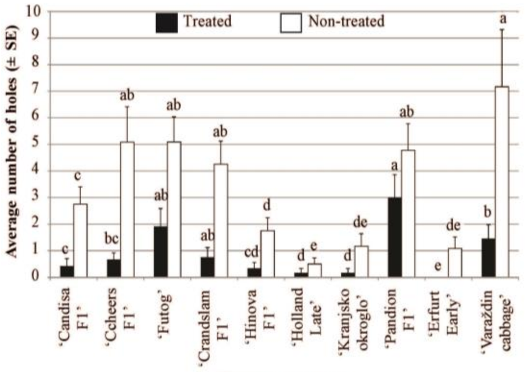

Figure 6. The average number holes in the heads of the ten cabbage genotypes with different manners of suppression of caterpillars in 2011.

stink bugs [1], as well as in the case of cabbage moths [7]; the purpose of our research is, however, justified by a large number of cabbage genotypes whose suitability for production varies with different geographic and climatic regions of Europe and the world.

In 2010 and 2011, we studied the extent of injuries in five cabbage cultivars and five hybrids caused by the first-generation cabbage moth caterpillars on leaves and heads and the crop of the studied genotypes. In the first year of the research we established on average more injuries on cabbage leaves than in the second year, while the reverse trend was confirmed on the heads. The caterpillars in both years caused relatively little injuries (feeding tracks), the most attacked and untreated genotype of cabbage in the experiment, 'Kranjsko okroglo', had the average index of injuries which did not exceed the value 2.5, which means that the lack of leaf mass due to feeding of the caterpillars was from 1 to 10%. The use of insecticides in both years, like in some related research [11], expectedly reduced the extent of injuries on leaves; these could not be prevented despite our intensive treatment.

The results of our research point to a relatively small extent of injuries caused by the first-generation cabbage moth caterpillars on cabbage leaves, which are nevertheless (confirmed by the results of our research) of economic importance; we thus do not exclude the need for insecticide treatment, without which the said caterpillars, which develop in 30 to 60 days, move into cabbage heads and leave feeding tracks; the survival of a large number of the first-generation caterpillars also means a larger second-generation of the harmful pest, which was by some related research [21] confirmed to be economically much more harmful to late cabbage cultivars and some other hosts (for example the sugar beet). No large differences in susceptibility to attacks by caterpillars of the studied harmful pest were detected between the cultivars and hybrids at the same intervals of assessment; the higher average indexes of injuries in the cultivars 'Varaždin cabbage' and 'Kranjsko okroglo' are the consequence of their longer growth period, the cultivars were thus exposed to larger and more harmful first-generation caterpillars.

The heads of the plants treated with insecticides were in both years considerably less damaged by the caterpillars than the heads of the untreated plants, the highest number of holes in heads was established in the early hybrids 'Pandion F1' and 'Candisa F1', as well as in the mid-early hybrid 'Cheers F1' and in the cultivar 'Futog'. In the first year the said genotypes had more than 2 holes in heads, after a year already as twice as much. By applying insecticides, we managed to reduce the number of holes in the first year below the acceptable one hole per head, and in the second year to less than two holes in the majority of cases. Slight injuries of heads in the mid-late genotypes, with the exception of the cultivar 'Varaždin cabbage' - the differences in the extent of its injuries in the two years cannot be explained - are the consequence of heads formation in the period, when the second-generation caterpillars had not yet appeared on the location.

Conclusions

We observed that the heads of the plants treated with insecticides were in most cases heavier than untreated plants. The largest failure of crops (approximately 40%) was in the first year detected in the hybrid 'Cheers F1', whose heads were at the time not heavily attacked by the studied caterpillars. A slightly bigger difference in the crops between the treated and the untreated plants of cabbage was detected in the second year of the experiment in the cultivar 'Kranjsko okroglo', whose heads were also among less damaged. Yet both genotypes had due to feeding of the caterpillars considerably damaged leaves, this was manifested by the largest failure of crops among the studied genotypes.

Although our research is not based on the results of chemical analyses, which could more precisely determine the influence of the selected chemical factors, for example, epicuticular wax [18, 23], glucosinolates [1, 3, 27] etc., on the plant's natural resilience to cabbage moth caterpillars, the results presented in the paper can be a reliable basis for future research into the factors of cabbage's resilience to this increasingly important polyphagous harmful pest.

Acknowledgements

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2.3 VSEBNOST GLUKOZINOLATOV V DESETIH GENOTIPIH ZELJA IN NJIHOV VPLIV NA PREHRANJEVANJE GOSENIC KAPUSOVE SOVKE (*Mamestra Brassicae* [L.])

BOHINC, Tanja, DEVETAK, Marko in TRDAN, Stanislav
Quantity of glucosinolates in 10 cabbage genotypes and their impact on feeding of the caterpillars of *Mamestra brassicae* [L.]
Archives of biological sciences, 2014, vol. 66 (2): 865-874
Sprejeto v objavo, glej prilogo G.

Leta 2011 smo preučevali vsebnost glukozinolatov v 5 sortah in 5 hibridih zelja, gojenih na prostem, da bi preučili njihov vpliv na prehranjevanje gosenic kapusove sovke (*Mamestra brassicae* [L.]). Izbrane genotipe smo razdelili v tri skupine, zgodnje (dolžina rastne dobe od 55 do 70 dni), srednje-zgodnje (80-90 dni) in srednje-pozne (110-140 dni), vzorce zelja za analizo glukozinolatov pa smo odvzeli v petih terminih, v katerih smo na genotipih ocenjevali tudi obseg poškodb zaradi gosenic preučevanega škodljivca. Ugotavljamo, da so prehranjevanju gosenic izpostavljeni predvsem srednje-zgodnji in srednje pozni genotipi zelja in da se vsebnost glukozinolatov med različnimi genotipi zelja razlikuje. Največjo vsebnost analiziranih glukozinolatov smo ugotovili v srednje poznih genotipih. Glucobrasicin je bil edini glukozinolat, ki smo ga ugotovili v vseh genotipih zelja, a je bil njegov antiksenotičen vpliv (r=0.20) zelo šibek. Ugotavljamo, da sinalbin deluje šibko negativno na prehranjevanje gosenic kapusove sovke v srednje-zgodnjih genotipih zelja (r=-0.34), medtem ko enako delovanje sinigrina na obseg poškodb lahko izpostavimo v srednje-poznih genotipih (r=-0.27). Med vsebnostjo gluconapina (r=0.87) in progoitrina (r=0.66) v srednje poznih genotipih ter obsegom poškodb gosenic smo potrdili močno oziroma zmerno korelacijo. Naša raziskava dokazuje, da so različni genotipi zelja različno dovzetni na poškodbe kapusovih sovk in da enega od dejavnikov naravne odpornosti zelja predstavljajo tudi glukozinolati. Kljub temu pa zaradi njihove variabilnosti v zelju zaenkrat še ne moremo natančno določiti nabor genotipov, ki bi v sistemih pridelovanja zelja dosegale višji pridelek na račun manjšega obsega poškodb kapusove sovke. Zato je potrebno v prihodnje še natančneje opredeliti vzroke za časovno in količinsko variabilnost glukozinolatov v križnicah.

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QUANTITY OF GLUCOSINOLATES IN 10 CABBAGE GENOTYPES AND THEIR IMPACT ON THE FEEDING OF *MAMESTRA BRASSICAE* CATERPILLARS

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Abstract - In 2011, we studied the glucosinolate content in 5 cultivars and 5 cabbage hybrids grown outdoors in order to study their influence on the feeding of cabbage moth caterpillars (*Mamestra brassicae*). The selected genotypes were categorized into three groups, early (the growth period from 55 to 70 days), mid-early (80-90 days) and mid-late (110-140 days), while the samples of cabbage for glucosinolate analysis were taken at five intervals, during which we also assessed genotypes for the extent of damage caused by caterpillars. We found that the feeding of caterpillars affected primarily the mid-early and mid-late genotypes of cabbage, and that the glucosinolate content among the different cabbage genotypes varies. The highest content of the analyzed glucosinolates was established in mid-late genotypes. Glucobrassicin was the only glucosinolate found in all cabbage genotypes, yet its antixenotic effect (r=0.20) was very low. We found that sinalbin negatively affects the feeding of cabbage moth caterpillars in mid-early cabbage genotypes (r=-0.34), while the same effect of sinigrin on the extent of damage can be observed in mid-late genotypes (r=-0.27). We have established a strong or moderate correlation between the gluconapin (r=0.87) and progoitrin (r=0.66) contents in mid-late genotypes and the extent of damage caused by caterpillars. Our research proves that different cabbage genotypes are responsible for different susceptibilities to damage by the cabbage moth, and that one of the factors of natural resistance of cabbage are also glucosinolates. Despite this, due to their variability in cabbage we cannot precisely determine the set of genotypes that would ensure a higher cabbage yield as a result of less damage caused by the cabbage moth. Thus, we need to identify in more detail the reasons for the time and quantum variability of glucosinolates in Brassicaceae.

Key words: Cabbage, genotype, glucosinolates, feeding preference, *Mamestra brassicae*

INTRODUCTION

Cabbage, which is in Europe among the most important vegetables, can defend itself against attacks by harmful pests in different ways. The research into the natural resistance of cabbage against attacks of selected harmful pests has so far confirmed a negative correlation between the content of epicuticular wax on cabbage leaves and the extent of damage done by the cabbage moth (*Phyllotreta* spp.), the cabbage stink bug (*Eurydema* spp.) and the onion thrips (*Thrips tabaci* Lindeman) (Trdan *et al.*, 2009); it was also found that the diamondback moth (*Plutella xylostella* L.) averagely leaves more eggs on the green genotypes of cabbage than on the red, though the harmful pest thrives better on the latter (Colares et al., 2013). Considerable, yet not sufficiently explained, is also the influence of glucosinolates on the appearance of the cabbage moth, the cabbage stink bug (Bohinc *et al.*, 2012; Bohinc et al., 2013ab) and the diamondback moth in cabbage (da Silva Carvalho et al., 2010), although some research into the oviposition of harmful pests (e.g. in the species *Delia floralis*) shows a greater significance of non-glucosinolates (Hopkins et al., 1997). Although the connection between the glucosinolate content in cabbage and its natural resistance against the cabbage moth has been already studied (Cartea et al., 2010), the significance of these substances is still not sufficiently explained, despite the fact that this research problem has been addressed for quite a long time (Cole et al., 1994; Gutbrodt et al., 2012).

Glucosinolates are characteristic secondary metabolites for the order Capparales (Schreiner, 2005). They can be found in 13 different botanical families; so far, they have been characteristic mostly for Brassicaceae (Bohinc et al., 2012). Their variability among plant species, among different organs of the same plant species, and their effect on some harmful pests have been dealt with by certain authors (Gouinguene and Stadler, 2005; Bohinc et al., 2013ab). Glucosinolates can differently influence the feeding of monophagous and polyphagous insects (Renwick, 2002; Bohinc et al., 2012). Among typical polyphagous insects is also the cabbage moth (*Mamestra brassicae* L.), which can successfully feed and develop on more than 70 host plants (Devetak et al., 2010).

Due to the known negative effects of synthetic insecticides – harmful pests can be resistant to them (Springate and Colvin, 2012) – their number on the market has been lately significantly reduced (Finch and Collier, 2000); as a result, there is a greater need to develop, optimize and implement environmentally acceptable ways of suppressing harmful pests in systems of food production. Here the knowledge about the natural resistance of cultivated plants against harmful pests is of the utmost importance. This also includes information about the preferences of polyphagous harmful pests for different species of hosts (Xue et al., 2010; Metspalu et al., 2013) or for different genotypes of the same plant species (Trdan et al., 2004, 2008).

The purpose of our research was to study the glucosinolate content in different genotypes of cabbage in order to identify their influence on the extent of feeding by cabbage moth caterpillars in a research area in Slovenia. We wish to prove that different genotypes of cabbage are differently susceptible to attacks by the cabbage moth, and that by selecting a genotype we can successfully control the extent of damage. The purpose of our research was based in the fact that glucosinolate content in the same plant species and even in the same genotype considerably depends also on environmental factors (Bohinc and Trdan, 2012); the results connected with the research of other genotypes of cabbage (Cartea et al., 2010) should therefore not be uncritically transferred into other environments.

MATERIALS AND METHODS

Study site and plant material

A field experiment was carried out in 2011 at the Laboratory Field of the Biotechnical Faculty, University of Ljubljana (46°04'N latitude, 14°31'E longitude, 300 m above sea level), Slovenia. The cabbage plants were grown in the Department of Agronomy's (Biotechnical Faculty) glasshouse according to the protocol described in Trdan et al. (2007). The survey consisted of 10 different cabbage genotypes (5 hybrids and 5 cultivars), which were classified into three groups of genotypes according the length of growing period: early ('Candisa F1', 'Pandion F1', 'Rdeče erfurtsko rano' [='Rdeče']) (the length of growing period between 55 and 70 days), mid-early ('Cheers F1', 'Grandslam F1', 'Futoško') (80-90 days), and mid-late ('Hinova F1', 'Holandsko pozno' [='Holandsko'], 'Kranjsko okroglo' [='Kranjsko'], 'Varaždinsko') (110-140 days).

Field evaluation

The cabbage seedlings were planted on May 4, 2011 in 4 blocks. The plants were not sprayed with insecticides, and each genotype represented a separate treatment (arranged randomly) within the block. The seedlings were planted in a grid of 0.40 x 0.30 m; each block consisted of one bed (breadth 1 m, length 25 m). The beds were covered by black polyethylene mulch. Drip irrigation tape was installed under the polyethylene mulch in the bed at a distance of 10-15 cm from the plant row. The injuries to the cabbage caused by *Mamestra brassicae* caterpillars were assessed 5 times (18 June, 9 July, 30 July, 5 August, 10 August) by the 5-grade visual scale. The plants were evaluated on the scale from 1 (no damage) to 5 (more than 25% leaf area eaten), as follows: 2) up to 2 % leaf area eaten, 3) between 3 and 10 % leaf area eaten and 4) 11-25 % leaf area eaten (OEPP/EPPO, 2002).

Determination of glucosinolates

Plant material (cabbage leaves) for the analysis of glucosinolates was sampled at five different intervals (the same days as the injuries of the caterpillars were assessed). The leaves were cut down with scissors. One sample represented a representative sample of the plants from one plot. The material was then freeze-dried (type: LIO-10P, producer: Kambič Laboratorijska oprema, Slovenia) and homogenized before extraction of glucosinolates. The lyophilized samples were stored in 50 ml bottles in a freezer (type: U3286S, producer: Sanyo) at -80°C. The glucosinolate extraction and analysis were performed according to ISO 9167:1-1992. The method was previously described by Bohinc et al. (2013a). In the samples, we determined the content of gluconapin, glucobrassicin, progoitrin, sinalbin, glucoiberin and sinigrin.

