JOURNAL OF PLANT PROTECTION RESEARCH Vol. 55, No. 4 (2015)

Review

Is the possibility of replacing seed dressings containing neonicotinoids with other means of protection viable in major Polish agricultural crops?

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Received: July 15, 2015
Accepted: November 5, 2015

Abstract: Following the limitations regarding the use of the neonicotinoids: clothianidin, thiamethoxam and imidacloprid there are no currently available insecticide seed dressings for oilseed rape in Poland. For maize here is only one seed dressing containing methiocarb available with a very narrow registered scope of use. The impact of limitations on protection possibilities of other major Polish agricultural crops is either negligible or non-existent. In consequence a group of economically important insect pests of maize [dungbeetles (Melolonthidae); click beetles (Elateridae); noctuid moths (Agrotinae)] and oilseed rape [leaf miners (Agromyzidae), turnip sawfly (*Athalia colibri* Christ.), cabbage weevils (Curculionidae), cabbage root fly (*Hylemyia brassicae* Bche.), diamond-back moth (*Plutella maculipennis* Curt.)] is left without any legal possibility of chemical control. For the other important pests of the early growth stage of oilseed rape development, there are only pyrethroids available together with one product containing chloropiryfos that can be applied once per vegetation season. Since both maize and oilseed rape are grown in Poland on the area of approximately 1 million ha (each crop), this situation raises concerns about production possibilities as well as development of pest resistance.

Key words: alternatives, clothianidin, economic consequences, imidacloprid, insecticides, limitation, maize, neonicotinoids, oilseed rape, protection, seed dressing, seed treatment, thiamethoxam, withdrawal, Poland

Introduction

In March 2013, the European Commission decided to change the conditions of approval for three active substances from the group of neonicotinoids: clothianidin, thiamethoxam and imidacloprid (Commission Implementing Regulation No. 485/2013). In practice this change means a significant limitation of the use of clothianidin, thiamethoxam and imidacloprid in a number of crops. The reason for this decision was the risk these substances posed to bees. According to the Regulation 485/2013, the risk may occur in several crops from exposure via dust, from consumption of residues in contaminated pollen and nectar, as well as in maize from exposure via guttation fluid. Taking into consideration these risks, the Commission decided that the three mentioned active substances should be prohibited for seeds of crops attractive to bees, and for seeds of cereals. However, these substances can be still used in winter cereals, seeds used in greenhouses and in some cases, foliar treatments after crop flowering.

The limitations changed the possibilities of chemical protection against pests of a number of crops throughout the European Union, among them are cereals, fruits, vegetables and herbs. Many of these changes have no impact on Polish conditions whatsoever because some uses have never been registered in Poland and many crops mentioned in Regulation 485/2013 (for example almonds, chestnuts, cotton or rice) are not grown in Poland. However, given that Poland has approximately 14.5 million ha of agricultural land (Central Statistical Office 2014b), and is a significant producer of numerous crops, it is indeed of interest to establish the impact of the limitations concerning the use of clothianidin, thiamethoxam and imidacloprid on agricultural production in Poland.

It is worth stressing that the aim of this paper is NOT to discuss the reasons for limitations concerning the use of clothianidin, thiamethoxam and imidacloprid. For the authors it is quite obvious that only the uses of plant protection products that are proven to be safe are authorised. The objective of this study is to establish the impact of the decision presented in Regulation 485/2013 on the production of major Polish agricultural crops.

Does limitation of the use of neonicotinoids really pose a problem in practice?

Table 1 presents all the major agricultural crops where clothianidin, thiamethoxam or imidacloprid were registered in Poland in 2013. Based on the table 1, we can

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Table 1. Major agricultural crops where uses containing clothianidin (C), thiamethoxam (T) or imidacloprid (I) were registered in 2013 in Poland and the impact of Regulation 485/2013

Crop	Which substances under discussion were registered for crop use in 2013?	Were any uses withdrawn following Regulation 485/2013?
Sugar beet	C, I, T	NO
Fodder beet	I, T	NO
Winter barley	I	NO
Spring barley	T	YES
Maize	I	YES
Winter wheat	I, T	YES
Winter oilseed rape	C, I, T	YES
Spring oilseed rape	I, T	YES
Potato	C, I, T	NO

Source: personal elaboration

state that in many agricultural crops commonly grown in Poland such as spring wheat, oats or rye, the analysed substances were not used and consequently the limitations had no impact on their production. In sugar beet, fodder beet, winter barley and potato, one or more of the substances were registered, but following the implementation of Regulation 485/2013 there have been no changes due to the fact that the uses were not limited by the Regulation. Only in the case of spring barley, maize, winter wheat as well as spring and winter oilseed rape, the limitation of uses or withdrawal of products actually has taken place. In other words, the implementation of Regulation 485/2013 influenced the possibilities of protection of five agricultural crops in Poland (if we count spring and winter oilseed rape as two separate crops).

