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Cabbage maggot *(Delia radicum)* as a potential rapeseed (*Brassica napus* L.) pest in the Czech Republic. Can we make use of the German experience?

Die Kohlfliege *(Delia radicum)* als potenzieller Schädling an Raps in der Tschechischen Republik. Nutzen wir Erfahrungen aus Deutschland?

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Abstract

Cabbage maggot *(Delia radicum)* belongs to one of the most significant pests of Brassicaceae vegetables (especially cauliflower) in the Czech Republic. Nowadays, it is also presented as a potentially major pest of rapeseed (*Brassica napus* L.). This work provides a historical overview of the cabbage maggot's occurrences on Brassicaceae vegetables in the Czech Republic territory up to the year 2005. In addition, it offers a prognosis of this pest's prospective spread. Based on the German experience, it can be assumed that the high concentration of rapeseed will cause a considerable spread of the cabbage maggot, and consequently, it will lead to an increase in the economic injury. Therefore, Czech growers are faced with another serious problem – there are no pesticides registered for the rapeseed usage to protect rapeseed plants against the cabbage maggot. However, the possibility of using rapeseed-registered pesticides against this crop's other pests is one of the solutions at hand. Moreover, other countries' observations may be successfully employed in an effort to solve this problem. In these countries, the damage caused by the cabbage maggot has been reduced by modification of the growing technology.

Key words: *Delia radicum*, cabbage maggot, spread, occurrence, rapeseed, canola, damage, prognosis, historical overview, Czech Republic

Zusammenfassung

Die Kohlfliege *(Delia radicum)* gehört in der Tschechischen Republik zu den bekanntesten Schädlingen der Kohlgemüse (vor allem des Blumenkohls). Gegenwärtig findet man die Kohlfliege auch als einen potentiellen Schädling an Raps *(Brassica napus* L.). Der vorliegende Beitrag bietet einen historischen Rückblick zum Vorkommen des Schädlings auf Kohlgemüse bis zum Jahr 2005 und eine Prognose zum Vorkommen an Raps. Fußend auf den Erfahrungen in Deutschland ist davon auszugehen, dass sich der Schädling in der Tschechischen Republik - wegen der großen Konzentration der Flächen mit Raps – in dieser Kultur stärker ausbreiten wird und damit auch die wirtschaftlichen Schäden zunehmen werden. Ein weiteres Problem ist: Gegen diesen Schädling gibt es zurzeit noch kein zugelassenes Insektizid. Es können aber zugelassene Insektizide, die gegen andere Schädlinge an Raps bestimmt sind, angewandt werden. Wir können Erfahrungen aus anderen Ländern nutzen, in denen die Kohlfliege durch eine Modifikation der Anbautechnologie eliminiert wird.

Stichwörter: *Delia radicum*, Kohlfliege, Verbreitung, Vorkommen, Raps, Schaden, Prognose, historischer Rückblick, Tschechische Republik

Introduction

Cabbage maggot *(Delia radicum)* belongs to major pests of Brassicaceae vegetables (namely cauliflower) in the Czech Republic, it is also a major radish pest (KAZDA et al., 2001). Moreover, it is presently reported to be a potentially significant rapeseed (*Brassica napus* L.) pest in some localities (KAZDA and FÁBRY, 2005).

The aim of this work is to compile a historical overview of significant cabbage maggot occurrences on Brassicaceae vegetables and rapeseed, and to work out a prognosis of the prospective spread of this pest in individual regions of the Czech Republic based on the gathered data.

Mapped cabbage maggot *(Delia radicum)* occurrences on Brassicaceae vegetables

The obtained data are divided into three time periods: 1923 to 1941, 1950s, and 1961 to 2005.

1923 to 1941

There are random data obtained from the Protection of Plants magazine available for this period of time (The Protection of Plants magazine uses the Latin term *Chortophilla brassicae* when referring to cabbage maggot). Cabbage maggot occurrences that had a significant economic impact are displayed in Figure 1. Damage was registered especially in fields that had been fertilized by fresh manure as this is where the destructive insect frequently lays its eggs.