Data analysis

The differences in the glucosinolate content on the leaves of cabbage cultivars were analyzed using a general one-way ANOVA. Prior to analysis, each variable was tested for homogeneity of the variance (Bartlett's test) and the data found to be non-homogenous were transformed to log (Y) prior to ANOVA. Kruskal-Wallis (KW) tests were also applied to analyze the impact of different factors on the glucosinolate level. The differences in glucosinolate content ($P<0.05$) between the different cabbage cultivars were identified using Duncan's multiple range test. We calculated correlations between the concentration of an individual glucosinolate and the level of injury caused by the caterpillars on cabbage leaves. All the statistical analyses were performed using Statgraphics Centurion XVI (2009).

RESULTS

We found that the content of glucobrassicin in the cabbage was significantly influenced by the date of sampling (ANOVA: $F=3.24$, $Df=4$, $P=0.0149$; KW test: $H=22.18$, $Df=4$, $P=0.0002$) and the genotype (ANOVA: $F=1.79$, $Df=9$, $P=0.0078$; KW test: $H=18.95$, $Df=9$, $P=0.0256$), while the content of gluconapin was influenced by the date of sampling (ANOVA: $F=7.13$, $Df=3$, $P=0.0445$; KW test: $H=4.55$; $Df=3$; $P=0.0501$). However, we found out that the content of gluconapin (ANOVA: $F=4.05$, $Df=1$, $P=0.0455$; KW test: $H=14.04$, $Df=1$, $P=0.0442$) and sinalbin (ANOVA: $F=18.58$, $Df=3$, $P=0.0082$; KW test: $H=16.0$, $Df=3$, $P=0.0088$) differed between genotypes, and that the content of sinalbin was not conditioned by the date of sampling (ANOVA: $F=1.48$, $Df=2$, $P=0.3130$; KW test: $H=4.5$, $Df=2$, $P>0.05$).

The content of sinigrin was also significantly influenced by the genotype of cabbage (ANOVA: $F=16.55$, $Df=5$, $P=0.0083$; KW test: $H=17.22$, $Df=5$, $P=0.0005$) and the date of sampling (ANOVA: $F=12.03$, $Df=3$, $P=0.0063$; KW test: $H=13.27$, $Df=3$, $P=0.0018$); we also found that the content of progoitrin in cabbage was conditioned by the genotype (ANOVA: $F=3.84$, $Df=2$, $P=0.0080$; KW test: $H=4.48$, $Df=2$, $P=0.0082$) and the date of assessment (ANOVA: $F=4.05$, $Df=2$, $P=0.0039$; KW test: $H=3.07$, $Df=2$, $P=0.0050$).

In view of our data, we can confirm that the content of glucoiberin in cabbage is influenced by the date of sampling (ANOVA: $F=9.16$, $Df=3$, $P=0.0002$; KW test: $H=14.52$, $Df=3$, $P=0.0022$) and the genotype (ANOVA: $F=25.14$, $Df=9$, $P=0.0099$; KW test: $H=23.93$, $Df=9$, $P=0.0044$).

The influence of the length of growth period in the genotypes of cabbage on the content of the analyzed secondary metabolites (general analysis)

The content of glucobrassicin does not differ between early, mid-early and mid-late genotypes of

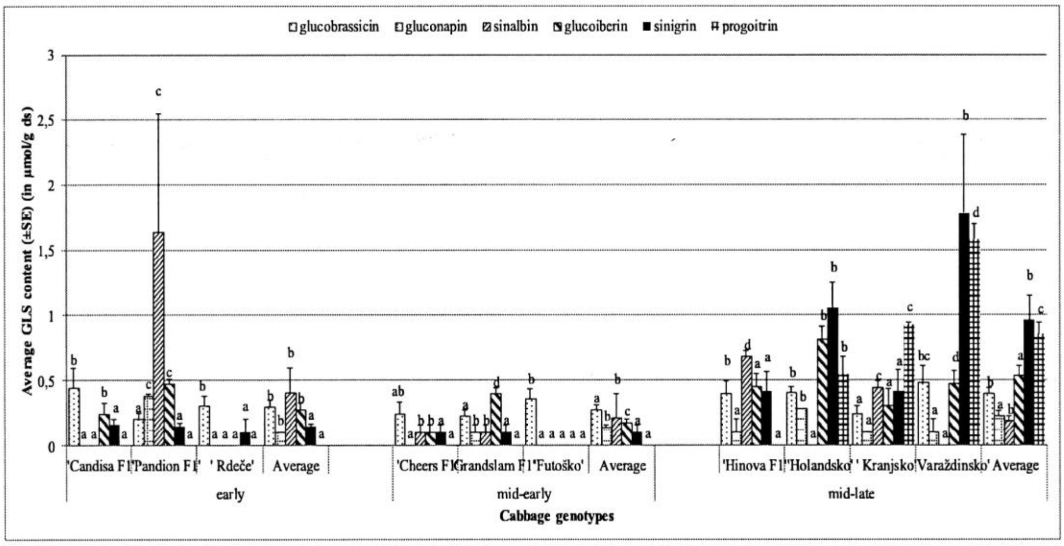

Fig 1. Average glucosinolate content (±SE) (µmol/g ds) in 10 cabbage cultivars from 3 groups according to the length of growing period. Lowercase letters represent differences between glucosinolate content in different cultivars belonging to the same group. Glucosinolates present in traces (<0.1 µmol/g ds) are evaluated as 0.1 µmol/g ds).

cabbage (ANOVA: F=1.57, DF=2, P>0.05; KW test: H=3.93, Df=2, P>0.05), yet we can confirm that the content of gluconapin is conditioned by the length of growth period of the genotypes (ANOVA: F=4.14, Df=2, P=0.0039; KW test: H=3.23, Df=2, P=0.0050). Mid-late genotypes on average contained 0.39±0.05 µmol/g ds of glucobrassicin, in mid-early genotypes we found 0.26±0.04 µmol/g ds, and in early genotypes 0.29±0.05 µmol/g ds. The content of gluconapin was the highest in mid-late genotypes. The content of sinalbin in general did not differ between the groups of genotypes (ANOVA: F=0.57, Df=2, P>0.05, KW test: H=0.38, Df=2, P>0.05). The content of sinigrin was highest in mid-late genotypes (0.96±0.19 µmol/g ds), which means that the content differs in the individual groups of genotypes (ANOVA: F=7.82, Df=2, P=0.0007; KW test: H=22.95, Df=2, P=0.0007). The content of glucoiberin differed in individual groups of genotypes (ANOVA: F=10.15, Df=2, P=0.0074; KW test: H=7.43, Df=2, P=0.0243), and was on average the highest in mid-late genotypes (0.54±0.08 µmol/g ds). Progoitrin was identified only in mid-late genotypes (ANOVA: F=10.14, Df=2, P=0.0497; KW test: H=7.98, Df=2, P=0.0354).

The content of sinigrin was on average higher in mid-late genotypes (1.99±0.31 µmol/g ds), while in early genotypes it was on average 0.38±0.01 µmol/g ds. The content of glucobrassicin (0.44±0.05 µmol/g ds) and gluconapin (0.57±0.05 µmol/g ds) was also higher in mid-late genotypes. Sinalbin was in our research present in a larger quantity in early genotypes (3.18±0.58 µmol/g ds), while the content of sinigrin was higher in mid-late genotypes (1.99±0.32 µmol/g ds).

The content of sinigrin was the highest in the samples of the cultivars 'Varaždinsko'. (1.78±0.75 µmol/g ds) and 'Kranjsko' (2.31±0.04 µmol/g ds), the content of glucobrassicin was higher in the samples of the hybrid 'Hinova F1' (0,39±0.14 µmol/g ds) and the cultivars 'Varaždinsko' (0.48±0.13 µmol/g ds) and 'Holandsko' (0.45±0.08 µmol/g ds), while the average content in the samples of the cultivar 'Rdeče' was 0.29±0.08 µmol/g ds, and in the hybrid 'Pandion F1' it was 0.18±0.04 µmol/g ds. The content of gluconapin was significantly the highest in the samples of the cultivar 'Holandsko' (0.27±0.06 µmol/g ds) and the hybrid 'Pandion F1' (0.24±0.08 µmol/g ds) (Fig. 1).

Gluconapin was present in traces (< 0.1 µmol/g ds) in the hybrids 'Candisa F1' at the first assessment (18 June) and 'Grandslam F1' at the second assess-

Table 1. Average values of five glucosinolates (except glucobrassicin) occurring in different cabbage genotypes (μmol/g ds) during the growth period

Date of sampling	Cabbage genotype	Glucosinolate				
		glucoiberin	progotrin	sinigrin	sinalbin	gluconapin
18th June	Pandion F1'	in traces	x	0.10±0.00	x	in traces
	'Rdeče'	in traces	x	0.10±0.00	in traces	x
	'Cheers F1'	in traces	x	0.10±0.035	x	x
	'Holandsko'	0.50±0.03	0.50±0.01	0.10±0.10	x	x
	'Candisa F1'	0.40±0.03	x	0.36±0.10	in traces	in traces
	'Grandslam F1'	0.52±0.08	x	0.10±0.00	x	x
	'Varaždinsko'	x	x	1.00±0.12	x	x
	'Hinova F1'	x	x	0.10±0.05	in traces	x
	'Kranjsko'	x	x	x	x	x
	'Futoško'	x	x	0.10±0.10	x	x
9th July	Pandion F1'	x	x	3.18±0.10		
	'Rdeče'	x	x	x	in traces	in traces
	'Cheers F1'	x	x	x	0.67±0.15	in traces
	'Holandsko'	x	x	0.10±0.00	in traces	in traces
	'Candisa F1'	x	x	x	in traces	
	'Grandslam F1'	x	x	x	in traces	in traces
	'Varaždinsko'	x	x	0.10±0.00	x	x
	'Hinova F1'	x	x	0.10±0.00	x	in traces
	'Kranjsko'	x	x	x	x	in traces
	'Futoško'	x	x	0.10±0.00	x	x
30th July	Pandion F1'	0.35±0.08	x	0.10±0.10	x	0.36±0.10
	'Rdeče'	x	x	x	x	in traces
	'Cheers F1'	in traces	x	in traces	x	x
	'Holandsko'	in traces	x	0.27±0.05	x	x
	'Candisa F1'	x	x	in traces	in traces	in traces
	'Grandslam F1'	x	x	in traces	x	in traces
	'Varaždinsko'	x	x	in traces	x	x
	'Hinova F1'	0.32±00.05	x	in traces	x	x
	'Kranjsko'	x	x	in traces	x	x
	'Futoško'	x	x	in traces	x	x

ment (9 July). The significantly highest quantity of sinalbin was present in samples of the hybrid 'Pandion F1' (1.64±0.92 μmol/g ds), while it was also detected in samples of the hybrids 'Cheers F1' (0.26±0.10 μmol/g ds) and 'Hinova F1' (0.24±0.09 μmol/g ds) and the cultivars of 'Kranjsko' (0.27±0.10 μmol/g ds). Progoitrin was confirmed in the samples of the mid-late cultivars 'Holandsko' (0.45±0.05 μmol/g ds) and 'Varaždinsko' (0.35±0.05 μmol/g ds), glucoiberin was among the studied glucosinolates found in the significantly highest quantity in the samples of the cultivar 'Varaždinsko' (0.47±0.24 μmol/g ds), while its content was lowest in early hybrids 'Candisa F1' (0.39±0.01 μmol/g ds) and 'Pandion F1' (0.47±0.07

Table 1. Continued

5th Aug	Pandion F1'	0.58±0.02	x	0.41±0.04	in traces	in traces
	'Rdeče'	x	x	in traces	x	in traces
	'Cheers F1'	in traces	x	in traces	x	in traces
	'Holandsko'	0.62±0.10	0.23±0.02	in traces	x	in traces
	'Candisa F1'	in traces	x	in traces	x	in traces
	'Grandslam F1'	0.28±0.04	x	x	x	in traces
	'Varaždinsko'	in traces	0.47±0.02	1.82±0.21	x	x
	'Hinova F1'	1.54±0.10	x	in traces	x	in traces
	'Kranjsko'	in traces	x	in traces	x	x
	'Futoško'	in traces	x	in traces	x	x
10th Aug	'Varaždinsko'	in traces	x	1.12±0.10	in traces	x
	'Hinova F1'	0.30±0.08	x	1.21±0.19	x	x
	'Kranjsko'	0.50±0.08	x	2.41±0.15	0.44±0.05	x
	'Holandsko'	1.23±0.16	0.62±0.05	2.71±0.10	in traces	0.81±0.10

x-not able to detect, in traces is evaluated as <0.1 µmol/ g ds

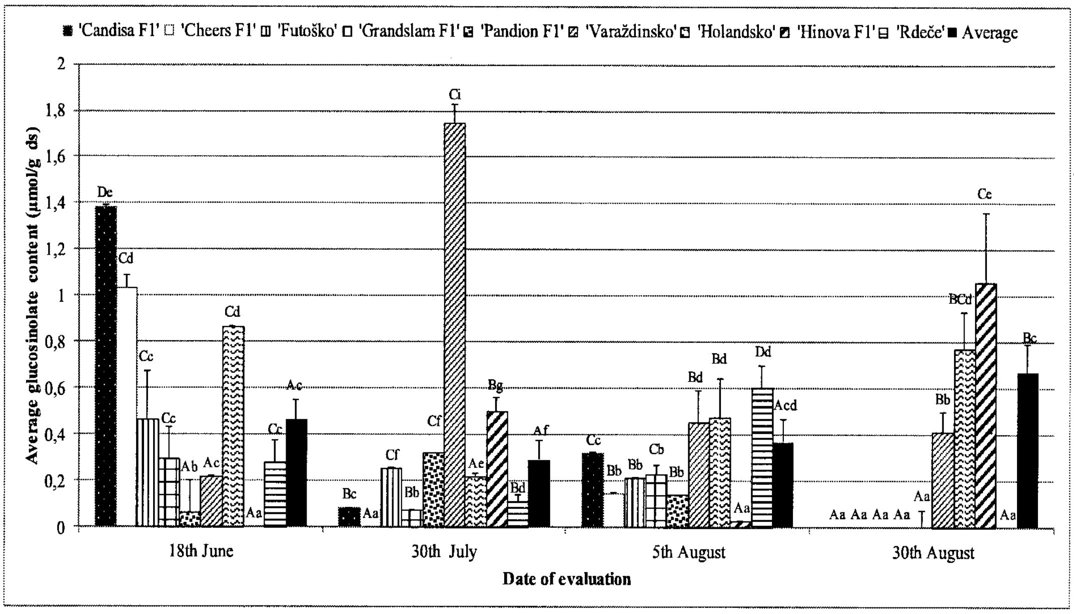

Fig 2. Average glucobrassicin content (±SE) (in µmol/g ds) in different cultivars (lowercase letters present the differences between cabbage cultivars on the same date of assessment; uppercase letters represent the differences between different dates of assessment concerning the same glucosinolate). To simplify Fig 2, 9th July is not presented.

