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Effects of within-field and landscape factors on *Dasineura brassicae* in winter oilseed rape cultivations in Skåne, southern Sweden

– A field survey with a special approach to pesticide-free control zones

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Effekter av fält- och landskapsfaktorer på *Dasineura brassicae* i höstrapsodlingar i Skåne
- En fältstudie med en särskild inriktning på bekämpningsfria zoner

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Contents

Abstract

Winter oilseed rape (*Brassica napus*) is the most common oilseed crop grown in the province of Skåne in southern Sweden, where this study was performed. *B. napus* is often associated with various insect pests. This study regards two of these; the cabbage seed weevil (*Ceutorhynchus obstrictus*) and the brassica pod midge (*Dasineura brassicae*). While direct infestations by *C. obstrictus* usually do not pose a major threat to *B. napus* cultivations, the attacks will often facilitate infestation by *D. brassicae,* which can cause considerable damage and subsequent yield loss through its destruction of pods. This study focuses on within-field and landscape factors that may affect abundance and damage by *D. brassicae* in 18 rape fields during spring and summer of 2018. Parameters investigated include chemical treatment, abundance of *C. obstrictus*, landscape complexity (proportion of e.g. forested areas), the proportional area of oilseed rape grown in the previous year, and distance to the nearest previous years' oilseed rape field. Effects of chemical treatments were assessed by establishing a *pesticide-free control zone* in each of the study fields. Samples were collected for nearly 10 weeks from April to July. Two field surveys of pod damages were performed during this period; the first during early pod set and the second during late pod set.

The results showed that chemical treatment had an effect on damages in early pod set. There was a progression in damage at the field edges to the field interior in early- and late pod set and in damages early in the crop season to later in the season. No relation between damages and the abundance of *C. obstrictus* and *D. brassicae* was found, nor between abundances of the study organisms. The gender ratio of *D. brassicae* displayed more males than females. An exceptionally warm and dry climate during the spring and summer of 2018 did have an impact on this study. The weather conditions affected the growth of the rapeseed plants and complicated the surveys of damages. The climate may also have affected the abundances of weevils and pod midges; indeed, a considerably lower number of weevils during this season compared to the number of weevils in a study carried out during the season of 2017 was shown. Analyses of damage between regions within the province showed no significant differences between them, and landscape complexity was not correlated to abundances of the study organisms or damages by *D. brassicae*. Positive correlations between the proportion of rapeseed fields from the previous year and damage by *D. brassicae* could be reported, however, these relationships were not consistent between damages in early- and late season or between damages at the field edge and in the inner parts of the fields. The distance to the nearest previous year's rapeseed field could not explain the abundances or damages, but a probable cause for this is the dense cultivation of rapeseed fields in Skåne.

Sammanfattning

Höstraps (*Brassica napus*) är den vanligaste oljeväxten som odlas i Skåne. Höstraps angrips ofta av olika skadedjur. I den här studien betraktas två av dessa; blygrå rapsvivel (*Ceutorhynchus obstrictus*) och skidgallmygga (*Dasineura brassicae*). Angrepp av viveln utgör vanligtvis inte ett stort hot mot höstrapsodlingar, men genom sina gnaghål i rapsskidorna möjliggör de för myggan att lägga sina ägg som senare utvecklas till små larver vilka kan orsaka betydande skador i rapsskidorna. Den här studien, som utfördes vid 18 rapsfält i Skåne under våren och sommaren 2018, fokuserar på vilka omständigheter inom fälten och i det omgivande landskapet som kan påverka förekomsten av myggor och vivlar samt skador orsakade av myggorna. Parametrar som undersökts inkluderar effekter av kemisk besprutning, fångstantal av vivlar, landskapskomplexitet (andel av exempelvis skogsklädda områden), andel vår- och höstrapsfält från 2017 års rapssäsong, och avståndet mellan rapsfälten och det närmaste höstrapsfältet från 2017 års rapssäsong. Effekter av kemisk behandling undersöktes med *kontrollzoner* där inga bekämpningsmedel använts. En kontrollzon per studiefält inrättades. Fällfångster av vivlar och myggor samlades in mellan april och juli under nästan 10 veckors tid. Två fältinventeringar av myggskador utfördes under fältstudieperioden; den första under rapsens tidigare skidutvecklingsstadie och den andra under det senare skidutvecklingsstadiet. Geografiska data hanterades i ett geografiskt informationssystem, ArcGIS.

Resultaten visade bland annat att kemisk behandling hade en effekt på myggskador i tidigt skidutvecklingsstadie. Inget samband mellan skador och fångstantal av vivlar och myggor hittades, inte heller mellan fångstantalet av arterna. Skidgallmyggehanarna var fler till antalet än honorna. Ett exceptionellt varmt och torrt klimat under våren och sommaren 2018 har påverkat den här studien. Väderförhållandena påverkade tillväxten av rapsplantorna och försvårade fältinventeringarna av skador. Vädret kan även ha påverkat fångstantalet av vivlar och skidgallmyggor, det faktum att ett betydligt lägre antal vivlar under den här rapssäsongen jämfört med antalet vivlar i en studie som utfördes under 2017 års rapssäsong, vittnar om detta. Inga tydliga skillnader i skador mellan olika regioner inom Skåne hittades, och undersökningar av landskapskomplexitet visade inte på samband med abundans av arterna eller skador orsakade av skidgallmygga. Positiva samband mellan andel av rapsfält från året innan och skador av skidgallmygga kunde redovisas, dessa samband var dock inte konsekventa mellan skador i tidigt- och sent skidutvecklingsstadie eller mellan skador i fältkant och i de inre delarna av fältet. Avståndet till närmaste föregående års rapsfält kunde inte förklara antalet myggor eller skador, men en trolig orsak till det är den täta odlingen av höstraps i Skåne och därmed komplikationer i att undersöka betydelsen av avstånd.

1. Introduction

1.1 Oilseed rape

Oleaginous seeds, or “oilseeds”, are oil-rich seeds from which the oil can be extracted. Oilseed crops, such as soybean, rapeseed, palm kernel and cottonseed, constitutes an important part of the world grain production (Carré & Pouzet, 2014). Next after soybean, oilseed plants in the family Brassicaceae, are the worlds’ second most common oilseed crops produced, and in European agriculture these crops represent the most common (Carré & Pouzet, 2014; Zajac et al., 2016). Brassicaceae consists of species of flowering mustard- and cabbage plants where many are of great economic importance. The Brassicaceae genus *Brassica* contains some of the most important species, such as cauliflower and broccoli (*Brassicae oleracea*), turnip (*Brassicae rapa*) and the oilseed brassica *Brassicae napus*, commonly called “rapeseed”, “rape” or “oilseed rape”, *hereafter* “OSR” (Bañuelos, Dhillon & Banga, 2013). *B. napus* provides one of the world´s main source of edible vegetable oil (Unal, Sincik & Izli, 2009), which is commonly called “canola oil”. There are two distinct types of OSR, winter oilseed rape, *hereafter* “WOSR” (*figure 1*), and spring oilseed rape, *hereafter* “SOSR”.

OSR is an annual herbaceous plant which normally grows 1-2 meters in height (Alford, 2003). The root system is long and thin and the plants usually have several erect branches that shoot both terminally and laterally from the stem and from which small yellow flowers develop in racemes. The foliage has a blue-green colour coated with a thin wax (Alford, 2003). The OSR fruits consist of long, narrow pods. The pods, which are green in the immature stages and become brown as they ripen, develop from two carpels in the ovary that result in the fruit having two pod walls but which are united in the immature pods. Inside the pod, the small, black seeds develop in two rows inside two chambers (locules) separated by a rigid thin wall (septum) which parts the pod on the inside. When the pod is ripe, the united pod walls eventually split open from the base and upward, which releases the seeds but leaves the septum intact (Alford, 2003).

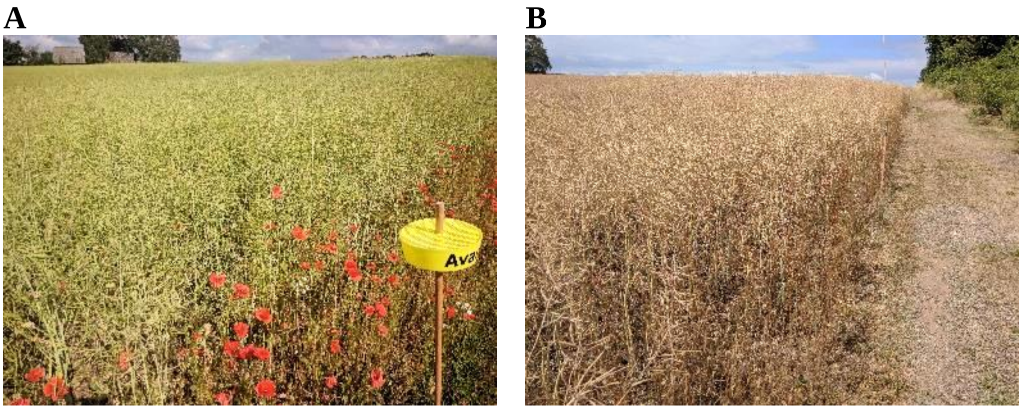


Figure 1. The edge of a WOSR- field earlier and later in the crop season. *1(A)*: in early season, the photo was taken in mid-June. *1(B)*: in late season, the photo was taken in mid-July (*photo:* Emma Johansson).

Of the two OSR- types, WOSR is often more commonly grown as it generally has better abilities to compensate for crop damage caused by pests, diseases or abiotic factors (Alford, 2003). WOSR is sown in August to early September and harvested when the pods are ripe in summer the following year. SOSR is sown in spring and harvested in summer the same year. In order to reduce possible crop diseases, OSR is usually grown in 3-4 year crop rotations with wheat or barley after a year of fallow and with break-crops of Leguminosae variants where peas or beans are commonly grown (Alford, 2003).

In Europe, OSR cultivation has increased considerably in the past ten years (Carré & Pouzet, 2014; Weymann et al., 2015). France and Germany are the biggest growers (Carré & Pouzet, 2014; Unal, Sincik & Izli, 2009; Weymann et al., 2015) and Austria, Denmark and Sweden form another group of important producers (Carré & Pouzet, 2014). The total acres of rape and turnip rape in Sweden in 2017 was 114 800 hectares, which is an increase in production by 24% from the year before (SCB, 2017; SCB, 2018). The larger part of this consisted of rape.

OSR is mainly grown for the oil in the seeds. Products derived from OSR include cooking oil, biofuel, lubricant, cattle fodder from the plant matter, and products for the making of soaps and synthetic rubber (Alford, 2008; Williams, 2010). The most common type of OSR cultivated in Europe is the winter-type (Alford, 2003; Bañuelos, Dhillon & Banga, 2013). This is also true for Sweden, where the WOSR- cultivation have markedly expanded in the past years. Most of the WOSR in Sweden is grown in the southernmost province; Skåne, where the total production in 2017 was 168 600 tonnes, which constitutes 47% of the total production in Sweden (SCB, 2018).

Success in growth of WOSR is dependent on several factors, including the soil quality, nitrogen supply, management and the genotype (Weymann et al., 2015). Weather conditions, such as solar radiation, temperature and precipitation during specific growth stages, also constitute significant factors affecting WOSR plant development (Takashima et al., 2013; Zajac et al., 2016; Weymann et al., 2015). High temperatures and drought stress during the initial stages of pod- and seed formation have been shown to negatively affect pod development (Angandi et al., 2000) and the maximum seed yield and oil content in seeds (Weymann et al., 2015). Drought stress during the early flowering- or seed development have also been shown to negatively affect the growth and development of WOSR plants and seeds in different ways (Bouchereau et al., 1996; Champolivier & Merrien, 1996; Hamzei & Soltani, 2012; Hatzig et al., 2018).

Apart from abiotic factors affecting WOSR growth and yield, there are also various fungal diseases (Alford, 2003, Depotter et al., 2016; Kania et al., 2018) and insect pests that occur in OSR cultivars and which may have significant impacts on production. Some examples of insect pests include the cabbage seed weevil (*Ceutorhynchus obstrictus*), the cabbage stem weevil (*Ceutorhynchus pallidactylus*), the brassica pod gall midge (*Dasineura brassicae*), cabbage flea beetles (*Psylliodes* spp.), the cabbage aphid (*Brevicoryne brassicaeand*) and pollen beetles (*Meligethes* spp.) (Alford, 2003). Only a few of these insect pests, however, pose serious threats to crop production (Alford, 2003; Vaitelyte et al., 2011).

This study involves two of the most important insect pests attacking WOSR in northern Europe; *C. obstrictus* and *D. brassicae* (Alford, Nilsson and Ulber 2003, Nilsson et al. 2015). While *C. obstrictus* may both possess the position as a primary pest and an important aggregate for *D. brassicae* infestation, damage by *D. brassicae* is typically dependent on preceding pod invasions by *C. obstrictus* and usually causes greater damage in WOSR crops. The following section provides introductions to these organisms.

1.2 The study organisms

1.2.1 *Ceutorhynchus obstrictus* - Cabbage seed weevil

The cabbage seed weevil, *Ceutorhynchus obstrictus* (Marsham) (Coleoptera: Curculionidae) [syn. *Ceutorhynchus assimilis* Payk.], belongs to a large genus of weevils with more than 100 described species in Europe (Korotyaev, 2008) in which many prefer plant species in the family Brassicaceae for feeding and as their plant hosts for oviposition (Sivčev et al., 2015). *C. obstrictus* is oligophagous on brassicaceous seed crops (Cárcamo et al., 2009) and has a particular preference for *B. napus* (Gunnarsson, 2016a; Váitelyte et al., 2011). In Europe, occurrence of *C. obstrictus* is especially common in regions where oilseed crops are produced (Cárcamo et al., 2009; Dosdall et al., 2002), where it has regularly become a serious pest in WOSR- crops (Cárcamo et al., 2009; Dosdall et al., 2002; Dosdall et al., 2006; Fergusson et al., 1999; Kovács et al., 2013).

Eggs of *C. obstrictus* are deposited into immature pods in the earliest stage of pod development when the petals have dropped and the pistil enlargement occurs (Dosdall et al., 2002). The female pierces a hole in the pod with her proboscis where she deposits an egg (Williams, 2010). The pod is tagged with a pheromone after oviposition to inhibit repeated usage by the female herself or other females (Fergusson et al., 1999; Haye et al., 2010). Usually one egg per pod is deposited (Alford, Nilsson & Ulber, 2003), however, one single female may lay between 24 and 240 eggs in total (Williams, 2010). The eggs hatch within 1-2 weeks, after which the larvae feed on the developing seeds. The larvae undergo three larval instar stages, which span through 2-4 weeks (Dosdall et al., 2006). When the larvae are fully developed, they chew out of the pod and drop to the ground where they burrow into the soil and pupate. The new generation of imaginal adults emerges approximately 2-3 weeks later, usually in July when the pods are maturing (Dosdall & Moisey, 2004; Stephansson & Åhman, 1998). This generation of adults then feeds on the pods until the end of the crop season (Haye et al., 2010) when they migrate to nearby overwintering sites among trees, bushes, tall grass, shrubs or underneath leaf litter where they initiate the period of adult diapause (Alford, 2008; Gunnarsson, 2016a; Williams, 2010). This same generation of adults becomes active again when the soil temperature rises to 10-15ºC (Ulmer & Dosdall, 2006) and the WOSR starts to develop flowers (Alford, Nilsson & Ulber, 2003), which may happen already in the end of April (Gunnarsson, 2016b), or in late May (Ulmer & Dosdall, 2006). After emergence, the adults move to nearby WOSR- fields where they feed on the developing flower buds or the pods until it is time for mating (Alford, Nilsson & Ulber, 2003; Dosdall & Moisey, 2004). Mating occurs approximately two weeks after hibernation ends (Alford, Nilsson & Ulber, 2003). The life cycle of *C. obstrictus* generates one generation per WOSR crop season (Jordbruksverket, 2016a).

While direct infestation by *C. obstrictus* does not typically pose a major threat to WOSR production, the attacks will usually facilitate infestation by *D. brassicae*, which is a much greater problem (Aiéro et al., 2018; Jordbruksverket, 2016b; Williams, 2010). Yet, infestations by *C. obstrictus* are usually controlled by the use of insecticides during the late flowering stage of the WOSR (Aiéro et al., 2018; Gunnarsson, 2016a). Some natural regulations of populations include; larval parasitism, predation and overwintering mortality of adults (Haye et al., 2010; Williams & Cook, 2010).

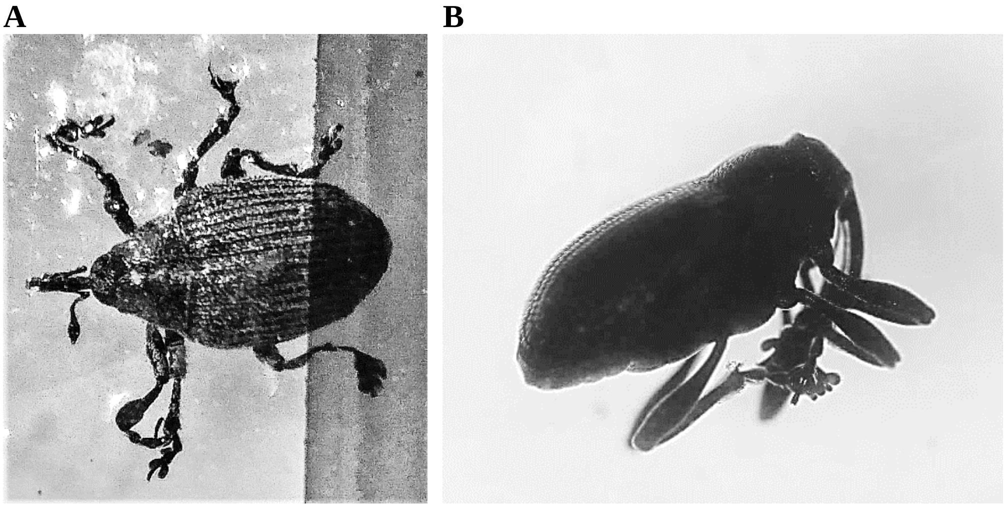


Figure 2. C. *obstrictus*. *2(A)*: above view (*photo*: Emma Johansson). *2(B)*: lateral view (*photo*: Eric Sandelin).

1.2.2 *Dasineura brassicae* Winn. - Brassica pod gall midge

The brassica pod gall midge (*Dasineura brassicae Winn*., Dipt. Cecidomyiidae), is a 0.7-2 mm sized (Stephansson & Åhman, 1998; Sylvén, 1970) dipteran which, together with *C. obstrictus*, belong to the most important group of insect pests of oilseed plant species in family Brassicaceae (Axelsen, 1992a). As for *C. obstrictus*, is *B. napus* also the *Brassica* species preferred by *D. brassicae* as a plant host for oviposition and development of its larvae (Åhman, 1985; Åhman, 1988).

The life cycle of *D. brassicae* begins in spring when the WOSR starts flowering (Graora et al., 2015). The adults emerge from the soil of fields where oilseed rape have been cultivated in the previous year (Alford, Nilsson & Ulber, 2003; Williams & Cook, 2010). Depending on the air- and soil temperature, emergence may already begin in mid-April (Graora et al., 2015), however, more commonly most gall midges appear in the end of May (Alford, Nilsson & Ulber, 2003; Stephansson & Åhman, 1998). The adult pod midges only live for 1-2 (Sylvén, 1970) or 3-5 (Isidoro et al., 1993) days, thus, the males and females may start to mate immediately at the location where they emerge. Shortly after mating the males die while the fertilized females fly to a nearby WOSR- field, navigating by vision (Murchie, Smart & Williams, 1997; Williams & Cook, 2010) and olfactory search (Molnár et al., 2018; Murchie, Smart & Williams, 1997; Williams & Cook, 2010). The females oviposit eggs inside immature pods (Moser et al., 2009; Stephansson & Åhman, 1998) and die shortly after oviposition (Åhman, 1987). Pod gall midges are poor flyers. Dispersion is therefore often dependent on wind strength and direction (Williams & Cook, 2010), thus, the midges usually do not reach more than a few hundred metres from their overwintering site (Moser et al., 2009; Zaller et al., 2008b), or, occasionally they may disperse up to 1-1.5 km if the wind is weak or absent (Stephansson & Åhman, 1998). Oviposition is usually only enabled through prior pod damage caused by *C. obstrictus* that, as mentioned in the previous section, creates pin-sized holes in the pods for feeding and oviposition of its larva (Hughes & Evans, 2003; Murchie & Hume, 2003; Åhman, 1987). The pod midges may however penetrate the pods themselves in certain cases, such as in the case of young pods (therefore more easily penetrated), or if the pods have been damaged due to other factors such as damages by insects other than *C. obstrictus,* or weather damages (Axelsen, 1992a; Nilsson, Vimarlund & Gustafsson, 2004). The female oviposits several clusters of eggs inside one pod, and one female may use up to three pods (Stephansson & Åhman, 1998; Åhman, 1987).

The eggs develops into 1-2mm white or yellow larvae only after a few days inside the pod (Alford, Nilsson & Ulber, 2003; Pavela, Kazda & Herda, 2007; Åhman, 1985). The third instar larvae releases an enzyme on the inner wall tissue of the pods to facilitate feeding, which results in pod distortion, discolouration and eventually desiccation and cracking that causes early shedding of the seeds. Ultimately, this will result in losses in crop yield (Alford, Nilsson & Ulber, 2003; Graora et al., 2015; Jordbruksverket, 2016b). The larvae feed on the pod for approximately 2-4 weeks before the pod cracks and eventually releases the larvae that fall to the ground, burrow down in the soil and spin cocoons (Alford, Nilsson & Ulber, 2003; Graora et al., 2015; Stephansson & Åhman, 1998). The larvae may then pupate within the cocoon which can give rise to a second generation of adults approximately two weeks later. This generation will then fly to a nearby SOSR- field (Williams, 2010). The first generation larvae can also enter winter diapause within the cocoon. The diapause may last until next spring before emergence of adults, or it may even last for a few years in the case of unfavourable climatic conditions (Alford, Nilsson & Ulber, 2003; Ferguson et al., 2004; Williams, 2010; Williams & Cook, 2010). A third and fourth generation *D. brassicae* can also emerge, but by the time of these generations' emergence, the cropping season will soon be over which decreases the probabilities for these females to find adequate hosts (Stephansson & Åhman, 1998). For every generation of *D. brassicae*, more adults enter diapause and then emerge in the following years (Hughes & Evans, 2003; Stephansson & Åhman, 1998), however, the mortality during overwintering is high (Stephansson & Åhman, 1998).

The foremost important natural regulation of populations of *D. brassicae* is predation by hymenopteran parasitoids (Ferguson et al., 2004; Gunnarsson, 2017b).

