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Agriculture (Poľnohospodárstvo), 69, 2023 (2): 47 – 65

Original article

DOI: 10.2478/agri-2023-0005

A CASE STUDY – THE OCCURRENCE OF PESTS IN STANDS OF NEWLY INTRODUCED ENERGY CROPS IN LARGE-SCALE PILOT EXPERIMENTS IN CONDITIONS OF CENTRAL EUROPE

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Tóth, Š., Tancik, J., Šoltysová, B., and Porvaz, P. (2023). A case study – the occurrence of pests in stands of newly introduced energy crops in large-scale pilot experiment in conditions of Central Europe. *Agriculture (Poľnohospodárstvo)*, *69*(2), 47 – 65.

The objective of this paper is to document the occurrence of pests recorded in a large-scale pilot field experiment, where a unique set of newly-introduced herbaceous energy crops was tested under conditions of eastern Slovakia. The set consisted of *Elymus elongatus, Secale cereanum, Silphium perfoliatum, Galega orientalis, Sida hermaphrodita, Panicum virgatum, Amaranthus* spp., *Panicum miliaceum, Sorghum sudanense,* and *Sorghum bicolor.* A total of 14 cultivars were tested on 4 sites during 4 crop years (2016 – 2020). At least 17 species of pests were recorded in total, as some of the species may represent the identity of the couple or several relative ones, which was rare only as usually a fower common species. The occurred pests list consists of *Anisoplia lata* Erichson, *Agriotes lineatus* L., *Capreolus capreolus* L., *Deroceras agreste* L., *Oulema gallaeciana* Heyden, *Lepisma saccharinum* L., *Lepus europaeus* Pallas, *Meloe proscarabaeus* L., *Metcalfa pruinosa* Say, *Microtus arvalis* Pallas, *Philaenus spumarius* L., *Psylliodes chrysocephala* L., *Rhopalosiphum padi* L., stemborers as any insect larva or arthropod boring into plant stem, *Sus scrofa* L., *Aleyrodes proletella* L., *Tettigonia viridissima* L., and *Trialeurodes vaporariorum* Westwood. Overall, the occurrence of pests was regular and scattered, and damages caused by them were negligible usually, but a total destruction of the crop stand even cultivar-specific was recorded too. Most of the meaningful pests are primarily field hunting animals and only secondarily commonly occurring insect species, which for further observations are desirable in order to capture the tendency of important pests' overpopulation, confirming respectively. Although even rare finding of the single caterpillar of *Xylena exsoleta exsoleta* L. was recorded in a buffer zone, within the experiment no newly introduced pest species was recorded.

Key words: energy crops, pests, pilot experiments, damage typology, moderate climate

In general, energy crops in Slovakia are not rightly considered to be weed-free and pest-free crops, due to their massive habitus and because they are mostly newly introduced crops. Thus, the prevailing agronomic opinion is that domestic pests do not prefer such crops, respectively occurred weeds have a lower competitive ability.

The pilot field experiments so far have been focused almost exclusively on production quantitative and qualitative aspects (Marišová *et al.* 2016; Kron *et al.* 2017; Cumplido-Marin *et al.* 2020; Makovníková *et al.* 2000; Giertl *et al.* 2022; Hauptvogel *et al.* 2022; Pauková *et al.* 2022; Šoltysová *et al.* 2022), or other agroecological issue (Šoltysová & Danilovič 2017; Hauptvogel *et al.* 2022; Mamirova *et al.* 2022), while original phytopathological studies

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are rare or still absent (Purger *et al.* 2008; Prasifka *et al.* 2011; Pszczółkowska *et al.* 2012; Seni 2018; Stefanovska *et al.* 2017; Iľková & Šütöová 2022). Many works related to energy crops are of the nature of model studies, or even field experiments which are usually small-plot trials at sheltered experimental workplaces where the natural occurrence of pests is limited in various ways.

The occurrence of pests in the cultivation of energy crops was dealt with by Cagáň *et al*. (2006), Purger *et al*. (2008), Pszczółkowska *et al*. (2012), Haan and Landis (2023), and others.

Purger *et al*. (2008) found out that small mammal abundance was twenty times higher in wheat *Triticum* spp. than in energy crop tall wheatgrass *Elymus elongatus*. Cagáň *et al.* (2006) found out the occurrence of the sugarbeet flea beetle *Chaetocnema tibialis* and barley flea beetle *Phyllotreta vittula* on the amaranth plants (*Amaranthus caudatus*, *Amaranthus retroflexus*). Pszczółkowska *et al*. (2012), recorded the occurrence of insect pests such as *Coreus marginatus*, *Lygus bugs* and *Aphis fabae* in *Sida hermaphrodita* stands. Haan and Landis (2023) compared attack rates of perennial and annual crops by pests. They found, that birds and small mammals were responsible for most attacks in annual crops early in the season and for most attack events in perennial crops were responsible for chewing arthropods.

An increase in the populations of the whitefly infesting the ornamental plants of the sida was found by Lourencao and Nagai (1994) and Mugerwa *et al.* (2021). Lourencao and Nagai (1994) recorded increased whitefly populations on the *Sida rhombifolia* crops and Mugerwa *et al.* (2021) recorded increased whitefly *Bemisia tabaci* populations on the *Sida acuta* crops.

The results of the study by Ntidi *et al.* (2016) showed that some crop species are very susceptible to nematodes (*Meloidogyne incognita, Meloidogyne javanica*). Greenhouse results showed that *Amaranthus tricolor* was identified as the most susceptible host for these nematodes.

According to Maharjan *et al.* (2020), *Nysius plebeius* Distant and *Nysius hidakai* Nakatani are one of the emerging pests of energy crops such sorghum (*Sorghum bicolor* L.) and millet (*Panicum miliaceum* L.). They found, that the oviposition and development periods of both *Nysius* varied significantly among seed species. The preferred seed species for oviposition were grain sorghum than grain millet.

The main aim of this work was to document the incidence of pests recorded in a huge, extraordinarily large system of pilot semi-operational field trials, where a set of newly-introduced energy crops was tested by growing them in marginal soil and different climatic conditions of eastern Slovakia.

MATERIAL AND METHODS

Crops, trial sites and agronomy

The huge system of large-scale pilot field trials with a set of newly-introduced energy crops (i) tall wheatgrass *Elymus elongatus* (Host) Runemark, (ii) perennial rye *Secale cereanum,* (iii) cup plant *Silphium perfoliatum* L., (iv) eastern galega *Galega orientalis* Lam., (v) virginia mallow *Sida hermaphrodita* (L.) Rusby, (vi) switchgrass *Panicum virgatum* L., (vii) amaranth *Amaranthus* spp., (viii) broomcorn millet *Panicum miliaceum* L., (ix) sudangrass *Sorghum sudanense* (Piper) Stapf, and (x) grain/graet millet *Sorghum bicolor* (L.) Moench was established on 4 sites located under continental Central European climate on marginal soil conditions. The trials were done in cooperation with local farmers within 70 km distance from Michalovce (Figure 1), the main characteristics of the sites can be found in Table 1. More details on the soil and climatic conditions of the trial sites are presented in related work (Tóth 2023).

