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Consequences of the neonicotinoid seed treatment ban on oilseed rape production – what can be learnt from the Swedish experience?

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Abstract

There has been great concern about negative effects on crop production resulting from the ban on insecticide seed treatments containing neonicotinoids. I examine how the neonicotinoid ban has affected crop protection and crop production in oilseed rape (*Brassica napus* L.) using Sweden as a case study and compare the Swedish situation with that in leading countries growing winter and spring oilseed rape, respectively. The cropping area of winter and spring oilseed rape in Sweden has increased by approximately 40% to around 100 000 ha and decreased by approximately 90% to around 4000 ha, respectively following the ban and there are trends for increased pest and disease pressure. Overall, however, the ban has not had any major impacts on total oilseed rape cropping area or crop yields per hectare of either winter or spring oilseed rape, which is in contrast to elsewhere in Europe. In Germany and the United Kingdom, for example, the cropping area has decreased following the ban on neonicotinoid seed treatments, attributed to increased insect pest pressure especially from cabbage stem flea beetle, *Psylliodes chrysocephala*. I conclude that winter oilseed rape has remained a viable crop to grow in Sweden without insecticide seed treatments, but that further investments into integrated pest management are needed for sustainable insect pest control in oilseed rape in the future.

Keywords: cabbage stem flea beetle; canola; *Phyllotreta*; turnip yellows virus

1 BACKGROUND

In Sweden and elsewhere in northern Europe, crop rotations are often dominated by cereals, particularly winter wheat (*Triticum aestivum* L.) and spring barley (*Hordeum vulgare* L.). Oilseed rape (*Brassica napus* L.) is the most important break crop in these cereal-dominated crop rotations. Growing oilseed rape as a break crop is key to healthier and more productive cereal crops,[1] and also produces valuable vegetable oil. Winter oilseed rape is the dominating form grown throughout most of Europe, with winter forms of oilseed rape (and turnip rape, *B. rapa* L.) accounting for over 95% of the total oilseed rape and turnip rape cropping area within the European Union (EU; Eurostat, https://ec.europa.eu/eurostat). Spring oilseed rape/canola is grown in northern regions, such as Scandinavia, the Baltic countries, Russia and Canada, as well as over the winter in Australia.[2–4] Winter oilseed rape typically has higher yield than spring oilseed rape but is not always an option in regions with shorter growing seasons and harsh winter conditions. Several insect pests attack oilseed rape throughout Europe and regularly reach densities that cause yield losses.[2,5,6] Insecticide seed treatments have been used for decades in oilseed rape in the EU to control some of these insect pests during crop establishment. These seed treatments have mainly targeted cabbage stem flea beetle (CSFB; *Psylliodes chrysocephala* L.) and aphids, especially peach-potato aphid (*Myzus persicae* Sulzer) vectoring turnip yellows virus (TuYV) in winter oilseed rape,[7,8] and flea beetles (*Phyllotreta* spp.) in spring oilseed rape.[2] Secondary pests targeted in both spring and winter oilseed rape were cabbage root fly (*Delia radicum* L.) and turnip sawfly (*Athalia rosae* L.). Insecticide seed treatments containing neonicotinoids were introduced in oilseed rape around 2000 in Sweden, replacing insecticide seed treatments containing carbamates and organophosphates.[9] They were used in both winter and spring oilseed rape until 2013, when they were restricted and subsequently banned in the EU (European Commission, https://ec.europa.eu/food/plant/pesticides/approval_active_substances/approval_renewal/neonicotinoids_en) due to a controversial ruling of neonicotinoids having negative effects on bees.[10–12] There have been great concerns about the negative effects of the neonicotinoid ban on crop production, including in oilseed rape.[13] With more

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than 5 years of experience in growing crops that are attractive to bees without neonicotinoid seed treatments, we can now evaluate how crop protection and crop production have been affected by the ban. I examine how the ban has affected crop production and crop protection in oilseed rape using Sweden as a case study and compare the Swedish situation with that in leading countries growing winter and spring oilseed rape.