Preliminary analysis (Table 2) indicates that the consequences of withdrawal vary from crop to crop. In the case of spring barley and winter wheat, one product for foliar application was withdrawn. It was the same product for both crops, that contained thiamethoxam and lambda-cyhalotrin, and was registered to control aphids and cereal beetles (it was withdrawn from the market, not subjected to a change of the label). For both spring barley and winter wheat there are numerous alternative chemical products. For protection of spring barley against aphids or cereal beetles there are 38 products containing 9 active substances, and for winter wheat there are 36 products containing 11 active substances. Therefore, it may be concluded that the implementation of Regulation 485/2013, in spite of some changes, has not resulted in posing problems for the protection of spring barley and winter wheat in Poland. For this reason these said crops will not be discussed further.

In the case of maize and oilseed rape, the limitations of use referred solely to seed dressings. As a consequence there are currently no insecticidal seed dressing for the protection of oilseed rape (neither spring nor winter) on the Polish market. For the protection of maize there is one seed dressing containing methiocarb as the active substance, with a very narrow registration range as an insecticide: only for a protection against the frit fly. The product is also registered as a repellent for maize protection against birds.

Table 2. General description of the withdrawn uses of neonicotinoids in the crops under discussion

Crop	Number of products withdrawn*	Application method	Controlled pests	Are there any chemical alternatives available?
Spring barley	1	spraying	aphids, cereal beetles	numerous (38 products/ 9 active substances)
Maize	3	seed dressing	frit fly, dung beetlesclick betles, noctuid moth	for frit fly 1 seed dressing containing methiocarb + 1 foliar product with 2 active substances, for the other pests no registered products
Winter wheat	1	spraying	aphids, cereal beetles	numerous (36 products/ 11 active substances)
Winter oilseed rape	6	seed dressing	cabbage weevils, cabbage rot fly, cabbage leaf miner, Flea beetles, turnip sawfly, aphids	no insecticidal seed dressing on the market, 9 foliar insecticides containing 5 active substances, registered for use in different growth stage
Spring oilseed rape	3	seed dressing	cabbage weevils, cabbage root fly, flea beetles, cabbage leaf miner, turnip sawfly, aphids	no insecticidal seed dressing on the market, 2 foliar insecticides containing 1 active substance

*withdrawn uses for a particular crop as well as total withdrawals from the market were considered

Source: personal elaboration

Table 3. Withdrawn seed dressings and alternatives for foliar application in maize and oilseed rape

Crop	Controlled pest	Withdrawn uses of seed dressings	Alternatives for foliar application
		active substance	active substance
Maize	dung beetles click betles, noctuid moth	imidacloprid	no alternatives
	frit fly	imidacloprid	thiacloprid and delthametrin
Spring oilseed rape	aphids, flea beetles	imidacloprid, beta-cyfluthrin	delthametrin
		thiamethoxam, metalaxyl-m, fludixonil	delthametrin
	leaf miners, turnip sawfly,cabbage weevils	imidacloprid, beta-cyfluthrin	no alternatives
	cabbage root fly, diamond-back moth	thiamethoxam, metalaxyl-m, fludixonil	no alternatives
Winter oilseed rape	flea beetles	imidacloprid, beta-cyfluthrin	delthametrin lambda-cyhalotrin
		imidacloprid	
		clothianidin beta-cyfluthrin	
		thiamethoxam, metalaxyl-m, fludixonil	
	turnip sawfly	thiamethoxam, metalaxyl-m, fludixonil	delthametrin
	aphids	thiamethoxam, metalaxyl-m, fludixonil	delthametrin alpha-cypermetrin chloropiryfos beta-cyfluthrin
	cabbage weevils, cabbage root fly, leaf miners	imidacloprid, beta-cyfluthrin imidacloprid	no alternatives

Source: personal elaboration of the register of authorized plant protection products (The register of authorized plant protection products 2015)

Seed dressing is generally regarded as a comparatively safe for the environment method of application of plant protection products due to a very well targeted application method, the reduction of off-target exposure, as well as the reduction of the amount of active substance used per hectare. Seed treatment provides early protection of crops against harmful soil-dwelling organisms and helps to avoid or reduce the number of foliar treatments (Stevens 2002; Taylor and Harman 2003).