The stands of the perennial crops were conducted in the autumn of 2016 (tall wheatgrass, peren-



Figure 1. Map of the trial sites.

T a b l e 1

The main characteristics of the trial sites

Site/locality	Soil category/ soil type	Altitude [m]	Terrain configuration	Climate	Human dwelling proximity/forest proximity
Site-1/ Malý Horeš	Loamy-sandy soil / light soil	120	Mild slope	Semi-arid	Close/close
Site-2/ Strážne	Clay soil/ heavy soil	100	Total flat	Semi-arid	Close/close
Site-3/ Pozdišovce	Clay-loamy soil/ heavy soil	115	Total flat	Semi-humid	Far away/close
Site-4/ Košický Klečenov	Clay-loamy soil/ heavy soil	340	Slope	Humid	Far away/close

nial rye and cup plant) and in the spring of 2017 (eastern galega, virginia mallow and switchgrass), the stands of the annual crops (amaranth, broomcorn millet and sudangrass) were established in a sequence of three years during spring of 2017 – 2019. All the crops were established by sowing, whereas soil tillage was done into a depth of 24 cm on each site in the autumn followed by high-quality pre-sowing preparation and nutrition treatments were differentiated. Within some of the crops, more than one cultivar was included in the experiment, an overview of the cultivars is part of Tables 4 and 5.

The experimental layout was a randomized block design, whereas the total area of the large-scale experiment was up to 10 ha, and up to 2.5 ha on each of the sites respectively, thus the area of each of crop/cultivar was 0.25 ha per site. None of the crops were treated by zoocide/insecticide or fungicide/ bactericide during the running of the experiment.

Weather and soil-climate data

During the experiment the course of weather as well as soil climate was monitored, the main data are presented in Table 2. The meteorological observation data were obtained from the Slovak Hydrometeorological Institute (SHMÚ meteorological stations closest to each experimental site, the network with officially guaranteed quality of data. The soil-moisture data were taken from the depth of 15 cm twice a day at 00.00 and 12.00 AM, and were measured by Em50 DECALOG Data Logger installed on each site.

Pests and rating, descriptive statistics

The experiment lasted 4 crop years in total, while the perennial crops were terminated in the autumn of 2020 and the annual crops were grown in sequence within 2017 – 2019 only. Over this period (September 2016 – September 2020) the experiment was periodically monitored during the main vegetation season (April – September) and the incidence of pests was recorded, the list of occurred pests is part of Table 3. In the periods out of the main growing season, the experiment was monitored occasionally, while regularly 1 time during the middle of winter. Authentic data was obtained based on visual observation, no pests specimens were collected. The presence of pests was recorded based on the presence of living individuals, or crop damage and the traces only in the case of higher animals.

The incidence of occurred pests was rated by the 9-point scale with values of 1 – 9, where 1 means a rare occurrence or scattered damage and 9 means total damage. The paper presents (i) the most valuable authentic data on the occurrence of recorded pests, and (ii) summarized data on the total incidence/occurrence of the pests. Authentic data are compiled and presented in such a way that all information on crop, cultivar, year, site and assessed pest occurrence can be compared at any time.To obtain the total occurrence/incidence data the descriptive statistics procedure was performed, the simple counting of the authentic cases by the species according to its rated occurrence.

T a b l e 2

The data on weather conditions and soil moisture, during the main vegetation period (from April to September)

Site/year	2017			2018			2019			2020		
Parameter	AT	SP	SM	AT	SP	SM	AT	SP	SM	AT	SP	SM
Site-1	18.2	283	21.0	19.6	225	19.6	19.0	365	20.2	16.9	402	18.3
Site-2	18.0	343	34.2	19.5	252	32.1	19.0	344	32.0	16.9	519	29.5
Site-3	18.2	324	23.7	19.6	245	20.4	18.1	465	31.5	17.3	447	27.8
Site-4	16.5	392	40.6	18.1	276	34.1	16.4	581	40.3	16.0	520	30.3

Note: AT – average daily air temperature [°C]; SP – the sum of precipitation [mm]; SM – soil moisture in the depth of 15 cm [%] of volumetric water content.

T a b l e 3

List of occurred pests in alphabetical order and a typology of the main damage

ABBR	Preferred name	Common name	Typology of main damage
A	*Anisoplia lata* Erichson	Cereal chafer	Eaters on plants
G	*Agriotes lineatus* L.	Wireworm	Eaters on roots
C	*Capreolus capreolus* L.	Roe deer	Grazing of plants, laying of plants
D	*Deroceras agreste* L.	Field slug	Eaters on leaves, netting
L	*Oulema gallaeciana* Heyden	Cereal leaf beetle	Eaters on leaves, leaf feeders (windowing)
E	*Lepisma saccharinum* L.	Silverfish	Larvae/nymphs (grubs) on plants
B	*Lepus europaeus* Pallas	Brown hare	Grazing of plants, shelters making
M	*Meloe proscarabaeus* L.	Oil beetle	Eaters on the roots
F	*Metcalfa pruinosa* Say	Mealy lantern fly	Sucking on plant, potential vector
I	*Microtus arvalis* Pallas	Common vole	Bitten plants, ground nets
P	*Philaenus spumarius* L.	Meadow spittlebug	Sucking on plants, potential vector
Y	*Psylliodes chrysocephala* L.	Cabbage stem flea beetle	Eaters on plants, herbivores
R	*Rhopalosiphum padi* L.	Bird-cherry aphid	Sucking on plants, potential vector
S	Any insect larva or arthropod boring into plant stem	Stemborers	Drilling the stems
U	*Sus scrofa* L.	Wild boar	Digging the soil, knocking down plants
T	*Tettigonia viridissima* L.	Great green bush cricket	Eaters on plants
V	*Trialeurodes vaporariorum* Westwood	Greenhouse whitefly	Sucking on plants, potential vector
W	*Aleyrodes proletella* L.	Cabbage whitefly	Sucking on plants, potential vector

Note: ABBR – abbreviation used in Tables 4 and 5, thus the shortest as possible.

RESULTS

Pests identity, the main and rare species

While running the experiment at least 17 pests' species were recorded in total, the overview of which is part of Table 3. Visual material is presented in Figures 4 – 8, and selected distant footage of the trial situation is added too. Some of the species may represent the identity of the couple or several relative ones, while a short description of the typology of the main damage observed is included as well (Table 3, Figures 6 – 7). The listed species can be considered as common pests under mild climate conditions of eastern Slovakia, which damage traditionally on different field crops as non-specific pests, excluding the *Anisoplia* spp. (Figure 4C) which can be considered as relatively new pests however, no newly introduced pests were recorded within the experiment. Although, there was an extraordinary finding of *Xylena exsoleta exsoleta* L. single caterpillar (Figure 5E) in the buffer zone which consisted of a spring barley belt.