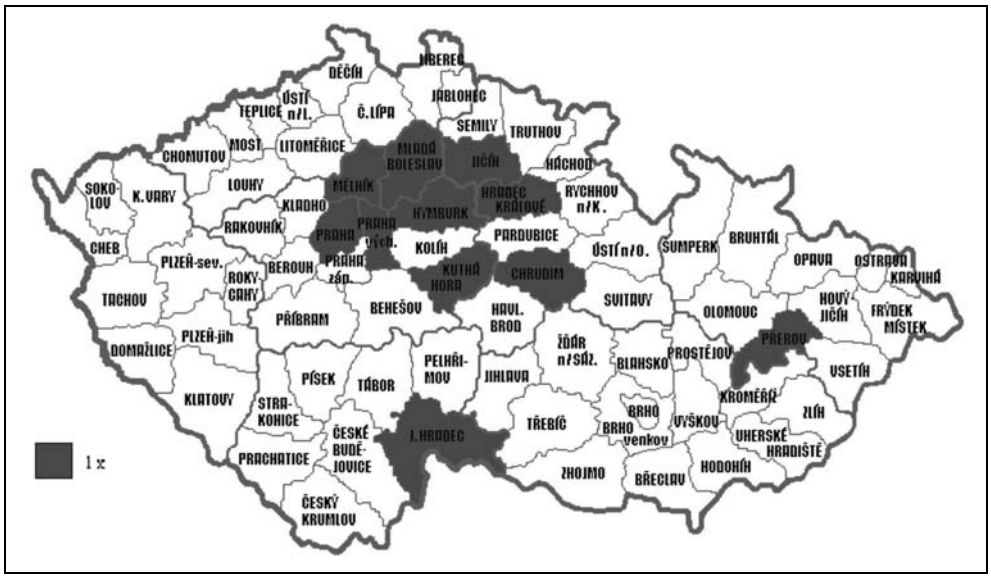

Figure 1.Harmful occurrences of cabbage maggot on Brassicaceae vegetables in the Czech Republic in 1921-1945 (sorted by the region, incomplete data).

Figure 2.Harmful occurrences of cabbage maggot on Brassicaceae vegetables and kale in the Czech Republic in 1961-2005 (sorted by the region; source: SPA Prague, CISTA Brno).

At that time, protective cuffs made of tar paper proved an effective means of plant protection against the cabbage maggot. These cuffs were put around young cole crops immediately after planting. The downfall of the described method of protection was the relatively high price of the cuffs (Anonymous author, 1924; Anonymous author, 1941; BLATTNÝ et al., 1941; BLATTNÝ et al., 1942; ROBEK et al., 1931; ROZSYPAL, 1942; SMOLÁK, 1925; STRANÁK et al., 1931; STRANÁK et al., 1932).

STRANÁK (1923) recommended a number of low-cost protective methods: grey sulphur, gasworks water, crushed peat, crushed wood impregnated by petroleum or carbolineum, lime paste, tobacco powder, and removal of the attacked plants. In addition, STRANÁK (1923) warned that cabbage maggot could cause up to 100% loss of Brassicaceae vegetables in some localities.

According to NOVÁK (1927), the number of cabbage maggot's generations depends upon climatic factors, and there are usually three generations per year. The most significant damage is caused by the first generation. Furthermore, NOVÁK (1927) presents results of an experiment, in which virtually all plants of cauliflower were severely damaged by the cabbage maggot but the plants of cabbage were not.

1950s

According to the 1950s' literature (for example, MILLER, 1956), the cabbage maggot occurred across the whole European region. By the end of the 19th century, it had spread in North America, where, likewise in Europe, it became one of the major pests. In 1950 s, cabbage maggot was considered a significant pest of cole crops. Cauliflower (*Brassica oleracea* L. convar. *botrytis* (L.) Alef. var. *botrytis* L.) was regarded the most frequently attacked cole crop species, followed by kohlrabi (*Brassica oleracea* L. convar. *acephala* (DC.) Alef. var. *gongylodes*), savoy cabbage and Brussels sprouts (*Brassica oleracea* L. convar. *capitata* (L.) Alef. var. *sabauda; Brassica oleracea* L. convar. *oleracea* var. *gemmifera* DC.) and cabbage (*Brassica oleracea* L. convar. *capitata* (L.) Alef.). Rapeseed (*Brassica napus* L.) was considered an occasional cabbage maggot's host plant only. An emulsion that consisted of 0.15% of carbolineum, DDT, and naphthalene was recommended to be used for the vegetables protection. It was also adviced that all the post-harvest residue should be burnt or composted with slacked lime. This process killed larvae and pupae that would have otherwise survived in the residue over winter. The suggested