µmol/g ds). In the samples of the cultivar 'Rdeče', the said glucosinolate was present in traces (Table 1).

Content of glucobrassicin at different intervals in the growth period

Glucobrassicin was the only glucosinolate found in all genotypes of cabbage. Fig. 2 shows the content of this substance at four from the five intervals of sampling. The content of glucobrassicin was at the first date of assessment highest in the genotype 'Candisa F1' (1.38±0.01 µmol/g ds), while in 'Hinova F1' we did not establish any content of this glucosinolate. On the third date of assessment, we

Table 2. Correlation between the mean level of injury caused by *Mamestra brassicae* caterpillars and glucosinolate concentration (P<0.05, Duncan's multiple range test) on mid-early and mid-late cabbage genotypes.

Cabbage group	Glucosinolate	r	a	b	p
mid-early genotypes	glucoiberin	-0.25	1.3091	-0.6948	0.0456*
	sinalbin	-0.34	1.50726	-0.6682	0.0454*
	sinigrin	-0.04	1.27132	0.7751	0.9600
mid-late genotypes	glucobrassicin	0.20	1.0580	0.1643	0.0498*
	gluconapin	0.87	-0.81	3.74	0.0241*
	sinalbin	-0.02	1.2078	-0.0666	0.9600
	sinigrin	-0.27	1.1087	0.0290	0.0426*
	progoitrin	0.66	0.2895	2.0231	0.0358*
	glucoiberin	0.27	0.9798	0.2210	0.1793

confirmed in the genotype 'Varaždinsko' the highest content (1.74±0.085), while at the fourth date assessment we found the highest content in the genotypes 'Varaždinsko' (0.45±0.14 μmol/g ds) and 'Holandsko' (0.47±0.17 μmol/g ds). At the last date of assessment, the content of glucobrassicin was among the highest in the samples of the genotype 'Hinova F1' (1.06±0.03 μmol/g ds).

The influence of glucosinolate content on the extent of damage in mid-early and mid-late genotypes of cabbage

Among the studied correlations between glucosinolate content and the extent of damage done by the caterpillars of *Mamestra brassicae* on cabbage leaves, we can point out the activity of glucoiberin (r=-0.25, P<0.05) and sinalbin (r=-0.34, P<0.05) (Table 2) in mid-early genotypes. A significant influence of the remaining glucosinolates was not established.

In mid-late genotypes of cabbage, we can talk about the significant influence of the four selected glucosinolates. We thus noted a weak correlation between the content of glucobrassicin and the extent of damage (r=0.20, P<0.05), and between sinigrin and the extent of damage (r=-0.27, P<0.05), a strong correlation between the content of gluconapin and the extent of damage (r=0.87, P<0.05), and a moderate correlation between the content of progoitrin and the extent of damage (r=0.66, P<0.05). We found that there was a significant negative correlation between the content of sinigrin and the extent of damage (r=-0.27, P<0.05)

In the remaining glucosinolates, we did not detect any significant correlation; the remaining values are presented in the Table 2.

DISCUSSION

The results of our research confirm the findings of some past studies (Moyes et al., 2000; Bohinc et al., 2013ab), namely that glucosinolate content in plants depends on different factors (the significance of many is still not precisely explained) and that their content in plants varies through the growth period. It has already established that differences in the content of these secondary metabolites also occur between genotypes of the same plant species (Kim et al., 2010). Our research defines these correlations in more detail. The results of our research indicate a higher content, and consequently the significance of glucosinolates for mid-early and mid-late genotypes of cabbage. For this reason, we studied in detail the correlation between the extent of damage done by the polyphagous cabbage moth caterpillars (*Mamestra brassicae*) and the content of glucosinolates in the selected groups of cabbage.

We thus established that glucobrassicin, which is one of the glucosinolates whose content in plants is also influenced by environmental factors (Kang et al., 2006; Bohinc and Trdan, 2012), was in our research present in all five cultivars and five hybrids of cabbage. In the research carried out by Bohinc et al. (2013ab), glucobrassicin was also the only glucosinolate present in all studied species of Brassicaceae. In view of the sensitiveness of this glucosinolate to environmental factors, our research established a weak correlation (r=0.20) between its concentration and the extent of damage in mid-late genotypes; we cannot classify it as a key secondary metabolite that would condition antixenosis in cabbage. Our finding that the content of progoitrin is higher in mid-late genotypes of cabbage is also consistent with the findings of our earlier research (Bohinc et al., 2013b). However, the added value of our results is the confirmed moderately strong positive correlation (r=0.66) between the content of progoitrin and the extent of damage done by cabbage moth caterpillars to leaves (a similar correlation was confirmed by Newton et al. (2010) for the louse *Brevicoryne brassicae* and cabbage), which was in the same group of cabbage genotypes confirmed also for gluconapin (r=0.87), whose antixenotic effects could be according to the reports by Fritz et al. (2010) increased by foliar application of jasmonic acid to cabbage.

Despite the fact that in our research sinigrin was, in comparison with other types of glucosinolates, present in large amounts in all mid-late cultivars, its influence on the extent of damage done by cabbage moth caterpillars was relatively weak (r=-0.27), so we cannot confirm the finding of Olsson and Jonasson (1994), who attribute to this substance a great antixenotic effects on leaf-eating caterpillars in cabbage. Sinigrin is known to have anticarcinogenic effects (Wang et al., 2012), and is consequently attributed a greater importance for healthy nutrition than in plant protection. The negative influence of sinigrin and sinalbin (which is a known stimulator of oviposition in cabbage root fly (*Delia* spp.)) on the feeding of *Mamestra configurata* caterpillars was mentioned also by Ulmer et al. (2001) (Gouinguene and Stadler, 2005), and we can to some extent confirm such correlation (r=-0.34) in mid-early genotypes of cabbage.

In view of the results of our research, in which we established that the content of the analyzed glucosinolates was the highest in mid-late cultivars, we can say that glucosinolates can be an important factor deterring cabbage moth caterpillars from feeding on these genotypes; these caterpillars are usually more harmful at the end of the growth period of the cabbage genotypes from the said group (Brandsaeter et al., 1998; Zalokar, 2011).

We can thus summarize that the selection of a cabbage genotype can be one of the indirect (alternative) measures for reducing the harmfulness of cabbage moth caterpillars. Much has been written about the positive effects of glucosinolates in human nutrition (Bjorkman et al., 2011), while, due to their variability (confirmed also in our research), we cannot speak of their universal applicability in plant protection (Bohinc et al., 2012). As key substances influencing the susceptibility of the studied cabbage genotypes to attacks by cabbage moth caterpillars were identified the glucosinolates gluconapin and progoitrin in mid-late genotypes, and sinalbin (by increasing its quantity in cabbage we reduced its susceptibility to attacks by the harmful pest) in mid-early genotypes, yet the potential nature of their antixenotic effects in cabbage will still have to be studied in more detail.

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2.4 KAPUSOVA SOVKA (*Mamestra brassicae* [L.]) IN ZELENJADNA SOVKA (*Mamestra oleracea* [L.]) – PREDSTAVITEV VRST IN UKREPOV ZA NJIHOVO SPREMLJANJE IN ZATIRANJE

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V prispevku sta predstavljena polifagna škodljivca, kapusova sovka (*Mamestra brassicae* [L.]) in zelenjadna sovka (*Mamestra oleracea* [L.]), ki v Sloveniji doslej nista bila načrtneje preučevana. Kapusova sovka, ki se pri nas pojavlja bolj številčno, najraje napada kapusnice, njene gosenice pa se najraje hranijo na zelju. V prispevku predstavljamo morfologijo, razširjenost, način spremljanja sezonske dinamike vrst ter njuno zatiranje. Varstvo vrtnin pred kapusovo sovko in zelenjadno sovko še vedno temelji zlasti na uporabi kemičnih insekticidov, čeprav je številčnost populacij omenjenih škodljivcev mogoče zmanjšati tudi z naravnimi sovražniki in ustreznimi agrotehničnimi ukrepi. S prepletanjem omenjenih ukrepov je namreč mogoče tudi ob močnem napadu pridelati zdrav in kakovosten živež.

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Cabbage moth (*Mamestra brassicae* [L.]) and bright-line brown-eyes moth (*Mamestra oleracea* [L.]) – presentation of the species, their monitoring and control measures

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ABSTRACT

The paper describes polyphagous pests, the cabbage moth (*Mamestra brassicae*) and bright-line brown-eyes moth (*Mamestra oleracea*), which were not systematically investigated up to now in Slovenia. The cabbage moth, which is more abundant, preferably attacks *Brassica* plants, and its caterpillars are especially harmful in the cabbage. The paper deals with the morphology, distribution and methods of monitoring the pest populations and discuss on their control. The protection of vegetables from both pests is primarily based on the use of chemical insecticides. However, the use of natural enemies and various agro-technical measures can also be very important in diminishing the populations of the pests. With interlacing of all of these approaches, healthy and quality food can be produced even in the growing seasons with high attack of the pests mentioned.

Key words: cabbage moth, *Mamestra brassicae*, bright-line brown-eyes moth, *Mamestra oleracea*, presentation, distribution, damage, monitoring, control

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KAPUSOVA SOVKA (*Mamestra brassicae* [L.]) IN ZELENJADNA SOVKA (*Mamestra oleracea* [L.]) – PREDSTAVITEV VRST IN UKREPOV ZA NJIHOVO SPREMLJANJE IN ZATIRANJE

V prispevku sta predstavljena polifagna škodljivca, kapusova sovka (*Mamestra brassicae*) in zelenjadna sovka (*Mamestra oleracea*), ki v Sloveniji doslej nista bila načrtneje preučevana. Kapusova sovka, ki se pri nas pojavlja bolj številčno, najraje napada kapusnice, njene gosenice pa se najraje hranijo na zelju. V prispevku predstavljamo morfologijo, razširjenost, način spremljanja sezonske dinamike vrst ter njuno zatiranje. Varstvo vrtnin pred kapusovo sovko in zelenjadno sovko še vedno temelji zlasti na uporabi kemičnih insekticidov, čeprav je številčnost populacij omenjenih škodljivcev mogoče zmanjšati tudi z naravnimi sovražniki in ustreznimi agrotehničnimi ukrepi. S prepletanjem omenjenih ukrepov je namreč mogoče tudi ob močnem napadu pridelati zdrav in kakovosten živež.

Ključne besede: kapusova sovka, *Mamestra brassicae*, zelenjadna sovka, *Mamestra oleracea*, predstavitev, razširjenost, škodljivost, spremljanje, zatiranje

1 INTRODUCTION

Cabbage moth (*Mamestra brassicae* [L.]) and bright-line brown-eyes moth (*Mamestra/Lacanobia oleracea* [L.]) are classified into family Noctuidae (owlet moths and underwings) and order Lepidoptera (butterflies, moths, and skippers). Both pests are polyphagous, their larvae feed with aboveground parts of plants in night and morning hours. During the day caterpillars are hiden under the leaves and in the aboveground plant parts near to the soil surface. Damage is visible on leaves and flowers of vegetables and occasionally also

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on fruits of horticultural plants. Cabbage moth is treated as one of the most important *Brassica* pest, while bright-line brown-eyes moth rather attacks tomato and lettuce. From time to time caterpillars from both species cause larger damage also on tobacco plants. Pests prefer specially grounds where weeds are grown or no herbicides are used (Sannino, 2005). In last period when rainy and not too hot summers prevailed, we observe also in Slovenia larger appearance of caterpillars from genus *Mamestra*. With the purpose of studying their bionomics and representative ratio ob both species we placed pheromone traps on two locations in the period from 2008 to 2009. The results of male catches will be used in preparing their control strategy and in present paper we present both pest species and measures for their monitoring and control if eventual outbreak in the near by future appears.

2 CABBAGE MOTH (*Mamestra brassicae* [L.])

2.1 Distribution and damage

Cabbage moth is distributed in Europe and in greater part of Asia (Pollini, 2006). It feeds mainly on *Brassica* plants, leaves of sugar beet, tobacco, sunflower and cereals. Beside these plants it makes damage to spinach, tomato, potato, mangold, lettuce and pepper. Metspalu *et al.* (2004) report that larvae of above mentioned pest most likely feed with leaves of white cabbage (*Brassica oleracea* convar. *capitata* var. *alba*) (Figure 1) and red cabbage (*Brassica oleracea* var. *capitata* var. *rubra*). As regards the susceptibility borecole (*Brassica oleracea* convar. *acephala* var. sabellica) follows the cabbage and the *Brassica* species, which attracts caterpillars less, is oilseed rape (*Brassica napus* L. subsp. *napus*).

Feeding of insects depends on the period between separate meals and the quantity of consumed energy in this time interval (Shimizu in Yagi, 1983). More than one thousand substances are known, which are emitted by the plants into the environment with the aim to attrack other organisms (Ulland, 2007). Volatile components affect directly on organisms in a way that they lure them to oviposit or they have an indirect role as an attractant for natural enemies of the pests.

Sannino and Espinoza (1998) report about the noxiousness of cabbage moth on peach fruits, while Pollini (2006) report about the same on pears. Caterpillars reach the branches which are closer to the ground and cause round bores in fruits (Corvi and Nardi, 1998). In a laboratory experiments, conducted by Sannino in Espinoza (1998), moths fed also on meadow plants such as ribwort plantain (*Plantago lanceolata* L.) and common sowthistle (*Sonchus oleraceus* L.). Caterpillars feed during the night time and are most noxious in autumn when they eat mainly leaves of vegetables.

Beside the mechanical damages, caterpillars lessen the quality of crops also through their excrements on flowers and leaves (Pelosini, 1999). Their indirect influence can be observed through the transmission of pathogenic fungi and bacteria into attacked plants (Corvi in Nardi, 1998).

Figure 1: Damage caused by *Mamestra* caterpillars on the exterior leaves of cabbage plant (left) and cabbage head (right) (photos: S. Trdan)

2.2 Morphology

The forewings are brown and mottled with a prominent white-edged stigma and a broken white subterminal line. The hindwings are grey, darker towards the termen. The species varies considerably in size, with a wingspan of 34-50 mm. The prominent spur on the tibia of the foreleg is a diagnostic feature (Pollini, 2006).