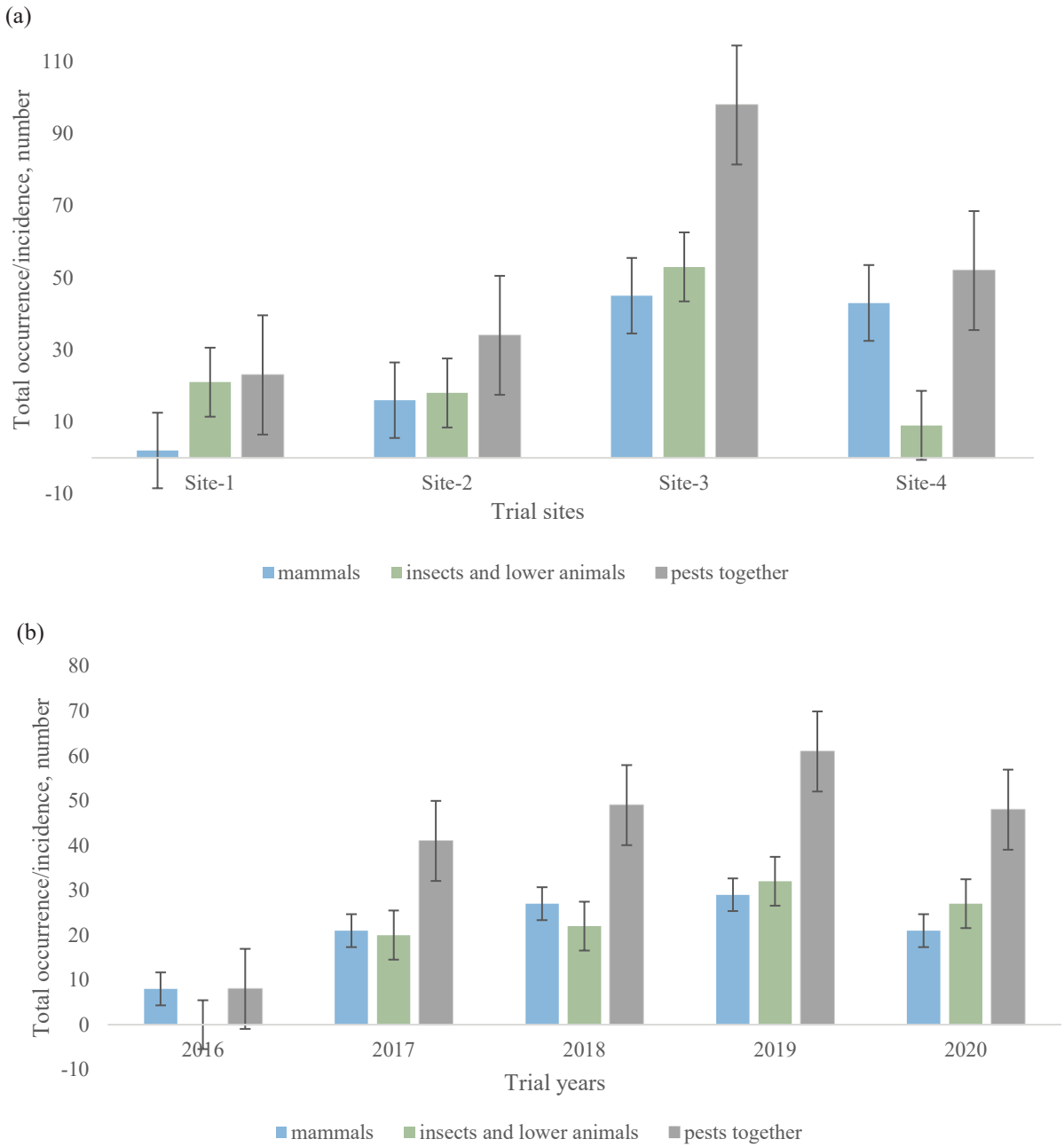


Figure 2. The total occurrence/incidence of the pests according to the sites (a) and years (b), standard deviation added.