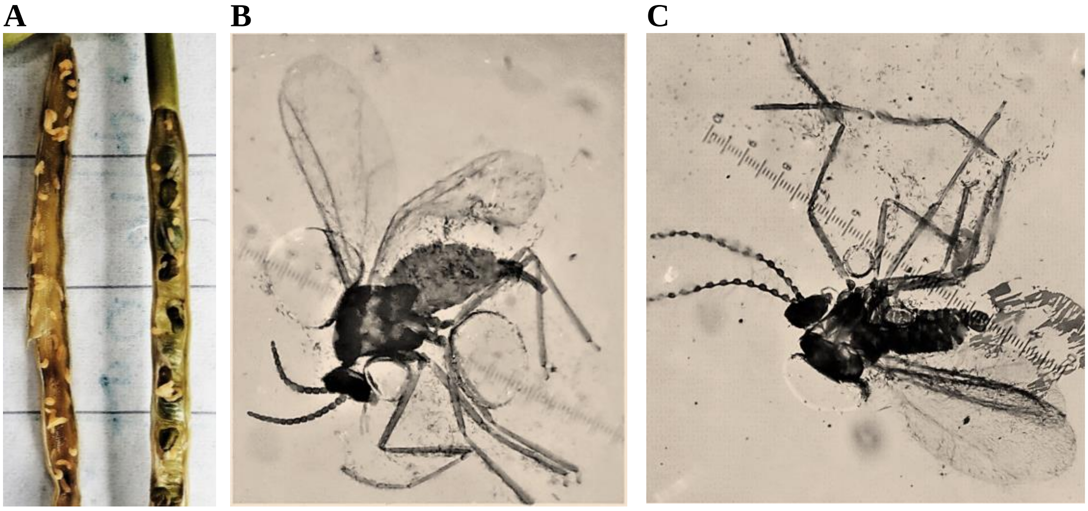


Figure 3. 3(A): Seeds- and *D.brassicae* larvae inside a *B. napus* pod. *3(B)*: A female of *D. brassicae* (note the ovipositor). *3(C)*: A male of *D. brassicae* (*photos*: Emma Johansson).

1.3 *D. brassicae* in Sweden

Abundance of *C. obstrictus* and WOSR- crop damages by *D. brassicae* in Sweden have been relatively restricted to the field edges and thus have not been an issue of importance in the past (Aiéro et al., 2018; Jordbruksverket, 2016b; Nilsson, Vimarlund & Gustafsson, 2004). However, in the past years the situation have been different. *D. brassicae* damages, along with drought in some years, caused considerable losses in crop yields in Skåne in 2015-2017 (Aiéro et al., 2018; Andersson et al., 2015; Gunnarsson, 2016b; Jordbruksverket, 2016b). In 2016, for example, drought and infestations by *D. brassicae* resulted in a kg/ha yield loss by almost 35% from the year before in southern Sweden (Gunnarsson 2016b; SCB, 2016; SCB, 2017) and caused significant yield losses in the eastern part of central Sweden (Aiéro et al., 2018).

There are no established forecasting methods, and hence no threshold values for insecticide treatments, for specific control of *D. brassicae*. The pod midges often migrate to the WOSR-fields continuously for a long period during crop season which makes them particularly difficult to control (Jordbruksverket 2017; Jordbruksverket, 2016b) and the reproductive success of *D. brassicae* in one crop season do not seem to automatically result in a worse or similar situation in the subsequent season (Nilsson, Vimarlund & Gustafsson, 2004). Hence the abundance and damages by *D. brassicae* is often not frequent between years. Moreover, because the pod midges are very small and die shortly after oviposition (Stephansson & Åhman, 1998), they are very difficult to detect in field. Insecticides for specific control of *D. brassicae* is thus not used in Sweden (Jordbruksverket, 2016a; Jordbruksverket, 2016b; Nilsson, Vimarlund & Gustafsson, 2004), but as there are recommendations for chemical treatments for the direct control of infestations by *C. obstrictus*, this indirectly concern control of attacks by *D. brassicae* as well (Aiéro et al., 2018; Gunnarsson, 2016a).

Other methods to regulate *D. brassicae* apply to a landscape-level spatiotemporal rotation. To avoid diseases and pests, cultivation of WOSR is practiced in crop- rotations, hence, is not cultivated in the same field for several consecutive years (Alford, 2003). Therefore, as the gall midges have a short adult life and cannot migrate far, predictions of abundance in one crop season may be based on the amount of closely located *Brassica* plant fields from previous crop seasons (Jordbruksverket, 2016b; Nilsson, Vimarlund & Gustafsson, 2004). A general recommendation is therefore to grow WOSR at safe distances to where WOSR was grown in the previous season (Stephansson & Åhman, 1998).

There are also other factors that can randomly affect the reproductive success and thus the magnitude of damages by *D. brassicae* in a particular season. Such factors include soil temperatures (Axelsen, 1992a; Nilsson, Vimarlund & Gustafsson, 2004), weather conditions (Nilsson, Vimarlund & Gustafsson, 2004), distances between hibernation fields and the WOSR- fields for oviposition (Jordbruksverket, 2016b; Moser et al., 2009), amount of forested land features in the neighbouring landscape (Zaller et al., 2008a), abundance of *C. obstrictus* (Åhman, 1987), and seasonal timing of pod development and emergence of adults (Stephansson & Åhman, 1998).

As previously mentioned, damage by *D. brassicae* has been a large problem in Skåne in the past three years (Aiéro et al., 2018; Andersson et al., 2015; Holmblad et al., 2017). The problem with *D. brassicae* in Skåne can therefore be expected to continue in the 2018 WOSR season. Presently it is not entirely known why populations of *D. brassicae,* and thus inflicted crop damages, increase in certain years (Gunnarsson, 2016b). However, as the climate becomes warmer and the winters become milder, the growth season of WOSR becomes longer and the acres of WOSR- cultivation expand further north (Berg, 2012). Along with these events, future prospects will possibly show that the already established problems with insect pests in WOSR- cultivation, in particularly the problems with *D. brassicae*, will also expand. It is therefore of relevance to obtain further knowledge about factors governing population density and severity of this pest.

1.4 Landscape factors

In extensive agricultural landscapes there will be a large number of insect pests whose life cycles are closely connected to the crops being cultivated (Alford, 2003). The ability of these insect pests to spread may increase in a fragmented landscape with expansive conventional farming systems where much of the natural vegetation has been removed since, for example, this can often result in a decline of natural predators (Bianchi, Booij & Tscharntke, 2006; Chaplin-Kramer et al., 2011; Mazi & Dorn, 2012; Thies et al., 2011; With et al., 2002).

Earlier studies have investigated the relations between abundances of insect pests and damages in crops and the distances to, - and areas of their host plants in the neighbouring landscape. Sometimes with contradictory results. As an example, Thies, Steffan-Dewenter & Tscharntke (2003) found no correlations between the total percentage of OSR in the surrounding landscape and the abundance of pollen beetles, while Zaller et al. (2008b) found a negative correlation between the same landscape parameter and organism but a positive correlation for another OSR pest; the stem weevil. When the abundances of *D. brassicae* and

C. obstrictus and the area of OSR in the surrounding landscape were investigated in two studies, either no relationship was found for *D. brassicae* (Zaller et al., 2008b) or was negatively correlated for both *D. brassicae* and *C. obstrictus* (Zaller et al. 2008a). Hence, clearly there are gaps of knowledge about the relations between landscape parameters and abundances and damages by *D. brassicae*, but understanding more about the ecology of *D. brassicae* may increase the chances of avoiding crop damages by this pest in the future.

This study focuses on three landscape parameters; the complexity of the landscape (proportion of e.g. forested areas) in the neighbouring landscape, the proportion of OSR-crops in the neighbouring landscape, and the distances to the closest WOSR- field from last year.

1.5 Objectives

The aim of this study is to examine how within-field and landscape factors affect and relate to pod damages caused by *D. brassicae* in 18 study fields with WOSR- cultivation in Skåne county, southern Sweden. A 24m x 20m zone which is free from application of chemical insecticides, in this study called a *Pesticide free-control zone*, hereafter "PFCZ", has been established in each of the study fields in order to investigate the effects of use by chemical treatments on damages by *D. brassicae*. Issues which are considered in this study include the distribution of damages within the fields, the abundance of *C. obstrictus*, the area of WOSR-fields in the previous year, the distance between the closest WOSR- fields from 2017 to the study fields, and landscape complexity. The parameters included in this study are chosen based on previous knowledge of the biology of the study organisms (*see* section 1.2) and based on the study by another student from last year (Rösvik, *unpublished*, 2017). Sex ratio of *D. brassicae* will also be assessed.

Study questions and hypotheses

- How does the phenology of abundances of the study organisms evolve as the crop season progresses? The hypothesis is that abundances of *D. brassicae* and *C. obstrictus* in traps will decrease later in crop season, whereas field damages will increase.
- What is the sex ratio of *D. brassicae* males and females determined by trap catches? Based on the notion that fertilized females migrate to WOSR-fields from the overwintering fields, it is hypothesized that more females than males will be found in the samples.
- Is the approach of *in situ* counting of weevils early in the crop season an applicable predictor of abundances of weevils later in the crop season and, hence, for the decision upon the use of chemical treatments in the field?
- What is the relation between abundance of *D. brassicae* and *C. obstrictus*?
- Are there any statistically significant differences in abundances of *D. brassicae* and *C. obstrictus* within- and outside of the PFCZ?
- Are there any statistically significant relationships between the abundance of *C. obstrictus* caught in the two trap types?
- How does abundances of *C. obstrictus* in the study conducted during the season of 2017 differ from abundances in this study?

- Damages by *D. brassicae* will be greater in the field border compared to 20m into the field in both early pod set (i.e. early in the crop season) and late pod set (i.e. later in crop season).
- Is damages by *D. brassicae* greater within the PFCZ compared to the surveyed parts of the WOSR- fields outside of the PFCZ?
- What is the relationship of damages by *D. brassicae* between early pod set and late pod set?
- What is the effect of abundances of *C. obstrictus* and *D. brassicae* and chemical treatments on damages by *D. brassicae*? It is hypothesized that damages by *D. brassicae* will correlate positively with the abundance of *D. brassicae* and *C. obstrictus*.
- Are there any difference in damages by *D. brassicae* and abundance of *D. brassicae* at different geographical directions within the study region?
- How does landscape factors, i.e. the proportion of forested- and grassy land types, the quantity of previous year OSR- fields, and the distance between the closest previous year WOSR- field centre points to the study fields centre points, relate to damages by *D. brassicae* and abundances of *D. brassicae* and *C. obstrictus*? On the account of the biology of the study organisms (*section 1.2.1* and *1.2.2*), landscape complexity is thought to correlate positively with abundance *C. obstrictus* and the proportion of OSR- fields from 2017 and distances between OSR fields in 2017 and 2018, is thought to correlate positively to abundance of *D. brassicae* or damage by *D. brassicae*.

Finally, a questionnaire was compiled and sent to the WOSR-growers after the crop season had ended. The questions were geared towards the management of the WOSR- cultivation and the farmers' perceptions regarding this years' abundances and damages of *C. obstrictus* and *D. brassicae* compared to the previous year.

2 Material and methods

All the maps presented in the report are produced in ArcGIS software (ESRI, Redlands, CA).

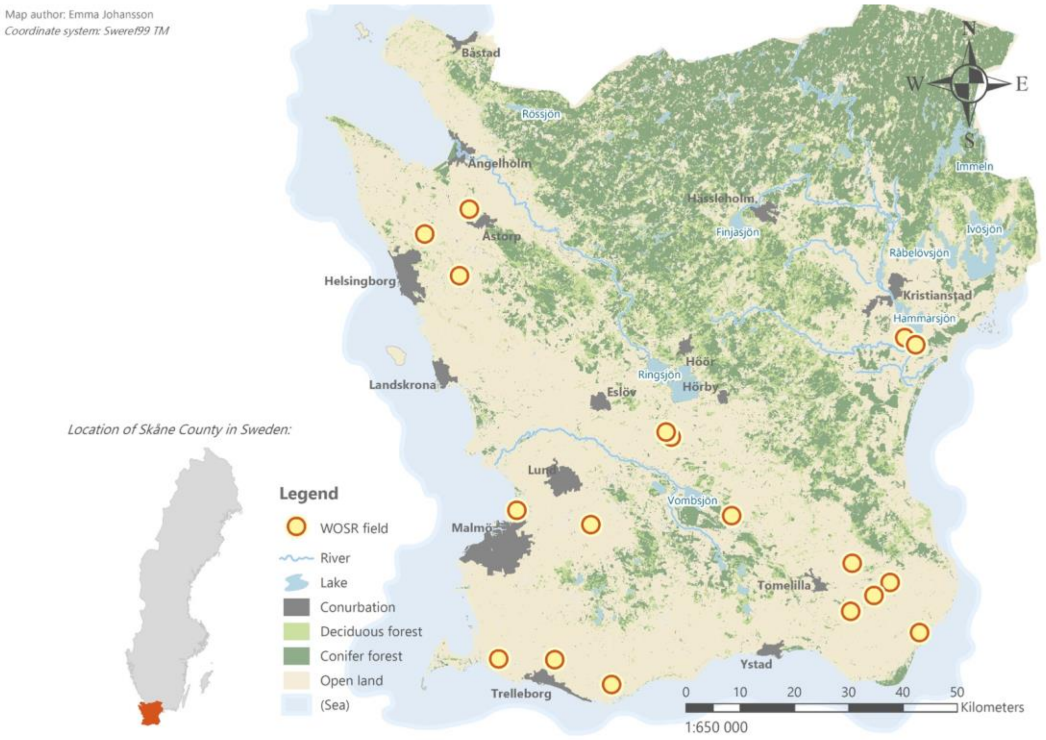
2.1 The study region

The study was conducted in the province of Skåne in Sweden's southernmost part (*figure 4*). This region is mainly characterized by arable land, which cover about 40% of the total land mass of the province (SCB, 2018). The two main crops cultivated in 2017 was Winter wheat, which covered ~24% of the total arable land, and spring barley that covered ~16%. OSR-crops constituted ~11% of the total arable land in Skåne in 2017, this is ~43% of all OSR grown in Sweden which makes Skåne the most important OSR-growing region in the country. Of the total hectares of OSR grown in Skåne in 2017, WOSR constituted 99.5% (SCB, 2018).

This study was performed in the summer of 2018. The province of Skåne has a mild climate relative to other more northerly parts of Sweden. The average temperature normally ranges between 15 to 17 ºC in July and the annual precipitation ranges between 500mm and 1000mm (SMHI, 2016a).

2.2 The study sites

The farmers that participated in this study were contacted through phone calls. Some of them had been participating in a similar study conducted last year, and some were participating for the first time. The selection of the study localities was primarily controlled by the willingness of the participants to leave a PFCZ in their field, and this did to some extent affect the number of participants in the study and the locations of the study sites within the study region. Ultimately 18 fields were included in the study (*figure 4*). The area of the fields can be viewed in the table in *appendix 1*.


Map author: Emma Johansson
Coordinate system: Sweref99 TM

Data source: GSD-Terrängkartan, GSD- Översiktskartan © Lantmäteriet & own coordinate data points

Figure 4. Map of Skåne and the localities of the WOSR- fields. Most towns, roads, lakes and watercourses in Skåne has been excluded in the map, however, the largest cities, towns, lakes and rivers are included for orientation purposes.

2.3 Fieldwork

2.3.1 Collection of trap samples

Field work was conducted for approximately 10 weeks between 18-04-26, when the first traps were placed in field, and 18-07-10 when the last traps were collected from the field. This period covered the beginning of blooming until shortly before harvest.

To mark PFCZ at each of the study fields, a red flag was placed in each corner of the PFCZ. The flags were taller than the height of the canopy when it was fully developed in order to be easily detected by the farmer when it was time to apply insecticides.

Two yellow pan traps (donated by Dupont) and two yellow sticky traps (20 x 25cm, purchased from *Borregaard BioPlant©*), were located at one edge of each field approximately in the middle of the field edge. One trap of each kind was placed at the field border within the PFCZ, and the other two traps were placed a few metres outside of the PFCZ. Both types of traps were attached to wooden sticks to locate the traps at a desirable height in the canopy of the WOSR- plants (*figure 5, 6*). The sticky traps were covered with wire netting to prevent unwanted animals (e.g. birds) from getting caught, and to prevent predation. For the same reason, the pan traps also had a net, which covered the hole of the bowl. To catch insects in the pan traps, they were filled with water and a small amount of dish washing detergent.

The traps were placed in field between 18-04-26 and 18-05-11. From the date when the traps had been placed in field to the date when they were taken down, each field was visited approximately once in a week to collect the samples and renew the traps. The fields were visited in the same order as the traps had been set up. At each visit, the sticky traps were covered with cling film and marked with locality, date, and if it was collected within the PFCZ or not. After collection, a new sticky trap was positioned on the stick. The contents of the pan traps were filtered through large tea filters which were then stored in plastic tubes filled with 70% ethanol and marked in the same way as the sticky traps. All samples were kept in a fridge after each collection until they were sorted and analysed.

The quantity of individuals of the study organisms were documented in lab. A stereo microscope was used when needed for identification and counting. On the sticky traps, the number of individuals of both species were counted, however in the pan trap samples, only individuals of *C. obstrictus* were counted. For identification and counting of individuals of *D. brassicae*, a 2 x 2cm grid was charted on an overhead transparent plastic sheet which was placed on top of the sticky traps. Using this grid was crucial for a systematic browsing of the traps and to prevent double-counting and oversight of individuals. Apart from individual counts of *D. brassicae*, gender was documented to allow for sex ratio analyses.

The traps were present in field between 55 and 74 days throughout the field work process. The difference in number of field days was due to the rather large amount of time it took to perform the field surveys of damages by *D. brassicae* at each study site, which disrupted the time sequence and schedule for field visits. In order to consider this variation in number of field days in the statistical analyses, the parameter of *individuals/day* was used as a metric of abundances of *C. obstrictus* and *D. brassicae* instead of applying the total number of individuals.

Figure 5. Yellow pan traps at the edge of two different WOSR- fields in the scene of late pod set. Right picture: the results of severe drought, the state of most WOSR- fields later in the crop season in this study due to the weather conditions in the summer of 2018 (*photo*: Emma Johansson).

Figure 6. A yellow sticky trap at the edge of a WOSR- field in late pod set. The trap is covered with wire netting (*photo*: Emma Johansson).

2.3.2 Field survey of damages by *D. brassicae*

Field surveys to record damages by *D. brassicae* were performed at two occasions. The first survey was conducted between 18-06-04 and 18-06-15, which was the period shortly after early pod formation, and the second survey was conducted between 18-07-02 and 18-07-10, which was the period of late pod formation. BBCH of the crops was 69-79 at the time of the first survey and 85+ at the time of the second survey (Lancashire et al. 1991). The basic methodology of the surveys followed a protocol by the *Swedish Board of Agriculture* (SBOA), however the methodology was somewhat adjusted, primarily to fit with the PFCZ-approach of this study. According to the protocol by SBOA, surveys of damages by *D. brassicae* are performed at two sites in each test field. At each location, a total of 20 WOSR-plants are inspected. One of the sites is located at the field edge and the other is located 20 metres into the field. The first-, the secondary-, and the main inflorescence of each WOSR-plant is inspected for damages. The percentage of damage of each plant is then obtained by counting all the pods and all the damaged pods at each inflorescence. Below is described how the surveys in this study were performed.

In this study, the approach for the field survey of damages differed in the first and second survey due to time- and labour constraints at the time of the first survey. Four locations and a total of 40 plants were checked for pod damages in the first survey, while ten locations and a total of 100 plants were checked for damages in the second survey. The first survey included two locations situated within the PFCZ where 10 plants located at the traps at the field edge of the PFCZ and 10 plants 20m into the PFCZ, were checked for damages. The other two sites were located outside of the PFCZ. In the second survey, the same locations as those included in the first survey were also included in this survey; however, an additional six locations which were located at the remaining three sides of the field, were also included. *Figure 7* shows the spatial configuration of the field surveys where each of the sample sites in the surveys represent an inspection of 10 plants.

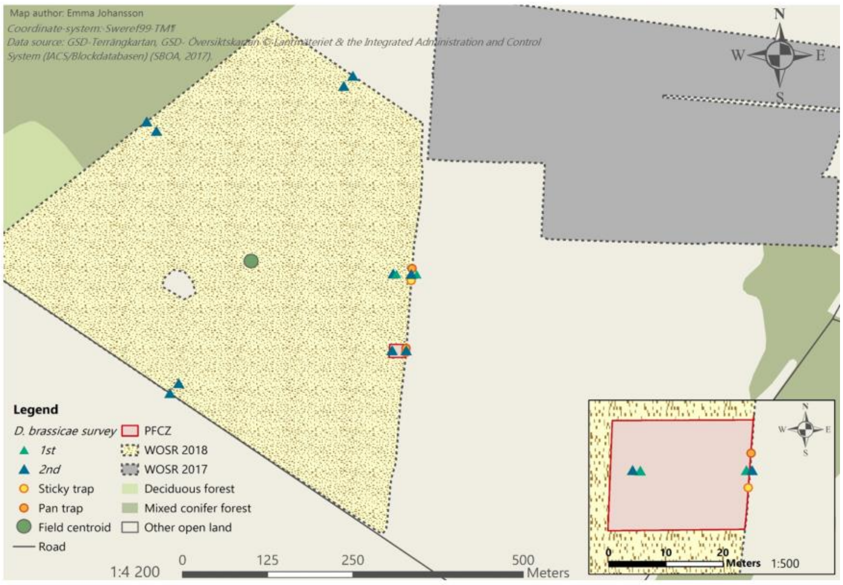


Figure 7. A WOSR- field in this study and the location of a nearby WOSR- field from 2017. The field centroid and the locations of sticky traps, pan traps, the PFCZ and *D. brassicae* survey sample sites, are marked. The small inserted figure shows a detailed view of the PFCZ and the traps and survey sample sites within it.

The final metrics of damages which was used in the statistics, was the mean percentage of damage for every *B. napus* plant. Non-infested pods, damaged pods and the number of bare pod stalks on the racemes on each florescence, was calculated. The number of bare pod stalks was subtracted in the calculations since such damages are likely caused by factors other than *D. brassicae,* such as pollen beetles (Zaller et al., 2008a).

2.3.3 Analyses of landscape factors

All data containing geographic information of the distribution of WOSR- fields from last year and ground-cover data which are included in the landscape analyses, was managed in ArcGIS (ESRI, Redlands, CA). Landscape complexity and the area of OSR- fields from 2017 was analysed within defined distances from the study fields. Four circular buffer zones with radiuses of 3000 metres, 2000 metres, 1000 metres and 500 metres were drawn around a centre point of each WOSR- field (*figure 8*). The sizes of the buffer zones were primarily chosen based on the current notion that *D. brassicae* usually do not disperse further than 0.5-1.5 km from its emergence sites (Moser et al., 2009; Stephansson & Åhman, 1998; Zaller et al., 2008b), while *C. obstrictus* may fly much further than 2 km from its hibernation sites (Dosdall et al., 2006; Tansey et al., 2010). Smaller buffer zones were not subtracted from the larger in the statistical analyses because usually it is not done in these types of analyses and hence to compare with previous studies it was not done in this study either.

Landscape variables used to describe the landscape complexity around the study fields included spatial information of land types in Skåne derived from the Swedish ground cover data (*Svensk marktäckedata*, SMD). Other landscape variables included the distances between the centre points of the closest WOSR- fields from last year and the centre points of the study fields, and the areas of OSR- fields in 2017. The SMD data, collected from the Swedish Environmental Protection Agency, consists of ground cover classes based on the European classification system CORINE land cover (Naturvårdsverket, 2014). According to this system, there can be different types (classes) of a particular land feature. For example, coniferous forest consists of six classes. In this study, the different types were reduced into a single land type- such as "coniferous forest". Ultimately this resulted in a total of 25 classes merged into 14 land types which were finally used in the landscape analyses (*table 1*). The metrics of landscape complexity constituted the summed total percentage of the different land types within each of the four buffer zones around each study field.