However, in the event where the possibility to use seed dressing does not exist, it is usually still possible to use foliar application after the germination of the crop, in order to control pests, although not always with equally good results. Are there possibilities to control pests of oilseed rape and maize in Poland in the lack of seed treatments? Table 3 shows the registered uses of withdrawn seed dressings and products currently registered for the combination crop/pest. The control of the frit fly in maize was not mentioned in table 3, as there is an alternative seed dressing as well as one registered insecticide for foliar application available on the market (table 2).

The crops affected by the implementation of Regulation 485/2013 are maize and oilseed rape (both spring and winter). In the case of maize and oilseed rape following the limitations, legal chemical protection against the group of insects listed in table 3 is no longer possible. For protection against the other pests, only products containing pyrethroids have remained on the market, and in the case of winter oilseed rape, there is also one product which contains a mixture of pyrethroide beta-cyfluthrin with chloropiryfos that belongs to the group of organophosphate insecticides.

For some time, the use of pyrethroids has given rise to concerns due to widespread pest resistance (Philippou *et al*. 2011; Węgorek *et al*. 2011; Zimmer and Nauen 2011; Heimbach and Müller 2012; Wrzesińska *et. al.* 2014). The resistance to chloropiryfos is also a known fact and the Anthropod Pesticide Resistance Database mentions over 70 species with proven resistance against chloropiryfos (Arthropod Pesticide Resistance Database 2015). So far among them there are no species listed on the label of the product registered for oilseed rape protection in Poland. The product however is quite new as it was registered in Poland in 2014, and following the application on such a large area the development of resistance in the pests of oilseed rape is not unlikely. Repeated application of pyrethroids without the possibility of interchangeable use, or (in case of winter oilseed rape) with the possibility of interchangeable use with only one product containing a substance with a different mode of action (chloropiryfos), only once per vegetation season on such a large area is difficult to recommend. However there are no other chemical methods available.

The scale of maize and oilseed rape production in Poland

In spite of fluctuating prices, in recent years, both oilseed rape and maize have been considered as the most profitable agricultural crops in Poland. The analysis

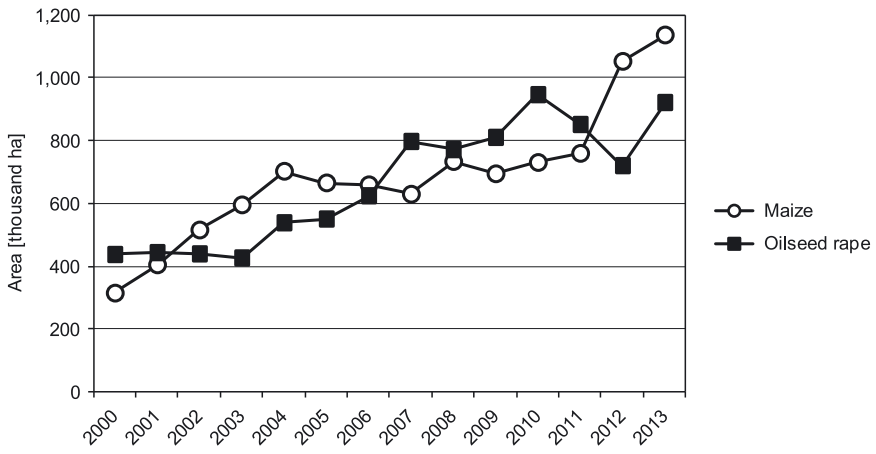

Fig. 1. Sown area of oilseed rape and maize in Poland during the years 2000–2013
Source: personal elaboration of Central Statistical Office data (Central Statistical Office 2003, 2007, 2010, 2014)

from different years of the current century reveal that production of these two crops has usually been lucrative (Kwaśniewski 2008; Skarżyńska 2007, 2009, 2013). The cultivation of winter oilseed rape in Poland during the years 2011–2013 was profitable even without provided subsidies (Skarżyńska 2014).

Following the market demand, the cultivated area for both oilseed rape and maize in Poland has increased since the beginning of the century as shown in figure 1. The area of oilseed rape differs from year to year, but since 2010 it often approaches 1 million ha (Central Statistical Office 2014b). Winter oilseed rape is the most popular form, usually exceeding 80% of total oilseed production, which in generally gives a higher yield. The area of maize exceeded 1 million ha in Poland in 2012 and 2013 years.