Figure 2: Different caterpillar instars of the cabbage moth (*Mamestra brassicae* [L.]) (photo: S. Trdan)

Eggs are slightly oblong and ridged lengthwise. A red-brown marking is in the middle of egg. An egg has 1.2 mm in diameter. First instar caterpillar is yellow-green and its three pairs of legs on thorax, a pair of appendages (anal prolegs) at the posterior end, and one to four pairs of abdominal prolegs in between are black. The caterpillars of first five instars have copper like head and abdomen is lightly green with white stripe which goes above stigmata. The sixth instar caterpillar is brown on dorsal side and yellow on ventral one and is 40 mm in length. Head stays copper like coloured (Figure 2). Pupa is 20 mm long and red-brown (Pollini, 2006).

2.3 Bionomics

First generation adults appear in Italy from the end of April till the beginning of June. Butterflies fly at night and look for cover between the plants during the day. After the copulation female lays up to 2500 eggs on lower surface of leaves in clusters from 25 to 350 eggs. Incubation period depends from the environmental factors. At 25 °C the incubation period is 5 days and at lower temperatures it lasts from 10 to 12 days. Larvae have up to six stages. First generation of pest develops in 20 to 30 days at temperature from 20 to 25 °C and the second one develops in autumn. It lasts from 40 to 60 days at 12 to 15 °C. Adult caterpillars pupate in the ground, at the depth from 2 to 4 cm. Butterflies come in sight again in July and fly till the first half of October. Species is most abundant between middle of September and middle of October. Butterflies lay eggs from which larvae of the second generation develops and after that overwinter as pupae (Pollini, 2006).

Cabbage moth has up to two or even three generations annually in Middle and South Europe, meanwhile Johansen (1996) from Norway reports only about one generation. It is characteristic for pupae of cabbage moth that they have diapause, which is a consequence of environmental temperature, photoperiod and food quality. Pupae diapause of first generation lasts till 80 days and in winter time for six months (Sannino in Espinosa, 1998).

3 BRIGHT-LINE BROWN-EYES MOTH (*Mamestra/Lacanobia oleracea* [L.])

3.1 Distribution and damage

Bright-line brown-eyes moth is distributed in the area of EuroAsia and North Africa. It's a polyphagous insect and most likely feeds with vegetables such as tomato, lettuce, cabbage, root and petiole celery and mangold. It feeds also on soybean, tobacco, sugar beet and even with trees like willow and elm tree. Pest attacks also fruit trees, mostly apple tree and peach tree (Pollini, 2006).

In the beginning caterpillars cause minor damages on lower surface of leaves and in later stages, when their feeding is more formed they can easily eat greedily the whole leaf mass. Damage made by caterpillars can be observed also on apples and peaches, particularly in extensive plantation where less plant protection products is used (Pollini, 2006).

3.2 Morphology

The forewings are brown and mottled with a prominent white-edged stigma and a broken white subterminal line. When forewings are stretched they amount from 30 to 50 mm. On wings there are two yellow spots and two spots of brown colour. Hind wings are grey. Thorax is red-brown and abdomen is lightly brown. Hind tibia is lacking a hooked terminal spur (INRA, 2008).

Eggs of bright-line brown-eyes moth are bright green, hemispherical and flattened on the substratum. They are 0.7 mm in length (Pollini, 2006). Caterpillars are dark green with a light brown head and dark and yellowish white light stripes along the body. These stripes are less visible when larvae are close to pupation. They measure 35 to 40 mm in length when fully grown (INRA, 2008). They go through five instars to pupate. Young caterpillars are often found in groups feeding near the egg mass. Older caterpillars disperse moving from plant to plant. Caterpillars actively feed for 10 to 18 days, descending into the soil to pupate. They have 16 legs and false legs together (Vacchi in Cioni, 2006). The pupa is yellowish green when formed, turns dark brown later and measures from 16 to 19 mm in length (Pollini, 2006). Pupation takes place in a loose silken cocoon 2 to 6 cm below soil surface. Complete developmental cycle lasts for 30 days (Vacchi in Cioni, 2006).

3.3 Bionomics

In the second half of April butterflies appear and still fly in May and June and stay active during the night time. Females of bright-line brown-eyes moth lay eggs similar as females of cabbage moth on the underside surface of the leaves in clusters of 200 to 800 eggs. Embrional development brings to an end after five to ten days. Young caterpillars leave some days together and then separate. After the end of development caterpillars pupate into the ground, at the depth of 10 cm. Adults of second generation fly from the end of July to August. Often they fly also in September and in the beginning of October. Caterpillars of second generation mature in second half of October and overwinter in diapause (Vacchi in Cioni, 2006).

4 MONITORING MOTHS FROM GENUS *Mamestra*

Moths (Noctuidae) control is based upon the application of chemical insecticides. To gain more reasonable and effective usage, plants should be treated in time when caterpillars are younger and feed only on outer leaves and at least 10 to 15 % of leaf area is damage. Convenient time for treating the attacked plants is evening or morning when caterpillars are more active (Vacchi and Cioni, 2006).

To achieve optimal efficiency of insecticides the caterpillars of cabbage moth must be smaller than 12 mm (Johansen, 1996). Older and larger caterpillars hide between plant leaves and are better protected against insecticides. Suchlike example is iceberg salad which offers due to the rosette compactness a good hideout to bright-line brown-eyes moth (Gengotti, 2008).

Because the development of cabbage moth and bright-line brown-eyes moth larvae depends mostly from the environmental temperature it is very uncertain to predict accurate time of treatment on a predefined area. That is why constant monitoring of butterfly seasonal dynamic is needed. Monitoring of adults can be done in different ways. Among more known and prosperous detection methods is usage of pheromone traps. With this method we can allure males and prevent copulation. The trap also helps to determine the most proper time to apply insecticides. Pop *et al.* (1999) refer that pheromone traps, which are used to control and monitor butterflies, can be improved with a supplement of ethers what makes such traps much cheaper. While pheromone traps help us to monitor the population dynamic of the pest, the expected damage assessment must be done through determination of oviposition and pertinent egg development (Corvi and Nardi, 1998).

Insect light traps with mercury bulbs with wavelength till 400 nm can be used to monitor moths. But their disadvantage is unselectivity that is why such traps are used in abundance research of different harmful, beneficial and indifferent species in the environment (Dodok, 2003). Following the results of the experiment in which many butterflies was determined with pheromone traps in the period of three years, Johansen (1996) developed a mathematical model for predicting of cabbage moth with consideration of daily temperature in Norway.

Butterfly catch of cabbage and bright-line brown-eyes moths is likely low with regard to the extent of the damage, which can be caused by caterpillars. Campagna (2005) quoted that this could be due to the polyphagous characteristic of these pests.

5 CONTROL OF CATERPILLARS FROM GENUS *Mamestra*

5.1 Chemical control

In controlling leaf moths still mostly are used organic phosphorus esters. In this group we classify active compounds such as chlorine pirifos-methil, phenitrotion and acephate (Pelosini, 1999). Sufficient efficacy in this relation we can attain also with pyrethroids (cypermethrin, deltamethrin, lambda-cyhalothrin, beta-cyfluthrin and tefluthrin). In Slovenia registered products for controlling cabbage moth are from a group of pyrethroids, a product on the basis of pyrethrin, a product which corresponds to oxadiazine and one from the group of insect development inhibitors (IRI). Pyrethroids which are registered in Slovenia are Fastac 10 % SC (alfa-cypermethrin) and Karate Zeon 5 CS (lambda-cyhalothrin). Latter is the only registered insecticides for controlling bright-line brown-eyes moth.

Two products are also used when controlling cabbage moth, namely pyrethrin (Spruzit powder) and indoxacarb (Steward). Active ingredient indoxacarb refers to the group of oxadiazines which is also advanced one. Insecticides from the oxadiazines group block Na-channels in nerve fibers. Target insects stop feeding, stay paralyzed and die soon. Product Steward is suitable for integrated production.

Chitinase inhibitors display minor danger for human being and are suitable specially for controling eggs and young larvae (Corvi in Nardi, 1998). Among inhibitors of insect development we assign active ingredients such as teflubenzuron, esaflumuron and lufenuron (Pelosini, 1999). The last one is registered in Slovenia and represents an active ingredient of product Match 050 EC.

If there are caterpillars of various developmental stages on the ground, Corvi and Nardi (1998) recommend the application of pyretroids or carbamates. Both groups of insecticides belong to neurotoxins and act as a contact or stomach insecticides. In case if we want controlling also other pest species on plants, the authors recommend the usage of organic phosphorus esters which acts through the respiratory system.

In case of cabbage moth control on cauliflower (*Brassica oleracea* var. *botrytis*) in autumn, Corvi and Nardi (1998) advise double treatment with synthetic insecticides (pyretroids, carbamates, organic phosphorus esters and growth regulators) and at least spraying with microbiological products on the basis of *Bacillus thuringiensis* var. *kurstaki*.

5.2 Crop protection with natural products

Beside the insecticides with chemical components, in integrated and biological production the products of natural origin are more and more used (Gengotti in Censi, 2004). Along effective natural products recon bacterium *Baccilus thuringiensis* var. *kurstaki*, which replaces in some places considerable amount of chemical products. Azadirachtin, rotenone and natural pyrethrin showed in some experiments good results when controlling cabbage moth and bright-line brown-eyes moth as well.

Azadirachtin is a natural insecticide present in the seeds of tropical plant *Azadirachta indica* A. Juss. Its characteristic is low toxicity to mammals. The product acts systemically while it is absorbed through the roots and leaves. From there it is transported to other parts of the plant. Azadirachtin has a wide spectrum of control, however it does not cause instant death of an insect but alters the life-processing behavior in such a manner that the insect can no longer feed, breed or undergo metamorphosis. Products from azadirachtin have short withholding period and are intended for preventive treatments (Gengotti in Censi, 2004).

Bacillus thuringiensis is an aerobic bacterium which produces toxin. This toxin activates in target organism after the consumption. Caterpillars which eat up treated parts of the plants immediately stops feeding and dies in few days. Bacterial subspecies *kurstaki* and *aizawai* are specially appropriate in controlling larvae from order Lepidoptera, while subspecies *tenebrionis* and *israelensis* have suitable insecticidal control of organisms from orders Coleoptera and Diptera. Benefit of products with active ingredient *Bacillus thuringiensis* var. *kurstaki* when compared to other products which are also used against cabbage moth and bright-line brown-eyes moth is the fact that product is nontoxic for vertebrates and does not harm beneficial insects. Due to the leaching and photolability spraying with abovementioned insecticidal product is needed to be repeated frequent.

Pyrethrins are compounds which are gained with maceration of flowers from plant *Chrysanthemum cinerariaefolium* Vis. and which are not toxic to mammals. They have a broad control spectrum but the problem causes their non selective control and weak persistence on plants which leads to reappeared presence of pest on plants in a short time (Gengotti in Censi, 2004). To prolong the persistence of products natural or synthetic compounds like for example piperonil butoxide are added (PBO).

Rotenon is obtained from tropical legume *Derris elliptica* (Wallich) Benth. Insecticides which contain aforementioned compound are very toxic for mammals and beneficial insects. Its characteristic is fast control to pest organisms and has longer withholding period as it comes up to ten days (Gengotti in Censi, 2004).

5.3 Biological control

Natural enemies of cabbage moth and bright-line brown-eyes moth are bacteria, birds, lizards and insects. The latter are the most important, particularly members of Diptera and Hymenoptera families. It is well known that natural enemies attack specially individuals of last generation, namely at the end of summer and in autumn (Vacchi, 2006).

Tramblay (1993) acknowledges that cabbage moth could have more than 50 different natural enemies. One of the most efficient is parasitoid *Trichogramma evanescens* Westwood which feeds with moth eggs and can reduce the pest population also up to 80 %. Similar efficiency can be observed also with *Trichogramma dendrolimi* Matsumura which can destroy 60 to 80 % of cabbage moth eggs. Beside the effective egg control this hymenopteran species is appropriate also for its simple host breeding. Takada *et al*. (2000) tried to breed *Trichogramma dendrolimi* exclusively on Mediterranean flour moth (*Ephestia kuehniella* Zeller) as a host species. After the twelve generation of parasitoid which bred on above mentioned host, the females of parasitoid *Trichogramma dendrolimi* still rather choose specimens of *Mamestra brassicae*. They also report that eggs found in cabbage moth cadavers were bigger from those found in Mediterranean flour moth cadavers and that female also laid two times more eggs in cabbage moth (Takada *et al*., 2000).

Beside aforementioned organisms, also some important parasitoids of moth caterpillars exist, such as *Meteorus gyrator* (Thunberg), *Exorista larvarum* (L.), *Exorista fasciata* (Fallén), *Nemoraea pellucida* (Meigen) and *Compsilura concinnata* (Meigen). Very important parasitoids *Amblyteles armatorius* (Förster) and *Pimpla instigator* F. are from family Ichneumonidae; their larvae feed with caterpillars of cabbage moth and bright-line brown-eyes moth (Sannino in Espinosa, 1998).

Sannino (1998) references on effective biological control of *Protapanteles praecipuus* (Papp) from family Braconidae in a laboratory experiment. This parasitoid lays more than ten eggs into the caterpillar which afterwards develop into the larvae. Moth caterpillar dies in few days and parasitoid larvae pupate outside the prey's body.

Meteorus gyrator appears in the area of North Europe, Great Britain, Asia and North Africa (Smethurst *et al*., 2004). This endoparasitoid has a wide spectrum of hosts, among which the most frequent from order Lepidoptera are owlet moths (Noctuidae), geometrid moths (Geometridae) and Lymantriidae (tussock moths). Only one egg is laid by the wasp in victim's body. Despite the general opinion that *Meteorus gyrator* is a superior adapted parasitoid (superparasitoid), Smethurst *et al*. (2004) ascertained that sometime in victim's body from which larva already came out, later laid egg or larva of wasp can still be found. Introduced phenomenon at this host indicates to incapability of separating between parasited and unparasited hosts. Among moths the wasp parasites mostly caterpillars of bright-line brown-eyes moth. A slow growth of wasp infected organisms compared to normal one is characteristic trait and after the end of parasitizing the host is exploited. Differences exist also in time of parasitoid development, which depends from the development of host organism. It was discovered that this wasp has the longest development in caterpillars of cabbage moth (Smethurst in sod., 2004).

Exorista larvarum appears infrequently and oviposites eggs on the surface of victim's body. Caterpillars which contain eggs are identified after the dark spot, which lies in the place where endoparasite entered the victim's body (Sannino in Espinosa, 1998).