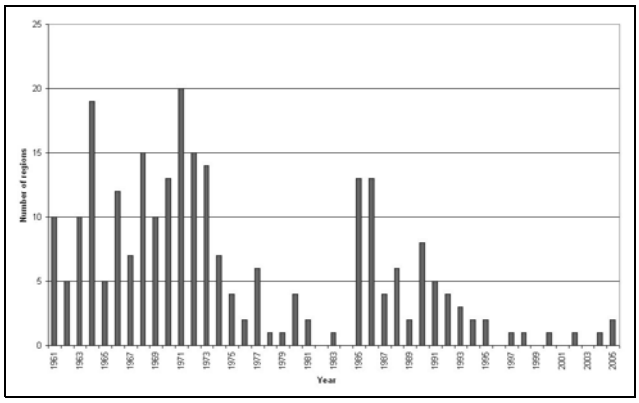

Figure 3.Numbers of regions with harmful occurrences of cabbage maggot on Brassicaceae vegetables and kale in the Czech Republic in 1961-2005 (source: CISTA Brno, SPA Prague).

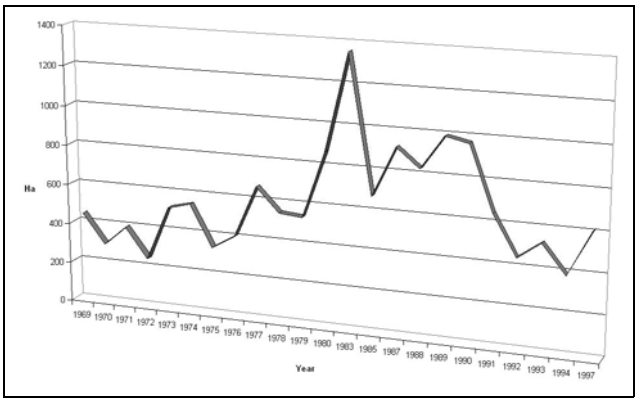

Figure 4.Area of Brassicaceae vegetables treated for cabbage maggot in the Czech Republic in 1969-1997 (in Ha; source: CISTA Brno, SPA Prague; incomplete data).

plant-growing measures included the removal of weeds of the cruciferous family and switching to autumn (instead of spring) farmyard manure fertilization as the smell attracts adult flies. Moreover, the 1950s sources advocated the application of potassium salt, calcium cyanamide, or ammonium sulphate 14 days prior planting.

In 1950 s, farmers stopped using the tar cuffs method due to its highly inconvenient application procedure (SMOLÁK, 1955).

1961 to 2005

A summary of surveys called "Some Pests and Diseases of Cultivated Plants Occurring in Czechoslovakia (in the Czech Republic)" from 1961 – 2005 sums up harmful occurrences of the cabbage maggot in the Czech Republic territory. The book was published by CISTA Brno and Bratislava (Central Institute for Supervising and Testing in Agriculture Brno and Bratislava). Since 1990, the data has only been published by the SPA Prague (State Phytosanitary Administration Prague). All the above-mentioned sources are purely informative in nature, and do not cover all cases of harmful occurrences of the cabbage maggot in the Czech Republic.

Figure 2 displays harmful occurrences of the cabbage maggot. Additionally, it presents graphs showing the number of regions where damage on Brassicaceae vegetables took place, as well as the area of Brassicaceae vegetables treated for the cabbage maggot in 1969 – 1997 (Figure 2–4).

The lower extend of damage on Brassicaceae vegetables is currently caused by the reduction of Brassicaceae-growing areas.

We present, for instance, the white cabbage (*Brassica oleracea* L. convar. *capitata* (L.) Alef. var. *alba* DC.) data: in 1999, this crop was grown on an area of 3, 788 ha in the Czech Republic, while in 2006, it was grown on 1, 310 ha only (BUCHTOVÁ, 2006).