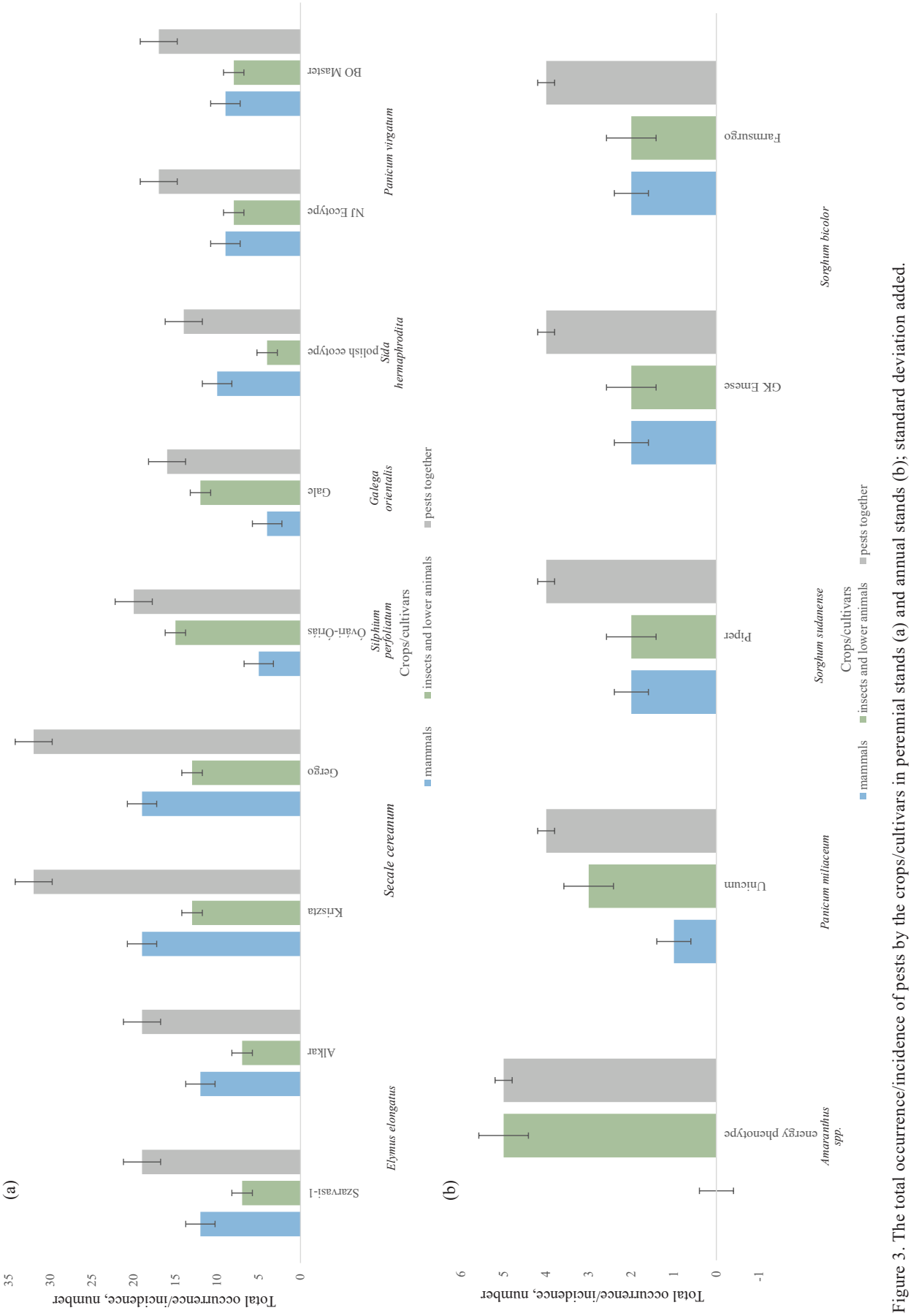


Figure 3. The total occurrence/incidence of pests by the crops/cultivars in perennial stands (a) and annual stands (b); standard deviation added.

Table 4

Rated occurrence of mammal pests, according to crops/cultivars, sites and years, during 2017–2020 and cabbage whitely observed in the summer 2020

Crop /year	Cultivar	2017				2018				2019				2020			
	Site	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Elymus elongatus	Szarvasi-1	–	I1	C1	U1	–	I1	C1	C1	–	I1	–	C1	–	I1	–	C1
	Alkar	–	I1	C1	U1	–	I1	C1	C1	–	I1	–	C1	–	I1	–	C1
Secale cereanum	Kriszta	B1	I1	B1C1	C1	–	I1	B1C1	C1	–	I1	B1C1	C1	–	I1	B1C1	C1
	Gergő	B1	I1	B1C1	C1	–	I1	B1C1	C1	–	I1	B1C1	C1	–	I1	B1C1	C1
Silphium perfoliatum	Óvári-Óriás	–	–	–	C1	–	–	B1	C1	–	–	–	C1	–	*W1	–	C1
Galega orientalis	Gale	–	–	–	C1	–	–	–	C1	–	–	–	C1	–	–	–	C1
Sida hermaphrodita	Polish ecotype	–	–	–	C1	–	–	C1U1	C1	–	–	C1U1	C1	–	–	C1U1	C1
Panicum virgatum	NJ Ecotype	–	–	U2	–	–	–	U3	C1U2	–	–	C1U2	C1	–	–	C1	C1
	BO Master	–	–	U1	–	–	–	U2	C1U1	–	–	C1U1	C1	–	–	C1	C1
Amaranthus spp.	Energy pheno-type	–	–	–	–	nc.	nc.	nc.	nc.	nc.	nc.	nc.	nc.	nc.	nc.	nc.	nc.
Panicum miliaceum	Unikum	nc.	nc.	nc.	nc.	–	–	C1	–	nc.	nc.	nc.	nc.	nc.	nc.	nc.	nc.
Sorghum sudanense	Piper	nc.	nc.	nc.	nc.	nc.	nc.	nc.	nc.	–	–	C1	C1	nc.	nc.	nc.	nc.
Sorghum bicolor	GK Emese	nc.	nc.	nc.	nc.	nc.	nc.	nc.	nc.	–	–	U2	C1	nc.	nc.	nc.	nc.
	Farmsurgo	nc.	nc.	nc.	nc.	nc.	nc.	nc.	nc.	–	–	U9	C1	nc.	nc.	nc.	nc.

Note: B – *Lepus europaeus* Pallas; C – *Capreolus capreolus* L.; I – *Microtus arvalis* Pallas; U – *Sus scrofa* L.; W – *Aleyrodes proletella* L., *insect; nc. – not cultivated; 1–9 – the 9 point scale of rated occurence/incidence, where 1 means a rare occurrence or scattered damage and 9 means total damage.

T a b l e 5

Rated occurrence of insects, slugs and other lower animals, according to crops/cultivars, sites and years, during 2017–2020 and roe deer observed in autumn 2016

Crop /year	cultivar	2017				2018				2019				2020			
	site	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Elymus elongatus	Szarvasi-1	T1	T1	*C2	*C5	–	–	M1R1	–	–	–	R1T1	–	–	–	R1	–
	Alkar	T1	T1	*C2	*C5	–	–	M1R1	–	–	–	R1T1	–	–	–	R1	–
Secale cereanum	Kriszta	A1L1	–	*C2D1	*C5	A1L1	–	R1	–	L1	–	L1R1	–	L1	L1	L1R1	–
	Gergő	A1L1	–	*C2D1	*C5	A1L1	–	R1	–	L1	–	L1R1	–	L1	L1	L1R1	–
Silphium perfoliatum	Óvári-Óriás	–	–	D1	–	V1	V1	L1	–	V1	P1V1	F1P1	–	V1	P1V1	F1V1	–
Galega orientalis	Gale	–	–	–	–	V1	V1	–	–	V1	P1V1	F1P1	–	V1	P1V1	F1V1	–
Sida hermaphrodita	Polish ecotype	–	–	–	–	–	–	–	–	–	–	F1P1	–	–	–	E1F1	–
Panicum virgatum	NJ Ecotype	–	–	G1	G1	–	–	G1	G1	–	–	G1	G1	–	–	G1	G1
	BO Master	–	–	G1	G1	–	–	G1	G1	–	–	G1	G1	–	–	G1	G1
Amaranthus spp.	Energy phenotype	Y1	Y1S1	Y1	Y1	nc.	nc.	nc.	nc.	nc.	nc.	nc.	nc.	nc.	nc.	nc.	nc.
Panicum miliaceum	Unikum	nc.	nc.	nc.	nc.	–	P1	P1R1	–	nc.	nc.	nc.	nc.	nc.	nc.	nc.	nc.
Sorghum sudanense	Piper	nc.	nc.	nc.	nc.	nc.	nc.	–	nc.	–	–	P1R1	–	nc.	nc.	nc.	nc.
Sorghum bicolor	GK Emese	nc.	nc.	nc.	nc.	nc.	nc.	–	nc.	–	–	P1R1	–	nc.	nc.	nc.	nc.
	Farmsurgo	nc.	nc.	nc.	nc.	nc.	nc.	–	nc.	–	–	P1R1	–	nc.	nc.	nc.	nc.