5.4 Interseeding and intercropping

With the aim to restrain the use of chemical products for plant protection and to lessen the number of pest organisms, the application of intercrops and mixed crops of two or more plants is used on farm holdings. Diverse ecosystem enable the presence of higher number of natural enemies which helps to control pest organisms.

Theunissen *et al.* (1995) reported about the findings in which white clover (*Trifolium repens* L.) as an intercrop can reduce the number of different pests on cole crops. Pests which are mentioned are cabbage aphid (*Brevicoryne brassicae* L.), flea beetles (*Phyllotreta* spp.), onion thrips (*Thrips tabbaci* Lindeman) and cabbage moth.

According to Wiech and Kalmuka (2004) white clover acts as the best intercrop against moth larvae. Larvae which move between the white clover plants during the search for the food are exposed to natural enemies such as beetles from the family Carabidae.

6 CONCLUSIONS

Representative members of owlet moths (Noctuidae), specially cabbage moth and bright-line brown-eyes moth, can cause serious troubles to cole crops and vegetable growers. To restrict their attacks beside the use of chemical insecticides also natural products which are environmentally friendly in larger extent are used. As important measure to take into consideration in vegetable production beside new insecticides is also soil cultivation. Among latter worth to mention are deep autumn cultivation with the aim to destroy overwintered pupae, use of interseeding, intercropping and cover crops.

Next to above mentioned measures, more significance is given to natural enemies of pest organisms. They harm or totally destroy eggs and moth caterpillars. Their application is recommended particularly for growing vegetables in greenhouses (hydroponics growing) where their efficacy is expected to be much higher. Some natural enemies of moths as parasitoid *Trichogramma evanescens*, represent remarkable potential in plant protection in the future and at the same time enable lower environmental burden. This is why more attention should be given in searching species from genus *Trichogramma* on the territory of Slovenia as momentarily we do not have any information on their abundance. If their domestic status will be confirmed, they could be introduced into food production systems.

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3 RAZPRAVA IN SKLEPI

3.1 RAZPRAVA

Kapusova sovka (*Mamestra brassicae* [L.]) in zelenjadna sovka (*Mamestra oleracea* [L.]) sta polifagna škodljivca, ki se podobno kot v drugih evropskih državah pojavljata tudi v Sloveniji. Zelje spada pri nas med najbolj razširjene vrste gojenih rastlin, saj se po podatkih statističnega urada prideluje na 350 ha njiv (Ministrstvo za kmetijstvo in okolje; http://www.mko.gov.si/uploads/media/Pregled_trga_zelenjave.pdf), kapusova sovka pa spada v zadnjih letih med pomembnejše škodljivce omenjene križnice. Na severu Španije je kapusova sovka na ohrovtu najpomembnejši škodljivec iz reda Lepidoptera (Cartea in sod., 2009b). Vrsta je zastopana v večjem delu Evrope in Azije, živi pa na območju med 30 in 70° severne geografske širine (Klingen in sod., 2002). Gosenice sovk vrtajo luknje v glavah kapusnic, hkrati pa rastline še onesnažijo z iztrebki in s tem zmanjšajo vrednost pridelka. Da bi bilo varstvo rastlin čim bolj učinkovito in manj obremenjujoče za okolje, je potrebno poznavanje dinamike razvoja škodljivcev. Poleg številčnosti gosenic kapusove sovke in zelenjadne sovke na obseg poškodb na zelju vpliva tudi dovzetnost gosenic do različnih genotipov. Med dejavnike, ki pri škodljivih žuželkah vplivajo na iskanje gostiteljev, sodijo barva in intenziteta svetlobe, ki se odbija od listnega površja, vonj, okus in otip gostitelja (Dabrowski, 1973, 1988, cit. po Jankowska, 2006; Renwick in Chew, 1994, cit. po Jankowska, 2006). Z namenom natančne preučitve pojavljanja obeh vrst sovk v Sloveniji, smo se odločili, da izvedemo raziskavo njune sezonske dinamike, poleg tega pa smo želeli preučiti naravno odpornost desetih genotipov zelja ter vpliv sekundarnih metabolitov glukozinolatov na napad gosenic sovk.

Z namenom preučitve sezonske dinamike obeh vrst škodljivih sovk smo med leti 2008 in 2010 preučevali pojavljanje odraslih samcev na dveh območjih v Sloveniji, in sicer na dveh lokacijah na Goriškem in na Laboratorijskem polju Biotehniške fakultete v Ljubljani. Zato smo za oba škodljivca na preučevanih površinah istočasno uporabili feromonske vabe tipa VARL+ madžarskega proizvajalca Csalomon® (Plant Protection Institute, Budimpešta). Razdalja med posameznimi vabami je bila do 10 metrov. Na Goriškem smo leta 2008 vabe postavili že 20.3., v naslednjem letu pa 4. aprila. Na Laboratorijskem polju Biotehniške fakultete so bile vabe leta 2008 postavljene 24.3., leta 2009 pa 16.4. V zadnjem letu poskusa v Ljubljani pa smo populacijo sovk začeli spremljati 14.4.2010. V poskusih smo tako na Goriškem kot v Ljubljani ugotovili, da razvije kapusova sovka dva rodova na leto. Podobno kot navaja Pollini (2006), se tudi pri nas prvi rod preučevanih sovk pojavlja od konca aprila do začetka junija. Metspalu in sod. (2004) pa omenjajo, da se v Estoniji navadno pojavlja le en rod sovk, ki prezimijo v razvojnem stadiju bube. Ta podatek med drugim tudi nakazuje povezavo pojava sovk v odvisnoti od povprečnih temperatur okolja. Zelenjadna sovka je bila v letih naše raziskave manj številčna od kapusove sovke. Na območju Ljubljane je prva tako razvila dva rodova letno, na Goriškem pa v dveletnem poskusu nismo ujeli nobenega osebka omenjenega škodljivca. Za ugotavljanje sezonske dinamike preučevanih škodljivcev smo uporabili vrednosti vsote efektivnih temperatur, katere smo izračunali kot razliko povprečne dnevne temperature in 10 °C, ki predstavlja predviden temperaturni prag pojava posameznega škodljivca. Računanje vsote efektivnih temperatur smo začeli s prvim januarjem in zaključili, ko se samci sovk niso več lovili v feromonske vabe. Rezultati ulova samcev kapusove sovke in zelenjadne sovke so bili prikazani s povprečnim številom ujetih samcev na dan (± standardna napaka) v povezavi s povprečno temperaturo in množino padavin.

Ugotovili smo še, da je na območju Ljubljane ob pojavu prvega rodu kapusove sovke vsota efektivnih temperatur med 85 in 336,9 °C. Vrh naleta prvega rodu je bil v letih 2009 in 2010 ugotovljen konec maja in v začetku junija. Let prvega rodu se je v vseh treh letih zaključil junija oz. julija pri vsoti efektivnih temperatur med 461 in 655,2 °C. Metulji drugega rodu pa so se pojavljali v juliju, in sicer pri vsoti efektivnih temperatur od 734,6 do 807,9 °C. Let drugega rodu sovk na Laboratorijskem polju Biotehniške fakultete se je leta 2008 zaključil že julija, medtem, ko so se metulji v letih 2009 in 2010 lovili še v septembru. Za razliko od kapusove sovke, je bila populacija zelenjadne sovke na območju Ljubljane precej manjša. Tako so se predstavniki prvega rodu pojavljali od konca aprila do začetka junija, ko se je vsota efektivnih temperatur gibala med 176,4 in 280,4 °C. Tudi zelenjadna sovka je bivoltilna, saj se je drugi rod pojavljal v juliju in avgustu. Vrh drugega rodu je bil zabeležen konec avgusta, ko je bila vsota efektivnih temperatur v letu 2010 1207,4 °C. Konec naleta v letih 2009 in 2010 smo zabeležili avgusta in septembra. Vsota efektivnih temperatur je bila tedaj med 1131,9 in 1312,3 °C.

Za razliko od rezultatov dobljenih na Laboratorijskem polju Biotehniške fakultete v Ljubljani, se na Goriškem v letih 2008 in 2009 odrasli samci zelenjadne sovke niso pojavljali. Predvidevamo, da ni bilo metuljev zelenjadne sovke na omenjenem območju zaradi intenzivne uporabe fitofarmacevtskih sredstev v preteklosti. Poleg tega prostor med njivskimi površinami zaradi uporabe herbicidov ni bil zatravljen, kar še dodatno negativno vpliva na življenje škodljivca. Podobno kot v Ljubljani, se je tudi na Goriškem prvi rod kapusove sovke pojavil v aprilu in maju pri vsoti efektivnih temperatur 86,6 oz. 285,4 °C. Vrh prvega rodu v letu 2008 je bil dosežen v drugi polovici julija, ko je bila vsota efektivnih temperatur 856,5 °C. V naslednjem letu pa smo zabeležili vrh populacije že v maju. Drugi rod sovk se je v dveletnem poskusu začel pojavljati v juliju in avgustu. Za razliko od poskusa v Ljubljani, se je leta 2008 na Goriškem let drugega rodu zaključil v začetku oktobra pri vsoti efektivnih temperatur 1633,9 °C, medtem ko se je v naslednjem letu drugi rod zaključil konec avgusta (vsota efektivnih temperatur 1526,4 °C).

Po navedbah nekaterih avtorjev imajo v rastlinah iz družine křižnic (Brassicaceae) pomembno obrambno vlogo pred napadi škodljivih žuželk tudi glukozinolati in produkti, ki nastajajo ob njihovem razpadu. Van Leur in sod. (2008) navajajo, da omenjene snovi predstavljajo obrambo pred različnimi škodljivci, specializirane organizme pa spodbujajo k prehranjevanju in odlaganju jajčec. Glukozinolati torej določajo odpornost gostiteljskih rastlin. Dekker in sod. (2009) poročajo, da je trenutno znanih prek 120 različnih glukozinolatov. Poleg odpornosti gostiteljskih rastlin na napad škodljivih organizmov, pa lahko glukozinolati negativno vplivajo tudi na učinkovitost parazitoidov in drugih skupin naravnih sovražnikov (Francis in sod., 2001). Spremembe v vsebnosti glukozinolatov so odvisne od genetskih in okoljskih dejavnikov ter v načinu pridelave (Fenwick in sod., 1983, cit. po Rosa in sod., 1996; Milford in Evans, 1991, cit. po Rosa in sod., 1996; Bohinc in Trdan, 2012). Poleg vsebnosti sekundarnih metabolitov in njihovega vpliva na škodljivce, so Stoleru in sod. (2012) ugotovili, da kapusova sovka povzroča manjšo škodo na zgodnjih sortah v primerjavi s poznimi sortami zelja.

Ker ima tudi naravna odpornost rastlin velik pomen v varstvu rastlin pred škodljivci, smo v poljskih razmerah preučevali dovzetnost desetih različnih genotipov zelja na napad gosenic kapusove sovke. Za gosenice prvega rodu je značilno, da poškodujejo liste in glave zgodnjih in srednje poznih sort zelja, medtem ko drugi rod gosenic poškoduje glave poznih genotipov zelja. V letih 2010 in 2011 smo zasnovali poskus na Laboratorijskem polju Biotehniške fakultete v Ljubljani, v katerega smo vključili pet hibridov in pet sort zelja. V raziskavi smo uporabili tri zgodnje, tri srednje zgodnje in štiri srednje pozne genotipe. Sadike smo posadili v štiri bloke, pri čemer smo jih polovico tretirali z insekticidnimi pripravki, na polovici sadik zelja pa insekticidov nismo uporabili. Pri slednjih smo pričakovali, da se bodo posamezni genotipi v kontekstu naravne odpornosti na napad gosenic sovk izrazili bolje od drugih, torej da bodo izkazali večjo naravno odpornost. Za kemično zatiranje gosenic smo uporabili insekticide iz skupin neonikotinoidov in piretroidov, obseg poškodb, ki so jih povzročale gosenice kapusove sovke, pa smo določali s 6-stopenjsko lestvico EPPO, kjer vrednost 1 predstavlja nepoškodovan list, 2 poškodbe do obsega 1 %, vrednost 3 pa pomeni, da je delež poškodb med 2 in 10 %. Stopnja 4 predstavlja obseg poškodb od 11 do 25 %, medtem ko je pri stopnji 5 poškodovana listna površina med 26 in 50 %. Največji delež poškodovane listne površine predstavlja šesta stopnja z obsegom, ki presega vrednost 50 %.

V letu 2010 smo indekse poškodb na listih zelja določevali v šestih terminih, vse do spravila glav posameznih genotipov. Iz rezultatov je bilo razvidno, da na intenziteto napada gosenic kapusove sovke vpliva datum ocenjevanja poškodb, razvojni stadij izpostavljenih rastlin in uporaba insekticidov, saj so bile rastline v blokih, kjer nismo uporabili insekticov, bolj poškodovane od tistih, ki so bile škropljene. Nepričakovano pa se je izkazalo, da genotip ni imel statistično značilnega vpliva na obseg poškodb na listih. Na vseh škropljenih genotipih zelja nismo ugotovili poškodb od gosenic sovk pri prvih dveh ocenjevanjih, 14.5.2010 in 4.6.2010. Od tretjega termina ocenjevanja naprej, pa so se poškodbe na zelju stopnjevale, kar sovpada s pojavom gosenic prvega rodu. Konec julija je bil največji obseg poškodb ugotovljen pri genotipu ‘Grandslam F1’, medtem ko je bil najnižji povprečni indeks poškodb med tretiranimi genotipi ugotovljen pri hibridu ‘Candisa F1’ in sorti ‘Kranjsko okroglo’. Med srednje poznimi genotipi se je sorta ‘Varaždinsko’ izkazala kot najbolj dovzetna za napad gosenic kapusove sovke. Za razliko od genotipov, ki so bili tretirani z insekticidi, je bilo na rastlinah, ki niso bile tretirane, po pričakovanju več poškodb. Tudi pri netretiranih genotipih v prvih dveh terminih vzorčenja poškodb na listih rastlin nismo ugotovili. Z največjim povprečnim indeksom poškodb sta pri netretiranih rastlinah v letu 2010 izstopali pozni sorti ‘Kranjsko okroglo’ in ‘Varaždinsko’. Med zgodnjimi genotipi je bil v zadnjem terminu ocenjevanja za poškodbe dovzeten tudi hibrid ‘Candisa F1’. Kljub temu, da v prvem letu poskusa genotip ni imel statistično značilnega vpliva na obseg poškodb se je med neškropljenimi rastlinami kot najmanj poškodovan izkazal hibrid ‘Grandslam F1’. Za vse preučevane sorte in hibride je bil največji povprečni indeks poškodb ugotovljen pri poznih terminih vzorčenja. V drugem letu poskusa smo na škropljenem zelju ponovno ugotovili, da je bila najvišja povprečna vrednost indeksa poškodb pri hibridu ‘Grandslam F1’(1,32±0,09).