Harmful occurrences of cabbage maggot on rapeseed

In the Czech Republic, cabbage maggot was not considered a major rapeseed pest up to 1993. In „Some Pests and Diseases of Cultivated Plants Occurring in Czechoslovakia (in the Czech Republic)" from 1961 to 2005, it is claimed to be only an occasional rapeseed pest in the course of the following years: 1994, 2000, and 2003 (the occurrences are shown in Figure 5 and 6.). Figure 6 - that displays cabbage maggot's harmful occurrences in rapeseed - confirms that this pest damaged this crop since 1995 only. Moreover, a slow increase in the severity of the damage is apparent.

Some authors of the annual summary of the rapeseed pests' occurrences (1990-2000), for example, KOPRNA (2001), do not mention cabbage maggot at all. However, in the subsequent period, it was referred to as a potential rapeseed pest in the Czech Republic in many texts (KAZDA and BARANYK, 2001; KAZDA and FÁBRY, 2005; HRUDOVÁ, 2003; ŠEDIVÝ, 2005).

Since 2005, areas of significant harmful occurrences of cabbage maggot have been specified. The increase in the cabbage maggot's emergence is related to the ever-increasing fields of rapeseed and Brassicaceae intercrops. For example, in 2006-2007, more than 350, 000 ha of land was seeded with Brassicaceae crops, mainly the winter rapeseed, and it has been predicted that the size of these areas would be growing in the future. Yet, cabbage maggot has been a very harmful pest in countries (Germany, Poland, France, Canada) with a high concentration of Brassicaceae crops (KAZDA and FÁBRY, 2005).

Details concerning cabbage maggot occurrences in individual years are stated below (MADAR, 2004; NOVÁK et al., 2000; VOŠTA et al., 2001):

1994 – 20% of roots were damaged by cabbage maggot's larvae in the Malý Bor locality (the Klatovy region).

2000 – In October, random high occurrences of cabbage maggot were found in the Hradec Králové region.

2003 – Scarce occurrences of larvae in roots were found in small fields in the regions of Hodonín and Ždár nad Sázavou from 9th to 15th June. A moderate larvae occurrence in roots was found from 2nd to 8th June in the Ždár nad Sázavou region (Jámy, Hlinné). Additionally, a moderate occurrence was locally found from 16th to 22nd June in the Olomouc region. Another high but sporadic occurrence of cabbage maggot's larvae in roots was recorded from 1st September to 5th October in the Opava region.

2005 – In autumn, a higher occurrence was observed in East Bohemia in the Hradec Králové and Pardubice regions, parts of the Náchod region – the neighbouring part of the Hradec region, also in Chrudim – except for a part of Hlinecko and a part of the Ústí nad Orlicí region (mainly Vysoké Mýto). A higher occurrence of cabbage maggot was recorded in the Bohemian-Moravian region, namely in the area of Vlašim, in the Jihlava and Trebíc regions. In the west Bohemian region, the highest larvae occurrence on rapeseed's roots was found in the warm area of Stankov (the Domažlice region). In autumn 2005, the number of plants that were extensively attacked by the maggots was reduced by up to 30%.

In 2006, Kazda monitored occurrences of cabbage maggot on rapeseed in Bohemian-Moravian Highlands. The occurren-