Table 1. The land types and their corresponding SMD- codes which were used to calculate landscape complexity.

Land type	**SMD code**
Non-urban park	1425
Urban green-areas	141, 1426
Orchard	222
Pasture land	231
Deciduous forest	3111, 3112, 3113
Coniferous forest	31211, 312121, 312122, 3122, 3123, 31212
Mixed forest	3131, 3132, 3133
Scrub	3241
Clear-cut	3242

Young forest	3243
Limnogenic wetland	411
Mire	4121
River/Stream	511
Lake/Pond	5121, 5122

Data including WOSR- fields in 2017 was derived from the *Integrated Administration and Control System* (IACS, “Blockdatabasen”), governed by the Swedish Board of Agriculture (SBOA). IACS include annually updated crop-specific codes for all the registered agricultural fields in Sweden. Distances between the centre points of the WOSR- fields and the centre point of the closest WOSR- field from 2017, were calculated in ArcGIS (*figure 9*). The data was then exported to Microsoft Excel to calculate the percentage of each land type and WOSR- field within each buffer zone for all the study sites. Both winter- and spring rape fields from 2017 were implemented in the calculations as *C. obstrictus* and *D. brassicae* may also attack SOSR (Graora et al., 2015; Stephansson, 1998). The amount of SOSR- fields within the buffer zones was, however, negligible relative to the number of WOSR- fields and was often not contained within the buffer zones. Data of WOSR- fields from 2018 other than the study fields, could not be included in the calculations as this information was not accessible at the time when these calculations were made.

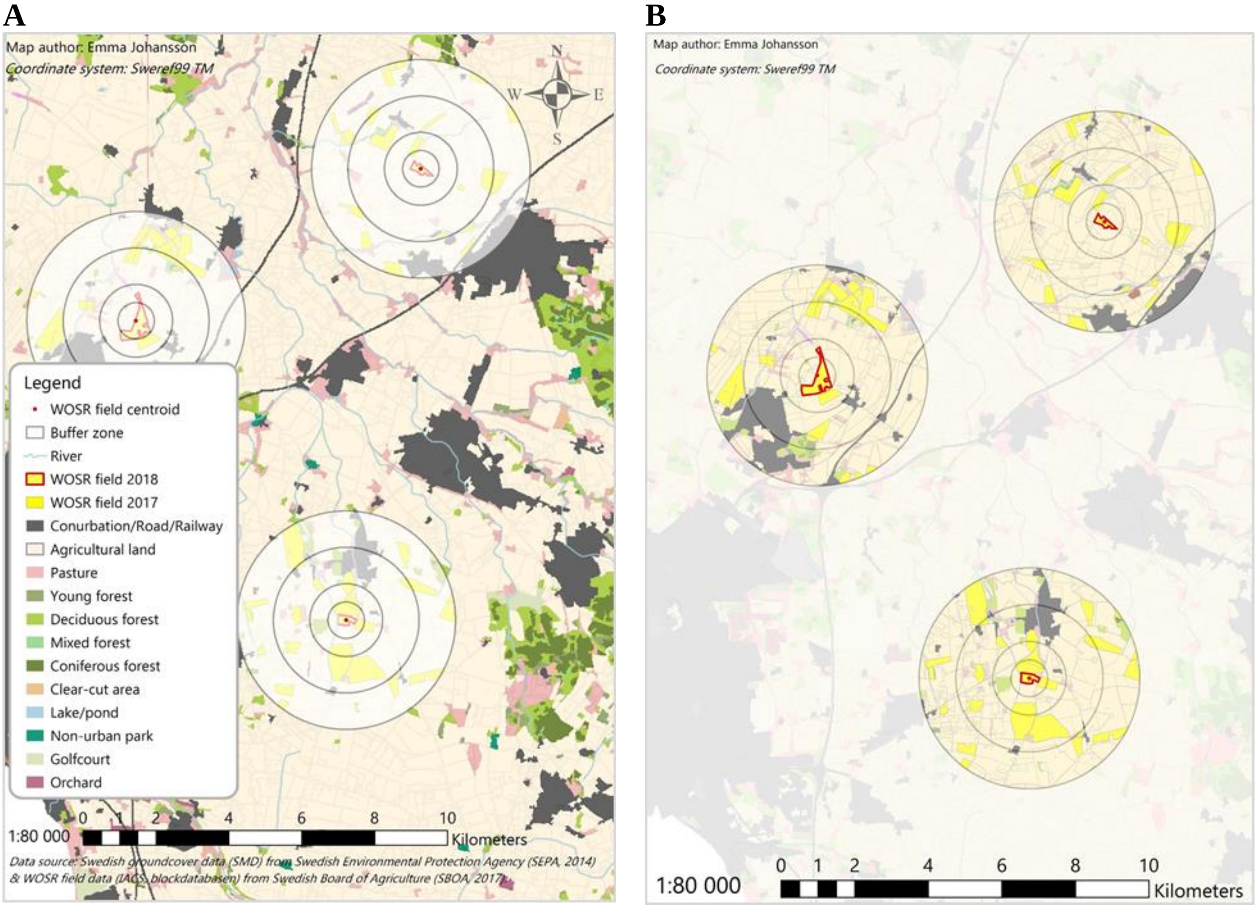


Figure 8. The maps show: the spatial arrangement of three of the WOSR fields included in this study, buffer zones around each WOSR field, agricultural field data (IACS), and Swedish ground cover data (SMD). *8(A)*: four buffer zones drawn around the centre points of three 2018 WOSR fields, the 2017 WOSR fields within the buffer zones are highlighted. *8(B)*: the geographic information within the buffer zones is extracted.

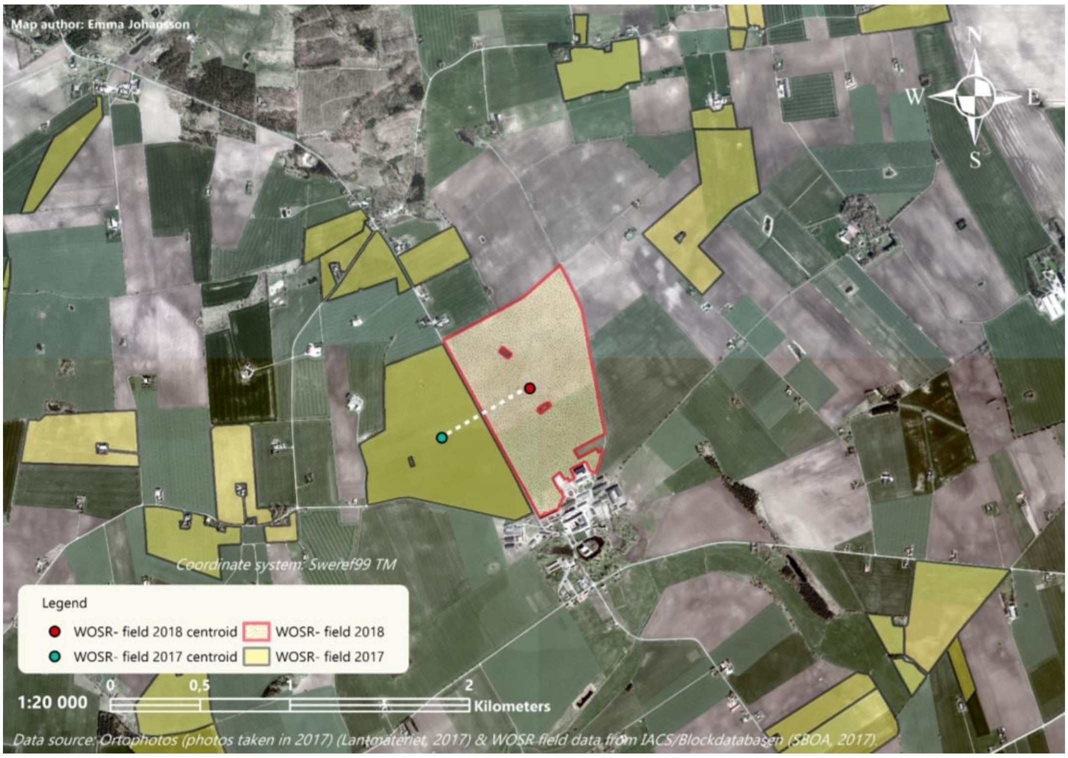


Figure 9. Ortophotos (from 2017) of the nearby landscape to one of the WOSR study fields, where the 2017 WOSR- fields are highlighted. The centre point of the study field and the centre point of the closest 2017 WOSR- field are marked. The dashed white line illustrates the distance between the fields' centroids.

2.4 Data management and statistical tests

The statistical analyses were performed using SPSS (vers. 12.0.1 for Windows, SPSS Inc., Chicago, IL, USA). SPSS was also used to generate most graphics. Microsoft Excel was used for data compilation, calculations and some graphics. Two graphics were also generated in R (R Core Team 2018) and ggplot2 (Wickham, 2016). All datasets were tested for normal distribution according to Kolmogorov-Smirnov and Shapiro-Wilk tests of normality before statistical analyses were performed (Ghasemi & Zahediasl, 2012). If the dataset to be analysed was normally distributed, applicable tests for normally distributed data was used, and likewise, equivalent tests for datasets which deviated from normal distribution was used if data was not normally distributed.

Mean trap catches of the study organisms throughout the period of field work were displayed with graphics computed in R statistical software and ggplot2.

Difference in abundances of *D. brassicae* males and females counted on the sticky traps was tested with a Mann-Whitney U-test and a Spearman rank correlation test was computed to assess the relation between males and females mean abundances.

A common way to determine if chemical treatments should be applied in the field is to look for *C. obstrictus* on the flower buds *in situ* in the earliest stage of development of the WOSR flowers, which is also the initial period of *C. obstrictus* immigration. Threshold values for application of chemical treatments in Sweden is 1-2 weevils/plant. To investigate if the number of counted weevils were related to the sizes of trap catches of weevils in this study, number of weevils were counted on ten plants within the PFCZ at each field visit during the first four weeks of fieldwork. This was then tested with spearman rank correlation tests to assess relations with total trap catches of weevils in the pan traps and the sticky traps in the first four weeks.

The relation between abundances of *D. brassicae* in the sticky trap samples and the abundances of *C. obstrictus* in the sticky trap- and in the pan trap samples, was examined with Spearman rank correlation tests.

Differences in abundance of *C. obstrictus* in the pan traps and *D. brassicae* and *C. obstrictus* in the sticky traps obtained within the PFCZ and outside of the PFCZ was tested in order to assess if chemical treatments would affect presences of individuals before they had reached the fields. Since these trap catches cannot be regarded as independent samples, the differentiations of abundances between the traps was calculated and tested with a One- sample t-test or Wilcoxon signed rank test.

The relation between abundance of *C. obstrictus* in the two trap types was tested in order to evaluate the efficiency of the trap types. This was tested with a Spearman rank correlation test.

Differences in mean abundances (catch/day) of *C. obstrictus* in sticky trap samples and pan trap samples in the study conducted during the season of 2017 (Rösvik, 2017) and the abundances in this study, were assessed with Mann-Whitney U-tests. Damages by *D. brassicae* was not compared due to considerable differences in the methodologies in the two studies and differences in abundances of *D. brassicae* could not be assessed because this parameter was not included in the 2017 study.

To test the differences in total mean percentage of damages by *D. brassicae* from within- and outside of the PFCZ at the field edge and 20m into the field in early- and late pod set, the datasets for each sample point were subtracted to obtain the differentiations in damages which was then tested with One- sample t-tests or Wilcoxon signed rank tests. To assess the progression of total mean damages within the PFCZ and outside of the PFCZ at the field edge and 20m into the field in early- and late pod set, Pearson- or Spearman rank correlation tests were computed.

The relationship of within-field damages by *D. brassicae* in the field border and 20m into the field between early- and late pod set was examined with Spearman- or Pearson correlation tests.

Multiple regression models were computed to evaluate the effects of abundance of *D. brassicae* in sticky traps and *C. obstrictus* in sticky traps and pan traps and chemical treatment on damages at the field border and 20m into the field within- and outside of the PFCZ in early- and late pod set.

Differences in damages by *D. brassicae* in a geographic perspective in early- and late pod set at the field border and 20m into the field, was examined using a factorial univariate analysis of variance or Kruskal-Wallis H test. The study sites were divided into five cardinal directions; Middle, Northeast, Northwest, Southeast and Southwest, accordingly to where within the study region the sites were located (*figure 10*).

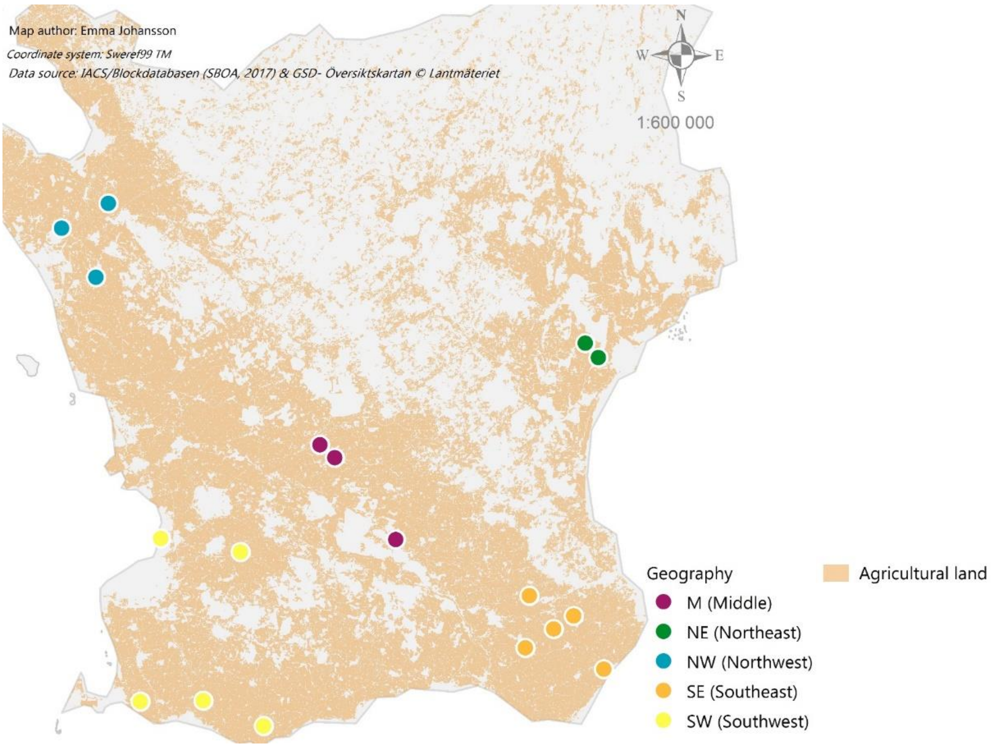


Figure 10. The map shows the categorization of the study sites into cardinal directions within the study region, Skåne. Agricultural land in Skåne is shown, other land-types are excluded.

Multiple regression models were computed to assess the relationship between abundances of *C. obstrictus* and *D. brassicae* and damages by *D. brassicae* within- and outside of the PFCZ at the field edge and 20m into the field against landscape complexity and hectare of OSR from 2017 within 3000, 2000, 1000 and 500 metres buffer zones. The distance to the centre point of the nearest WOSR- field from 2017 from the study fields' centre points were also included in the models. This landscape parameter was also tested with single correlation analyses using Spearman rank or Pearson correlation tests.

3 Results

3.1 Abundances of *D. brassicae* and *C. obstrictus* throughout the crop season

A total of 3372 weevils and 8015 pod midges were caught during the field study, where 794 of the weevils were caught in the sticky straps and 2578 weevils were caught in the pan traps. *Figure 11* shows the mean trap catches of *D. brassicae* and *C. obstrictus* per day with a trend line and ±95% confidence intervals throughout 2.5 months, which cover the whole period of field work. There were large, and sometimes extreme, variances in trap catches between the samples. The data in these figures is thus shown in Log10 to fit all samples in order to display complete trends in the phenology of the species. The set-up of traps at the fields in the beginning of this study was, as explained earlier, not performed during one single day. This occurred between 18-04-26 and 18-05-11. Since the fields were visited once a week from the day the traps had been located in field, the dates for the field visits do not appear in a strict chronological order. The date intervals thus represents one emptying round at each field, which results in overlaps of the dates in *figure 11*.

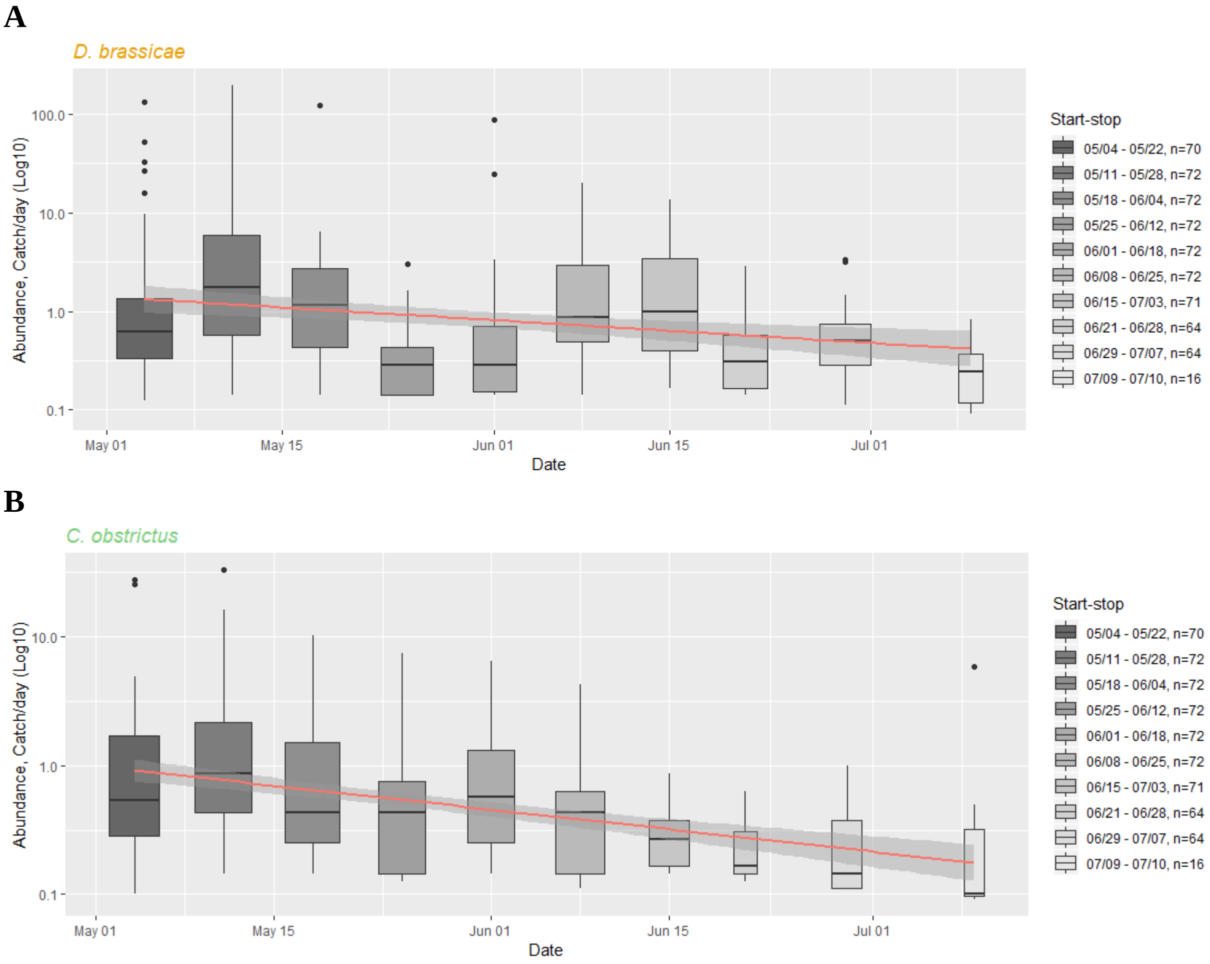


Figure 11. Box plots showing mean abundance of *11(A) D. brassicae* and *11(B) C. obstrictus* and trend lines adjusted to the data and with ±95% confidence interval. The x-axis shows general dates for the field visits and the legends displays the specific dates and the total number of samples for each visit. The figures are created in R statistical software (R Core Team 2018) using ggplot2 statistical software (Wickham, 2016).

3.2 Difference in, and relation of, abundance of *D. brassicae* male and female

A total of 8015 *D. brassicae* midges were counted on the sticky traps. Of these, 6066 were males and 1957 were females, giving the proportion male as ~0.76. *Figure 12* shows the trend of abundance of males and females over the period of fieldwork. The date intervals overlap because of the same reason already explained in *section 3.1*.

The test results showed a statistically significant difference in abundances per day of *D. brassicae* males and females, where mean abundance of males was larger (U=82, n=36, $p<0.05$, mean/day$^{\text{males}}$=2.66, mean/day$^{\text{females}}$=0.88), large outliers were not excluded in this test (*figure 13*). Differences in male and female abundances were also tested with the outliers excluded. This dataset was still not normally distributed and did also show a statistically significant difference between abundances of males and females (U=66, n=33, $p<0.05$, mean/day^{males}=1.1, mean/day^{females}=0.38). A positive correlation was found between males and females mean abundances per day (r=0.562, n=18, p<0.05) when the outliers were not excluded (*figure 13*). The relation between male and female abundances were also tested with the outliers excluded, and this did not show a statistically significant relation between male and female abundances (r=0.414, n=18, p>0.05).

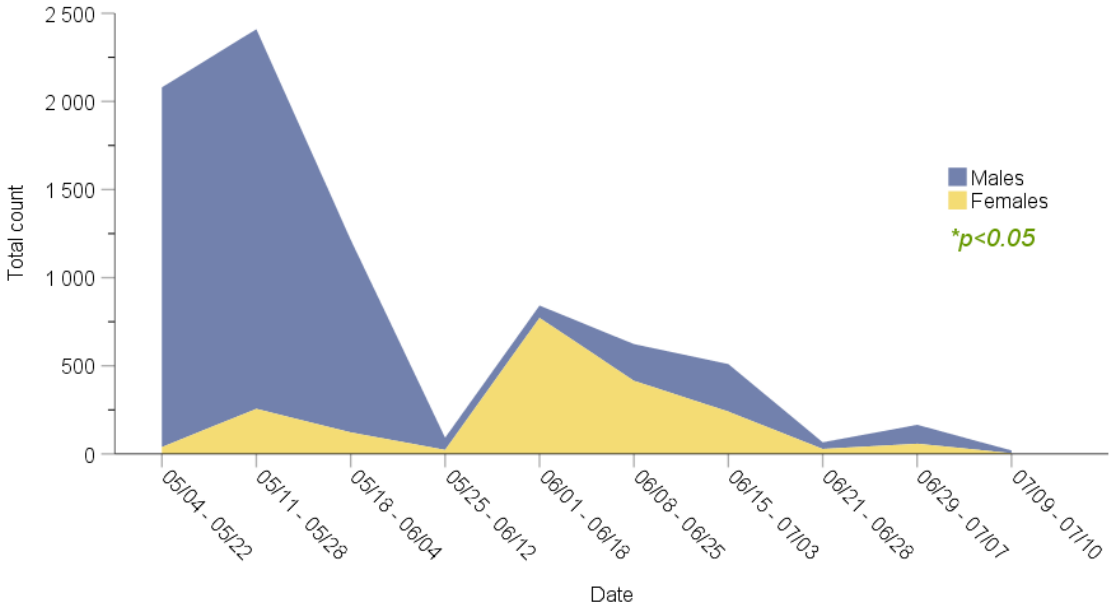


Figure 12. Total abundance of males and females throughout the crop season. Both male- and female data is displayed staring from 0 on the y-axis The x- axis shows the time period for each of the ten visits to the fields during the period of fieldwork. The date-periods overlap due to the differences in dates when the traps were located in field.