Zelo zanimive rezultate smo ugotovili pri genotipih zelja, na katerih nismo uporabili insekticidov. Tako na genotipih ‘Candisa F1’, ‘Cheers F1’, ‘Hinova F1’, ‘Holandsko pozno' in ‘zgodnje Erfurtsko’ nismo našli poškodovanih listov med rastno dobo. Obratno pa sta bili najbolj poškodovani sorti 'Kranjsko okroglo' in 'Futoško' v obdobju od junija do avgusta. Med zgodnjimi sortami se je kot bolj dovzetna za poškodbe gosenic sovk izkazala sorta 'Pandion', med srednje poznimi pa hibrid 'Grandslam F1'.

Poleg povprečnega indeksa poškodb smo v poskusu preučevali še maso glav (pridelka) in število lukenj v glavah. Zlasti masa pridelka je bila pogojena z uporabo insekticidov in genotipom, število lukenj v glavah zelja pa ni pomembneje vplivalo na povprečno maso rastlin. V prvem letu poskusa smo največjo maso glav na tretiranih rastlinah ugotovili pri hibridu 'Cheers F1' in je znašala 2475,83±274,64 g. Najmanjšo povprečno maso glav pa smo ugotovili pri sorti 'Kranjsko okroglo'(120,92±17,60 g). Prav tako smo tudi pri netretiranih rastlinah ugotovili, da je bil pridelek najnižji pri sorti 'Kranjsko okroglo'. Hkrati pa pri omenjeni sorti nismo ugotovili poškodb zaradi gosenic kapusove sovke. Brez poškodb so bile še tretirane in netretirane rastline sorte 'Holandsko pozno' in 'Varaždinsko' ter hibrid 'Hinova F1'. Z najvišjo povprečno maso glav je pri netretiranih rastlinah izstopal hibrid 'Grandslam F1' (1567,83±146,3). Med netretiranimi genotipi zelja se je kot najbolj dovzetna za poškodbe v glavah izkazala sorta 'Futoško' (3,17±1,35 lukenj/glavo), sledil pa ji je hibrid 'Grandslam F1'.

V poljskem poskusu v letu 2011 smo ugotovili, da je bila povprečna masa glav pri hibridu 'Cheers F1' najvišja tako na škropljenih kot neškropljenih rastlinah. Med netretiranimi genotipi so se kot najmanj produktivni izkazali 'Futoško'(540,36±107,91g), 'Holandsko pozno' (471,17±86,37 g) in 'Kranjsko okroglo' (509,33±74,27 g). Glede na veliko število izvrtin v glavah pa so izstopali še genotipi 'Varaždinsko', 'Futoško', 'Cheers F1' in 'Pandion F1'.

V dveletnem poskusu smo dokazali, da je za pridelavo tržno zanimivih glav zelja nujno potrebna uporaba insekticidov. Poleg tega ima pri pridelavi pomembno vlogo tudi izbor genotipa glede na dolžino rastne dobe, saj smo v raziskavi odkrili, da so bile najbolj poškodovane glave zeljnih sort in hibridov z dolgo rastno dobo. Dejstvo, da so bili pozni genotipi bolj poškodovani kot zgodnji, lahko pripišemo pojavu gosenic drugega rodu kapusove sovke. Zato lahko izbor odpornega genotipa uvrstimo med pomembnejše ukrepe integrirane pridelave zelja, o čemer so sicer poročali že številni avtorji (Mardani-Talaei in sod., 2012). Na odpornost sort ali hibridov po navedbah Trdana in sod. (2004) in Cartea in sod. (2009b) lahko vplivajo tudi fizikalne komponente zelja, kot je na primer vosek, ki vpliva tudi na prehranske lastnosti zelja. Poleg voska Cartea in sod. (2009b) dodajajo, da so glukozinolati ključnega pomena pri odpornosti rastlin na napad škodljivih žuželk, pri privlačnosti ali odvračalnemu učinku rastlin na škodljivce. Ob poškodbi rastlinskega tkiva glukozinolati, ki se nahajajo v vakuolah, pridejo v stik z encimom mirozinazo in razpadejo v različne toksične spojine, ki vplivajo na polifagne škodljivce (Kos in sod., 2012).

V letu 2011 smo preučevali tudi vsebnost glukozinolatov v petih sortah in petih hibridih zelja, z namenom, da ugotovimo njihov vpliv na prehranjevanje gosenic kapusove sovke in s tem posledično na obseg poškodb na listih zelja. Van Leur in sod. (2008) poročajo, da se gosenice kapusove sovke manj intenzivno prehranjujejo in posledično počasneje razvijajo na listih kapusnic, ki so bogate na vsebnosti glukozinolata glukobarbarina. Zato smo se odločili, da v izbranih genotipih zelja preučimo vsebnost glukozinolatov glukonapina, glukobrasicina, progoitrina, sinalbina, glukoiberina in sinigrina ter poskušamo ugotoviti njihove povezave z obsegom poškodb zaradi gosenic sovk na listih zelja. V izbor genotipov zelja smo vključili predstavnike treh skupin, in sicer zgodnje (dolžina rastne dobe od 55 do 70 dni, hibrida 'Candisa F1', 'Pandion F1' in sorta 'Rdeče erfurtsko rano'), srednje zgodnje (80 do 90 dni, 'Cheers F1', 'Grandslam F1' in 'Futoško') ter srednje pozne genotipe (110 do 114 dni, 'Hinova F1', 'Holandsko pozno', 'Kranjsko okroglo' in 'Varaždinsko'). Vzorce listov posameznih genotipov smo nabrali v petih terminih med rastno dobo. Ugotovili smo, da je bilo največ poškodb zaradi gosenic kapusove sovke na srednje zgodnjih in srednje poznih genotipih zelja, hkrati pa je bila vsebnost glukozinolatov med posameznimi genotipi različna. Po navedbah nekaterih avtorjev naj bi bila koncentracija glukozinolatov v svežih rastlinah odvisna zlasti od časa sajenja, okoljskih razmer in dolžine rastne dobe (Cartea in sod., 2008 cit. po Kim in sod., 2010). Za razliko od kapusove sovke, ki je polifagna žuželčja vrsta, Rosa in sod. (1996) poročajo, da nekatere bolhače, kot sta na primer vrsti *Phyllotreta cruciferae* in *Phyllotreta striolata*, privlačijo predvsem kapusnice v zgodnjih razvojnih stadijih, ko je v listih višja koncentracija alilnih glukozinolatov. O podobnem vplivu na škodljivca *Pieris* spp. pišejo tudi Aplin in sod. (1975) ter Nair in McEwen (1976), ki poročata o poškodbah vrste *Hylemia brassicae* na mladih rastlinah. Po najvišji koncentraciji glukozinolatov so izstopali zlasti srednje pozni genotipi zelja; pri glukozinolatih glukobrasicin, glukoiberin in sinigrin pa so se vrednosti spreminjale glede na čas vzorčenja. Razlike v koncentracijah glukozinolatov se niso kazale samo v času nabiranja vzorcev, ampak tudi med posameznimi genotipi. Slednje opisujejo tudi Rosa in sod. (1996) in nekateri drugi avtorji (Josefsson in sod., 1972; Rodman, 1980). V naši raziskavi smo ugotovili, je bil glukobrasicin kot edini metabolit prisoten v vseh preučevanih genotipih, hkrati pa je kazal nizek antiksenotski vpliv na ličinke sovk. Vsebnost sinalbina ni bila pogojena s časom nabiranja vzorcev, medtem ko se vsebnost glukobrasicina ni razlikovala med preučevanimi zgodnjimi, srednje zgodnjimi in srednje poznimi genotipi. Vsebnost glukonapina je bila pogojena z dolžino rastne dobe posameznih sort in hibridov. Kot zanimivost velja omeniti, da je bil progoitrin ugotovljen le pri srednje poznih genotipih. Za razliko pa je bil sinalbin v večji koncentraciji prisoten le v zgodnjih genotipih, medtem ko je bil sinigrin v večjih koncentracijah ugotovljen pri srednje poznih genotipih. Največ sinigrina sta vsebovali sorti 'Kranjsko okroglo' in 'Varaždinsko', največja koncentracija glukobrasicina pa je bila ugotovljena v hibridu 'Hinova F1' in sortah 'Varaždinsko' ter 'Holandsko pozno'. Med preučevanimi genotipi je bilo največ glukoiberina ugotovljenega pri pozni sorti 'Varaždinsko', medtem ko je bila koncentracija tega glukozinolata najmanjša pri zgodnjih genotipih. Giamoustaris in Mithen (1995) za glukoiberin ugotavljata, da negativno vpliva na polifagne škodljivce. Hkrati pa Poelmann in sod. (2009) še dodajajo, da samice kapusove sovke pogosteje odlagajo jajčeca na rastline z nizko koncentracijo glukoiberina.

S preučevanjem različnih glukozinolatov smo ugotovili, da se glukobrasicin pojavlja pri vseh genotipih. V raziskavi smo tudi potrdili predhodne navedbe Newtona in sod. (2010), da obstaja pozitivna korelacija med vsebnostjo progoitrina in obsegom poškodb na listih zelja, ki jih povzročajo gosenice kapusove sovke. Obratno je bilo pri glukozinolatu sinigrinu, ki kljub prisotnosti v vseh preučevanih genotipih, ni imel antiksenotskega vpliva na gosenice sovk, kar sicer omenjata Olsson in Jonasson (1994). Slednja navajata, da ima sinigrin antiksenotski vpliv na gosenice, ki se prehranjujejo s kapusnicami. Van Loon in sod. (2002) v raziskavi, ki je bila opravljena na kapusovem molju (*Plutella xylostella* L.), celo poročajo, da je sinigrin spodbujal prehranjevanje gosenic četrte razvojne stopnje. Za omenjenega škodljivca, ki je prehransko specializiran in napada predvsem rastlinske vrste iz družine kapusnic, je znano, da ima sposobnost izločanja sulfatnih ionov iz glukozinolatov, kar omogoča, da ob razpadu glukozinolatov ob delovanju encima mirozinaze ne pride do tvorbe metabolitov, ki bi bili strupeni za škodljivca (Ratzka in sod., 2002). Za glukozinolate je bilo tudi ugotovljeno, da zmanjšujejo privlačnost kapusnic za polifagne metulje (Mithen in sod., 1995), hkrati pa spodbujajo odlaganje jajčec pri samicah specializiranih škodljivih organizmov (Moyes in sod., 2000).

3.2 SKLEPI

V obdobju 2008-2011 smo izvedli raziskavo, v kateri smo preučevali sezonsko dinamiko dveh vrst metuljev iz rodu *Mamestra*, kapusovo sovko (*Mamestra brassicae* [L.]) in zelenjadno sovko (*Mamestra oleracea* [L.]), poleg tega smo ugotavljali naravno odpornost desetih genotipov zelja, ki se pogosto pridelujejo na slovenskih kmetijah, v povezavi z vsebnostjo glukozinolatov v omenjenih genotipih. Raziskava naravne odpornosti je potekala s poljskimi poskusi, ki smo jih izvajali na Laboratorijskem polju Biotehniške fakultete v Ljubljani, sezonsko dinamiko obeh vrst škodljivih žuželk pa smo poleg v Ljubljani spremljali še na Goriškem. Poleg poljskih smo izvedli še laboratorijske poskuse, ki so bili izvedeni na Inštitutu za hmeljarstvo in pivovarstvo Slovenije v Žalcu, na Oddelku za agrokemijo in pivovarstvo. Sezonsko dinamiko obeh vrst sovk smo spremljali s feromonskimi vabami tipa VARL+ na dveh območjih v Sloveniji, na Goriškem in v Ljubljani. Na Goriškem (lokaciji Miren in Orehovlje) smo raziskavo izvajali v letih 2008 in 2009. V obeh letih preučevanja populacij s feromonskimi vabami smo, v nasprotju s pričakovanji pred začetkom izvajanja poskusa, ugotovili, da na Goriškem zelenjadna sovka ni prisotna. Kapusova sovka pa se je tam številčno pojavljala, potrdili pa smo pojav dveh rodov omenjenega škodljivca na leto. Pojav odraslih osebkov je bil pogojen s povprečno temperaturo zraka, hkrati pa smo za obe območji, ugotovili, da je ulov odraslih samcev sovk pogojen tudi z množino padavin.

Na Laboratorijskem polju Biotehniške fakultete je raziskava, kjer smo ugotavljali sezonsko dinamiko obeh vrst sovk, potekala med leti 2008 in 2010. Tudi v tem poskusu se je kapusova sovka izkazala za bivoltilno vrsto, kar smo lahko potrdili tudi za zelenjadno sovko. Omenjena ugotovitev potrjuje zastavljeno hipotezo o razvoju dveh rodov letno za posameznega škodljivca. Zelenjadna sovka se je sicer pojavljala manj številno od kapusove sovke. Zaradi nizke številčnosti samcev zelenjadne sovke vrhov naleta nismo mogli določiti, razen v zadnjem letu poskusa, ko se je izkazalo, da je bil vrh dosežen konec avgusta. Iz rezultatov poskusa smo ugotovili, da je zelenjadna sovka, v primerjavi s kapusovo sovko, manj pomemben škodljivec v Sloveniji, tako da ne predstavlja večje nevarnosti za pridelavo zelenjadnic pri nas. Rezultati raziskave potrjujejo naše predvidevanje, da se sezonska dinamika posameznega škodljivca razlikuje glede na lokacijo poskusa.