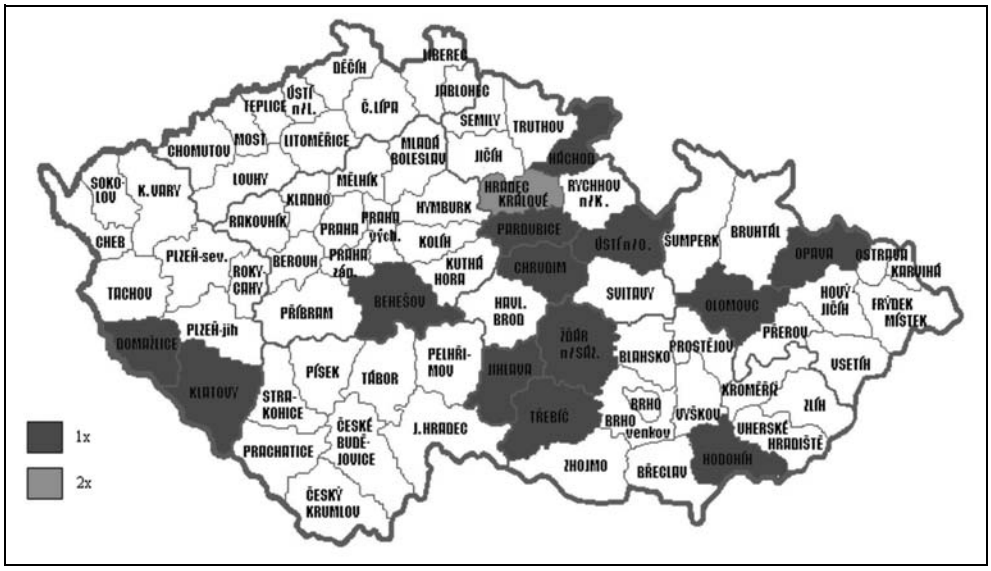

Figure 5.Harmful occurrences of cabbage maggot on rapeseed in the Czech Republic in 1961-2005 (sorted by the region; source: CISTA Brno, SPA Prague, Union of Oilseeds Growers and Processors Prague).

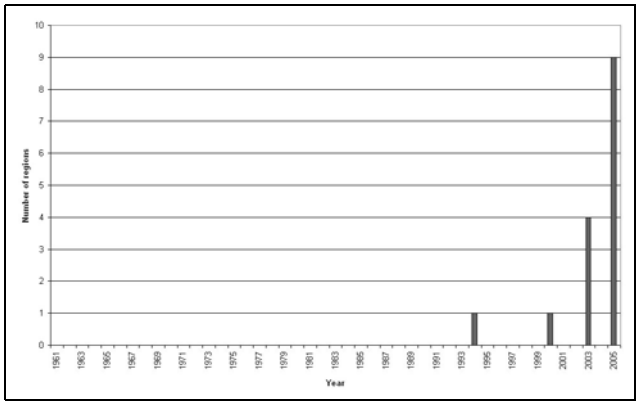

Figure 6.Numbers of regions with harmful occurrences of cabbage maggot on rapeseed in the Czech Republic in 1961-2005 (source: CISTA Brno, SPA Prague).

ces were not disastrous in nature and the pest did not cause a major injury. Cabbage maggot preferably infested well-developed plants. Their habitus bore the reminiscence of Brassicacae crops that are more commonly attacked by this pest.

The occurrence of the cabbage maggot on the rapeseed vegetation is influenced by the concentration of rapeseed fields as well as the distance of the newly seeded rapeseed from the previous year's rapeseed field. It may also be concluded that warmer regions are more susceptible to the occurrence of cabbage maggot. All cabbage maggot occurrences have only been systematically monitored on the winter rapeseed so far, the spring rapeseed has not been examined in relation to this pest yet (KAZDA and FÁBRY, 2005).

Larvae can be found on the roots of the winter rapeseed throughout its vegetation. They usually do not inflict any direct damage to the roots from April to the time of harvest. However, the damage caused by cabbage maggot is sometimes put in connection with the extensive attack on the roots by fungus *Verticilium* sp. On the contrary, the occurrence of cabbage maggot in autumn may cause the death of the plants in autumn or in the course of the overwintering period due to the weakened root system. The first generation of cabbage maggot causes the most significant damage to rapeseed, just like to Brassicaecae vegetables. Once the taproot is infested, the affected plants are easy to pull out of the soil. If the weather is dry, it is possible that even moderately infested plants might be damaged because its newly formed substitute roots are not able to compensate for the original taproot. If the weather is humid and warm, the roots may be attacked by soil fungi – *Lephtosphaeria maculans* and *Verticiulium dahlidae*.

The prognosis of the cabbage maggot occurrence

Based on the above presented facts, it can be concluded that the Czech Republic is predisposed to spreading of this pest on the rapeseed vegetation. The factors below clearly support this theory:

- Increasing areas of rapeseed and Brassicaceae intercrops.
- Ever-increasing weed infestation of fields by Brassicacaea crops, especially rapeseed and Brassicaceae weeds.
- Reduction of Brassicaceae vegetables' fields and consequent search for new host plants.
- Limited selection of market crops, namely sugar beet, in the Czech Republic, due to the European Union's reforms concerning the production of sugar beet (KRÁLOVÁ, 2006).
- The expansion of tillageless plant growing.
- In many localities, rapeseed is seeded much earlier than it used to be in the past – at the beginning of August. The growth regulators are applied to the plants and thus, in October, the plants' habitus and size bear the resemblance of Brassicacaeae vegetables.