2 IMPACT OF BAN ON OILSEED RAPE CROPPING PATTERNS IN SWEDEN

Both winter and spring oilseed rape are grown in Sweden. The production of winter oilseed rape has dominated in the southernmost part of the country (e.g., Skåne, latitude 56°N), while spring oilseed rape has been the dominant form grown further north (e.g., around lake Mälaren, latitude 59–60°N), and both forms have been grown in intermediate regions (e.g., Västra Götaland and Östergötland). This cropping pattern is partly shaped by biophysical constraints, with the growing season in northern areas often being too short for both harvesting a preceding cereal crop and planting winter oilseed rape in time for it to establish sufficiently for overwintering. Following the ban on neonicotinoid seed treatments in 2013 there has been a clear shift in the ratio between the two forms of oilseed rape grown in Sweden, with the cropping area of winter oilseed rape increasing by approximately 40% at the expense of spring oilseed rape cropping area, which decreased by approximately 90% (Figure 1a). Factors that coincided with the ban, such as longer growing seasons, favorable conditions for autumn planting, milder winters and the introduction of more winter-hardy oilseed rape cultivars likely facilitated this shift. Because of these opposing trends between winter and spring oilseed rape cropping area, the total oilseed rape cropping area has remained approximately stable. Regionally, the winter oilseed rape cropping area has remained stable in the south (Figure 1b) but has increased further north, where both forms of oilseed rape used to be grown (Figure 1c,d). In the northern growing area around Lake Mälaren, a slight increase in the cropping area of winter oilseed rape has not fully compensated for the sharp decline in spring oilseed rape cropping area (Figure 1d), causing an overall reduction in oilseed rape cropping area. In this region, farmers' crop rotations have likely become more cereal-dominated and less diverse as a result. The ban has had no clear effects on yield per hectare of either winter or spring oilseed rape (Figure 2), although spring oilseed rape yields should be interpreted with care considering the strong concurrent reduction in cropping area. Average winter oilseed rape yields were 3090 kg ha^{-1} in 2010–2014 (prior to the ban) and 3290 kg ha^{-1} in 2015–2019 (following the ban), whereas average spring oilseed rape yields were 1860 kg ha^{-1} in 2010–2013 (prior to the ban) and 1850 kg ha^{-1} in 2014–2019 (following the ban) (Figure 2). Because higher-yielding winter oilseed rape has replaced lower-yielding spring oilseed rape, while total cropping area and hectare yields of both forms have remained approximately stable, there is a trend that total oilseed rape production (kg $year^{-1}$) has increased in Sweden over the last decade.

3 CROP PROTECTION IN WINTER OILSEED RAPE FOLLOWING THE BAN

3.1 Cabbage stem flea beetle

CSFB colonize emerging winter oilseed rape plants in autumn.[14] Adults feed on the seedlings and the larvae develop over winter inside the plant.[15] Both adult and larval feeding reduce plant numbers and vigor.[5] CSFB is usually confined to the southern