V letih 2010 in 2011 smo na Laboratorijskem polju Biotehniške fakultete v Ljubljani ocenjevali obseg poškodb na listih preučevanih genotipov zelja, ki jih povzročajo gosenice kapusove sovke. Zelju smo določali povprečne indekse poškodb na listih, poleg tega smo tehtali še maso glav in šteli izvrtine v glavah zelja. Raziskavo, ki je trajala prek celotne rastne dobe smo opravili na desetih genotipih zelja, bolj natančno na petih sortah in petih hibridih. Razvojne stadije posameznih rastlin smo spremljali z lestvico BBCH za listnato zelenjavo, ki oblikuje glave. V poskusu smo izbrali genotipe, ki se pogosto pridelujejo v Sloveniji. Namen raziskave je bil preučiti naravno odpornost preučevanih genotipov z uporabo lestvice EPPO za določanje poškodb na rastlinah. V prvem letu poskusa smo ugotovili, da so na obseg poškodb, ki so jih povzročile gosenice kapusove sovke, vplivali uporaba insekticidov, razvojni stadij rastlin in datum ocenjevanja poškodb. Ugotovili smo, da genotip zelja ni imel signifikantnega vpliva na obseg poškodb, ki so jih na listih zelja povzročile gosenice sovk. Iz rezultatov poskusa je razvidno, da je bil povprečni indeks poškodb na listih najmanjši pri prvih dveh ocenjevanjih, kar sovpada z začetkom napada gosenic kapusove sovke. Tako smo pri prvih ocenjevanjih dobili podobne rezultate tako na tretiranih rastlinah kot na netretiranih rastlinah zelja. Med rastlinami, ki niso bile škropljene, sta bili za poškodbe najbolj dovzetni sorti 'Kranjsko okroglo' in 'Varaždinsko'. Ugotovitev ovrže našo hipotezo, da bi bili domača in udomačena sorta bolj odporni na napade gosenic kapusove sovke v primerjavi z ostalimi genotipi. Kot najbolj odporen genotip neškropljenega zelja pa je bil hibrid 'Grandslam F1'. V drugem letu poskusa smo ugotovili, da na povprečni indeks poškodb vplivajo štirje dejavniki: datum ocenjevanja poškodb, razvojni stadij rastlin, uporaba insekticida in, za razliko od leta 2010, tudi genotip. Kot bolj občutljiva sorta zelja, ki ni bila tretirana z insekticidi, se je ponovno izkazala sorta 'Kranjsko okroglo', sledi pa ji sorta 'Futoško'. Na neškropljenem zelju poškodb nismo našli tudi na hibridih 'Candisa F1', 'Cheers F1', 'Hinova F1' in sortah 'Holandsko pozno' in 'Erfurtsko rano'.

V raziskavi smo poleg ugotavljanja povprečnega indeksa poškodb vključili še določanje povprečne mase glav ter ugotavljanje števila izvrtin v glavah. Z analizo variance (ANOVA) smo leta 2010 ugotovili, da ima statistično značilen vpliv na maso glav uporaba insekticidov in genotip. Število izvrtin v glavah pa ni imelo značilnega vpliva na povprečno maso glav. Iz rezultatov raziskave lahko sklepamo, da je večji obseg poškodb na sortah 'Kranjsko okroglo' in 'Varaždinsko' posledica dolge rastne dobe, ki poleg gosenic prvega rodu sovk vključuje še pojav drugega rodu gosenic kapusove sovke. Dejstvo, da so bili za poškodbe najbolj dovzetni genotipi z dolgo rastno dobo potrdi naše predvidevanje glede obsega poškodb in dolžino rastne dobe rastlin. Tako lahko trdimo, da so genotipi z daljšo rastno dobo bolj dovzetni na napade kapusove sovke.

Hkrati z analizo poškodb smo leta 2011 izvedli še laboratorijsko določanje vsebnosti šestih glukozinolatov v desetih genotipih zelja. Med preučevanimi glukozinolati so bili glukonapin, glukobrasicin, progoitrin, sinalbin, glukoiberin in sinigrin. V poskusu se je izkazalo, da je vsebnost posameznih glukozinolatov v listih zelja pogojena z razvojnim stadijem rastlin in genotipom. Med prej omenjenimi sekundarnimi metaboliti smo ugotovili šibko korelacijo med vsebnostjo glukobrasicina in obsegom poškodb pri srednje poznih genotipih zelja. Poleg tega smo tudi ugotovili, da je bila pri srednje poznih genotipih signifikanto negativna korelacija med vsebnostjo sinigrina in deležem poškodb. Zaradi tega omenjenemu glukozinolatu ne moremo pripisovati večjega pomena pri antiksenotskem vplivu na kapusovo sovko. Glede na številčnost poškodb in analizo o vsebnosti glukozinolatov v različnih genotipih zelja ne moremo potrditi delovne hipoteze, da imajo različne koncentracije glukozinolatov ključen vpliv na stopnjo poškodovanosti rastline.

4 POVZETEK (SUMMARY)

4.1 POVZETEK

Kapusova sovka (*Mamestra brassicae* [L.]) in zelenjadna sovka (*Mamestra oleracea* [L.]) sta škodljivi vrsti iz rodu Lepidoptera, ki sta bili pri nas v preteklosti le malo raziskani. Ker gre za polifagna škodljivca, ki poleg zelenjadnic napadata tudi druge rastlinske vrste, smo se odločili preučiti sezonsko dinamiko odraslih osebkov obeh škodljivih vrst na dveh območjih, in sicer na Goriškem in na Laboratorijskem polju Biotehniške fakultete v Ljubljani. Ker je poskus trajal med leti 2008 in 2010, lahko danes zlasti za kapusovo sovko dokaj natančno trdimo, da je v Sloveniji bivoltilna žuželčja vrsta, katere metulji se začnejo tako na Goriškem kot na območju Ljubljane pojavljati v obdobju od druge polovice aprila do začetka junija. Vsota efektivnih temperatur ob pojavu prvega rodu pa znaša med 85 in 336,9 °C (VET), temperaturni prag za pojav škodljivca je bil določen pri 10 °C. Vrh prvega rodu je dosežen v maju in juniju. Nalet drugega rodu omenjenega škodljivca se začne v juliju, konča pa v septembru ali oktobru. Za obe lokaciji se je izkazalo, da so odrasli organizmi številčni, kar potrjuje upravičenost uporabe fitofarmacevtskih sredstev za zatiranje kapusove sovke. Za razliko od kapusove pa je bila populacija zelenjadne sovke maloštevilčna, na Goriškem se v feromonske vabe ni ujel noben odrasel samec. V poskusu, ki je potekal na Laboratorijskem polju Biotehniške fakultete v Ljubljani, pa se je v vabe ujelo nekaj samcev zelenjadne sovke, tako da smo lahko določili osnovne podatke o njeni populacijski dinamiki. Iz dobljenih rezultatov lahko ugotovimo, da se prvi rod zelenjadne sovke v Sloveniji pojavi konec maja ali v začetku junija, medtem ko se metulji drugega rodu lovijo konec julija in v začetku avgusta. Drugi rod omenjena sovka zaključi z letom v septembru. Rezultati naše raziskave o majhni številčnosti zelenjadne sovke na preučevanih območjih pa nam omogočajo sklepanje, da ta škodljivec pri nas ne predstavlja večje nevarnosti za pridelavo vrtnin in poljščin. Ugotavljamo, da so imele pomemben vpliv na ulov samcev kapusove sovke in zelenjadne sovke tudi padavine, saj se je v naših poljskih poskusih izkazalo, da je ob večji množini padavin ulov metuljev manjši.

V letih 2010 in 2011 smo izvedli poljski poskus, kjer smo ugotavljali obseg poškodb, ki jih povzročajo ličinke kapusove sovke na desetih genotipih zelja, povprečno maso glav in število izvrtin v glavah. Z nanosom sintetičnih insekticidov na polovico rastlin smo želeli primerjati 10 različnih genotipov med seboj glede na njihovo naravno odpornost na napad gosenic kapusove sovke. Med preučevanimi genotipi zelja je bilo pet hibridov (‘Candisa F1’, ‘Pandion F1’, ‘Cheers F1’, ‘Grandslam F1’ in ‘Hinova F1’) in pet sort (‘Zgodnje erfurtsko’, ‘Futoško’, ‘Varaždinsko’, ‘Kranjsko okroglo’ in ‘Holandsko pozno’). Hibridi in sorte so pripadali skupinam zgodnjih, srednje zgodnjih in srednje poznih genotipov. Poškodbe, ki so jih gosenice povzročale na listih rastlin, smo ocenjevali s 6-stopenjsko lestvico poškodb EPPO (Guidelines…, 2002), ki predstavlja rahlo prilagojeno EPPO lestvico za določanje poškodb kapusovega bolhača (*Phyllotreta* spp.) na kapusnicah.

Na tretiranih in netretiranih genotipih zelja smo v letu 2010 ugotovili, da so bile poškodbe zaradi gosenic razmeroma nizke v preučevanem terminu med 14.5.2010 in 4.6.2010. To lahko pripišemo dejstvu, da so se ličinke v omenjenem obdobju šele začele pojavljati, in so bile zato maloštevilčne. Vzporedno z rastjo in razvojem zelja se je postopoma povečeval tudi povprečni indeks poškodb zaradi gosenic, kar kaže na odvisnost obsega poškodb od razvojnega stadija škodljivca. Tako smo pri večini genotipov zelja zasledili najvišjo povprečno vrednost indeksov poškodb pri zadnjih ocenjevanjih, torej 22.7.2010 in 5.8.2010. Največje odstopanje med tretiranimi rastlinami zelja pa smo leta 2010 ugotovili pri hibridu 'Grandslam F1'. Na podlagi obsega poškodb na različnih genotipih zelja, lahko trdimo, da so najmanj dovzetne za napade gosenic preučevanih škodljivcev zgodnje sorte in hibridi oz. rastline s kratko rastno dobo. Omenjeni genotipi se izognejo napadu ličink drugega rodu kapusove sovke in množičnemu napadu gosenic prvega rodu. Našo ugotovitev potrjuje tudi dejstvo, da sta se v istem letu v blokih, kjer zelja nismo tretirali z insekticidi, srednje pozni sorti 'Varaždinsko' in 'Kranjsko okroglo' izkazali kot najbolj dovzetni za poškodbe na vehah. Zaradi tega pridelava omenjenih sort brez uporabe insekticidov ni smotrna. V drugem letu poskusa so po obsegu poškodb ponovno izstopali srednje zgodnji in srednje pozni genotipi zelja. Med tretiranimi genotipi je glede na največji povprečni indeks poškodb najbolj izstopal hibrid 'Grandslam F1' z vrednostjo 1,32±0,09, glede največje mase glav je v letu 2010 izstopal hibrid 'Cheers F1' z 2475,83±274,64g. Najmanjšo maso glav smo ugotovili pri sorti 'Kranjsko okroglo', ki je bila tudi med bolj poškodovani v prvem letu poskusa. Kljub temu se je izkazalo, da istega leta ni bilo ugotovljenih izvrtin v glavah tako pri tretiranih kot netretiranih rastlinah sorte 'Kranjsko okroglo'. Poškodbe pri omenjenem genotipu smo potrdili predvsem na vehah. Podobno smo ugotovili pri tretiranih in netretiranih genotipih 'Hinova F1', 'Holandsko pozno' in 'Varaždinsko'. V letu 2011 smo najmanj lukenj v glavah zelja našli pri genotipih 'Holandsko pozno', 'Kranjsko okroglo' in 'zgodnje erfurtsko', podobno kot v prvem letu poskusa.

Pri genotipih zelja iz poljskega poskusa, kjer smo določali povprečne indekse poškodb, smo leta 2011 izvedli tudi analizo vsebnosti glukozinolatov, sekundarnih metabolitov, ki vplivajo tako na prehranjevanje kot ovipozicijo ličink polifagnih in specializiranih žuželčjih vrst. V zelju smo določali vsebnost šestih različnih glukozinolatov, in sicer glukonapina, glukobrasicina, progoitrina, sinalbina, glukoiberina in sinigrina. Poskus smo zastavili tako, da smo v petih časovnih intervalih nabirali liste zelja različnih genotipov, ki niso bili škropljeni z insekticidi. Vzorce smo nato zamrznili in homogenizirali, ekstrakcija glukozinolatov pa je potekala v skladu s postopkom ISO 9167:1 (1992). Raziskava se je izvajala z analizo HPLC z uporabo detektorja DAD na Inštitutu za hmeljarstvo in pivovarstvo Slovenije v Žalcu. Vsebnost glukozinolatov v listih in posledično tudi ostalih tkivih rastlin je odvisna od različnih dejavnikov. V naši raziskavi smo ugotovili, da se delež glukozinolatov v listih zelja spreminja glede na fenofazo rastline, natančneje se je izkazalo, da je bila koncentracija glukozinolatov višja v srednje zgodnjih in srednje poznih genotipih. Poleg tega smo še ugotovili, da je bil glukobrasicin prisoten v vseh preučevanih genotipih, hkrati pa smo odkrili rahlo korelacijo med koncentracijo spojine in obsegom poškodb pri srednje poznih genotipih. Kljub temu ne moremo trditi, da je ravno glukobrasicin glukozinolat, ki ključno vpliva na prehranjevanje gosenic kapusove sovke. Tudi za progoitrin smo ugotovili, da je njegova koncentracija večja v srednje poznih genotipih kot v zgodnjih. Kljub temu smo zasledili pozitivno korelacijo (r=0,66) med vsebnostjo progoitrina in obsegom poškodb, ki so jih naredile ličinke kapusove sovke na listih zelja. Podobno smo ugotovili tudi pri glukonapinu (r=0,87). Pri glukozinolatu sinigrinu, ki je bil prisoten v večjih količinah pri srednje poznih genotipih nismo zasledili, da bi lahko imel antiksenotski vpliv na škodljive organizme. Na podlagi trenutnih raziskav, ki so bile narejene na glukozinolatih v kapusnicah lahko sklepamo, da izbira primernega genotipa pripomore k odpornosti rastlin, kljub temu pa to ni zadosten ukrep za pridelavo zdravega pridelka zelja, ki bi pridelovalcem tudi zagotavljal donosnost. Hkrati pa tudi ni mogoče posplošiti delovanja omenjenih sekundarnih metabolitov na več različnih škodljivcev, saj se različni škodljivi organizmi na sestavo in koncentracije glukozinolatov v zelju odzivajo različno. Zato je za zatiranje gosenic kapusovih sovk poleg izbire genotipov zelja, ki so prilagojeni okoljskim razmeram v Sloveniji še vedno v določeni meri nujno potrebna uporaba ustreznih insekticidov.

4.2 SUMMARY

The cabbage moth (*Mamestra brassicae* [L.]) and the bright-line brown-eye (*Mamestra oleracea* [L.]) are harmful species from the order Lepidoptera, which have in the past not been sufficiently researched in Slovenia. Since they are polyphagous harmful organisms which attack, besides vegetables, also other plant species, we decided to study the seasonal dynamics of adult specimens of both harmful species on two areas, in the region of Nova Gorica and at the Laboratory Field of the Biotechnical Faculty in Ljubljana. Since the experiment was carried out in the period between 2008 and 2010, we can be today quite certain that the cabbage moth in particular is in Slovenia a bivoltine insect species, whose moths began appearing in the Nova Gorica region as well as in the area of Ljubljana in the period from the second half of April to the beginning of June. The sum of effective temperatures upon the emergence of the first generation is between 85 and 336.9 °C (SET) and the developmental threshold of the pest defined at 10 °C. The first generation peaks in May and June. The onset of the second generation of the said harmful organism commences in July and it is concluded in September or October. The adult organisms were numerous at both locations, which justifies the application of phytopharmaceutical products for suppressing the cabbage moth. Unlike the cabbage moth population, the bright-line brown-eye population was not numerous, no adult male was obtained by pheromone traps in the field trial at Nova Gorica. In the experiment carried out at the Laboratory Field of the Biotechnical Faculty in Ljubljana the lures attracted some male specimens of the bright-line brown-eye, so we were able to determine the basic data on its population dynamics. From the obtained results we can conclude that the first generation of the bright-line brown-eye in Slovenia appears at the end of May or in the beginning of June, while the second-generation moths are caught at the end of July and in the beginning of August. The said moth concludes its second generation by a flight in September. The results of our research on scarcity of the bright-line brown-eye at the studied areas enable us to conclude that this harmful organism in Slovenia does not represent any substantial risk for the production of garden and field vegetables. We have established that precipitations also considerably influenced the catch of male specimens of the cabbage moth and the bright-line brown-eye moth, because in our field experiments we caught less moths when the amount of precipitations was higher.