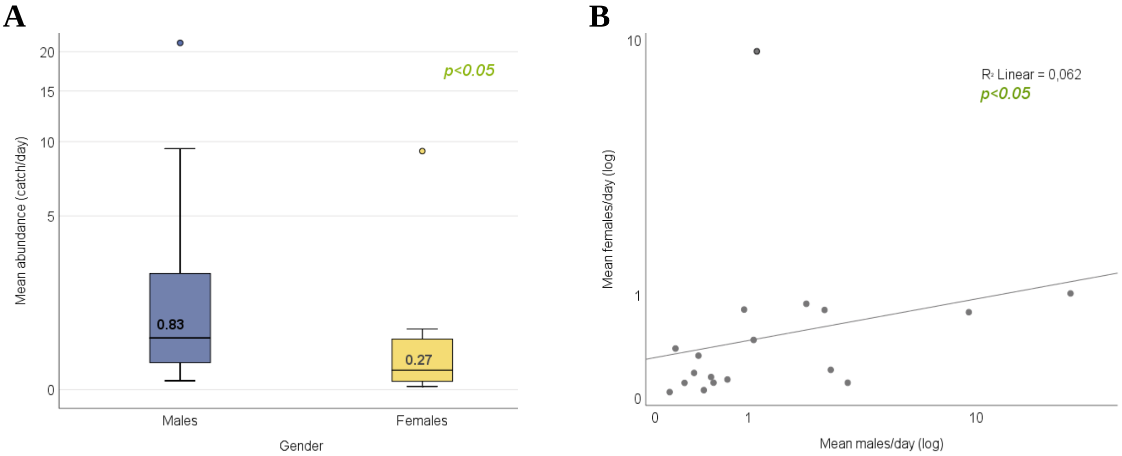


Figure 13. Difference, and relation of *D. brassicae* males and females mean abundances per day. *13(A)*: Boxplot showing the differences in mean trap catches of males and females per day. Medians are also displayed in digits. The circles display outliers. *13(B)*: Scatter plot with regression line showing a positive correlation between males and females mean abundance (catch/day). This have been log-transformed due to large outliers in the dataset.

3.3 Relation between trap catches and the number of *C. obstrictus* counted on WOSR-plants

During the first 4 weeks of field research, number of weevils per ten plants was visually counted *in situ* during each field visit in order to assess the relationship between trap catches and the number of *C. obstrictus* spotted on WOSR-plants. The fields were visited consistently once a week in the first 4 weeks of fieldwork, hence the total number of *C. obstrictus* could be applied in these analyses instead of using the metrics of *mean trap catches/day* as was used in other analyses regarding abundances of weevils.

Positive correlations were found between the total number of weevils counted on ten plants and the total trap catches of weevils in the pan traps (r=0.570, n=18, p=0.014) and in the sticky traps (r=0.676, n=18, p=0.002) within the PFCZ (*figure 14*). Weevils were not counted outside of the PFCZ.

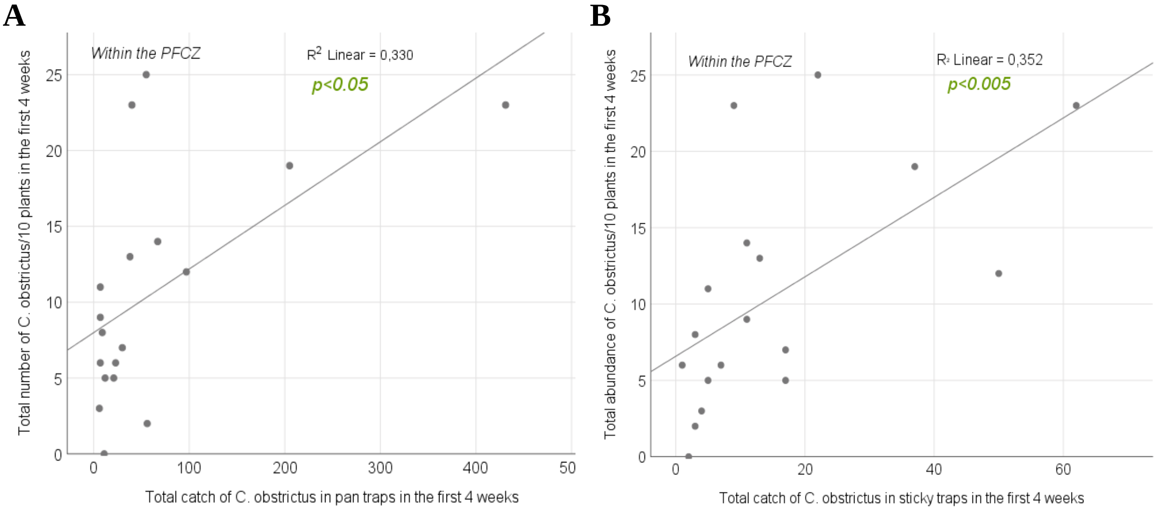


Figure 14. Scatterplot with regression line displaying the total number of weevils per 10 plants that were visually counted *in situ* within the PFCZ in the first 4 weeks of fieldwork in relation to total trap catches of weevils within the PFCZ. *14(A)*: Total trap catches of weevils in the pan traps in the first 4 weeks. *14(B)*: Total trap catches of weevils in the sticky traps in the first 4 weeks.

3.4 Relation between abundances of *D. brassicae* and *C. obstrictus*

The relation between abundances of *D. brassicae* and *C. obstrictus* was examined with correlation tests. The test results did not show any significant correlation between abundances of *D. brassicae* and abundance of *C. obstrictus* in the pan traps (r=-0.063, n=18, p>0.05) or abundance of *C. obstrictus* in the sticky traps (r=0.034, n=18, p>0.05) at the study sites. *Figure 15* display the mean trap catches of midges and weevils at the study sites.

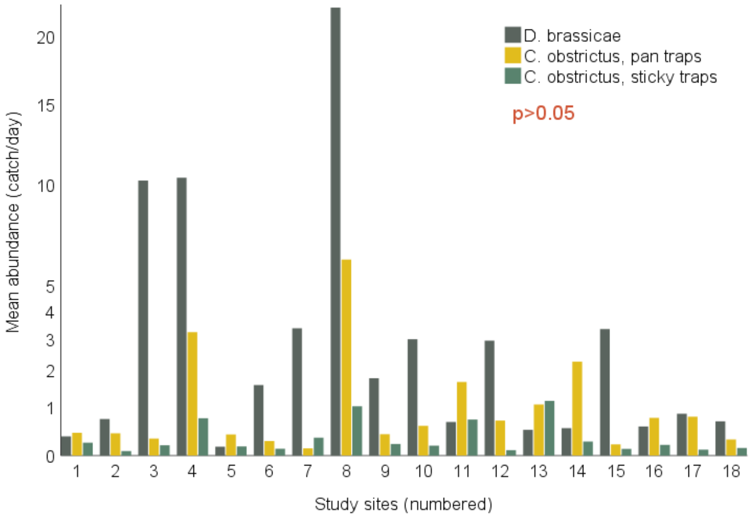


Figure 15. Bar chart showing mean abundances of *D. brassicae* in sticky traps and mean abundances of *C. obstrictus* in sticky traps and pan traps at the study sites.

3.5 Differences in abundances of *D. brassicae* and *C. obstrictus* within- and outside of the PFCZ

Differences in abundance of *C. obstrictus* in the pan traps and *D. brassicae* and *C. obstrictus* in the sticky traps obtained within the PFCZ and outside of the PFCZ was tested. The test results showed no statistically significant difference in abundance between the sticky traps for *D. brassicae* (Z=-0.849, n=18, p>0.05) or in the sticky traps for *C. obstrictus* (Z=-0.166, n=18, p>0.05) or in the pan traps for *C. obstrictus* (t_{17}=1.208, n=18, p>0.05) at the study sites.

3.6 Relation of abundance of *C. obstrictus* between the trap types

The relationship between trap catches of *C. obstrictus* in different trap types was assessed in a correlation analysis. The test results demonstrate a positive correlation between the two trap types (r=0.496, n=18, p=0.036) (*figure 16*).

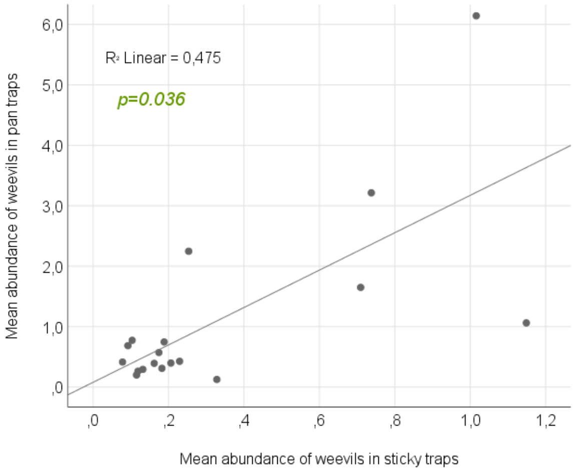


Figure 16. Scatter plot with regression line showing mean *C. obstrictus* trap catches from the two different trap types; yellow pan trap and yellow sticky trap at the study sites.

3.7 Difference in abundance of *C. obstrictus* between the season of 2017 and 2018

Difference in abundance of *C. obstrictus* between a study in the season of 2017 and abundance in this study was examined. The metrics of *mean catch/day* for each season was compared. These comparisons only provide a general overview of the quantity of *C. obstrictus* in this study compared to last year because the field methodology differ somewhat between the study in 2017 and 2018. In 2017, 19 fields were included and there were four sticky traps and two pan traps which were located at different borders of the fields, while in this study, there were 18 study sites with two sticky traps and two pan traps at each field and that were located at the same border of the fields (*figure 7*). Moreover, the traps were located in field during a longer period of time in this study and some of the study sites differs between the studies in 2017 and 2018.

Mean abundances (mean catch/day) of *C. obstrictus* in sticky traps in 2017 was 2.58, while it was 0.33 in the study in 2018. Mean abundance in pan traps was 12.50 in 2017 and 1.11 in 2018. There were often large variations in catches between the samples in the study in 2017 and in the study in 2018. The test results showed a statistically significant difference between the abundance of *C. obstrictus* in 2017 and 2018 for sticky traps (U=37, n=37, p<0.001) and for pan traps (U=23, n=37, p<0.001) (*figure 17*).

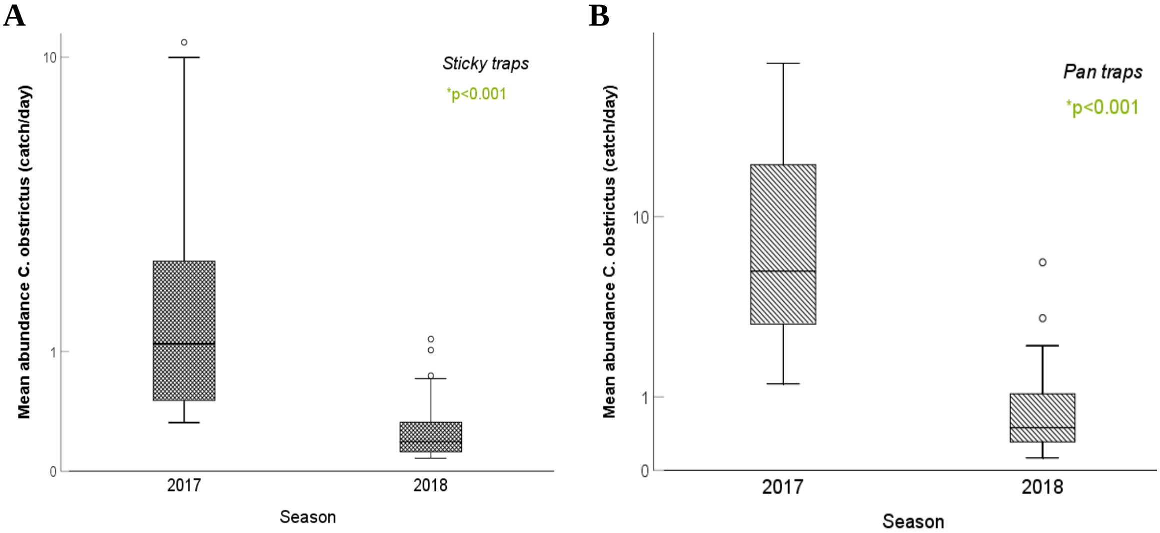


Figure 17. Boxplots showing a general overview of mean abundance of *C. obstrictus* in sticky trap- and pan trap samples during the season of 2017 and 2018. The graphs display mean abundance of all the study fields in 2017 and 2018. *17(A)*: abundance in sticky trap samples. *17(B)*: abundance in pan trap samples. Note that the abundance have been log-transformed in order to also illustrate the differences between the samples.

3.8 Differences in within- field damages by *D. brassicae* in early- and late pod set

Within- field differences in damages by *D. brassicae* at the field edge and 20m into the field within- and outside of the PFCZ in early- and late pod set was assessed. In order to display the extent of the spread and distribution of damages within the fields, all combinations tested are displayed in figures regardless if the tests show statistical significances or not.

Early pod set

Table 2 and *figure 18* presents the results of the tests of differences in damage between the field edge and 20m into the field within- and outside of the PFCZ.

Table 2. Results of T-tests of differences in damage at the field edge and 20m into the field within- and outside of the PFCZ in early pod set.

Test $^{\text{early pod set}}$	**Within the PFCZ**			**Outside of the PFCZ**		
	Test value	*n*	*p- value*	*Test value*	*n*	*p- value*
Field edge vs. 20m	-0.032 (t)	18	>0.05	0.931 (t)	18	>0.05

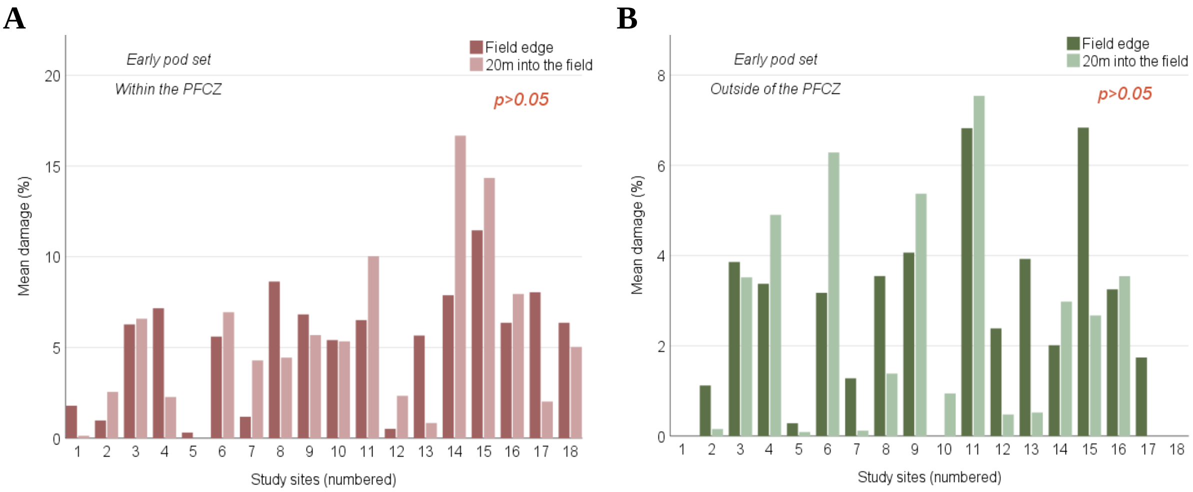


Figure 18. Bar charts of differences in damages between the field edge and 20m into the field in early pod set. *18(A)*: differences between the sample locations within the PFCZ. *18(B)*: differences between the sample locations outside of the PFCZ.

Differences in damages between the sample locations at the field edge within the PFCZ and the location at the field edge outside of the PFCZ, and the locations 20m into the field within the PFCZ and 20m into the field outside of the PFCZ, was also tested. *Table 3* and *figure 19* display these test results.

Table 3. Results of T-tests of differences in damage of the sample locations at the field edge within the PFCZ and at the field edge outside of the PFCZ and the sample locations 20m into the field within the PFCZ and 20m into the field outside of the PFCZ in early pod set.

Test $^{\textit{early pod set}}$	**Field edge**$^{\textbf{within the PFCZ}}$			**20m into the field**$^{\textbf{within the PFCZ}}$		
	Test value	*n*	*p- value*	*Test value*	*n*	*p- value*
Field edge$^{\textbf{outside of the PFCZ}}$	4.573 (t)	18	**<0.001**	-	-	**-**
20m into the field$^{\textbf{outside of the PFCZ}}$	-	-	-	3.370 (t)	18	**0.004**

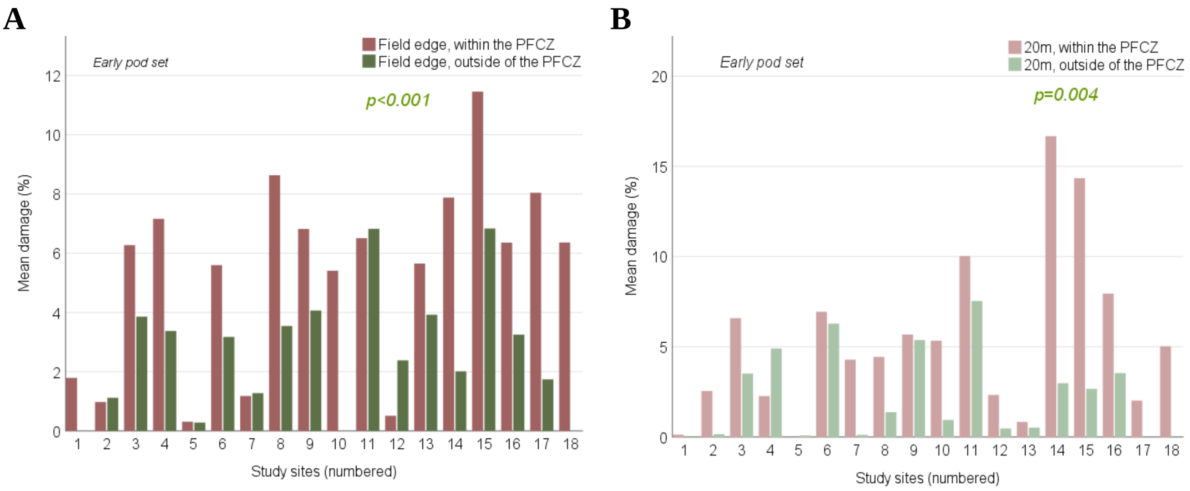


Figure 19. Bar charts showing within-field differences in mean damage by *D. brassicae* between the sample locations at the field edge and 20m into the field within- and outside of the PFCZ in early pod set. *19(A):* differences between the sample locations at the field edge within- and outside of the PFCZ. *19(B):* differences between the sample locations at the inner part of the field within- and outside of the PFCZ.

To assess the progression of damages between the field edge and 20m into the field within- and outside of the PFCZ in early pod set, correlation analyses were computed. Positive correlations were wound. *Table 4* and *figure 20* display these test results.

Table 4. Results of correlation analyses of damage at the field edge and 20m into the field within- and outside of the PFCZ in early pod set.

Test $^{\textit{early pod set}}$	**Within the PFCZ**			**Outside of the PFCZ**		
	Test value	*n*	*p- value*	*Test value*	*n*	*p- value*
Field edge vs. 20m	0.614 (r)	18	**<0.01**	0.692 (r)	18	**<0.01**

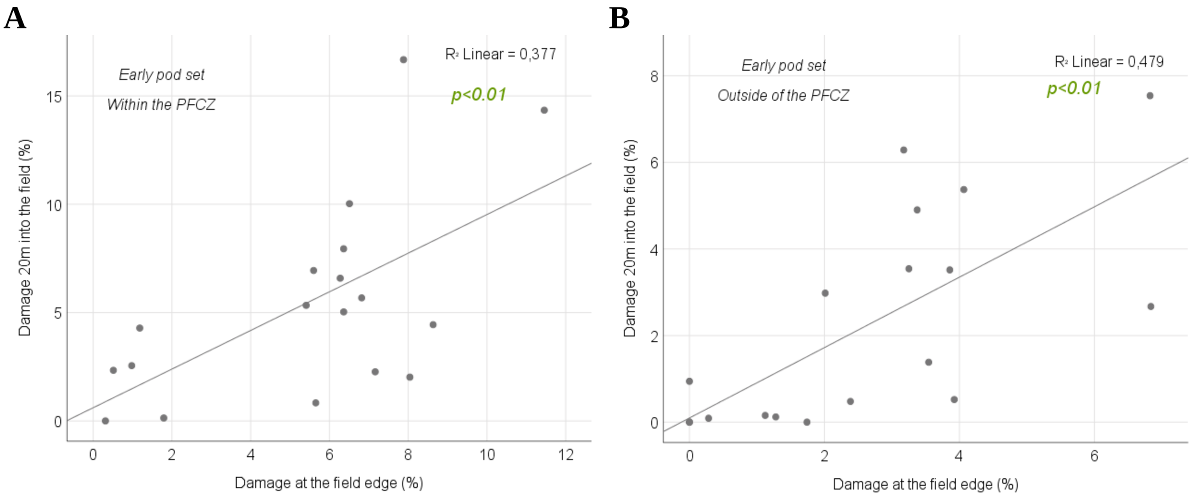


Figure 20. Scatter plots with regression lines of the relationship between mean percentage of damage at the field edge and 20m into the field within- and outside of the PFCZ in early pod set. *20(A)*: within the PFCZ. *20(B)*: outside of the PFCZ.

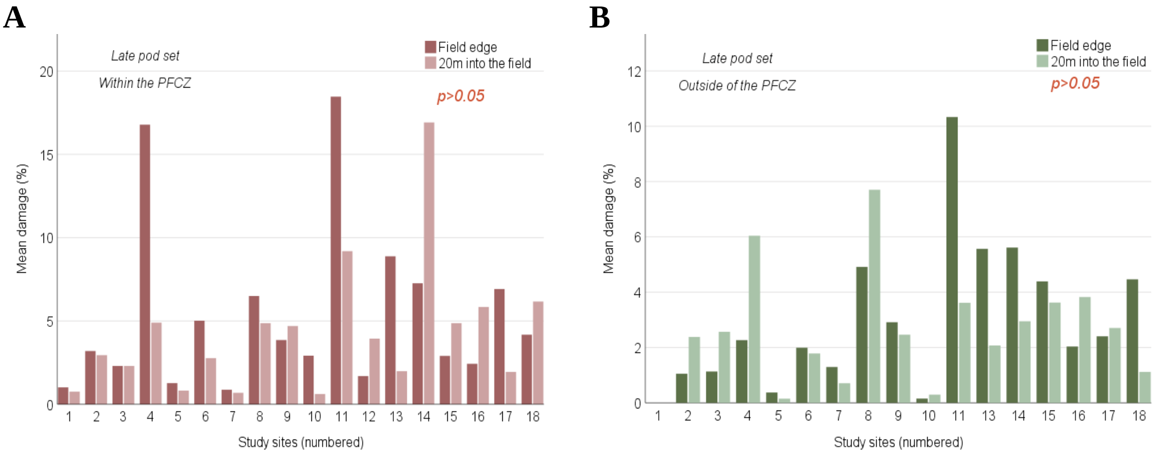
Late pod set

Since the study design in late pod set also included sample locations at the remaining borders of each test field apart from where the PFCZ was located, analysis of differences in damage between the edges and 20m into the field outside of the PFCZ includes two tests. Unfortunately only 17 study fields could be included in the analyses that regarded analyses at the field edge outside of the PFCZ due to loss of sample notes of one sample point at the field edge outside of the PFCZ, during data compilation. *Table 5* and *figure 21* presents the results of the tests, where statistically significant difference was found between the field edge and 20m into the field outside of the PFCZ when samples at all the field borders were included in the analysis.