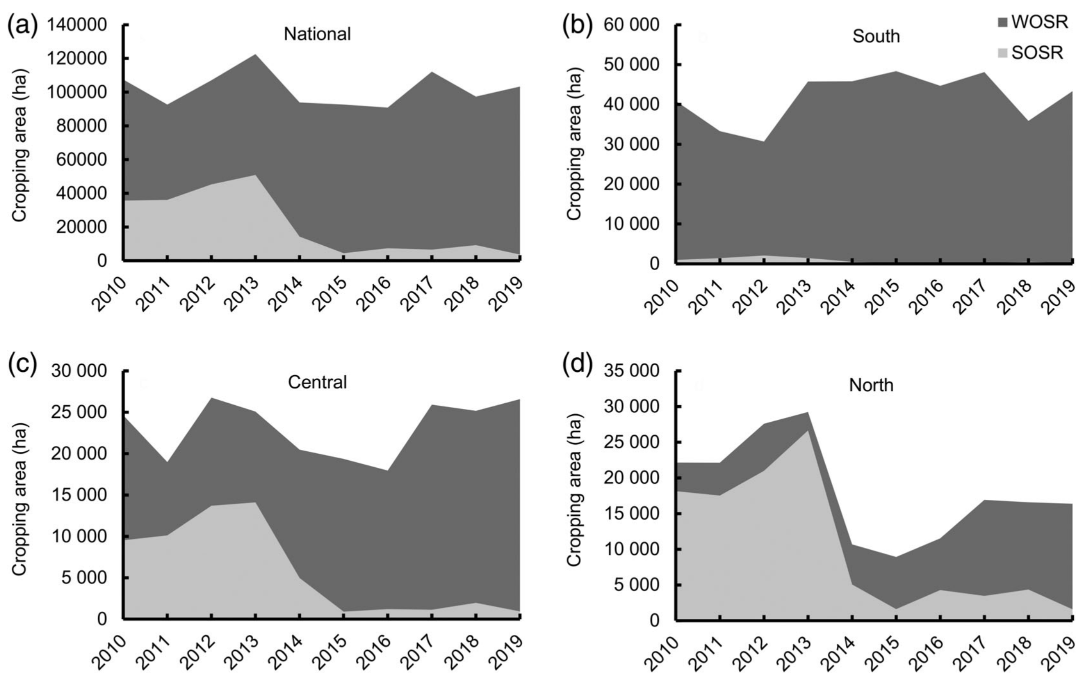

FIGURE 1. Stacked area graphs with winter oilseed rape (WOSR) and spring oilseed rape (SOSR) cropping area in hectares in (a) Sweden, and in (b) southern (Skåne county), (c) central (Västra Götaland and Östergötland counties) and (d) northern (Södermanland, Stockholm, Uppsala and Västmanland counties around lake Mälaren) growing areas of Sweden, 2010–2019. Neonicotinoid seed treatments were used until 2013, meaning that the first crops of SOSR and WOSR grown without neonicotinoid seed treatments were harvested in 2014 and 2015, respectively. Data source: Statistics Sweden (Örebro).

and coastal growing areas in Sweden.[16] Population abundance of CSFB has increased in Sweden following the neonicotinoid ban (Figure 3a).

3.2 Turnip yellows virus

TuYV is a virus infecting oilseed rape with often diffuse symptoms that resemble plant stress and nutrient-deficiency, such as reddening and yellowing of leaves.[17] TuYV infection decreases oilseed rape yields by 11–26%.[18] Aphids, especially peach-potato aphid, are the main vectors of TuYV.[17] TuYV is not regularly monitored in Sweden, but a screening of 20 leaf samples in 21 fields (in one field, 90 leaf samples) in southernmost Sweden (Skåne) in spring 2019 indicated that an average of 78% of the samples were infected with TuYV (A. Kvarnheden, unpublished data). This is considerably higher than infection rates detected during surveys between 2003 and 2005, which were typically below 20%.[19] These limited data indicate that TuYV is increasing.

4 CROP PROTECTION IN SPRING OILSEED RAPE FOLLOWING THE BAN

4.1 Flea beetles

Phyllotreta flea beetle adults colonize and feed on seedlings in newly established spring oilseed rape fields,[20] leading to crop plant loss, delayed and uneven crop growth and seed yield loss.[21] Monitoring flea beetle crop injury levels does not indicate that injury levels have increased in Sweden following the seed treatment ban (Figure 3b), suggesting that factors other than insecticide seed treatment regulate flea beetle long term crop injury patterns.

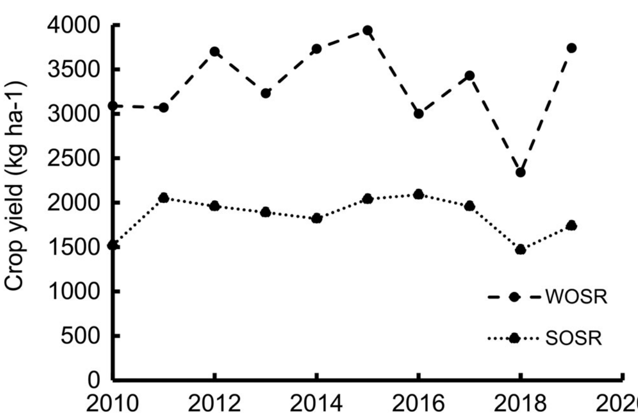

FIGURE 2. Winter oilseed rape (WOSR) and spring oilseed rape (SOSR) yield (kg ha^{-1}) during the period 2010–2019 in Sweden. Neonicotinoid seed treatments were used until 2013, meaning that the first crop of SOSR and WOSR grown without neonicotinoid seed treatments were harvested in 2014 and 2015, respectively. Data source: Statistics Sweden (Örebro).