Because of the increasing areas of the rapeseed fields, further spreading of the cabbage maggot on rapeseed can be presumed. The spread may not only occur in locations where it has already been reported, but also in localities with intensive growing of vegetables due to the area reduction of the Brassicaceae crops (Figure 7).

No critical figures have been set out for rapeseed in terms of the commencement of treatment. The efficacy of insecticides has proven problematic, too. As per results from Germany, the insecticides' maximum effectiveness is 50% (KAZDA and FÁBRY, 2005; ŠEDIVÝ, 2005). The signalisation on the grounds of the maggots' raid on the signal cauliflower plants that is frequently used in vegetables growing cannot be used for rapeseed treatment due to its extreme difficulty. The same applies for the use of a benzyl benzoate-based repellent that is currently being tested. In the experiments, the repellent managed to reduce the laid eggs by 50%, nevertheless, its usage is very impractical. Protection by the means of irrigation or mechanical barriers is also unrealistic (BOCÁK, 1995; BREZÍKOVÁ and ROD, 2003; HAVUKKALA et al., 1984; KUŽMA et al., 2002; LÁSKA, 1978; MINÁR et al., 2007; SKINNER and FINCH, 1986).

Figure 7.Areas of predicted cabbage maggot occurrence on rapeseed in the Czech Republic (sorted by the region).

Treatment possibilities???

To assess the biological efficacy on available insecticides, results obtained by testing the insecticides on Brassicaceae vegetables can be taken into consideration. In 2002 to 2003, we conducted tests with granulated diazion and chlorpyrifos-based pesticides on cabbage and cauliflower on SPA Brno. Four hundred plants (a hundred in each repetition) were examined in each variety. Two trials were carried out for each crop (one trial per year). The biological efficacy was calculated according to the Abbott formula (software UPAV[1]). Table 1 and 2 display the acquired results.

The results confirm that cabbage maggot attacks mainly cauliflower. It is necessary to point out that the major insecticide that is used against the cabbage maggot on Brassicaceae vegetables in the Czech Republic is based on the active ingredient chlorpyrifos. It is a granulated insecticide that is applied with special applicators in high hectare doses (up to 30 kg.ha^{-1}), and it is not registered for rapeseed application. However, this amount of the insecticide is possible to use on rapeseed from both the economic and ecotoxicologic viewpoints. Carbofuran-based insecticides are licenced to be used for treating seed production. However, these insecticides are not registered for rapeseed treatment (Minár et al., 2007).

Futhermore, an insecticide based on the active ingredient fenitrothion is also used for treatment of Brassicaceae plants (in the form of irrigation). This insecticide is not registered for rapeseed usage either, but even if it was, the above presented form of application is unsuitable for rapeseed anyway (Minár et al., 2007).

Findings regarding the effectiveness of different insecticides against cabbage maggot have been obtained from Germany. An insecticide based on imidacloprid and beta-cyfluthrin (a substance used for a chemical treatment) achieved biological efficacy in the range of 40-60% (Erichsen, 2006). No insecticides against the cabbage maggot have been registered in the Czech Republic yet. Insecticides already registered for the rapeseed usage against the crop's other pests may be used to control the cabbage maggot. One of these insecticides is, for example, the above mentioned chemical substance based on imidacloprid and beta-cyfluthrin. This insecticide holds a registration against two beetles of *Phyllotreta* – the cabbage stem flea beetle *(Psylliodes chrysocephala)* and the cabbage gall weevil *(Ceutorhynchus pleurostigma)*. Additionally, chlorpyrifos- and cypermethrin-based insecticides registered for controlling the turnip ceutorhynchus *(Ceutorhynchus napi)* and the cabbage seedstalk curculio (*Ceutorhynchus pallidactylus)* may be employed, too. (Kazda, 2006; Minár et al., 2007).

As discussed above, the Czech Republic currently provides optimal conditions for the spread of the cabbage maggot on rapeseed. Although it is a minor pest at the moment, the possibility of its future pervasive spread cannot be ruled out. Germany may serve as an example: there were only minimal cabbage maggot occurrences in 1997 - 1999, nevertheless, in 2000 - 2003, a gradual spread and infestation of plants by up to 60% took place. In northern Germany, there are localities with plant damage of up to 90%. Some of the commonly recommended prevention and treatment measures are stated below (Kazda and Fábry, 2005; Erichsen, 2006).