Note: A – *Anisoplia lata* Erichson, D – *Deroceras agreste* L., E – *Lepisma saccharinum* L., F – *Metcalfa pruinosa* Say, G – *Agriotes lineatus* L., L – *Oulema gallaeciana* Heyden, M – *Meloe proscarabaeus* L, P – *Philaenus spumarius* L., R – *Rhopalosiphum padi* L., S – any insect larva or arthropod boring into plant stem, T – *Tettigonia viridissima* L., Y – *Psylliodes chrysocephala* L, V – *Trialeurodes vaporariorum* Westwood; C – *Capreolus capreolus* L., *mammals, observed on emerging stands during autumn of 2016; nc. – not cultivated; 1–9 – the 9 point scale of rated occurence/incidence, where 1 means a rare occurrence or scattered damage and 9 means total damage.



(A)



(B)



(C)



(D)

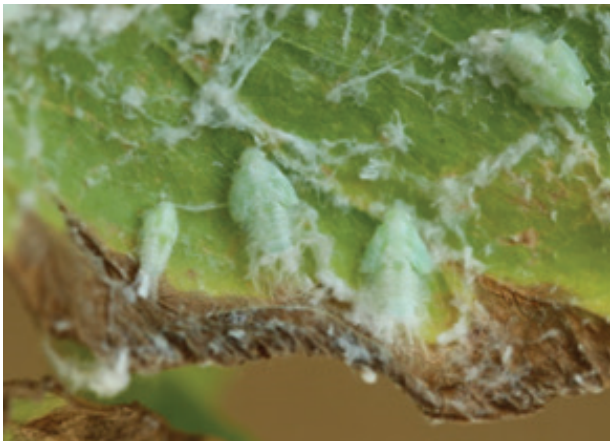


(E)



(F)

Figure 4. A – Imago of oil beetle *Meloe proscarabaeus* L. captured in tall wheatgrass *Elymus elongatus* (Host) Runemark stand on Site-3, Pozdišovce March 2018; B – Colony of bird-cherry aphid *Rhopalosiphum padi* L. on the leaf of tall wheatgrass *Elymus elongatus* (Host) Runemark on Site-3, Pozdišovce Jun 2017; C – Imago of shaggy cereal beetle *Anisoplia villosa* Erichson on the ear of perennial rye *Secale cereanum* on Site-1, Malý Horeš Jun 2017; D – An insect larva boring a stem of amaranth *Amaranthus* spp. on Site-2, Strážne September 2017; E – Froghopper, meadow spittlebug *Philaenus spumarius* L. on leaf of eastern galega *Galega orientalis* Lam. on Site-3, Pozdišovce August 2019; F – Imago of great green bush cricket *Tettigonia viridissima* L. climbing on prolongated ear of tall wheatgrass *Elymus elongatus* (Host) Runemark on Site-1, Malý Horeš Jun 2017; photo: Š.Tóth.



(A)



(B)



(C)



(D)



(E)

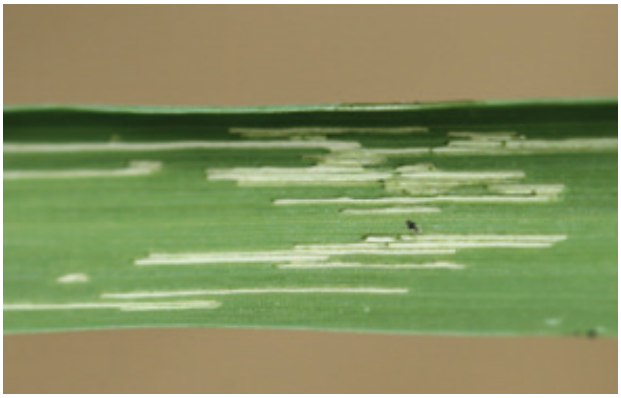
Figure 5. A – Nymphs of mealy lantern fly *Metcalfa pruinosa* Say on a leaf of eastern galega *Galega orientalis* Lam. on Site-3, Pozdišovce August 2020; B – Adult of corn ground beetle *Zabrus tenebrioides* L., captured on the buffer strip on Site-3, Pozdišovce April 2017; C – Imago of cabbage whitefly *Aleyrodes proletella* L. on a stalk of cup plant *Silphium perfoliatum* L. on Site-2, Strážne August 2020; D – Imago of meadow spittlebug *Philaenus spumarius* L. on a stalk of cup plant *Silphium perfoliatum* L. on Site-2, Strážne August 2020; E – The extra-ordinary finding of single caterpillar *Xylena exsoleta exsoleta* L. in spring barley buffer strip on Site-3, Pozdišovce May 2020; photo: Š.Tóth.



(A)



(B)



(C)



(D)



(E)



(F)