5 PERSPECTIVE AND INTERNATIONAL OUTLOOK

In winter oilseed rape, there are trends for increased pest and disease pressure from both CSFB and TuYV in Sweden following the ban, but complete crop failure due the lack of insecticide seed treatments is uncommon. Because the ban on neonicotinoids has coincided with a series of mild autumns and winters, which favor both CSFB populations[22] and the aphids vectoring TuYV,[17] the relative role of the ban versus climatic factors for the increased pest and disease pressure is, however, difficult to disentangle.

The increased cropping area of winter oilseed rape in Sweden, despite trends for increased pest and disease pressure from CSFB and TuYV, is in contrast to major winter oilseed rape producing countries in Europe. In Germany and the UK, for example, the winter oilseed rape cropping area has decreased following the ban on neonicotinoid seed treatments, attributed to increased insect pest pressure especially from CSFB.[23–25] The harsher winter climate could be a contributing factor to the more manageable situation in Sweden, limiting CSFB reproduction[26] and overwintering success.[22] In addition, spraying with pyrethroids remains a viable chemical control option. Pyrethroid resistance in CSFB, which is common in other parts of Europe,[27,28] is not yet widespread in Sweden, although first signs of resistance development can be observed.

In spring oilseed rape, monitoring does not support the assertion that pest pressure from *Phyllotreta* flea beetles has increased following the ban. Still, the rapid loss of spring oilseed rape growing area following the ban suggests a causative relationship between availability of insecticide seed treatments and farmers' willingness to grow the crop. Spring oilseed rape cropping area in Sweden declined as much as 70% in the year following the ban (2014), before any experience of growing spring oilseed rape without insecticide seed treatments was available. Previously experienced difficulties with securing crop establishment due to low field efficacy of imidacloprid-based seed treatments, which led to a shift to clothianidin-based seed treatments in spring

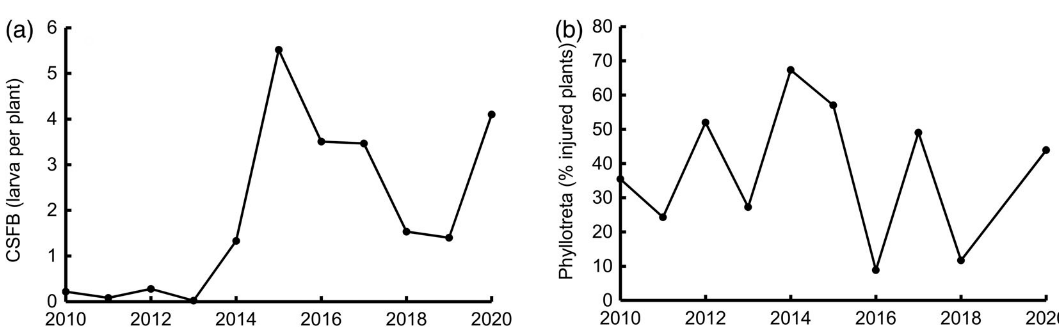

FIGURE 3. Number of cabbage stem flea beetle larva (CSFB) per plant for the period 2010–2020 in samples collected in spring from 7–20 winter oilseed rape fields per year in Skåne, Sweden (a) and percent spring oilseed rape plants injured by flea beetles during 2010–2020 in plots not sprayed with insecticides in 5–24 spring oilseed rape fields per year in the counties Stockholm, Uppsala and Västmanland, by lake Mälaren in Sweden (b). Data is missing for 2019). Neonicotinoid seed treatments were used until 2013, meaning that the first crops of spring and winter oilseed rape grown without neonicotinoid seed treatments were harvested in 2014 and 2015, respectively. Data source: Swedish Board of Agriculture (Jönköping).

oilseed rape in Sweden,[29] could have influenced this risk aversion. Another factor that further lessened interest in growing spring oilseed rape in 2014 was the severe attacks by diamondback moth (*Plutella xylostella* L.) in 2013.[30] Flea beetle pest pressure was also higher in 2014 than in any subsequent year following the ban (Figure 3b), and this might have further discouraged farmers from planting spring oilseed rape in subsequent years.