Table 5. Results of T-tests of differences in damage at the field edge and 20m into the field within- and outside of the PFCZ in late pod set.

Test *late pod set*	**Within the PFCZ**			**Outside of the PFCZ***			**Outside of the PFCZ**		
	Test value	*n*	*p- value*	*Test value*	*n*	*p- value*	*Test value*	*n*	*p- value*
Field edge vs. 20m	0.973 (t)	18	>0.05	0.659	17	>0.05	4.939 (t)	17	**<0.001**

* Includes only the sample locations at the field edge where the PFCZ was located.



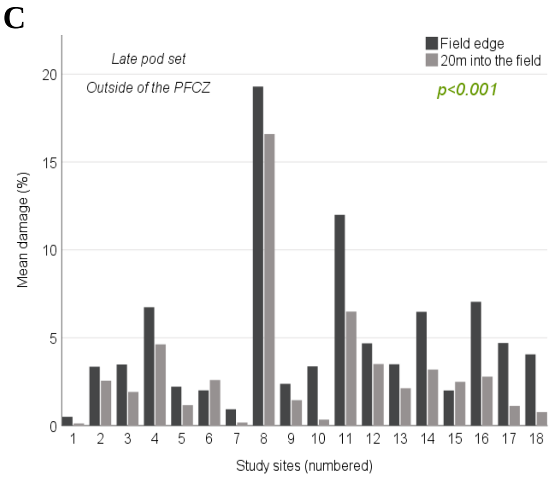


Figure 21. Bar charts of differences in damages between the field edge and 20m into the field in late pod set. *21(A)*: differences between the sample locations within the PFCZ. *21(B)*: differences between the sample locations outside of the PFCZ when only the field border where the PFCZ was located are included. *21(C)*: differences between the sample locations outside of the PFCZ when all the field borders are included.

Differences in damages between the sample locations at the field edge within the PFCZ and the location at the field edge outside of the PFCZ, and the locations 20m into the field within the PFCZ and 20m into the field outside of the PFCZ, was also tested. Only the field border where the PFCZ was located are included in these analyses. *Table 6* and *figure 22* display these test results.

Table 6. Results of T-tests of differences in damage of the sample locations at the field edge within the PFCZ and at the field edge outside of the PFCZ and the sample locations 20m into the field within the PFCZ and 20m into the field outside of the PFCZ in late pod set.

Test $^{\textit{late pod set}}$	**Field edge**$^{\textbf{within the PFCZ}}$			**20m into the field**$^{\textbf{within the PFCZ}}$		
	Test value	*n*	*p- value*	*Test value*	*n*	*p- value*
Field edge$^{\textbf{outside of the PFCZ*}}$	-3.053 (Z)	17	**0.002**	-	**-**	**-**
20m into the field$^{\textbf{outside of the PFCZ*}}$	-	-	-	-1.459 (Z)	18	>0.05

* Includes only the sample locations at the field edge where the PFCZ was located.

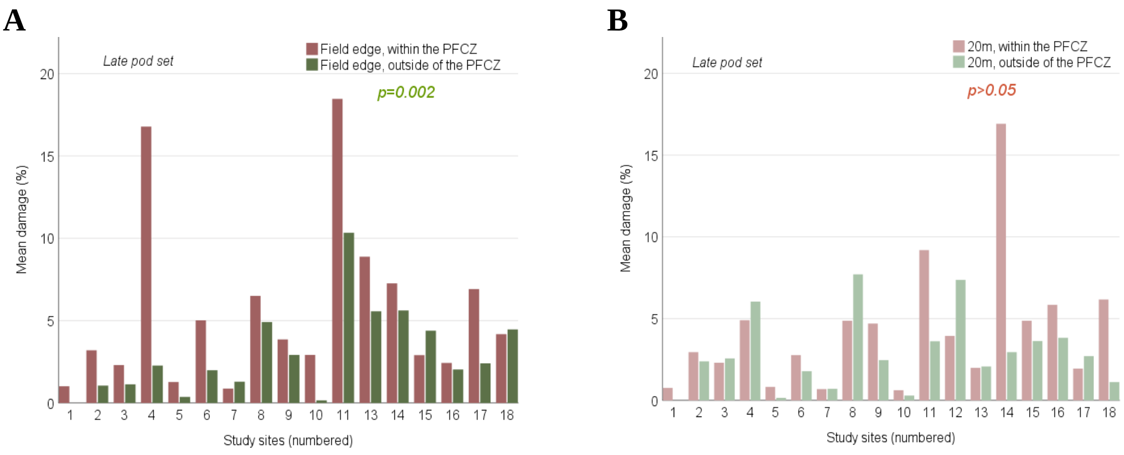


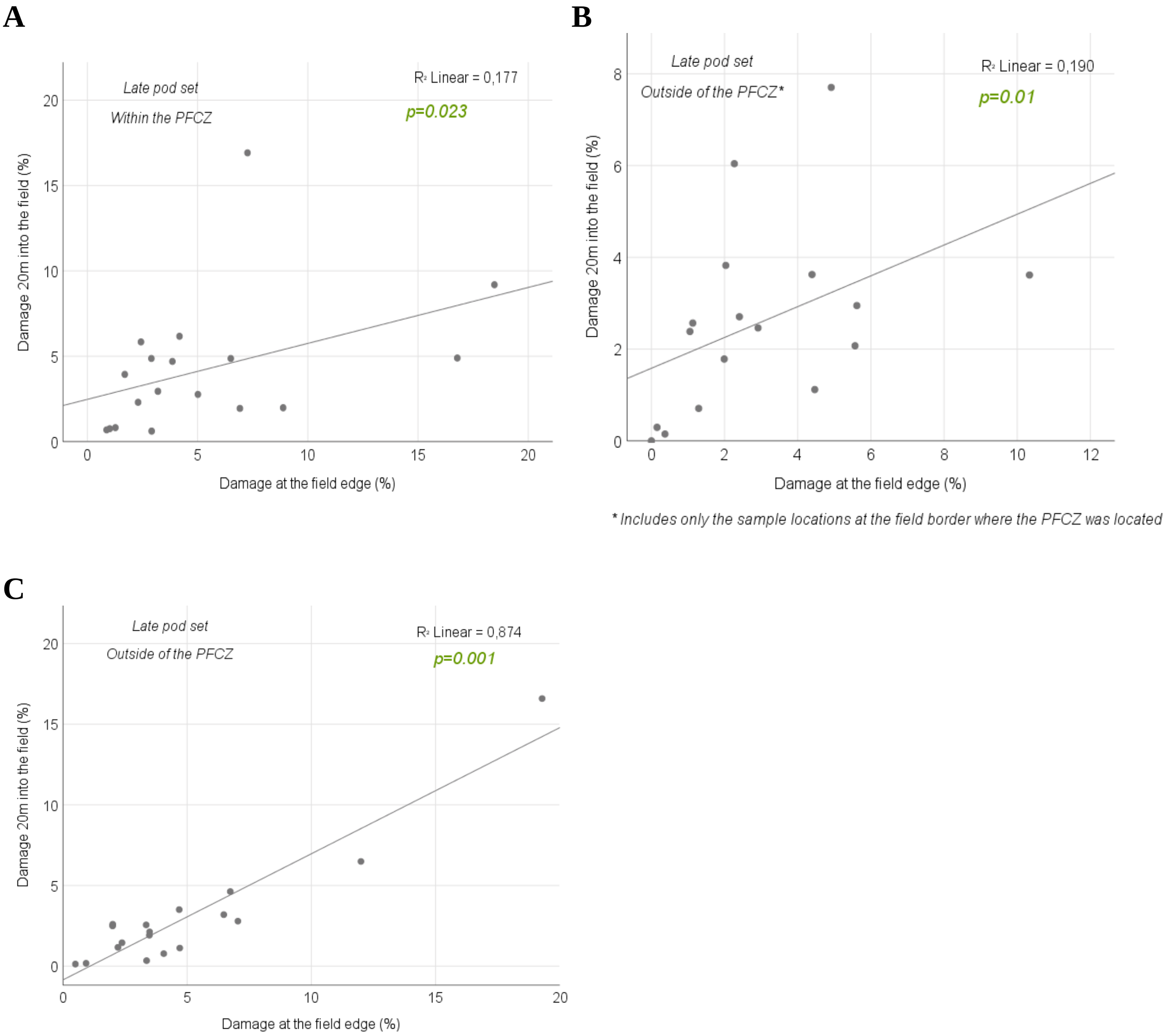
Figure 22. Bar charts showing within-field differences in mean damage by *D. brassicae* between the sample locations at the field edge and 20m into the field within- and outside of the PFCZ in late pod set. *22(A):* differences between the sample locations at the field edge within- and outside of the PFCZ. *22(B):* differences between the sample locations at the inner part of the field within- and outside of the PFCZ.

To assess the progression of damages between the field edge and 20m into the field within- and outside of the PFCZ in late pod set, correlation analyses were computed. Positive correlations were found. *Table 7* and *figure 23* display the test results.

Table 7. Results of correlation analyses of damage at the field edge and 20m into the field within- and outside of the PFCZ in late pod set.

Test $^{late\ pod\ set}$	**Within the PFCZ**			**Outside of the PFCZ***			**Outside of the PFCZ**		
	Test value	*n*	*p- value*	*Test value*	*n*	*p- value*	*Test value*	*n*	*p- value*
Field edge vs. 20m	0.534 (r)	18	**0.023**	0.603 (r)	17	**0.01**	0.701 (r)	18	**0.001**

* Includes only the sample locations at the field edge where the PFCZ was located.



** Includes only the sample locations at the field border where the PFCZ was located*

Figure 23. Scatter plots with regression lines of the relationship between mean percentage of damage at the field edge and 20m into the field within- and outside of the PFCZ in late pod set. *23(A)*: within the PFCZ. *23(B)*: outside of the PFCZ, only includes sample locations at the field border where the PFCZ was located. *23(C)*: Outside of the PFCZ, includes sample locations at all the field borders.

Relationship of damages within- and outside of the PFCZ between early- and late pod set

Correlation tests of damages at the field edge and 20m into the field within- and outside of the PFCZ between early- and late pod set, was computed in order to assess the progression of damages from early in the crop season to later in the season. Positive correlations were found. *Table 8* and *figure 24* and *25* display the test results.

Table 8. Results of the correlation analyses of damages in early- and late pod set at the field edge and 20m into the field within- and outside of the PFCZ.

Test $^{\textit{early- and late pod set}}$	**Within the PFCZ**			**Outside of the PFCZ***		
	Test- value	*n*	*p- value*	*Test- value*	*n*	*p- value*
Field edge	0.606 (r)	18	**<0.01**	0.652 (r)	17	**<0.01**
20m into the field	0.595 (r)	18	**<0.01**	0.466 (r)	18	0.051

*Includes only the sample locations at the field edge where the PFCZ was located.

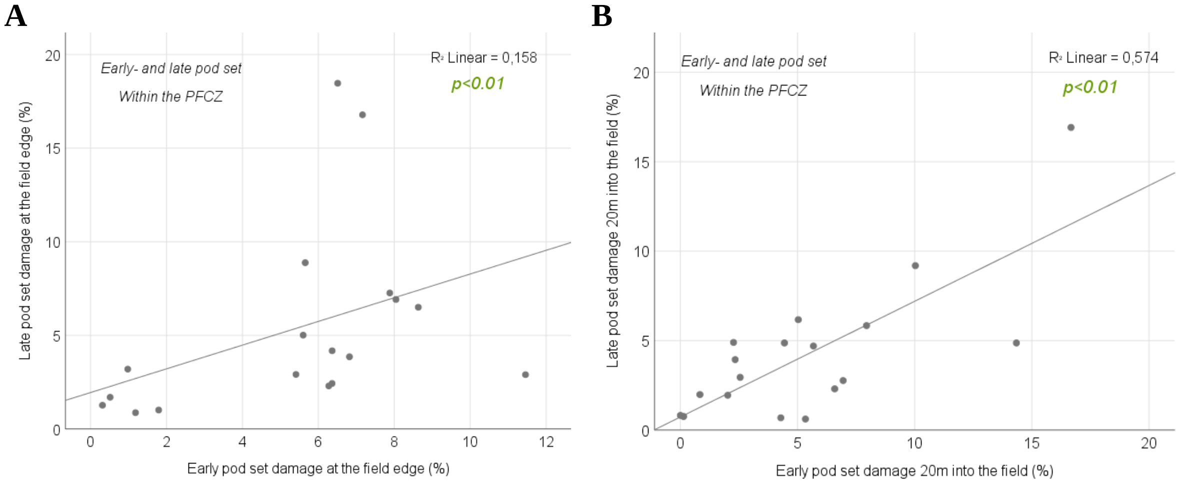


Figure 24. Scatter plot with regression lines of damages in early- and late pod set within the PFCZ. *24(A)*: Relations of damages at the field edge. *24(B)*: Relations of damages 20m into the field.

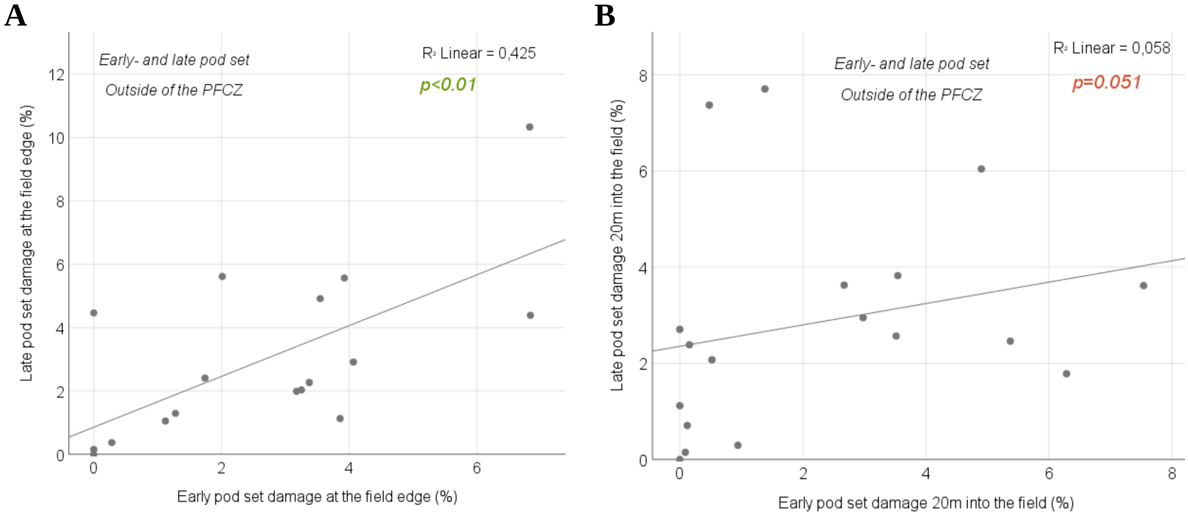


Figure 25. Scatter plot with regression line of the relation between damages outside of the PFCZ in early- and late pod set. *25(A)*: damages at the field edge. *25(B)*: damage 20m into the field.

3.9 Effect of abundances of *C. obstrictus* and *D. brassicae* and chemical treatments on damages

The effect of chemical treatments and abundance of *D. brassicae* and *C. obstrictus* on damages by *D. brassicae* within- and outside of the PFCZ in early- and late pod set, was assessed in multiple regression models.

The independent variables in the regression analyses; abundances of *D. brassicae* and *C. obstrictus* and chemical treatment, were checked for multicollinearity prior to the analyses. Multicollinearity can be assessed through the variance inflation factor (VIF), which represents the increase or amplification of variance of a dependent factor due to correlations between the predicting factors (Weisberg, 2005). The lowest possible variance inflation factor is 1 and generally it should not exceed 10 (Robinson & Schumacker, 2009). *Table 9* presents the variance inflation factors between the independent variables included in the regression models.

Table 9. The variance inflation factor (VIF) of the independent variables included in the regression models.

Predicting factors	***D. brassicae***	***C. obstrictus***$^{\textbf{Sticky traps}}$	***C. obstrictus***$^{\textbf{Pan traps}}$	**Chemical treatment**
D brassicae	-	1.664	1.669	1.007
C. obstrictus$^{\textbf{Sticky traps}}$	1.219	-	1.170	1.066
C. obstrictus$^{\textbf{Pan traps}}$	1.077	1.031	-	1.045
Chemical treatment	1.153	1.667	1.855	-

Since all the variables indicate low collinearity in these tests, they could be used simultaneously in the regression models. However, since trap catches of *C. obstrictus* were positively correlated in a previous analysis (*figure 16*), and both pan trap- and sticky trap catches represent the same independent factor; abundances of weevils, these variables were not used in the same regression models despite the low variance inflation factors.

Early pod set

Abundances of *D. brassicae* or *C. obstrictus* had no statistically significant effects on damages at the field edge or 20m into the field, however effects of chemical treatments could be shown in all models but one (*figure 26* and *27*). *Table 10-13* shows the test results from the multiple regression models in early pod set.

Table 10. Results of the multiple linear regression model for field edge damages in early pod set and the effects of chemical treatment and abundances of *D. brassicae* and *C. obstrictus* in sticky traps. Statistically significant p- values are marked.

Model		**B**	**Std. Error**	**VIF**	**p- value**
Damage, field edge	- Chemical treatment	2.946	0.910	1.045	**0.003**
	- Abundance$^{\textit{D. brassicae}\text{, sticky traps}}$	0.074	0.064	1.077	0.259
	- Abundance$^{\text{C. obstrictus, sticky traps}}$	-1.435	1.279	1.031	0.270
Model summary					
R^2	**Adjusted R^2**	**F**	**df**	**p- value**	
0.267	0.198	3.887	3,35	**0.18**	

Table 11. Results of the multiple linear regression model for damages 20m into the field in early pod set and the effects of chemical treatment and abundances of *D. brassicae* and *C. obstrictus* in sticky traps. Statistically significant p- values are marked.

Model		**B**	**Std. Error**	**VIF**	**p- value**
Damage, 20m	- Chemical treatment	3.138	1.248	1.045	**0.017**
	- Abundance$^{\textit{D. brassicae}\text{, sticky traps}}$	-0.002	0.088	1.077	0.981
	- Abundance$^{\text{C. obstrictus, sticky traps}}$	-2.610	1.755	1.031	0.147
Model summary					
R^2	**Adjusted R^2**	**F**	**df**	**p- value**	
0.220	0.146	3.002	3,35	**0.045**	

Table 12. Results of the multiple linear regression model for damages at the field edge in early pod set and the effects of chemical treatment and abundances of *D. brassicae* and *C. obstrictus* in pan traps. Statistically significant p- values are marked.

Model		**B**	**Std. Error**	**VIF**	**p- value**
Damage, field edge	- Chemical treatment	2.975	0.934	1.066	**0.003**
	- Abundance$^{\textit{D. brassicae}\text{, sticky traps}}$	0.072	0.070	1.066	0.306
	- Abundance$^{\text{C. obstrictus, pan traps}}$	-0.140	0.332	1.170	0.677
Model summary					
R^2	**Adjusted R^2**	**F**	**df**	**p- value**	
0.242	0.171	3.414	3,35	**0.029**	

Table 13. Results of the multiple linear regression model for damages 20m into the field in early pod set and the effects of chemical treatment and abundances of *D. brassicae* and *C. obstrictus* in pan traps. Statistically significant p- values are marked.

Model		**B**	**Std. Error**	**VIF**	**p- value**
Damage, 20m	- Chemical treatment	3.318	1.272	1.066	**0.014**
	- Abundance$^{\textit{D. brassicae}\text{, sticky traps}}$	0.020	0.095	1.219	0.831
	- Abundance$^{\textit{C. obstrictus}\text{, pan traps}}$	-0.572	0.452	1.170	0.215
Model summary					
R^2	**Adjusted R^2**	**F**	**df**	**p- value**	
0.205	0.131	2.757	3,35	0.058	

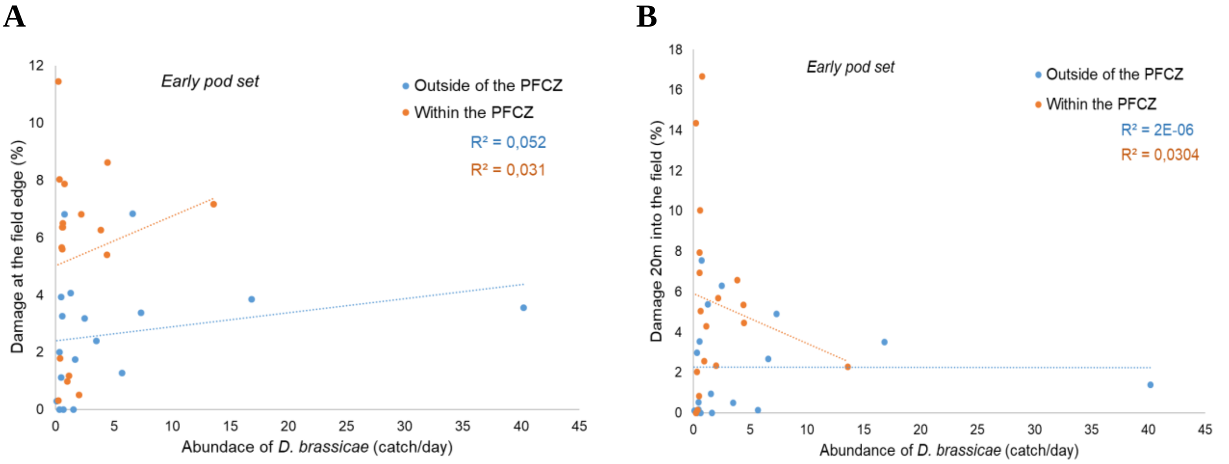


Figure 26. Scatter plots with regression lines showing abundance of *D. brassicae* in relation to damages by *D. brassicae* in early pod set. *26(A)*: damages at the field edge within- and outside of the PFCZ. *26(B)*: damages 20m into the field within- and outside of the PFCZ.