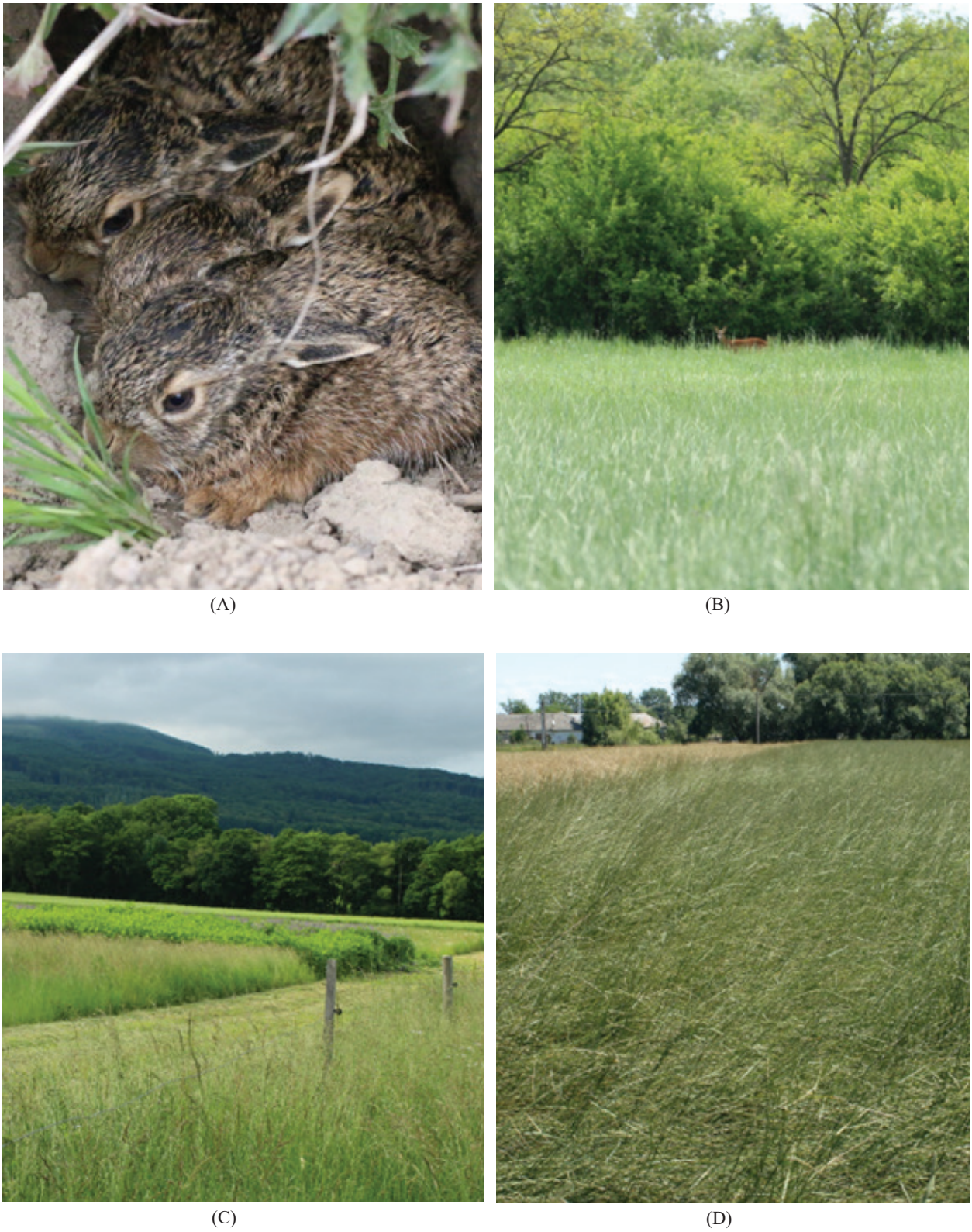
Figure 6. A – Eaters on leaves in the early growth of amaranth *Amaranthus* spp. caused by cabbage stem flea beetle *Psylliodes chrysocephala* L. on Site-2, Strážne May 2017; B – Elongated eaters caused by field slug *Deroceras agreste* L. during wet conditions on seedling of perennial rye *Secale cereanum* on Site-3, Pozdišovce September 2016; C – Prolongated eaters on leaves typical for cereal leaf beetle *Oulema gallaeciana* Heyden on the a leaf of perennial rye *Secale cereanum* on Site-1, Malý Horeš May 2018; D – Field slug *Deroceras agreste* L. eaters on seedling of cup plant *Silphium perfoliatum* L. on Site-3, Pozdišovce May 2017; E – Ground nests of common vole *Microtus arvalis* Pallas built newly in perennial rye *Secale cereanum* stand on Site-2, Strážne October 2019; F – Above ground nest of harvest vole *Micromys minutus* Pallas built on stalks of tall wheatgrass *Elymus elongatus* (Host) Runemark on Site-2, Strážne August 2017; photo: Š.Tóth.



(A) (B)

(C) (D)

Figure 7. A – Severe traces of extremely overpopulated roe deer *Capreolus capreolus* L. in emerging stands of tall wheatgrass *Elymus elongatus* (Host) Runemark on Site-4, Košický Klečenov November 2016; B – Pathway and resting place of roe deer *Capreolus capreolus* L. in stands of switchgrass on Site-4, Košický Klečenov September 2019; C – Total demolition of the stand of *Sorghum bicolor* L. variety of Farmsurgo caused by a herd of wild boar *Sus scrofa* L. on Site-3, Pozdišovce September 2019; D – Digging of wild boar *Sus scrofa* L. on the verge of stands of switchgrass *Panicum virgatum* L. on Site-4, Košický Klečenov February 2018; photo: Š.Tóth.



(A) (B)

(C) (D)

Figure 8. A – Young field hare *Lepus europaeus* Pallas in a ground nest under the stand of tall wheatgrass *Elymus elongatus* (Host) Runemark on Site-3, Pozdišovce March 2017; B – Adult of roe deer *Capreolus capreolus* L. in cautious attitude as disturbed on a distance of 150 m on the verge of the stand of tall wheatgrass *Elymus elongatus* (Host) Runemark and forest nearby on Site-3, Pozdišovce May 2019; C – From early spring, with the exception of the year of establishment, stands of perennial energy crops are characterized by higher growth, therefore providing shelter for wild animals as a source of food, Site-4, Košický Klečenov May 2020; D – Proximity of human dwelling, probably the most important factor affecting the total rare occurrence of hunting wild animals on Site-2, Strážne July 2020; photo: Š.Tóth.

Like stemborers (Figure 4D), which is the common name for any insect larva or arthropod that bores into plant stems, the observed occurrence of the most common roe deer *Capreolus capreolus* L. (Figure 8B) may represent species such as red deer *Cervus elaphus* L. or fallow deer *Cervus dama* L., which are less common and were rarely recorded on the monitored experimental sites. The same can be valid for

1. bird-cherry aphid *Rhopalosiphum padi* L. representing several aphid species,
2. also field slug *Deroceras agreste* L. can represent a couple of slugs spp.,
3. while oil beetle *Meloe proscarabaeus* couple of *Meloe* spp.,
4. as well cereal chafer *Anisoplia lata* Erichson couple of chafers,
5. wireworm *Agriotes lineatus* L. represents a couple of *Agriotes* spp. and corn ground beetle *Zabrus tenebrioides* L.,
6. cabbage stem flea beetle *Psylliodes chrysocephala* L. may represent a couple of *Phyllotreta* spp. and several *Chaetocnema* spp.,
7. cereal leaf beetle *Oulema gallaeciana* Heyden represents the less common wheat leaf beetle *Lema cyanella* L.,
8. meadow spittlebug *Philaenus spumarius* L. can represent other froghoppers or many leafhoppers as weed leafhopper *Psammotettix alienus* L.,
9. great green bush cricket *Tettigonia viridissima* L. can represent several grasshoppers,
10. and cabbage whitefly *Aleyrodes proletella* L. may represent greenhouse whitefly *Trialeurodes vaporariorum* Westwood.

Furtherly, the observed common vole *Microtus arvalis* Pallas is the most common/frequent vole, which represents less frequent spp. as water vole *Arvicola terrestris* L., which stays on fields especially near watercourses, or harvest vole *Micromys minutus* Pallas, which occurs only in a few locations in the southern regions of Slovakia as in other voles. Also, the common hamster *Cricetus cricetus* L., which is included in the list of protected species has not been identified however in the past it was abundant and was able to cause considerable damage. This can currently also be a threat if the common hamster occurs locally and proliferates, which can happen especially in the stands of some perennial grasses. Like none the occurrence of the very rare common hamster, there was recordec no occurrence of European mole *Talpa europaea* L., otherwise a very common and expected pest.

Pests rating

Data on the rate of recorded pests' occurrence, and the intensity of damages respectively, are presented in Tables 4 and 5 according to the crops, sites and years, while the tested cultivars were monitored separately as are listed. Overall, despite the comprehensiveness of the monitoring consisting of the considerable extent of the experiment and its relatively long period time, the incidence of pests was low with a small exception (Table 6).