- The maximum representation of rapeseed (Brassicaceae crops) in the rotation of crops must be kept at 12.5%.

[1]It is a computer software designed by Perutka and Filkuka from the Stata Phytosanitary Administration in Brno. This software is used for the statistic processing of most registration trials with plants protecting solutions in the Czech Republic.

Table 1. Biological efficacy of insecticides against cabbage maggot on Brassicaceae vegetables

Insecticide– active ingredient	Cauliflower	Cabbage
chlorpyrifos (10 kg.ha^{-1})	49.7 and 50.3%	88.2 and 93.7%
chlorpyrifos (11 kg.ha^{-1})	45.9 and 55.9%	87.3 and 88.9%
diazinon (10 kg.ha^{-1})	38.7 and 41.9%	80.0 and 85.0%
diazinon (11 kg.ha^{-1})	45.9 and 54.7%	85.6 and 87.3%

Table 2. Percentages of the affected area of plants on the control variant without treatment

Insecticide – active ingredient	Percentage of the affected plants' area on the control variant
Cauliflower	6 – 20%
Cabbage	8 – 14%

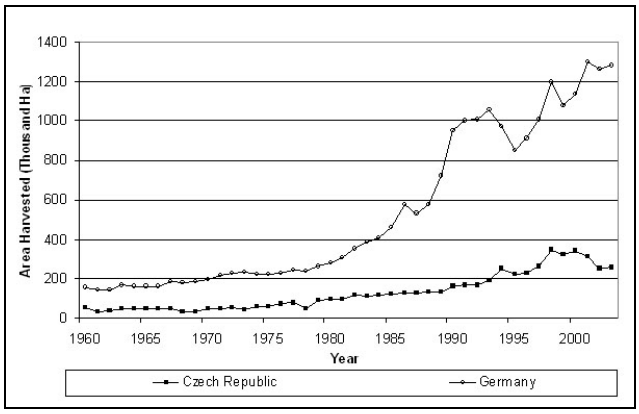

Figure 8.Harvested area of rapeseed in the Czech Republic in comparison with Germany (Source: Faostat).

- Volunteer rapeseed plants must be destroyed (immediately after harvest).
- Postharvest residue must be destroyed, especially in cases when rapeseed is grown on the neighbouring field.

BOCÁK and ROD (1994) say that the cole crops and rapeseed protection against the cabbage maggot is difficult because of the following reasons:

- Permanent presence of ovipositing female flies in the crop.
- Hidden placement of eggs.
- Larvae's concealed life.

BOCÁK and ROD (1994) add that in an ideal environment, the cabbage maggot's eggs are destroyed by ground beetles and rove beetles by up to 70%. Nevertheless, this means of control is not adequately effective because the natural entomofauna has been significantly diminished due to the usage of chemicals in agriculture. Therefore, ways (for example RILEY et al., 2007) to positively influence the occurrence of certain natural predators of the cabbage maggot are being sought.

According to the experts from Canadian University in Alberta (DOSDALL et al., 2003), the damage inflicted by cabbage maggot can be reduced to a certain extend by modification of the growing technologies. For instance, the number of cabbage maggot's eggs may be eliminated by keeping weeds in the rapeseed vegetation longer, or by growing rapeseed with particular crops in the undersowing. These methods shorten the effective oviposition time because the cabbage maggot does not always land on the host plant and has to repeat its testing flights more often. It is necessary to add that although leaving weeds in the rapeseed vegetation (postponed application of herbicides) reduces the damage inflicted by cabbage maggot, the yield loss caused by later herbicides application is not compensated for.

Methods of genetic engineering offer possible solution, too. For example, experiments with introgression of the white mustard's resistance genes to cabbage maggot (*Sinapis alba* L.) are in progress (EKUERE et al., 2005).

Conclusion

It is presumed that the cabbage maggot will gradually spread in rapeseed fields, mainly due to the increase of the rapeseed-growing areas in the Czech Republic (Figure 8). The control of this pest is restrained by the fact that there is no insecticide registered for the rapeseed usage. The possibility to take advantage of some insecticides already registered for the rapeseed usage against other pests is one of the options when trying to control the cabbage maggot. The non-existence of a methodology of prognosis and signalisation of treatment is a significant issue as well.

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