In Poland land in good agricultural condition is about 14.5 million ha in total and that includes over 10.3 million ha of sown area (Central Statistical Office 2014b). The combined area of oilseed rape and maize production is close to 2 million ha or 20% of the sown area in Poland. They are therefore very important crops in Poland, both from the point of view of land area, as well as being a significant source of income for farmers.

The impact of losses caused by insects on the production of maize and oilseed rape in Poland

The infestation and losses caused by pests depend on the conditions experienced in a particular season, and therefore their harmfulness differs from year to year. In Polish climate and agriculture conditions as a rule, insects pose a bigger threat for oilseed rape than for maize. On average, on a nationwide scale it is estimated that insects cause losses amounting to 15–20% of the grain yield of maize and up to 50% in oilseed rape (Mrówczyński 2013). On a local scale, insects are capable of totally destroying an oilseed rape crop. Based on the table 3 we can conclude that currently there is a lack of chemical control for a group of economically important organisms, which are harmful for oilseed rape and maize.

The pests of oilseed rape mentioned in table 3 occur throughout the whole country and are economically important causing significant losses Cabbage weevils, (especially *Ceutorhynchus quadridens* Panz and *Ceutorhynchus napi* Gyll., with growing importance of *Ceutorhynchus assimillis* Payk.) and cabbage gall midge (*Dasyneura brassicae* Winn.) present the highest threat however, other pests may also be the reason of significant losses in the crop of oilseed rape (Mrówczyński 2013).

All pests of maize listed in table 3 as lacking the possibility of chemical control methods (Melolonthidae, Elateridae and Agrotinae) are economically important in Poland. Due to their biological cycles, some of them cause considerable losses in selected years (Bereś and Pruszyński 2008). Melolonthidae and Elateridae occur throughout Poland; however, the significant losses caused by them in maize are local. Their potential harmfulness is the highest on the areas where maize is grown in monoculture, as well as on fields adjacent to meadows, pastures, forests and plantations of perennial grasses, where these insects find a suitable place to develop and to complete their life cycle which lasts several years. The most economically important for maize among Agrotinae is the turnip moth (*Agrotis segetum* Denis & Schiffermüller) that feeds on young maize to gather strength to pupate. Their last gradation in Poland took place in 2010 when the losses caused in maize were significant on a nationwide scale. Therefore it is likely that a follow-up gradation may occur soon.

The high potential of losses caused by insects in oilseed rape was the reason why insecticidal seed dressing was used on the majority of seeds before sowing. Although the exact data are difficult to find, it may be estimated that prior to withdrawals, certainly over 90% of seeds of oilseed rape in Poland underwent insecticidal seed treatment before sowing. In maize this percentage was considerably lower.

Are there any methods of insect control in maize and oilseed rape available?

The chemical control of harmful organisms is not the only plant protection method in use and because of the requirements of integrated pest management other means

should definitely be applied; for instance prevention methods, as well as non-chemical methods of pest control (Matyjaszczyk 2015).

Biological, physical and other non-chemical methods of pest control may sometimes bring excellent results. A very good example of their successful utilisation is pest control in glasshouses (Sosnowska and Fiedler 2010). In arable crops there are fewer such possibilities, but some methods, such as mechanical weeding are traditionally popular in Poland (Matyjaszczyk 2013). Unfortunately, there are few viable non-chemical intervention methods available for insect control in arable crops. One of them is the control of the European corn borer (*Ostrinia nubilalis* Hbn) in maize using the beneficial organism *Trichogramma,* which is used in Poland on an area exceeding 5,000 ha, and growing (Bereś 2013). However, for the pests listed in table 3, there are no such possibilities available.

Facing the absence of intervention methods, it seems that the only methods available in the protection of oilseed rape and maize against the discussed pests are prevention methods. Obviously, maintaining the crop in good condition may bring some positive results, since stronger plants are usually more tolerant to pest pressure. Proper crop rotation, an early sowing term and the use of cultivars that develop early, as well as higher sowing density may also bring some results in prevention of losses caused by some pests occurring both in maize and oilseed rape (Mrówczyński 2013). The infestation of pests can also be significantly limited by the activity of different entomophagus organisms such as fungi, nematodes and others. However, in case of crops grown on large plantations, this beneficial effect is usually much lower than on the areas with high biodiversity and a large number of small plots. Given that maize and oilseed rape are currently grown in Poland on a comparatively large area and often on large farms (Central Statistical Office 2014a), the beneficial effect of entomophagous organisms is not likely to be sufficient to prevent economic loses from pest pressure.