Mammals

Most harmful

The pest with the highest level of damage was the wild boar *Sus scrofa,* whose herd was able to eliminate the experimental stand of great millet *Sorghum bicolor,* while it was selectively the Farmsurgo cultivar at Site-3, whereas the nearby stand of grain millet *Sorghum bicolor* cultivar of GK Emese was less damaged on the site. The stand of Farmsurgo cultivar was completely destroyed in the phenophase of technological maturity when a few days before planned harvest the plants were heavily eaten and their remains were rolled down and left lying on the ground, or they were trampled down into the soil and their machine harvest was impossible.

A second and more frequent type of damage caused by the wild boar was tearing up the soil and damaging the roots of plants. Such damage appeared in both locations, which were characterized by a greater distance from human dwellings, in the stands of several crops and especially of perennial ones and were more typical for the period outside the main growing season. The switchgrass cultivar of NJ Ecotype was the most affected by wild boar digging, after the first and second main growing seasons at Site-3, where Farmsurgo was damaged totally.

Most frequent

In general, the most frequently occurring pests

T a b l e 6

The total occurrence/incidence of the pests according to the rating scale as the authentic occurrence on the trial sites was achieved by the species during the trial period from autumn 2016 till autumn 2020

Pest / occurrence	1	2	3	4	5	6	7	8	9
Mammal species									
Lepus europaeus Pallas	11	–	–	–	–	–	–	–	–
Capreolus capreolus L.	56	4	–	–	4	–	–	–	–
Microtus arvalis Pallas	16	–	–	–	–	–	–	–	–
Sus scrofa L.	8	5	1	–	–	–	–	–	1
Insects, slugs and other lower animals									
Anisoplia lata Erichson	4	–	–	–	–	–	–	–	–
Aleyrodes proletella L.	1	–	–	–	–	–	–	–	–
Deroceras agreste L.	3	–	–	–	–	–	–	–	–
Lepisma saccharinum L.	1	–	–	–	–	–	–	–	–
Metcalfa pruinosa Say	6	–	–	–	–	–	–	–	–
Agriotes lineatus L.	16	–	–	–	–	–	–	–	–
Oulema gallaeciana Heyden	15	–	–	–	–	–	–	–	–
Meloe proscarabaeus L.	2	–	–	–	–	–	–	–	–
Philaenus spumarius L.	12	–	–	–	–	–	–	–	–
Rhopalosiphum padi L.	16	–	–	–	–	–	–	–	–
Stemborers	1	–	–	–	–	–	–	–	–
Tettigonia viridissima L.	6	–	–	–	–	–	–	–	–
Psylliodes chrysocephala L	4	–	–	–	–	–	–	–	–
Trialeurodes vaporariorum Westwood	12	–	–	–	–	–	–	–	–

Note: – without record.

were the roe deer *Capreolus capreolus* L., the common vole *Microtus arvalis* Pallas, and the field hare *Lepus europaeus* Pallas. Mainly the populations of tall wild animals in Slovakia have been characterized for a long time by multiple overpopulations, while their harmful occurrence is only difficult to bear for many common field crops. As roe deer and field hare individuals grazed the stands of each energy crop, alternately preferring the crops according to their own choice and also temporally, probably according to the phenophase of the crops and the presence of other feed. From grazing damage, plants were able to regenerate depending on to what extent and when their parts were eaten. Plants that were eaten by voles were only able to regenerate to a lesser extent and usually only by forming new shoots from underground parts.

The second category of damage, caused by the common vole, roe deer and field hare to a greater frequency than in wild boar, was the creation of ground nets, resting places and shelters, probably within the closer study of which certain preferences may also appear later.

Insects, slugs and other lower animals

In general, the most frequent insect pests were the wireworm beetle *Agriotes lineatus* L. and the cereal leaf beetle *Oulema gallaeciana* Heyden, which occurred in each of the four sites, especially in the stands of grassy crops. Both adults were not charac-

terized by high harmfulness, however, the wireworms, as the larvae developing in the soil damaged the roots of the plants to a greater extent. The occurrence of wireworms may be related to damage caused by wild boars, which are probably searching for larvae when digging the ground.

The rape-flea beetle *Psylliodes chrysocephala* and stemborers occurrence was crop-specific, the eating of leaves by the flea beetle was recorded mainly on young plants of amaranth and appeared on each of the sites, while the damage caused by stemborers appeared only at one of the sites and was recorded on pre-mature plants in the second half of the growing season. Also, the occurrence of cereal chafer *Anisoplia lata* was crop- and site-specific, whose imagos were recorded only in one of the sites and concerned only with both cultivars of perennial rye.

The occurrence of the cabbage whitefly *Aleyrodes proletella* L. was observed on a stalk of cup plant and eastern galega on Site-1 and Site-2 regularly from 2018. The occurrence of greenhouse whitefly *Trialeurodes vaporariorum,* as well as silverfish *Lepisma saccharinum,* was recorded on several crops, but also only on one of the sites (Site-3), especially greenhouse whitefly in the period time of the year that was characterized by a higher temperature, or moth fish under wetter weather respectively. The occurrence of the bird-charry aphid was also the most typical of the same site in general, probably, because of the intermediate host plant *Prunus padus* growing nearby, while it was recorded on several crops and especially on both cultivars of tall wheatgrass and, similarly on cultivars of perennial rye. On the contrary, the occurrence of the mealy lantern fly *Metcalfa pruinosa* concerned only the same single site and in particular stands of eastern galega and virginia mallow, but it was rather only a rarity than a scattered occurrence and represented a diversification of observations mainly during the warm and wet season of late spring till early summer. Mainly, wet conditions were typical for the appearance of the field slug *Deroceras agreste,* which damaged different crops, but especially the leaves of young plants of both cultivars of perennial rye.

DISCUSSION

Overall, the occurrence of the pests was regular and scattered, whereas their harmfulness was usually negligible, however, the destruction of the stand was also recorded even as variety specific. Most meaningful pests were primarily field-hunting animals and only secondarily some of the commonly occurring insect species that damage as a rule different field crop stands, excluding the *Anisoplia* spp. as relatively new pests.

Despite expectations, the occurrence of some common and non-specific pests was not recorded, while on the contrary, the occurrence of some pests was surprising and may be considered as a site-specific rarity, as mainly concerns harvest vole *Micromys minutus* and to some extent also the herd of fallow deer *Cervus dama* even with an albino individual.

Although no newly introduced pests were observed, the single finding of the sword-grass moth individual caterpillar can be considered as the most extraordinary record of the experiment. The caterpillar was found in a buffer strip with the spring barley at Site-3 Pozdišovce in Jun 2020, more precisely on the lower stem part of spring barley plant in the phenophase of milky maturity, on which it was just feeding. The plant was markedly damaged by the eating, the caterpillar was discovered while checking the cause of the damage. Due to the specifics, the finding can be considered to be a rarity, whereas the possible causalities of which are not further investigated, and the caterpillar is not included among the listed pests.