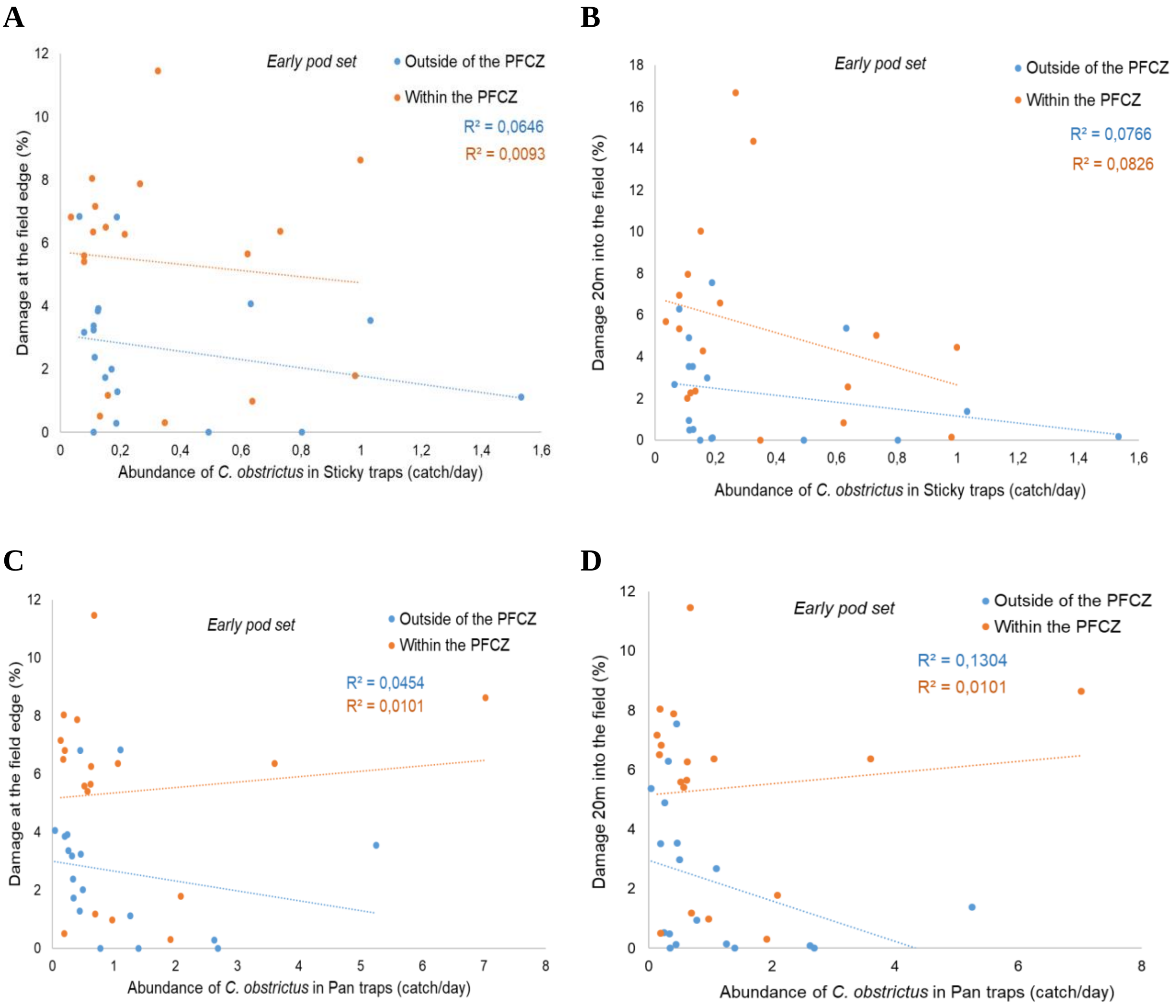


Figure 27. Scatter plots with regression lines showing abundance of *C. obstrictus* in relation to damages by *D. brassicae* within- and outside of the PFCZ in early pod set. *27(A)*: damages at the field edge in relation to abundances in sticky trap samples. *27(B)*: damages 20m into the field in relation to sticky traps samples. *27(C)*: damages at the field edge in relation to abundance in pan trap samples. *27(D)*: damages 20m into the field in relation to abundance in pan trap samples.

Late pod set

No statistically significant effect of abundance of *D. brassicae* in sticky traps or *C. obstrictus* in either trap type on damages at the field edge and 20m into the field could be found in late pod set. Neither could any effect of chemical treatment be found. *Table 14-17* shows the test results from the multiple regression models.

Table 14. Results of the multiple linear regression model for field edge damages in late pod set and the effects of chemical treatment and abundances of *D. brassicae* and *C. obstrictus* in sticky traps.

Model		**B**	**Std. Error**	**VIF**	**p- value**
Damage, field edge	- Chemical treatment	2.655	1.414	1.046	0.070
	- Abundance$^{\textit{D. brassicae}\text{, sticky traps}}$	0.105	0.099	1.077	0.297
	- Abundance$^{\textit{C. obstrictus}\text{, sticky traps}}$	-1.409	1.970	1.031	0.480
Model summary					
R^2	**Adjusted R^2**	**F**	**df**	**p- value**	
0.123	0.038	1.448	3,34	0.248	

Table 15. Results of the multiple linear regression model for damages 20m into the field in late pod set and the effects of chemical treatment and abundances of *D. brassicae* and *C. obstrictus* in sticky traps.

Model		**B**	**Std. Error**	**VIF**	**p- value**
Damage, 20m	- Chemical treatment	1.738	1.082	1.045	0.118
	- Abundance$^{\textit{D. brassicae}\text{, sticky traps}}$	1.122	0.077	1.077	0.121
	- Abundance$^{\text{C. obstrictus, sticky traps}}$	-0.612	1.522	1.031	0.690
Model summary					
R^2	**Adjusted R^2**	**F**	**df**	**p- value**	
0.117	0.035	1.418	3,34	0.256	

Table 16. Results of the multiple linear regression model for damages at the field edge in late pod set and the effects of chemical treatment and abundances of *D. brassicae* and *C. obstrictus* in pan traps.

Model		**B**	**Std. Error**	**VIF**	**p- value**
Damage, field edge	- Chemical treatment	2.815	1.418	1.064	0.056
	- Abundance$^{\text{D. brassicae, sticky traps}}$	0.129	0.104	1.219	0.226
	- Abundance$^{\text{C. obstrictus, pan traps}}$	-0.460	0.499	1.167	0.363
Model summary					
R^2	**Adjusted R^2**	**F**	**df**	**p- value**	
0.364	0.048	1.575	3,34	0.215	

Table 17. Results of the multiple linear regression model for damages 20m into the field in late pod set and the effects of chemical treatment and abundances of *D. brassicae* and *C. obstrictus* in pan traps.

Model		**B**	**Std. Error**	**VIF**	**p- value**
Damage, 20m	- Chemical treatment	1.789	1.093	1.066	0.111
	- Abundance$^{\textit{D. brassicae}\text{, sticky traps}}$	0.129	0.080	1.219	0.123
	- Abundance$^{\textit{C. obstrictus}\text{, pan traps}}$	-0.156	0.389	1.170	0.690
Model summary					
R^2	**Adjusted R^2**	**F**	**df**	**p- value**	
0.117	0.035	1.418	3,35	0.255	

3.10 Abundance and damage by *D. brassicae* in a geographic perspective

Differences in abundance and damage by *D. brassicae* in a geographic perspective for early- and late pod set at the field border and 20m into the field, were examined. There was no statistical significant difference in abundance of *D. brassicae* between the cardinal directions ($x^2(4) = 5.229$, n=18, $p>0.05$) or of damage between the cardinal directions at the survey conducted at the field borders in early pod set ($F_{4,13} = 1.708$, $p>0.05$) or in late pod set ($x^2(4) = 8.342$, $p>0.05$). Statistical significant difference could be found between the cardinal directions at the survey conducted 20m into the fields in early pod set ($F_{3,13} = 8.987$, $p<0.001$), no post hoc test were conducted due to low sample size. No statistical significance could be found for the survey conducted 20m into the fields in late pod set ($x^2(4) = 8.719$, $p>0.05$).

Figure 28 show damages by *D. brassicae* in a geographic perspective in early- and late pod set and *figure 29* is complementing this demonstration with a map of a general overview of the total damage caused by *D. brassicae* for each of the surveys in early- and late pod set at the study sites in the study region. *Figure 30* shows the regional distribution of OSR-fields in 2017 at a larger scale; within 30km of the study sites centre points. The purpose with this figure is to show an overview of the distribution of OSR- fields in relation to the distribution of OSR-fields within the study region. Total area of OSR- fields within 30km of the five cardinal directions and the percentage of OSR- fields of the total land area of the 30km buffer zone (excluding coast and sea), are shown in *table 18*. Note that this information is not used in any statistical tests, it is only presented in a descriptive purpose to visually (*figure 30*) show the spatial distribution and proportion of OSR- fields within a much larger geographic area around the study fields.

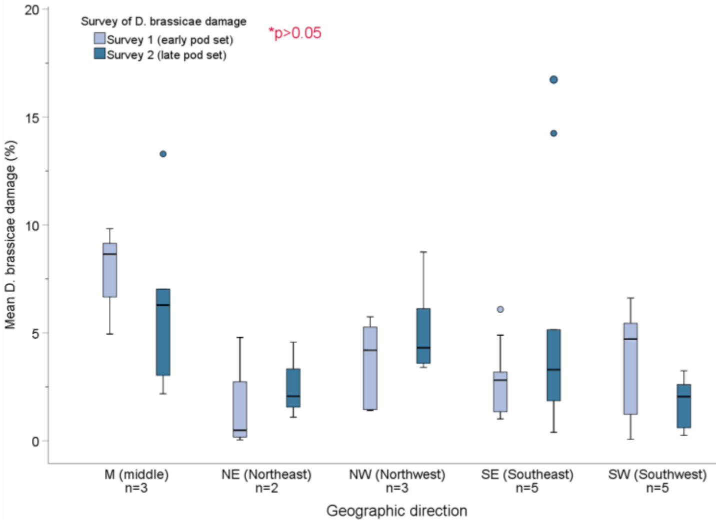


Figure 28. Boxplot showing mean damages by *D. brassicae* in survey 1 (early pod set) and 2 (late pod set) in a geographical perspective (p>0.05). Number of sites (n) at each geographic location is shown. Outliers are indicated by circles.

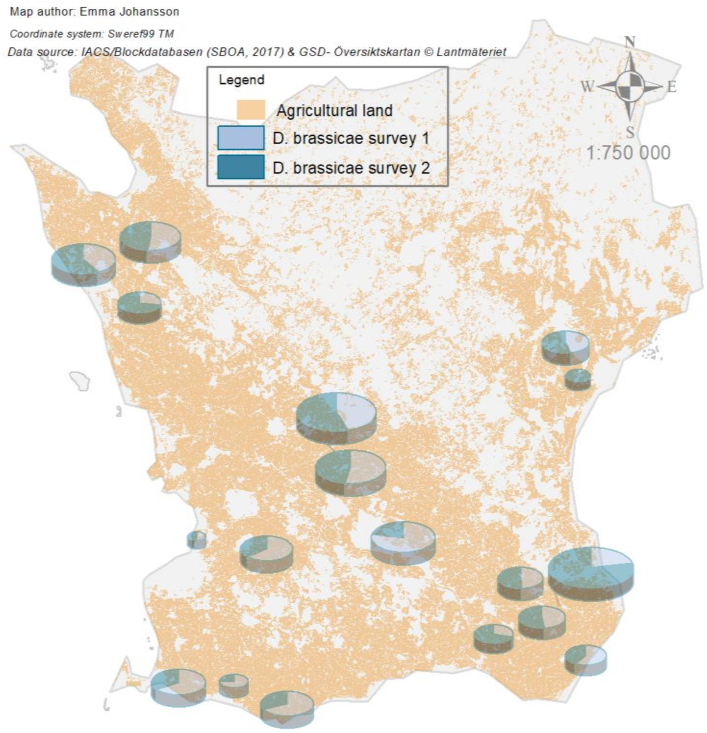


Figure 29. The map show a general overview of damages by *D. brassicae* for each of the surveys 1 and 2 at the study sites. The pie charts show the relative mean damages of survey 1 and 2 and the chart sizes represent the relative total mean damage at each study site. Agricultural land in Skåne county is shown, other land types are excluded.

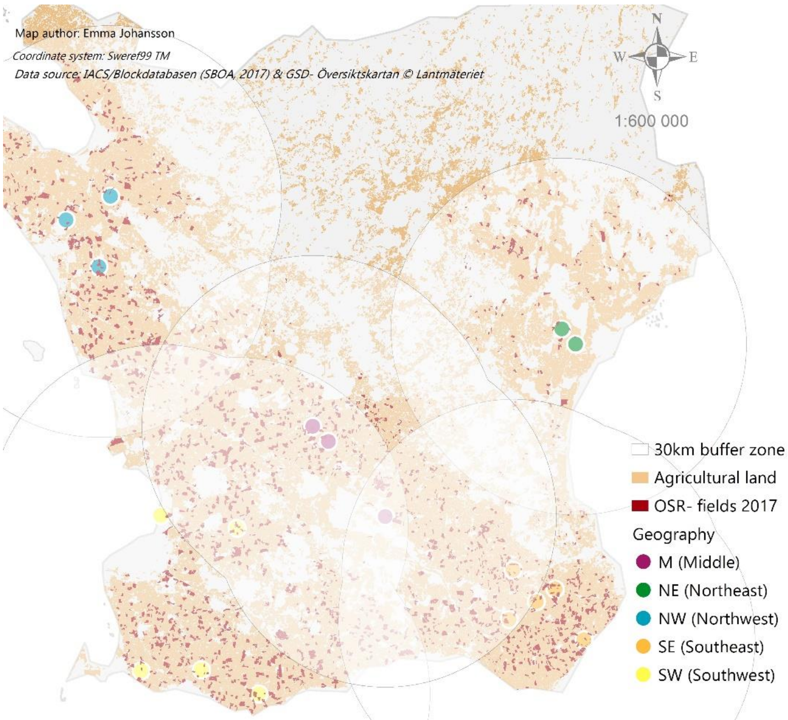


Figure 30. The map shows the regional distribution of OSR-fields in 2017 within 30km of the study sites centre points.

Table 18. Total area of OSR- fields within 30km of the five cardinal directions and the percentage of OSR- fields of the total land area (coast and sea are excluded) of the 30km buffer zones. The areas were calculated in ArcGIS.

Cardinal direction	Area of OSR- fields within 30km (ha)	Proportion of OSR- fields within 30km (%)
M	22210	5.6
NE	2890	1.3
NW	11597	4.9
SE	12004	6.3
SW	23798	8.5

3.11 Analyses of landscape factors

The analyses of landscape factors includes landscape complexity (proportion of forested or grassland land types) within the buffer zones, the proportion of OSR- area within the buffer zones, and the distance to the centre point of the nearest OSR- field from last year to the study fields' centre points. These parameters are assessed in relation to their effect on the abundances of the study organisms and damages by *D. brassicae*.

The proportion of agricultural land within all buffer zones varied between 18.6% and 100%. The mean proportion of agricultural land within the buffer zones is shown in *table 19*.

Table 19. Mean percentage of agricultural land within the buffer zones.

Buffer zone	Agricultural land (mean %)
3000m	78.6
2000m	82.2
1000m	87.1
500m	93.6

The distances between the centre points of the fields in this study and the centre points of the closest WOSR- field from last year is shown in *figure 31*.

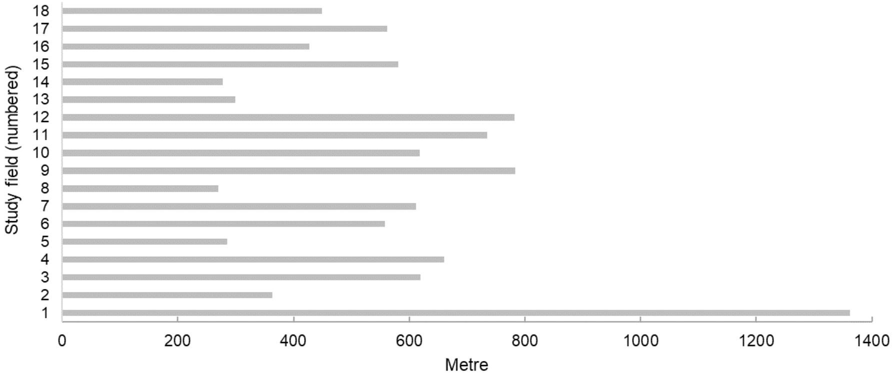


Figure 31. Distance (in metre) between the centre point of the centre point of each study field and the centre point of the closest WOSR- field from 2017 to each study field.

The effects of the percentage of landscape complexity, percentage of hectare of OSR from 2017 and the distance between the centre point of the nearest WOSR- field from 2017 to the study fields centre points on damages by *D. brassicae* and on the abundances of *C. obstrictus* and *D. brassicae*, were examined with linear multiple regression models. When all the independent variables are tested for collinearity between them, some large variance inflation factors appear (*table 20*) and extremely large variance inflation factors are associated to the models where all the independent variables are included in the same analyses (*table 21*). Because of the weakness of these models, collinearity between the variables at the same spatial scales were tested (*table 22*).

Table 20. Variance inflation factors of all the independent variables when collinearity is tested between them. Complexity is the landscape complexity, Ha OSR is the percentage of OSR hectares and distance is the distance between the study fields' centre points to the centre point of the nearest WOSR- field from 2017.

	Complexity 3000m	Complexity 2000m	Complexity 1000m	Complexity 500m	Ha OSR 3000m	Ha OSR 2000m	Ha OSR 1000m	Ha OSR 500m	Distance
Complexity 3000m	-	7.260	20.546	29.693	36.505	34.673	36.521	36.161	32.477
Complexity 2000m	13.983	-	21.396	63.360	68.251	62.014	69.701	69.402	70.236
Complexity 1000m	14.852	8.036	-	16.510	26.407	25.566	26.186	25.901	25.581
Complexity 500m	9.204	10.198	7.076	-	9.895	10.921	11.225	11.199	4.616
Ha OSR 3000m	9.647	9.366	9.648	8.436	-	2.734	8.713	8.810	7.610
Ha OSR 2000m	8.966	8.327	9.140	9.111	2.676	-	6.855	8.567	8.851
Ha OSR 1000m	2.851	2.825	2.826	2.827	2.574	2.069	-	2.079	2.842
Ha OSR 500m	1.931	1.925	1.913	1.930	1.781	1.770	1.422	-	1.907
Distance	5.301	5.952	5.772	2.431	4.700	5.585	5.941	5.827	-

Table 21. Variance inflation factors of all the independent variables when all the variables are included in the regression models at all spatial scales (3000, 2000, 1000 and 500 metres).

	Complexity 3000m	Complexity 2000m	Complexity 1000m	Complexity 500m	Ha OSR 3000m	Ha OSR 2000m	Ha OSR 1000m	Ha OSR 500m	Distance
VIF-value	36,525	70,341	26,419	11,322	9,653	9,445	2,851	1,951	5,961

Table 22. Variance inflation factors of all the independent variables when only the variables at the same spatial scales are included in the regression models.

	Complexity 3000m	Complexity 2000m	Complexity 1000m	Complexity 500m	Ha OSR 3000m	Ha OSR 2000m	Ha OSR 1000m	Ha OSR 500m	Distance
Complexity 3000m					1.823				1.265
Complexity 2000m						1.269			1.058
Complexity 1000m							1.088		1.036
Complexity 500m								1.513	1.501
Ha OSR 3000m	1.724								1.265
Ha OSR 2000m		1.239							1.058
Ha OSR 1000m			1.074						1.036
Ha OSR 500m				1.050					1.501

Since the variance inflation factors between the landscape variables at the same spatial scales were low, these combinations were ultimately computed in separate regression models in order to analyse the effects of landscape parameters on abundances of the study organisms and damages by *D. brassicae* (*table 23*). The significance value (p) of the F- statistic, R^2, adjusted R^2 and the test value (F) of the model summary for each of the computed models, is also shown. The variance inflation factors are not shown, however they were below 2 in all the models.

Table 23. Results of regression analyses where the effects of landscape parameters at the same spatial scales on damages by *D. brassicae* and abundances of *D. brassicae* and *C. obstrictus* were assessed. No statistically significant F- statistic results could be displayed. Statistically significant- and close to statistically significant results within the models are marked as these models were also computed in subsequent stepwise regression models to further analyse the data.

Model	**Damages in *Early pod set***				**Damages in *Late pod set***				**Abundance *D. brassicae***	**Abundance *C. obstrictus***	
										Sticky traps	**Pan traps**
	PFCZ		**Outside PFCZ**		**PFCZ**		**Outside PFCZ**				
	Edge	**20m**	**Edge**	**20m**	**Edge**	**20m**	**Edge**	**20m**			
Complexity 3000m	0.403	0.219	0.216	0.850	0.396	0.272	0.570	0.576	0.678	0.449	0.720
Ha OSR 3000m	0.199	0.067	0.257	0.187	0.200	**0.048**	**0.040**	0.116	0.515	0.596	0.187
Distance	0.763	0.899	0.574	0.592	0.851	0.820	0.476	0.537	0.542	0.691	0.474
Model summary											
p - value	0.470	0.262	0.606	0.767	0.596	0.161	0.075	0.235	0.563	0.726	0.315
R^2	0.160	0.241	0.119	0.076	0.122	0.299	0.380	0.255	0.132	0.087	0.217
Adjusted R^2	-0.020	0.079	-0.069	-0.122	-0.066	0.149	0.247	0.095	-0.054	-0.109	0.050
F	0.891	1.483	0.633	0.383	0.650	1.993	2.855	1.595	0.708	0.443	1.296
Complexity 2000m	0.474	0.234	0.452	0.587	0.746	0.511	0.922	0.735	0.815	0.843	0.961
Ha OSR 2000m	0.117	**0.051**	0.405	0.541	0.884	**0.068**	**0.075**	**0.075**	0.198	0.809	0.162
Distance	0.526	0.770	0.876	0.610	0.703	0.462	0.236	0.327	0.552	0.400	0.301
Model summary											
p - value	0.335	0.205	0.816	0.670	0.952	0.213	0.126	0.180	0.401	0.857	0.290
R^2	0.209	0.271	0.063	0.102	0.023	0.267	0.327	0.286	0.184	0.052	0.228
Adjusted R^2	0.040	0.115	-0.138	-0.091	-0.186	0.110	0.183	0.134	0.009	-0.151	0.063
F	1.233	1.737	0.313	0.528	0.112	1.700	2.267	1.873	1.050	0.255	1.380
Complexity 1000m	0.848	0.435	0.465	0.608	0.593	0.725	0.964	0.661	0.875	0.655	0.999
Ha OSR 1000m	0.701	0.701	0.750	0.707	0.643	0.289	**0.073**	**0.048**	**0.078**	0.885	0.118
Distance	0.372	0.445	0.849	0.513	0.825	0.281	0.149	0.148	0.407	0.470	0.191
Model summary											

p - value	0.818	0.777	0.898	0.878	0.907	0.548	0.162	0.141	0.252	0.823	0.255
R^2	0.062	0.073	0.040	0.046	0.037	0.136	0.299	0.314	0.246	0.061	0.245
Adjusted R^2	-0.139	-0.126	-0.165	-0.159	-0.169	-0.049	0.149	0.167	0.085	-0.140	0.083
F	0.310	0.368	0.196	0.244	0.182	0.736	1.992	2.140	1.525	0.303	1.512
Complexity 500m	0.592	0.152	0.452	0.850	0.769	0.164	0.864	0.795	0.428	0.952	0.917
Ha OSR 500m	0.943	0.203	0.882	0.790	0.851	**0.043**	0.993	0.714	0.346	0.179	0.666
Distance	0.313	0.234	0.646	0.548	0.676	0.172	0.289	0.275	0.823	0.344	0.305
Model summary											
p - value	0.779	0.290	0.893	0.929	0.971	0.095	0.681	0.683	0.606	0.442	0.681
R^2	0.073	0.228	0.041	0.031	0.071	0.356	0.099	0.098	0.119	0.170	0.099
Adjusted R^2	-0.126	0.063	-0.164	-0.177	-0.194	0.218	-0.094	-0.095	-0.069	-0.008	-0.094
F	0.365	1.380	0.202	0.149	0.078	2.578	0.511	0.508	0.632	0.954	0.512

The models in the regression analyses which had the lowest F- statistical p- values, were also tested in forward selected stepwise regression analyses. The purpose with the stepwise regressions tests was to assess if the independent variable in the former regression models would better explain the dependent variable when the other independent variables were excluded from these models. The models with statistically significant results are shown in *table 24* and *25* and is illustrated in *figure 32* and *33*. Note that the non-significant variables in the stepwise regression models in *table 24* and *25* have not been excluded from the tables in order to demonstrate their significance value (p) in these models. The results from the stepwise regressions remained the same when other scales of landscape complexity were added in the models, thus, the proportion of OSR- fields was still the only variable affecting damages.