The lack of insecticide seed treatments and the sharp decrease in cropping area of spring oilseed rape in Sweden is in contrast to the situation in Canada, the leading grower of spring oilseed rape/canola. In Canada, insecticide seed treatments containing neonicotinoids remain permitted and in use, and alternative diamide and sulfoxamine insecticide seed treatment control options against flea beetles are also available (Canola Council of Canada, https://www.canolacouncil.org/canola-encyclopedia/plant-establishment/seed-treatments). The situation also differs when comparing Sweden to other EU Member States such as Finland, where spring oilseed rape is grown and where neonicotinoids continued to be in use following emergency authorisations[31] until replacement seed treatments became available.

Less information is available on how secondary insect pests in both winter and spring oilseed rape have been affected by the ban in Sweden or other parts of Europe. Cabbage root fly, turnip sawfly and stem mining weevils (*Ceutorrhyncus* spp.) are all examples of pests that could be affected by a lack of seed treatments.

The use of foliar applications of pyrethroid insecticides against both CSFB in winter oilseed rape and flea beetles in spring oilseed rape has likely increased in Sweden following the ban. This would be similar to patterns of increased use of spray insecticides in winter oilseed rape reported in the UK.[7] The environmental effects of such shifts in insecticide use are unclear. The effects of pyrethroid foliar sprays and neonicotinoid seed treatments on insect natural enemies might be similarly negative.[32] For bees and other pollinators I speculate that they are less exposed to early-season foliar application of pyrethroids compared to neonicotinoid insecticides applied as seed treatments, because the latter translocate into pollen and nectar.[33] Where the oilseed rape cropping area has remained stable or increased following the ban, bees have therefore likely benefitted. However, in cases where the ban has reduced the oilseed rape cropping area it remains unknown how pollinators have been affected. Very few studies have specifically tested whether the benefits for pollinators from foraging on mass-flowering crops, such as oilseed rape,[34] outweigh the costs of neonicotinoid exposure in those same crops[35] (but see Balfour et al. and Rundlöf and Lundin[36,37]).

Seed treatments replacing neonicotinoids are currently entering the market in the EU.[38] In 2020 in Sweden, a limited quantity of winter oilseed rape was seed-treated with the systemic insecticide flupyradifurone. Negative effects of these new compounds on beneficial insects have, however, already been reported,[38] making their future regulatory status uncertain. Future strategies for crop protection against insect pests in oilseed rape in the EU should therefore be prepared for a situation in which insecticides will be limited in their availability.[25]

One option for making insecticide seed treatments more compatible with the fundamental principles of integrated pest management (IPM) is to develop forecasting tools that can predict when and where insecticide seed treatments will be economically justified, and only use them in such cases.[39] Historical management of CSFB in Sweden provides an example of such an approach.[16] By developing a forecast for pest damage based on larval counts in winter and spring, and building a collaboration among researchers, authorities, advisors and industry, a pest management strategy was deployed in which seed treatments against CSFB were only used in years when economic thresholds were expected to be exceeded.[16] Similar prognosis tools for flea beetles in spring oilseed rape have so far proven difficult to develop,[40] but further research on whether autumn populations of flea beetles can be linked to crop damage in the following spring is warranted.[41]

More generally, further investment into research on IPM is needed for sustainable insect pest control in oilseed rape. There are alternatives to insecticide seed treatments for CSFB, TuYV and *Phyllotreta* flea beetle control. Alternative CSFB control options include reducing tillage intensity,[42] intercropping oilseed rape with frost-sensitive legumes,[43,44] or delaying seeding[45] (but see Valantin-Morison et al.[42]). The efficacy of insecticide seed treatments for TuYV control might be limited to begin with,[46] and an alternative TuYV control option is to use TuYV-resistant cultivars,[47] delay seeding to narrow the time window for aphids to vector the virus in the autumn or to use insecticide spraying against the aphids, although the availability of registered and effective products is currently limited. Alternatives to seed treatments for *Phyllotreta* flea beetle control include no-till,[48–50] early seeding,[51,52] increased seeding rates[49,52,53] and insecticide spraying with pyrethroids based on economic thresholds.[54] Further necessary steps are to evaluate the practicality and reliability of combinations of these and other innovative control options in commercial farming as part of comprehensive IPM programs.

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