Finally, it can be also discussed that in the previous papers based on small-plot experiments based on the better-protected research base with some of the crops solved within the presented work based on large-scale semi-operational trials, the presence of no pests was observed (Kron *et al.* 2017; and many other papers).

Higher animals

By Mikulka *et al.* (2018), Machálek *et al.* (2018) and Gubka *et al.* (2021) wild boar *Sus scrofa* belongs to problematic species of European ecosystems, always consuming at least one of energy-rich

foods, a traditional one if is available and if not a supplementary feed often substituted for nutritionally whereas predominantly maize was always preferred. Wild boars can consume the whole forest crop, depending on their population and the size of the crop. The present work confirms certain preferences of wild boars (mainly damage of great/grain millet *Sorghum bicolor* on Site-3 in 2019) when the tested energy crops are considered. Concerning digging (mainly damage of switchgrass *Panicum virgatum* on Site-3 in 2017 and 2018) one of the objects of wild boar most probably can be the wireworm beetle *Agriotes lineatus* L. whose larvae developing under ground and which the wild boars are searching for.

In the study of Purger *et al.* (2008), were tested the dominant nest predators of bird species using artificial ground nests. Each of the nests contained one plasticine dummy egg. The artificial plasticine eggs were placed for predator identification from tooth and bill imprints. A significantly higher proportion of plasteline eggs were damaged in wheat *Triticum* spp. (80%) than in tall wheatgrass *Elymus elongatus* (48%), and small mammal abundance was higher in wheat (80%) than in tall wheatgrass (33%). However, the major predators in wheat were birds (16%) and mammals (84%), while in tall wheatgrass all predation (100%) was caused by mammals. Although the majority of nests were destroyed by red fox *Vulpes vulpes*, there was no significant difference between the types of predators in the two habitats, wheat and tall wheatgrass. Although the East Slovak Lowland and the close areas are exceptionally important from the point of view of the occurrence of bird species (Repel 2021), the specifics of bird species occurrence in stands of energy crops have not yet been investigated.

It can be assumed that the occurrence of some difficult-to-see insect pests can most likely be indicated by the presence of otherwise harmless birds, e.g., wireworms as well as corn ground beetle belongs to the most common insect pests that occur and are sought after by birds. If the field is infested with insect pests with voracious larvae that develop underground, such as wireworms, the success of establishing energy crops can be questionable because the emerging seedlings are usually the most threatened by such pests.

Insect pests

The level of grain losses because of cereal chafer depends on the phase of grain formation in the ears (Mendigaliyeva *et al.* 2018). In the phases of the formation of milk and milk-wax stage of ripeness, grain losses consist of grains eaten from inside by the beetle of the *Anisoplia austriaca*. The plants can no compensate for the damage caused by beetles in the period of formation-ripening of grain, when the number of beetles reached 5.5 to 7.0 specimens/m^2, which exceeded the economic threshold of damage and, therefore, the chemical treatment of crops was carried out. The occurrence of this pest has been recorded so far only on perennial rye, where it can cause significant damage most probably on seed stands mainly. The presented research shows that the occurrence of this pest has been recorded so far only on perennial rye, where it can cause significant damage most probably on seed stands mainly.

Study by Cagáň *et al.* (2006) documents the occurrence of the sugarbeet flea beetle *Chaetocnema tibialis* and barley flea beetle *Phyllotreta vittula* on cultivated and weedy amaranth plants (*Amaranthus caudatus* and *Amaranthus retroflexus*) in Slovakia. The authors found out, that a negative effect on populations of the beetles had low temperatures in the winter and high temperatures in the summer. A serious pest of amaranth is *Myzus persicae* (Seni 2018) also known under the name green peach aphid. Dry weather conditions, which are typical of the East Slovak Lowland, are favourable for aphids and the heavy rainfall decreases their numbers on plants of amaranth. The nymphs and adults of *Myzus persicae* sucking of plant sap from amaranths and the result is yellowing and drying of their leaves. The presented research documents the occurrence of further three insect pest species. *Panicum virgatum* has its own pests that can harm or even destroy the plant. *Blastobasis repartella* was common in plots *Panicum virgatum* has grown for 5 years and the polyphagous *Papaipema nebris* was located in newly established stands of *Panicum virgatum* (i.e., first and second year). *Blastobasis repartella* is a moth in the family *Blastobasidae* and *Papaipema nebris* is a moth of the family *Noctuidae*. By Prasifka *et al.* (2011), the larvae perforate the proaxis, basal nodes, and internodes of above-ground stems of *Panicum virgatum* and the result is damage or decomposition of plants.

None of both the moth species was recorded within the research submitted however, permanent monitoring and continuous observations are needed in the future.

Sida hermaphrodita is susceptible to certain pests. By Pszczółkowska *et al.* (2012), the possible insect pests of *Sida hermaphrodita* are *Coreus marginatus*, *Lygus bugs* and *Aphis fabae*. None of these pests have been confirmed.

CONCLUSIONS

This paper documents the occurrence of pests species recorded in a huge system of large-scale pilot field experiments, where a set of energy crops, as the majority of them newly introduced, was tested under climatic conditions of eastern Slovakia. A total of 14 cultivars were tested, whereas growing them on 4 sites with marginal soils for 4 years from autumn 2016 till autumn 2020. While running the experiment at least 17 species of pests were recorded in total, whereas the occurrence of pests was regular and scattered, damages caused by them were usually negligible, but the destruction of a crop stand even crop/variety-specific was also recorded. Many of the meaningful pests is primarily field hunting animals and only secondarily commonly occurring insect species, which for further observations are desirable in order to capture the tendency of important pests' overpopulation, and to confirm the pest status respectively. Even though some rare findings were also recorded in a buffer zone, no newly introduced pest species were recorded during the experiment however, what also requires further monitoring. In the previous small-plot experiments with some of the crops tested within the presented work, the presence of no pests was recorded while tested on a better-protected research base. Concerning the small-plot versus large-plots phenomenon, it can be concluded, that the professional monitoring of productive plantations of energy crops is required too, due to the conditions of large areas being more diverse. Thus, the pest status of occurred species will show up earlier, whether existing common species or an undesired newly introduced species.

Acknowledgements. This research was done with the support of HORIZON 2020 / FLAGSHIP project BIOSKOH ID: 709557 BBI-FLAG Innovation Stepping Stones for a novel European Second Generation BioEconomy support and Operational Programme Integrated Infrastructure within the project: Sustainable smart farming systems considering the future challenges 313011W112, co-financed by the European Regional Development Fund.

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Received: April 24, 2023
Accepted: August 23, 2023