Table 24. Results of forward regression analyses where a positive correlation between the percentage of OSR- fields at a 3000m and 2000m scale on damages at the field edge outside of the PFCZ in late pod set, could be shown.

Model	**Damages in *Late pod set***
	Outside PFCZ, edge
Complexity 3000m	0.324
Ha OSR 3000m	**0.016**
Distance	0.279
Model summary	
p - value	0.016
R^2	0.311
Adjusted R^2	0.268
F	7.224
Complexity 2000m	0.862
Ha OSR 2000m	**0.034**
Distance	0.217
Model summary	
p - value	0.034
R^2	0.252
Adjusted R^2	0.205
F	5.384

Table 25. Results of forward regression analyses where a positive correlation between percentage of OSR- fields at a 500m scale and damages 20m into the field within the PFCZ in late pod set, could be shown.

Model	**Damages in *Late pod set***
	PFCZ, 20m
Complexity 500m	0.451
Ha OSR 500m	**0.044**
Distance	0.481
Model summary	
p - value	0.044
R^2	0.231
Adjusted R^2	0.183
F	4.802

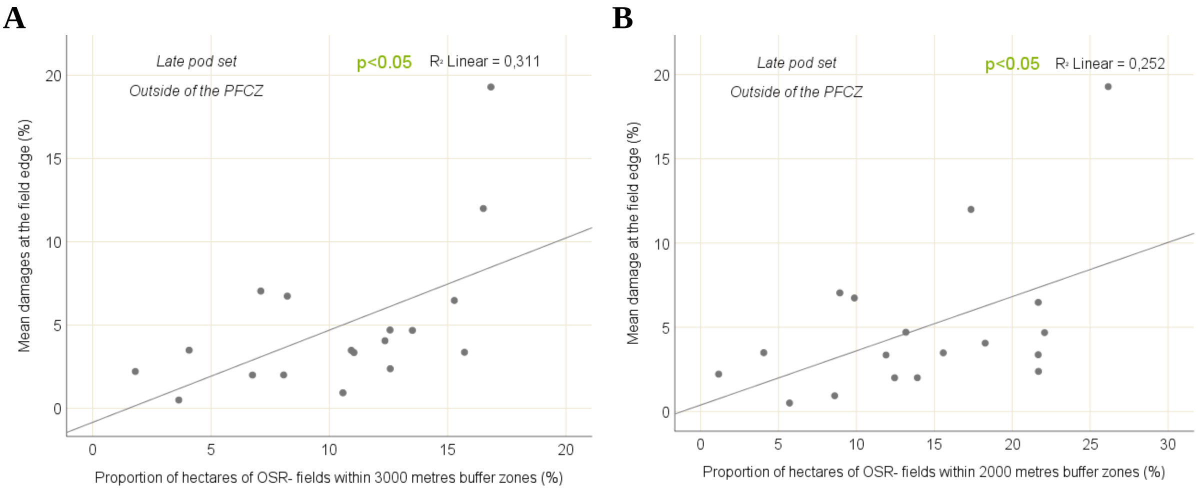


Figure 32. Scatter plots with regression lines showing mean percentage of damage at the field edge in relation to percentage of hectares of OSR- fields within 3000 and 2000 metres buffer zones. *32(A)*: within 3000 metres. *32(B)*: within 2000 metres.

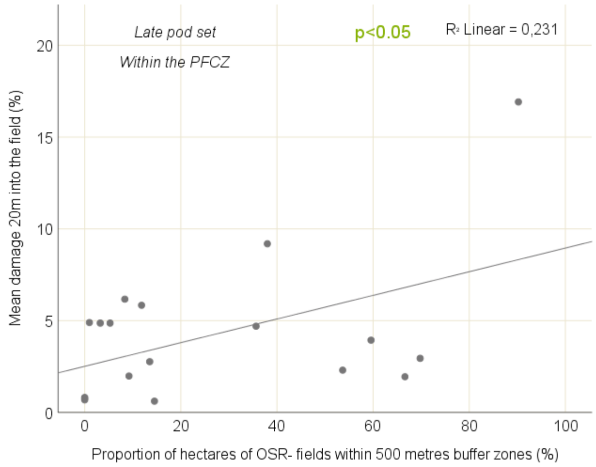


Figure 33. Scatter plot with regression line showing mean percentage of damage at the field edge in relation to percentage of hectares of OSR- fields within 500 metres buffer zones.

3.12 Questionnaire

A questionnaire (*Appendix 1*) was compiled and sent to the WOSR farmers after the crop season had ended. The questions were geared towards the management of the WOSR cultivation, the yields of 2018, and the farmers' perceptions regarding this years' abundances and damages of *C. obstrictus* and *D. brassicae* compared to the previous year. 13 out of 17 farmers responded. A table with answers regarding insecticide treatments and use is provided in *appendix 1*.

All farmers but two estimated that the quantity of *C. obstrictus* in the season of 2018 was less, or a lot less, than in the previous year. This is also consistent with the results seen in this study (*figure 17*). One farmer estimated the numbers of *C. obstrictus* to be larger than the year before and one farmer estimated it to be the same as in 2017.

Upon the question if the length of the period of the WOSR crop season deviated from previous years, all farmers answered that the crop season was shorter than normal and that the flowering of the WOSR in spring started and ended earlier than normal. Two farmers replied that the time of threshing occurred approximately two weeks earlier than usual, one claimed one week earlier and two respondents answered 10-14 days earlier than usual.

The seasonal timing of chemical applications varied between 04-05-18 and 24-05-18. The current general threshold for application of chemical treatments in WOSR- fields is 1-2 weevils per WOSR- plant (Aiéro et al., 2018). There are currently no threshold values for *D. brassicae*, however Gunnarson (2016c and 2017b) suggested that the threshold for weevils can be lowered to 0.5 weevils per plant if pod midges are also spotted in the field. The decisions of the farmers upon the use of insecticides was thus primarily based on checking for weevils in the field, but also checking trap catches in yellow pan traps during the earliest stages of flowering. Some farmers also took advises from extensionists, from media, and from newsletters by the Swedish Board of Agriculture or other parties within the agricultural sector.

All farmers but one recalled that the extent of damages caused by *C. obstrictus* and *D. brassicae* in the WOSR was less, or a lot less, than the year before. However, all farmers but one also answered that the final WOSR crop yield was less than the year before. The lower yields were, according to the respondents, primarily a result of the drought in 2018 and generally not because of insect damages. One farmer answered that his WOSR crop yield was reduced from normal yields by 75%, another by 50%, another by half a tonne and yet two others by one tonne. The farmer that did not recall damages by *C. obstrictus* and *D. brassicae* to be less this year, responded that the extent of damages by these pests was too difficult to determine because of the overall poor visual appearance of the WOSR due to damages caused by drought.

4 Discussion

4.1 Abundances of *D. brassicae* and *C. obstrictus* throughout the crop season

As was hypothesized, abundances of both study organisms declined as the season progressed, however, the decline was more distinct for *C. obstrictus* than for *D. brassicae* (*figure 11*). This was expected since adults of *C. obstrictus* becomes active in the end of April (Gunnarsson, 2016b), or in late May (Ulmer & Dosdall, 2006) when they migrate to OSR- fields. The new generation usually does not appear until July (Dosdall & Moisey, 2004; Stephansson & Åhman, 1998), but these individuals are possibly not caught in traps as they stay in the WOSR- fields until they move out of the fields to find hibernation grounds (Alford, 2008; Gunnarsson, 2016a; Williams, 2010). *D. brassicae* may arrive to the fields inconsistently throughout the crop season and emerge in two or more generations each season (Williams, 2010). The phenology of the abundance of midges can therefore be expected to fluctuate considerably relative to abundances of weevils.

One interesting observation in the phenology of *D. brassicae* is the two increases in abundance in May and June. This is possibly a reflection of two generations since it occurs in the proper time for the arrival of the first and second generation to the fields (Alford, Nilsson & Ulber, 2003; Stephansson & Åhman, 1998). It is reasonable to think that most of the individuals later in the crop season were hatched in the current WOSR-field, which could explain the lower number of midges caught in the traps in the later increase compared to the earlier increase. Furthermore, Axelsen (1992a) proposed that pre-pupae mortality due to predation or desiccation may contribute to a smaller population in the second generation midges compared to the first generation.

An interesting result regarding abundances is the lack of correlation between the species seen in *section 3.4*, this is further discussed in *section 4.4*.

4.2 Difference in, and relation of, abundance of *D. brassicae* male and female

Both male and female *D. brassicae* were found in the sticky trap samples, but males were overrepresented (*figure 12* and *13*). A common belief, suggested in several earlier studies (in e.g. Alford, 2008; Axelsen, 1992a; Molnár et al., 2018; Stephansson & Åhman, 1998; Williams, Martin & Kelm, 1987; Åhman, 1985), is that fertilized females, but not males, migrate to OSR- fields from their overwintering- and mating sites as these sites are usually not associated with the host plant. This theory can be supported in the laboratory study by Williams & Martin (1986) where it was found that females of *D. brassicae* were attracted to crushed WOSR- leaves but males were not. Moreover, the adult pod midges are short lived (Isidoro et al., 1993; Stephansson & Åhman, 1998) thus the males will die soon after mating and females die soon after oviposition of the eggs, which supports the theory that the males may not migrate to WOSR- fields after mating if this occur at the emergence site. Because of this prior notion of the biology of *D. brassicae,* it was hypothesized that, in contrast to the results, more females than males would be found in the sticky trap samples. However, another study also found both females and males in samples from traps which were located in a current WOSR- field (Graora et al., 2015), and furthermore, in this study there was also a positive correlation between males and females when the outliers had not been excluded from the dataset. These extreme values affected the statistical results, but yet have not been discarded from the dataset as they may contain important information. An interpretation is that these outliers are associated with a higher abundance at these locations, and if they are removed from the analyses, data of *D. brassicae* abundance is thus lost. The fact that some samples contained low relative abundances compared to all the other samples reveals something about the flight and migration behaviour of *D. brassicae*. This could for instance be reflections of a swarming behaviour of the pod midges. Swarming of *D. brassicae* have indeed been observed near WOSR- fields before (Gunnarsson, 2017a, c).

The results illustrated in *figure 12* and *13* are quite surprising and they suggests that there is a discrepancy in earlier beliefs regarding the biology of *D. brassicae* midges in the period immediately after their emergence as adults from the hibernation fields.

One explanation could be that the first priority of the females after emergence is perhaps not mating, although mating could occur at the emergence site anyway. Instead, the first concern of the females is perhaps to find the closest WOSR-field. If so, the males may follow the females to this field, a process controlled by the attraction of the males to the sex pheromones of virgin females. Mating between virgin females and males will in such case occur in the current WOSR-fields. Indeed, this theory can be supported in the study by Williams & Martin (1986) where females of *D. brassicae* were attracted to WOSR-leaves but not to males and males were attracted to both live and dead virgin females but not to WOSR-leaves, live or dead mated females, dead virgin females of which the ovipositor had been removed, or other males. Evidence of sex pheromones of virgin females were also found in Isidoro et al. (1993).

Continuing on this theory, in addition to the difference in host plant and pheromone cue search between males and females, there is a difference in the relative diel flight activity of the sexes. It has been shown that males of several species of gall midges (van Lenteren & Schettino, 2003) including *D. brassicae* (Williams, Martin & Kelm, 1987), fly more than the females. Hence, if the males in their search for virgin females fly more than females between different crops, the chances of more males than females being caught in the traps may perhaps increase regardless of the relative abundances of males and females at a site. It is reasonable to predict that the females barely fly outside of the field once they have reached an appropriate host field since they may then await a male for mating or search for suitable pods. In field research, this could therefore generate a male-biased sex ratio in the samples. Hence, it cannot be concluded that the results in this study represent a true difference in distribution of sexes since it could possibly be a reflection of differences in the flight activity between the sexes. In future investigations of sex ratios, it may be useful to locate sticky traps at all the borders of each study field and also to put some traps further within the fields.

As a final remark, evidence of monogeny in several species in the family Cecidomyiidae (Tabadkani, Khansefid & Ashouri, 2011), including in *D. brassicae* (Murchie & Hume, 2003), have been shown elsewhere. However, this cannot be considered as a possible answer to the skewed sex ratio in this study as such an analysis requires an altogether different methodology.

4.3 Relationship between trap catches and the number of *C. obstrictus* counted on WOSR-plants

There are several early-season measures for deciding if chemical treatments should be used in the field. A common approach is to look for *C. obstrictus* on flower buds *in situ* in the earliest stage of development of the WOSR flowers. Indeed, in the questionnaires, some of the farmers responded that they checked for weevils in the field when they decided upon the use of chemical treatments in their field (*section 3.11*). The current threshold values for application of chemical treatments in Sweden is 1-2 weevils/plant (Aiéro et al., 2018), or 0.5 weevils if pod midges are also detected (Gunnarsson, 2016c, 2017b).

To assess the adequacy in counting weevils *in situ* early in the crop season as a predictor for abundances of weevils later in the crop season, number of weevils were counted on ten plants within the PFCZ at each field visit during the first four weeks of fieldwork. The counted weevils were then tested with total trap catches of weevils in both trap types in the first four weeks.

The analyses showed positive correlations between the counted number of weevils on plants and the trap catches in both pan traps and sticky traps (*figure 14*). Although this measure cannot be adopted for direct predictions of the extent of damages by *D. brassicae*, it still provides valuable information for the farmer. These results reveal that, at least in this study, field observations of *C. obstrictus* early in the season could be used as an applicable predictor of the extent of presence of *C. obstrictus* in the field later in the season. Ultimately, if a large number of weevils are spotted on the flower buds early in the season that could be a reason to be concerned about later infestations by *D. brassicae* as well.

4.4 Relation between abundances of *D. brassicae* and *C. obstrictus*

No statistically significant correlation was found between abundances of *D. brassicae* and *C. obstrictus* (*section 3.4*).

The general belief is that *D. brassicae* is more or less dependent on the presence and abundance of *C. obstrictus* for their own oviposition, as they usually cannot pierce the rape pods themselves and instead utilizes the pre-pierced holes made by *C. obstrictus* (Hughes & Evans, 2003; Åhman, 1987). The lack of relation between abundances of *D. brassicae* and *C. obstrictus* in this study may therefore seem surprizing, however, although abundances of these organisms can be strongly related in reality, this may not be true for abundances in trap samples. Possibly the best explanation to the result seen in this study is that, since the migrations of pod midges and weevils into WOSR- fields is presumably independent of the other species, abundances in trap catches cannot be expected to covariate either.

Although no statistically significant relation was found between abundances of *D. brassicae* and *C. obstrictus,* an interesting observation can still be seen in *figure 15* where abundance of *C. obstrictus* in pan traps seem to follow abundance of *D. brassicae* at the two localities where most individuals of *D. brassicae* were found. Perhaps would this trend generate a statistically significant relation if the weather conditions in 2018 were different as these unusually dry and warm conditions may have impeded the emergence of *D. brassicae* and the flight of *C. obstrictus* (the weather conditions in 2018 is further discussed in *section 4.7, page 47*). Indeed, although abundances of pod midges could not be compared to the study conducted in 2017 (Rösvik, 2017), abundances of weevils in sticky trap samples and pan trap samples were significantly higher in 2017 compared to this study (*figure 17*).

Dosdall & Mason (2010) argued that abundance and rate of spatial expansion of *C. obstrictus* have shown considerable declines in dry years, and earlier studies have suggested (Axelsen, 1992b; Nilsson, Vimarslund, Gustafsson, 2004) and shown (Axelsen, 1992a; Axelsen, Fink & Kjær, 1997; Graora et al., 2015) that emergence of *D. brassicae* may markedly decrease or even stop in very dry years as more larvae may then enter diapause. The reason for this is not entirely understood and have not been studied much, however, Axelsen (1992b) proposed that low soil humidity as a consequence of drought during the spring and summer may prevent pupation of *D. brassicae* since this, according to this paper, has been shown for other species of gall midges. Another explanation could be that a significant proportion of larvae and pupae die in very dry soils as a consequence of desiccation (Axelsen, 1992a). An unusually dry climate could thus delay, or prevent, the emergence of *D. brassicae* adults. In addition, Graora et al. (2015) suggested that the reduction in activity of the species in unfavourable climatic condition, such as drought, could be a strategy of survival. This may be especially true for *D. brassicae* as it has been proposed in other studies that pod midges may hibernate for several years before emergence as adults in case of unfavourable climatic conditions (Alford, Nilsson & Ulber, 2003; Ferguson et al., 2004; Hughes & Evans, 2003; Williams, 2010; Williams & Cook, 2010).

Furthermore, presumably because of unusually high temperatures in 2018 (see discussion in *section 4.7, page 47*), the WOSR flowering ended earlier than normal and as a consequence of that, the period of flowering was shorter than usual according to some farmers (*section 3.11*). It is thus possible that the phenological development of the WOSR was to some extent asynchronous with the migrations of *C. obstrictus* this season. The WOSR development may have already completed its optimal growth phase for oviposition of *C. obstrictus* by the time some of the populations of weevils arrived to the crops (Veromann et al., 2006). However in order to assess this possibility, it would have been necessary to start collecting trap samples of *C. obstrictus* earlier than as was done in this study since *C. obstrictus* may arrive to the fields already in the end of April during normal climatic conditions (Gunnarsson, 2016b). Ideally, the emptying of traps at all the fields should have started in early- to mid-April in order to examine a possible asynchronous situation between the phenological development of the WOSR and the emergence of *C. obstrictus* through the phenology of abundance. Another method for assessing if a shorter flowering period of the WOSR have affected the abundance and infestation of *C. obstrictus*, could be to sample in both WOSR and SOSR as SOSR is sown in spring and thus flowers later than WOSR (Ekbom, 2010). A problem with this approach is, however, that *C. obstrictus* have high preferences for WOSR (Gunnarsson, 2016a; Váitelyte et al., 2011; Veromann et al., 2006) which adds bias to such an investigation. Regarding the weather conditions, it should also be mentioned that diel weather conditions may affect the flight activity of *C. obstrictus* and *D. brassicae* in a short term as well.

Finally, since *C. obstrictus* hibernate during winter, it may also be the case that unusually low temperatures in February and Mars (SMHI, 2018d, e), resulted in significant mortality of hibernating adults. Indeed, in an 8 week experiment by Cárcamo et al. (2009), it was shown that survival of hibernating adults of *C. obstrictus* decreased significantly at -5°C relative to 5°C. Ultimately, as low infestations by *C. obstrictus* will likely reduce infestations by *D. brassicae*, overwintering mortality could influence the analysis of the relation between abundances of the species.

4.5 Differences in abundances of *D. brassicae* and *C. obstrictus* within- and outside of the PFCZ

There were no statistically significant differences in abundance between the sticky traps within- and outside of the PFCZ for *D. brassicae* or *C. obstrictus* or in the pan traps for *C. obstrictus*.

These results were quite expected. Previous research has suggested that *C. obstrictus* (Tansey et al., 2010a; Tansey et al., 2010b) and *D. brassicae* (Molnár et al., 2018; Murchie, Smart & Williams, 1997; Williams & Cook, 2010) orients to WOSR- field by means of visual- and olfactory cue search. Unless the chemical treatment affects the colour of the WOSR- flowers or the scent of the WOSR- plants, it should not affect the migration of weevils and pod midges to the WOSR-fields. Abundances in traps which are placed at the field edges where the weevils and midges first arrive to the fields, should thus not differ regardless if the traps are located within a pesticide-free zone or not. If chemical treatments have an effect on damages by *D. brassicae*, which was indeed shown in this study (*table 10-13*, *figure 18*, *figure 21A*), insecticides can be expected to affect the presence and abundances of the weevils and midges once they have arrived to the WOSR-field but not during the migration stage prior to arrival.

4.6 Relation of mean trap catches of *C. obstrictus* between the trap types

Most samples were in a lower catch range, but despite this, the test showed a positive correlation between abundance of *C. obstrictus* in the two trap types (*figure 16*). Although the pan traps generated larger samples sizes per week compared to the sticky traps and the average number of weevils was low, these results reveals that both trap types can be used to monitor abundances of *C. obstrictus*. The effectiveness of the trap types have been confirmed in another study where *C. obstrictus* was monitored in field studies (Smart, Blight & Hick, 1997). An issue with the pan traps is that the water within the cups evaporates during the period between regeneration of the traps. Despite that the cups were generously filled with water after collecting each sample in this study, the pans were often dry when the traps were visited a week later. Evaporation of water in the pans is possibly not an important issue with, for the season, normal temperatures and normal amount of precipitation during the period of field work. Indeed, un-baited water-filled pan traps have been used as an applicable tool to monitor insect pests in WOSR-cultivation in this study region many times before (Jordbruksverket, 2017a; Jordbruksverket, 2016c; Jordbruksverket, 2015; Jordbruksverket, 2014). However during this study, the climatic conditions were characterized with unusually low amount of precipitation and uncharacteristically high mean temperatures which began already in April (SMHI 2018a, b, c, see further discussion regarding the weather on *page 47*). This have presumably affected the sample sizes of *C. obstrictus* in the pan traps in this study. Hence, in such dry weather conditions as these, the sticky traps may be a better option for *in situ* observations and for field research in general.

Bycatches in terms of other insects is inevitable when using either trap type. However, the smaller sample catches in the sticky traps in combination with the fact that the samples do not have to be sorted from other insects, result in faster post-processing of these samples compared to the pan trap samples (Östrand 2011). Sticky traps is thus possibly better suited for a farmer who wants to monitor *C. obstrictu*s *in situ* as analysing these samples requires less material and time.