In 2010 and 2011 we carried out a field experiment to determine the extent of damage caused by the cabbage moth larvae on ten cabbage genotypes, the average mass of heads and the number of mining holes in heads. We applied synthetic insecticides on half of the plants in order to compare ten different genotypes in regard to their natural resilience to attacks by the cabbage moth caterpillars. Among the studied cabbage genotypes were five hybrids (‘Candisa F1’, ‘Pandion F1’, ‘Cheers F1’, ‘Grandslam F1’ in ‘Hinova F1’) and

five cultivars (‘Early Erfurt’, ‘Futog’, ‘Varaždinsko’, ‘Kranjsko okroglo’ and ‘Holland late’). The hybrids and the cultivars belonged to the groups of early, mid-early and mid-late genotypes. Injuries on the plants' leaves caused by caterpillars were assessed by 6-grade EPPO scale (Guidelines …, 2002), which is slightly adjusted EPPO scale for assessing damage done by the cabbage flea beetle (*Phyllotreta* spp.) on brassicas.

The treated and the untreated cabbage genotypes in 2010 displayed relatively low levels of damage caused by caterpillars in the interval between 14.5.2010 and 4.6.2010. This can be attributed to the fact that the larvae in the said period had only just begun to appear and were consequently not numerous. The average index of damage caused by caterpillar rose gradually – parallel with the growth and development of cabbage, which points to correlation between the extent of damage and the developmental stages of the pest. Thus the majority of cabbage genotypes displayed the highest average value of damage indexes at the last assessments, i.e. 22.7.2010 and 5.8.2010. The highest deviation among the treated cabbage plants was in 2010 established in the hybrid ‘Grandslam F1’. On the basis of the extent of damage on different cabbage genotypes we can say that the least susceptible to attacks by the caterpillars of the studied harmful pests are early cultivars and hybrids or plants with short growth period. The said genotypes evade the attacks of the second generation cabbage moth larvae and the massive attacks of the first generation caterpillars. Our finding is also confirmed by the fact that the mid-late cultivars ‘Varaždinsko’ and ‘Kranjsko okroglo’ in the blocks containing cabbage which was not treated with insecticides in the same year proved as the most susceptible to damage on outer leaves. The production of the said cultivars without insecticides is thus not reasonable. In the second year of the experiment the mid-early and the mid-late cabbage genotypes again stood out in regard to the extent of damage. Among the treated genotypes the hybrid ‘Grandslam F1’ stood out in regard to the highest average index of damage with the value 1.32±0.09, the hybrid ‘Cheers F1’ stood out in regard to the highest mass of heads in 2010, which was 2475.83±274.64 g. The lowest mass of heads was established in the cultivar ‘Kranjsko okroglo’, which was also among most damaged in the first year of the experiment. It nevertheless turned out that in the same year no mining holes appeared in the heads of both treated and untreated plants of the cultivar ‘Kranjsko okroglo’. Damage in the said genotype was observed primarily on outer leaves. Similar held true for the tretated and the untreated genotypes ‘Hinova F1’, ‘Holland late’ and ‘Varaždinsko’. In 2011 the genotypes ‘Hollands late’, ‘Kranjsko okroglo’ and ‘Early Erfurt’ had the least mining holes in cabbage heads, which is similar to the first year of the experiment.

The cabbage genotypes from the field experiment (which aimed to determine the average indexes of damage) were in 2011 also analysed for the content of glucosinolates, the secondary metabolites which influence both feeding and oviposition of larvae of polyphagous and specialised insect species. We were determining the contents of six different glucosinolates in cabbage, namely gluconapin, glucobrassicin, progoitrin, sinalbin, glucoiberin and sinigrin. At five intervals during the experiment we collected cabbage leaves of different genotypes which had not been treated with insecticides. The samples were then frozen and homogenized, while the extraction of glucosinolates was carried out in accordance with the procedure ISO 9167:1 (1992). The research was performed with the HPLC analysis by applying a DAD detector at the Slovenian Institute of Hop Research and Brewing in Žalec. The glucosinolates content in leaves and consequently also in other tissues of plants depends on different factors. In our research we found out that the share of glucosinolates in cabbage leaves varies according to the plant's phenophase, to be more precise – it turned out that glucosinolates concentration was higher in the mid-early and the mid-late genotypes. Apart from this, we also found out that glucobrassicin was present in all of the studied genotypes, at the same time we established a slight correlation between the compound's concentration and the extent of damage in the mid-late genotypes. Despite this, we cannot say that glucobrassicin is the glucosinolate which decisively affect the feeding of the cabbage moth caterpillars. The concentration of progoitrin was also higher in the mid-late genotypes than in the early ones. We nevertheless established a positive correlation (r=0.66) between the progoitrin content and the extent of damage done by the cabbage moth larvae on cabbage leaves. Similar held true for gluconapin (r=0.87). In regard to the glucosinolate sinigrin, which was present in larger quantities in the mid-late genotypes, we did not detect any antixenotic effect on harmful organisms. On the basis of the current studies of glucosinolates in brassicas, we can conclude that the selection of appropriate genotype increases the resilience of plants, but this is nevertheless not a sufficient measure for the production of healthy cabbage which would also ensure profitability for its producers. We also cannot generalise about the effects the said secondary metabolites have on other different harmful organisms, since different harmful organisms react differently to the composition and concentrations of glucosinolates in cabbage. Suppressing the cabbage moth caterpillars thus to a certain extent still necessitates the application of appropriate insecticides – besides the selection of cabbage genotypes adjusted to the environment in Slovenia.

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PRILOGA A

Slikovno gradivo - splošno

Priloga A1: Feromonska vaba tipa VARL+ madžarskega proizvajalca Csalomon® uporabljena za lovljenje samcev kapusove sovke (*Mamestra brassicae* [L.])

Priloga A2: Odrasli osebek kapusove sovke (foto: S. Trdan)

PRILOGA B

Slikovno gradivo – poškodbe sovk

Priloga B1: Poškodbe gosenic sovk iz rodu Mamestra na listu zelja, ki ni bilo tretirano z insekticidi (foto: M. Devetak)

Priloga B2: Gosenica kapusove sovke (*Mamestra brassicae* [L.]) na listu zelja (foto: M. Devetak)

Priloga B3: Gosenice kapusove sovke se prek dneva zadržujejo v glavah zelja (foto: M. Devetak)

PRILOGA C

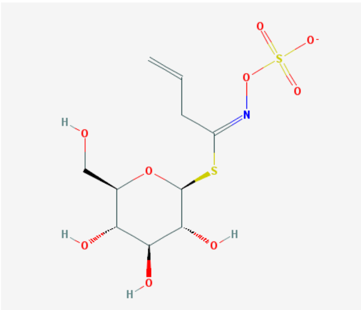
Slikovno gradivo – postavitev poskusa

Leta 2010 smo na Laboratorijskem polju Biotehniške fakultete zasnovali poskus, kjer smo preučevali naravno odpornost desetih genotipov zelja (*Brassica oleracea* var. *capitata*) (foto: M. Devetak)

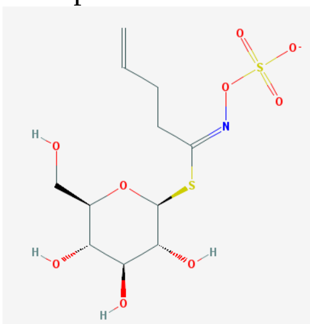
PRILOGA D

Slikovno gradivo – strukturne formule glukozinolatov

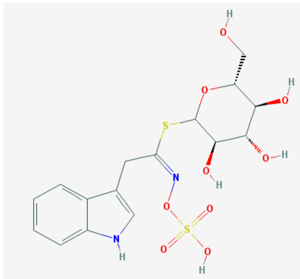
Sinigrin:



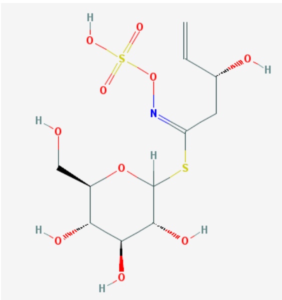
Glukonapin:



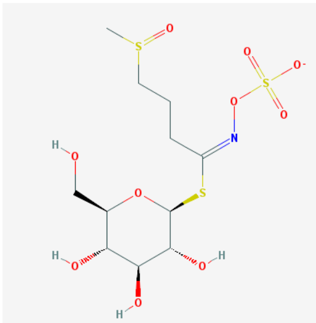
Glukobrasicin:



Progoitrin:



Glukoiberin:



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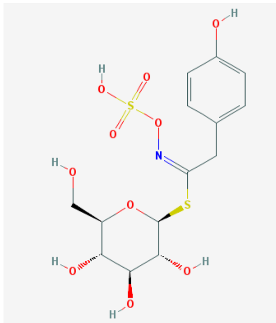

PRILOGA E

Dovoljenje za objavo članka iz revije »Horticultural Science (Prague)«

ČESKÁ AKADEMIE ZEMĚDĚLSKÝCH VĚD

Horticultural Science (Prague)
Editorial Office
Slezská 7, 120 00 Prague 2, Czech Republic

Marko Devetak
University of Ljubljana
Biotechnical Faculty, Department of Agronomy
Jamnikarjeva 101, SI-1111 Ljubljana, Slovenia

Acceptance letter Prague, March 24, 2014

Dear Dr. Devetak,

This is to confirm, that the manuscript No. 209/2013-Hortsci **Seasonal dynamics of cabbage armyworm (Mamestra brassicae L.) and bright line brown-eyes moth (Mamestra oleracea L.) in Slovenia,** written by M.DEVETAK,T.BOHINC,M.KAČ,STRDANhas been accepted for publishing in Horticultural Science journal.

We agree, with the intent that part of the PhD thesis of one of the authors is included in presented in the paper and its electronical version.

The article will be published in Issue 2/2014 of the Horticultural Science (Prague) journal.
The Impact Factor of our journal is for year 2012 - 0.786.

Sincerely yours,

Ing. Eva Karská

Ing. Eva Karská
Executive Editor

Česká akademie zemědělských věd
Těšnov 65 ④
117 05 Praha 1

PRILOGA F

Dovoljenje založbe »WFL Publisher«, da se lahko članek iz poglavja 2.2 uporabi kot del doktorske disertacije

From: WFL Publisher Ltd. <info@world-food.net>
Date: 2014-04-10 10:16 GMT+02:00
Subject: [Fwd: kind request related manuscript "Natural resistance of ten cabbage genotypes to cabbage moth (Mamestra brassicae [L.]) attack under field conditons" - urgent]
To: Bohinc Tanja <tanja.bohinc@gmail.com>

Dear Mr. Marko Devetak

We do authorize Mr. Marko Devetak to use the published paper in the electronical version of PhD (one year after defending). Just mention the full journal reference/citation.

"Natural resistance of ten cabbage genotypes to cabbage moth (Mamestra brassicae [L.]) attack under field conditons*« which was accepted for publication in the Journal of Food, Agriculture and Environment*, and

published in volume 11, no. 3-4, p.908-914.

Sincerely
Ramdane Dris PhD.

--
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PRILOGA G

Dovoljenje založbe »Archives of Biological Sciences, Belgrade« za uporabo članka v doktorski disertaciji

ARCHIVES OF BIOLOGICAL SCIENCES, BELGRADE

International and Multidisciplinary Journal Established in 1948
Official Journal of the Serbian Biological Society
Editor-in-Chief: Prof. Dr. Božidar P. M. Ćurčić
Institute of Zoology, Faculty of Biology, University of Belgrade
Studentski Trg 16, 11000 Belgrade, Serbia
Tel.: + 381 11 3281 789 and 2187 266 ext. 103; fax: + 381 11 2638 500
E-mail: bcurcic@bio.bg.ac.rs and bpmcurcic@yahoo.com

Belgrade, 15 April 2014

PERMISSION

Dear Mr Marko Devetak,

This is to confirm that Mr Marko Devetak from the University of Ljubljana, Biotechnical Faculty, Department of Agronomy, Jamnikarjeva 101, SI–1111 Ljubljana, Slovenia, published the paper entitled „QUANTITY OF GLUCOSINOLATES IN 10 CABBAGE GENOTYPES AND THEIR IMPACT ON THE FEEDING OF *MAMASTRA BRASSICAE* CATERPILLARS“ together with Tanja Bohinc and Stanislav Trdan. The paper appeared in the *Archives of Biological Sciences, Belgrade*, Vol. 66 , issue 2, pp. 865-874, 2014.

The permission of ABS is granted to Mr Devetak since his doctoral dissertation has to be published in paper and electronical version.

Thank you for your consideration,

СРПСКО БИОЛОШКО ДРУШТВО БЕОГРАД

B. Ćurčić

Prof. Dr. Božidar Ćurčić, Editor-in-Chief, ABS
President, Serbian Biological Society
President, National Commision of Serbia for cooperation with UNESCO
UNESCO Stakeholder

PRILOGA H

Dovoljenje založbe »Acta agriculturae Slovenica« za uporabo članka v doktorski disertaciji

Acta agriculturae Slovenica
Biotehniška fakulteta
Jamnikarjeva 101
1000 Ljubljana

Zadeva: Izjava

Spoštovani!
S to izjavo dovoljujemo Marku Devetaku, da v njegovi disertaciji iz člankov poleg treh IF člankov priloži tudi članek »Cabbage moth (Mamestra brassicae L.) and bright-line brown-eyes moth (Mamestra oleracea L.) - presentation of the species, their monitoring and control measures«, ki je bil objavljen v reviji AAS leta 2010 (95, 2: 149-156) in da se članek lahko uporabi v doktorski disertaciji, ki bo predstavljena v tiskani in elektronski obliki.

Lep pozdrav!

Glavni urednik:
Prof. dr. Franc Batič

V Ljubljani, 14.04.2014