So far observed consequences

Since seed dressings ceased to be used in the autumn of 2013 and the oilseed rape harvested in 2014 was still protected by the seed dressing, the 2014/2015 vegetation season will be the first when the observation of results of a lack of insecticidal seed dressing will be possible. In agriculture, results coming from one agricultural season are usually not regarded as sufficient to draw scientific conclusions. However, the first information from the autumn of 2014 reported a higher infestation of pests of winter oilseed rape. As farmers growing oilseed rape are aware that a crop requires protection, they monitored the occurrence of pests and usually used foliar treatments. Therefore, the complete destruction of plantations of winter oilseed rape in the autumn of 2014 was seldom and took place predominantly in the south-western part of Poland (Opolskie and Dolnośląskie regions). However, a significant increase in insecticidal foliar treatments throughout Poland was recorded. The detailed reports from the net of governmental COBORU stations distributed in all the regions of Poland and working with assessments of varieties showed that in 35 locations where the field trials with varieties of winter oilseed rape were performed, a significant increase in the use of foliar insecticides took place. The average number of treatments of oilseed rape in the autumn of 2014 was the highest within the last 5 years (earlier data were not provided), and almost twice higher than in the autumn of 2011, which was in the second place as regards the number of insecticidal foliar treatments (Broniarz *et al*. 2015). Additionally, there were also reports from Germany of a significant increase in the number of foliar treatments of winter oilseed rape with insecticides in the autumn of 2014 (Heimbach and Brandes 2015; Heimbach 2015).

Conclusions

The implemented limitations of use of three neonicotinoids: clothianidin, thiamethoxam and imidacloprid influenced the possibility of using seed dressing for maize and oilseed rape (both spring and winter) against insects in Poland. Currently, for some of the economically important insects of these crops there are no possibilities of chemical control, whereas for the others the only remaining option is that of foliar treatments with pyrethroids and one product with organophosphate chloropiryfos. The impact of the limitations on protection possibilities of other major Polish agricultural crops is either negligible or non-existent.

In maize, the impact on production possibilities is predicted to be lower than in oilseed rape mainly due to the biology of the crop because with proper crop rotation, field location and cultivation techniques it is possible to limit the harmfulness of most maize insect pests. In the case of maize, there is also an insecticidal seed dressing containing methiocarb remaining on the market. This product has a very narrow registered scope of use but it is not unlikely that in spite of a narrow registration it may also have some protective function against other pests of the early growth stage of maize.

Oilseed rape yield can be strongly affected by insect pests. In the autumn of 2014, a high infestation of insects in winter oilseed rape was observed in Poland. Farmers increased the number of foliar insecticide treatments in comparison with previous years when the seed dressings were available. Due to a lack of protection by seed dressing it can be assumed that the root systems of some oilseed rape plants were damaged. Fortunately for farmers, the winter of 2014/2015 was uncommonly mild in Poland and winter losses of plants were very limited. Therefore, the yield will significantly depend on spring weather and especially if plants with damaged root systems will have a sufficient water supply. Regardless of the weather conditions, it should be stressed that offspring of insect pests of oilseed rape that survived the winter will affect the production of oilseed rape in the next season. As their infestation increased in the autumn of 2014, the higher than normal loses in the next season are expected. It may be therefore predicted that the lack of availability of insecticidal seed dressing will influence the profitability of oilseed rape production in Poland.

Both oilseed rape and maize are important crops in Poland, given that the area of oilseed rape approached 1 million ha, while maize exceeded 1 million ha in the recent years. Maize and oilseed rape are also important sources of income for Polish farmers. Faced with the problem of protection availability, it may be expected that the profitability of oilseed rape and probably also maize will decrease in the following vegetation seasons. This outcome can influence the reduction of their growing area. The question remains as to what farmers can grow as an alternative to these crops.

Seen from the point of view of sustainability and the biodiversity of the agricultural environment, the reduction of area for oilseed rape, and possibly also maize in Poland may be even regarded as beneficial, provided that they would be replaced with less intense crops, recommended in crop rotation as positively influencing soil quality, such as legumes. However, from the perspective of the farmer, obviously the profitability of production is of crucial importance. Currently, very few arable crops that can be grown in Poland are on a similar level of profitability as oilseed rape and maize. This situation raises numerous interesting questions as regards the sources of farmers' income.

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