4.7 Differences in within- field damages by *D. brassicae* in early- and late pod set

Differences in damage between the field edge and 20m into the field

Spatial patterns of movements and attacks by insect pests within WOSR- fields, is often different between species (Ferguson et al., 2003; Williams & Ferguson, 2010). The patterns of attacks by *C. obstrictus* can be relatively concentrated in the field edges in the beginning of the crop season but then later in the season become more irregularly aggregated and complex as the weevils move further towards the field centre (Ferguson, 2003; Ferguson et al., 2000; Hausammann, 1996; Murchie, Williams & Perry, 1999; Williams & Ferguson, 2010). The spatial distribution of attacks by *D. brassicae* display a more constant pattern, where damages are generally much more severe at the field edges throughout the entire crop season (Ferguson, 2003; Gunnarsson, 2016c; Jordbruksverket, 2017a; Jordbruksverket, 2016c; Jordbruksverket, 2015; Nilsson, Vimarlund & Gustafsson, 2004). It was therefore hypothesized that damages by *D. brassicae* would be greater in the field edges than 20m into the fields, however, in order to assess the spread of damages within the fields and throughout the season, both the edges and 20m into the fields were inventoried. By monitoring and learning how the distribution patterns of infestation of certain insect pests are expressed, it can assist in decisions upon the use of pesticides (Čuljak et al., 2016; Ferguson et al., 2003).

In late pod set, there was no difference in damages between the field edge and 20m into the field within the PFCZ, but there was a statistically significant difference outside of the PFCZ, with greater damages at the field edge (*figure 21C*). These findings are consistent with earlier findings of edge-distributed damages by *D. brassicae* (Ferguson et al., 2003; Gunnarsson, 2016c). One reason why this could not be found in early pod set in this study (*figure 18*) could be because only one edge of each study field was surveyed and thus this result may be an issue of sampling method. To inventory only one border of the field may not be sufficient for this analysis since it is possible that weevils and midges, for many possible reasons, occur more frequently at the other borders of the field than at the border that was inventoried.

Why there were no difference in damages at the field edge and 20m into the field within the PFCZ in both early- and late pod set (*figure 18A* and *21B*), could be a matter of the size of the PFCZ. Indeed, Nilsson (2009) argued that damages are often most extensive at the field edges and become less prominent approximately 30m into the field. Further in another report, the spatial distribution pattern of damages by *D. brassicae* was rather extensive within approximately 30m from the field edges (Ferguson et al., 2004) and yet another study found considerable damages within the first 20m (Warner et al., 2000). The PFCZ in this study stretched 24m into the field and the surveys of damages were conducted 20m into the field (*figure 7*). It is thus possible that the PFCZ needs to extend further into field in order to better assess the distribution of damages within it, or at least to observe more apparent differences between damages at the field edge and further into the field. A different study design for assessing the effects of pesticides could include entire control-fields which are free from chemical treatments. But this approach includes other practical- and economic constraints, and it will likely involve further issues with confounding factors due to possible differences in the local environments surrounding the fields.

It is also possible that the lack of differences in damages between the field edge and 20m into the field in early pod set and within the PFCZ, were due to technical sampling problems. Especially considering the drought in 2018 (see further discussion regarding the drought on *page 47*) as the pods which were damaged by *D. brassicae* were very similar in visual appearance to the pods that were damaged by drought.

In early- and late pod set, damages were greater at the field edge within the PFCZ compared to the edge outside of the PFCZ (*figure 19A* and *22B*) and in early pod set, damages 20m into the field were greater than 20m into the field outside of the PFCZ (*figure 19B*). These results clearly demonstrates that chemical treatments have an effect in controlling damages by *D. brassicae*. However, it also indicates that since chemical treatments is effective in early season but the effect seem to cease later in the season, it shows that effective control of damage by *D. brassicae* may not be susceptible to the number of insecticide treatments carried out in the field after the first application but rather that the timing and location of the first application may be more important. Indeed, the timing of insecticide application, the number of applications and the specific insecticide used, are important concerns when evaluating effectiveness of chemical treatment on certain insect pests at specific locations. The data in this study is analysed on the presumptions that all the farmers used insecticide treatments aimed for *C. obstrictus* at least one time during the season and that they were equally careful to not apply chemicals in the PFCZ, but the questionnaires reveal differences between the fields and sometimes this information was never provided (see table in *appendix 1*). These are important considerations when analysing the result of effects of chemical treatments. Moreover, it is also possible that the drought in 2018 may have obscured the effects of chemical treatments - especially in late pod set (see further discussion regarding the drought on *page 47*).

Relationship of damages at the field edge and 20m into the field within- and outside of the PFCZ between early- and late pod set

In this discussion upon the relationship of damages between early- and late pod set it must first be mentioned that, of obvious reasons, it is not possible that damages in late pod set could be less than damages in early pod set, yet such conditions are sometimes shown in *figure 24* and *25* (*section 3.8*) and in *figure 29* (*section 3.10*). These are unreasonable results and are presumably a consequence of the practical difficulties of surveying damages due to a severe drought in 2018, which have possibly masked and impeded the results of damages.

Indeed, the weather during the summer of 2018 deviated from what is normal in several perspectives. 2018 started with mild winter conditions in January (SMHI, 2018d), but the temperatures in February and Mars were unusually low (SMHI, 2018d, e). Later this year, the spring and summer period at the time and location of this study was characterized by an unusually low amount of precipitation and unusually high temperatures, and this began already in April (SMHI, 2018a, b, c). Some days in May, June and July were in fact the highest ever recorded in some parts of southern Sweden (SMHI, 2018a). As a consequence, parts of southern Sweden were affected by severe drought which resulted in significantly lower yields in several crops. The total production of cereals, as an example, is estimated to be 46% less than in the previous year which is the lowest yield recorded in almost 60 years (Jordbruksverket, 2018). The climatic conditions is confirmed to have had significant effects on the growth of oilseed crops as well. Due to the drought, the total yield of WOSR in 2018 has been estimated to 32% lower than in the previous year and 33% less than the average for the last five years (Jordbruksverket, 2018). The drought was experienced in all of the WOSR-fields in this study (*section 3.11*) and it had negative effects on the inventories of damages as the infested pods and the pods damaged by drought were often very similar in visual appearance. It should also be mentioned that the autumn of 2017 was very rainy (Jordbruksverket, 2017b; SMHI, 2017a, b). This resulted in significantly less acres of WOSR sown in 2017 compared to previous years as the persistent rain deteriorated conditions for sowing WOSR in autumn (Jordbruksverket, 2017b). Many farmers experienced practical difficulties in driving out into the fields because of flooding, and the floods further resulted in lower oxygen levels in the soils and thus poor conditions for WOSR cultivation. Hence, the combined effects of wet weather conditions in autumn 2017 and dry conditions in summer of 2018, have resulted in less acres and lower yields of WOSR in 2018.

Nonetheless, despite the weather circumstances during the autumn of 2017 and the summer of 2018, some interesting results regarding within-field damages between early- and late pod set could still be shown. These are further discussed below.

As mentioned earlier, there is a tendency for *D. brassicae* to be distributed at the edges throughout the crop season (Ferguson, 2003; Jordbruksverket, 2017a) while *C. obstrictus* is often distributed at the edges only in the immigration stages (Murchie et al., 1999). These distribution patterns are consistent with the results seen in this study since there were positive correlations for edge distributed damages between early- and late pod set (*figure 24A* & *25B*) and greater damages at the field edges compared to further into the field later in the crop season (*figure 21C*).

By examining the spatiotemporal patterns of damages by *D. brassicae* in earlier- and later occasions during the crop season, it provides a general overview of damages within a field and ultimately may provide a clue of the final yield in comparison to the yields in previous years. As damages in the field edges and 20m into the field in early- and late pod set were positively correlated within the PFCZ (*figure 24B*) and the damages within the PFCZ were often greater than the damages outside of the PFCZ (*figure 19* and *figure 22A*), it indicates that damages within the WOSR-fields may be of economic importance later in the crop season and that the use of chemical treatments could be a legitimate option to prevent considerable damages. However, since a positive correlation was also found for damages at the field edge but not 20m into the field outside of the PFCZ in early- and late pod set (*figure 25B*), these results also demonstrates that damages at the field edges may still be significant also later in the crop season regardless of the use of pesticides early in the season.

Murchie et al. (2001) suggested that when contact insecticides to target *D. brassicae* is used, these should be applied from mid- to late morning to be most effective since this time, according to their research, is when most adult pod midges are active. The use of pesticides have indeed been successful to control *D. brassicae* (Pavela, Kazda & Herda, 2009; Vaitelyte et al., 2011) elsewhere. But as mentioned previously, treatments for specific control of *D. brassicae* is not used in Sweden since its abundance may fluctuate within a field and throughout a crop season depending on several external factors (Jordbruksverket, 2016b; Moser et al., 2009) and since pod midges are very difficult to detect in field due to their small size and short adult life (Stephansson & Åhman, 1998). Consequently, it is difficult to establish threshold values for pod midges (Nilsson, 2009) and there are therefore no methods to forecast infestations which also makes it difficult to determine the need for chemical control of *D. brassicae* in a particular season. Furthermore, as insecticides are aimed for control of *C. obstrictus* but it is infestations by *D. brassicae* that is the primary purpose with the use of these chemicals, the trade-off between applying chemicals or refraining can be rather complex. Additionally, in previous experiments the effect of chemical treatments on *C. obstrictus* have been shown to vary between different localities (Gunnarsson, 2016d). The reason for this can be variations in the timing of appearance of weevils at different locations, which in such case emphasize the importance of timing of insecticide application, and again, demonstrates the complexity of specific control of *D. brassicae* by the use of insecticides.

By analysing the results in this study one may think that an alternative option for managing further spread of damages by *D. brassicae* into the field, could be to prophylactically apply insecticides only in the field edges before flowering and the arrival of weevils (Ferguson et al., 2003). Prophylactic applications, however, have been tested in Skåne in previous research but it had no success in controlling weevils in these experiments (Gunnarsson, 2016d). Another problem with this approach is that *C. obstrictus* migrate to the WOSR- fields earlier than *D. brassicae*, hence, application of insecticides before flowering would, if it was effective, target the newly arriving weevils but not the pod midges. Furthermore, post-flowering applications may harm beneficial parasitoids (Gunnarsson, 2017b).

Another approach could be to apply chemicals at the field borders after flowering. Indeed, application of insecticides at the end of blooming have had positive effects on the control of *C. obstrictus* in Skåne in previous experiments (Gunnarsson, 2016a) and this is currently the common method for the control of *C. obstrictus* in Sweden, but then usually the whole field is treated and not just the edges. Application of chemical treatments after flowering at only the field edges, however, would target the earliest arriving pod midges and the late weevils that may migrate from nearby SOSR- fields and which have also shown to be distributed at the field edges (Murchie et al. 1999). This approach has further benefits of limiting potential harm to pollinators and natural predators in the central parts of the field (Ulber, Klukowski & Williams, 2010). On the contrary, Murchie et al. (1999) showed that insecticides that are used in the WOSR- crops during blooming or post-blooming can still harm parasitoids of *C. obstrictus,* and besides, insecticide treatments confined to the field edges may not be a sufficiently effective method during seasons with heavy attacks. Another problem with applying insecticides only in the field edge is the possible harm to natural predators that may forage in the field and use the field edges as corridors to move between fields (Nilsson & Ullvén, 2014; Tamburini et al., 2016). There is limited research on which other natural enemies there are that can attack *D. brassicae* apart from some species of hymenopterans (Ferguson et al., 2004; Gunnarsson, 2017b). However, since weevils and pod midges fall to the ground before pupation, it is reasonable to believe that they can also be attacked on the ground by other terrestrial generalist arthropods (Axelsen, 1992a), such as spiders and ground beetles. In concern of possible natural predators, including hymenopterans and other beneficial insects that may reside in small semi-natural corridors around- and between fields in the agricultural landscape (Jonsson et al., 2015; Nilsson & Ullvén, 2014; Tamburini et al., 2016), insecticides should be avoided at the field edges.

4.8 Effects of abundances of *C. obstrictus* and *D. brassicae* and chemical treatments on damages

The multiple regression models showed that in early pod set there was an effect of chemical treatments but no other variables (*table 2-7* and *figure 19* and *20*) and no effect of any variable was seen in late pod set (*table 14-17*). These test results demonstrates the importance of chemical treatment for damages, however, they also suggest that since damages by *D. brassicae* were not significantly affected by the abundances of pod midges and weevils within- or outside of the PFCZ, trap catches of *D. brassicae* and *C. obstrictus* are not able to explain damages at the study sites. ´

As already discussed on *page 46*, and as seen in the table in *appendix 1*, this study lack information regarding insecticide treatment for some of the study fields (see *section 3.12*). Although the data in this study is processed on the assumptions that all the farmers used insecticide treatments aimed for *C. obstrictus* in their field and that they were equally careful to not apply chemicals in the PFCZ, there is at least one farmer that did not use insecticides (see *appendix 1*) and there is no guarantee of equal application procedures by the farmers. Moreover, since WOSR is often attacked by insect pests other than the pests revised in this study (Alford, 2003), some of the insecticides used in the fields are not aimed for *C. obstrictus* and would thus not be effective in the control of this species. The timing of insecticide application, the number of insecticide applications and the specific insecticide used, are important concerns when evaluating the effectiveness of chemical treatment on specific pests at specific sites. Hence, since some of this information is not provided for all the study fields and since these factors sometimes differ between the fields, this can be expected to have affected these analyses of chemical treatments on damages. However, the evidence of an effect of chemical treatments in early pod set (*table 2-7*, *figure 19* and *20*) and the fact that there were greater damages within the PFCZ compared to outside of it in early pod set (*figure 19*) and at the field edge in late pod set (*figure 22A* and *23*), still demonstrates that a significant number of farmers used chemical treatments that were effective in controlling damage by *D. brassicae* through the control of *C. obstrictus*. Another possible explanation to why no effect of chemical treatment was seen in late pod set in the regression analyses (*table 14-17*) apart from differences in chemical applications by the farmers, could be that the drought in 2018 may have obscured the effects of treatments later in the crop season since the drought became more prominent as the season progressed. Indeed, all but one farmer responded that their final WOSR crop yield was less than normal and that this was due to the drought and not primarily a result of insect damages (*section 3.12*).

It is intuitive to believe that abundances of *D. brassicae* and damages by *D. brassicae* would correlate positively. The lack of relation between these variables in the regression analyses was thus not expected. An explanation to this could be that because *D. brassicae* is a small and fragile species and weak flyer, its migration to WOSR-fields can be controlled by a rather high rate of passive wind diffusion (Williams & Cook, 2010; Sylvén, 1970). It is thus possible that in the statistical model assessing the question of effects of abundances on damages, the number of individuals which are trapped on the yellow sticky traps through visual cue search, may fail to reflect abundances of individuals that, partly through wind currents, are reaching the field at the particular sites where the traps are located. Hence, the sticky trap catches will in such case fail as an applicable parameter in this analysis and thus no effect of abundance is detected in the regression model. It is possible that the results would have been different if individuals of *D. brassicae* would also have been counted from the pan traps. However, counting midges in pan trap samples includes other practical- and time constraints which are not associated with counting midges on sticky traps, and so this is unfortunately not a reasonable task in practice.

As mentioned in *section 1.2.2*, *D. brassicae* is more or less dependent on the presence and abundance of *C. obstrictus* as the pod midges utilizes holes in the pods made by *C. obstrictus* (Hughes & Evans, 2003; Åhman, 1987). The lack of effect of abundance of weevils on damages was thus not expected either, however, some studies have proposed that *D. brassicae* may oviposit its larvae in pods that have been damaged by other insects, diseases or sheared by wind (Axelsen, 1992b; Fergusson, 2003; Hughes & Evans, 2003), or maybe damaged by drought. This could explain why abundances of weevils was not statistically correlated to damages in the regression analyses. Furthermore, since *C. obstrictus* lay a single egg inside each pod (Alford, Nilsson & Ulber, 2003) while *D. brassicae* lay large clusters of eggs inside each pod (Stephansson & Åhman, 1998; Åhman, 1987), a few weevils may support a much larger population of pod midges (Ferguson, 2003). These circumstances may also affect analyses of the importance of abundances of weevils on damages. In addition, and as was already discussed in *section 4.4*, it may also be the case that unusually low temperatures in February and March in 2018 (SMHI, 2018d, e), resulted in considerable mortalities of hibernating adults of both weevils and midges. The results seen in the regression models are also consistent with the lack of relationship between abundances of *C. obstrictus* and *D. brassicae* shown in this study (*section 3.4*). The drought can also be an important factor in these regression analyses. As the drought obstructed the inventory of damages, this could certainly also have affected the relationships between abundances and damages.

Another issue to consider is the distance between rows of which the WOSR is sown. The spaces between rows can vary between fields depending on the preferences of the farmer. Shorter spaces between rows generates additional growth to the main inflorescence and thus usually results in a shorter period of attacks by insect pests. Larger spaces generates additional growth to the first- and secondary inflorescence and other lateral shoots and hence results in broader plants and may consequently induce a longer period of attacks by insect pests. Row spaces were not considered in this study and cannot be accounted for in the analyses, but nevertheless, it should be mentioned that the structure of the WOSR stand is a factor which may contribute to the effects of abundances of *C. obstrictus* and *D. brassicae* on damages.

As a final remark, the results of these regression analyses could also be a matter of study design. Both the inventory of damages in early pod set and the placement of traps at only one edge of the field, may be too limited to assess the effect of abundances on damages. The investigations of damage and the location of traps should perhaps be applied to all edges of the study fields in order to address this study question.

4.9 Damage by *D. brassicae* in a geographic perspective

As *D. brassicae* is a poor flyer and usually does not migrate far from the field where they emerge as adults (Moser et al., 2009, Stephansson & Åhman, 1998), it was predicted and expected that damages would be more severe in areas where there are more OSR- fields. However, there was no statistically significant difference in abundance or damage by *D. brassicae* between the cardinal directions at the survey conducted at the field borders in neither early pod set nor late pod set. Statistical significant difference could however be found between the cardinal directions at the survey conducted 20m into the fields in early pod set, but not in late pod set.

One explanation to the lack of difference in abundance and damages between the geographical directions of the study sites could perhaps be found by viewing *figure 30*, where the number of OSR- fields seem to be quite evenly spread in an agricultural landscape that covers large parts of Skåne. Specialized species, such as *D. brassicae*, tend to be more dependent on a continuity in the landscape compared to generalist species that utilize different habitats (Steffan-Dewenter & Tscharntke, 2000; Tscharntke et al., 2002). Thus, while the large-scale landscape of Skåne can be described as highly fragmented as is characterized by extensive agricultural land (SCB, 2018), it provides a habitat continuum for the species that are specialized within arable habitats. This is especially true for those species depending on crops that are commonly produced, which is the case with WOSR and *D. brassicae* in Skåne. The landscape surrounding the study fields, is thus perhaps not varied enough to be able to answer the question of differences between cardinal directions in this study. For example, Thies, Steffan-Dewenter & Tscharntke (2003) showed that parasitoids contribute to combating insect pest populations, such as *D. brassicae*, in rapeseed and that structurally complex landscapes (e.g. with different forested habitats), support parasitoids populations. However, insecticides can harm parasitoids (Ulber, Klukowski & Williams, 2010), so comparing variations in abundance and damage caused by *D. brassicae* between sites that are all located in a homogeneous agricultural landscape where insecticides are used regularly, can become problematic when factors that can affect these differences are possibly similar at all the study sites. Furthermore, Stephansson and Åhman (1998) argued that damage caused by *D. brassicae* have been observed to increase in forest areas due to the wind protection provided by these habitats, which could also be shown in a study by Zaller et al. (2008a). Again, this illustrates that there may be several confounding factors that affect the abundance and damage of *D. brassicae* at different locations and it demonstrates the complexity of assessing the variations between sites in such a wide geographic perspective.

Another explanation to the lack of difference in damage between the cardinal directions could be that the study sites may not have been sufficiently clustered for this analysis. The sites may instead have been too spread across the region for a possible regional difference to show. If this is the case, the number of study fields would probably have to be larger. The difference found between the cardinals direction at the survey of damages conducted 20m into the fields in early pod set is possibly not a result of a difference between cardinal directions, but is perhaps a response of different confounding within-field and landscape factors. Indeed, in two other studies, Zaller et al., (2008a) and Zaller et al., (2008b) there was no relationship between *D. brassicae* damages and area of OSR- fields. This demonstrates that factors at larger landscape levels is possibly less important to damages and that other, more local factors, are more important for the control of damages at a certain site.

Although differences between the cardinal directions could not be verified statistically in most cases, an interesting observation can be seen when comparing *figure 29*, *figure 30* and *table 18*. The NE part of the study region show a visually less number OSR- fields, lower area of total OSR- within 30km of the study fields, and the overall lowest percentage of mean damage compared to the other cardinal directions. The SW and M directions had the highest total area of OSR- fields within a 30km radius and also a slightly higher mean percentage of damage in early pod set. This trend is also to some point reflected in the percentage of OSR- fields of the land area within 30km of the cardinal directions.

Finally, and as was mentioned earlier, for natural reasons it is not reasonable that damages in late pod set would be less than damages in early pod set as *figure 24, 25* (*section 3.8*) and *figure 29* (*section 3.10*) display. This, as was mentioned before, is presumably a result of the practical difficulties of surveying damages due to the drought in 2018 (see *page 47*).

4.10 Analyses of landscape factors

The discussion of the relation between landscape parameters and the abundance of *C. obstrictus* and *D. brassicae* and damages by *D. brassicae,* is first discussed in regards to landscape complexity and then areas of, and distance to, OSR- fields from 2017.

4.10.1 Landscape complexity

In the multiple regression analyses of the relationship between landscape complexity and abundances of *C. obstrictus* and *D. brassicae* and damages by *D. brassicae*, the F- statistics were not statistically significant in any of these models (*table 23*). This result was also displayed in the stepwise regression models (*table 24* and *25*). Hence, landscape complexity, as it was defined in this study, cannot explain abundances of *C. obstrictus* or *D. brassicae* or damages by *D. brassicae* in these models.

These results were not expected since *C. obstrictus* overwinter in natural or semi- natural vegetation, hence land types including such elements is of great importance in the life cycle of this species (Williams, 2010). *C. obstrictus* is a mobile species that may actively search for Brassica fields and migrate across larger distances (Dosdall et al., 2006; Tansey et al., 2010), which means it is often affected by landscape conditions from a broader perspective (Perović et al., 2010). The SMD ground cover data which were used to define landscape complexity only included land types that may contain potential hibernation spots for *C. obstrictus*. It was therefore expected that abundance of *C. obstrictus* would respond to landscape complexity at the larger spatial scales since the larger buffer zones at 3000m and 2000m include a higher percentage of suitable overwintering habitats than the smaller buffer zones, which largely consists of agricultural land. However, one explanation to the absence of statistically significant relationships, could perhaps be ascribed to a measurement failure of capturing the appropriate scale. The SMD data is perhaps not precise enough for these analyses. This data source provides impressive and accurate information on spatial land- coverage within the study region. However, small vegetated patches or corridors that may include hibernation spots for *C. obstrictus* and that may be scattered within the extensive agricultural landscape at the very most local scales and thus are important for this analysis, is perhaps unsuccessfully recorded in the dataset of landscape complexity. Indeed, Ulmer & Dosdall (2006) could demonstrate that the primary overwintering microhabitat of *C. obstrictus* is below leaf litter underneath trees at the field margins. Such small habitats that are this close to fields, are perhaps not registered in the SMD data as land types other than agricultural land.

Moreover, the larger buffer zones do indeed encompass lower mean percentage of agricultural land and thus higher percentage of natural or semi-natural vegetated land types than the smaller buffer zones (*table 19*), but they are still essentially characterized by agricultural land. In such an agricultural landscape that is homogenous in both larger and smaller spatial scales, populations of *C. obstrictus* may be rather dispersed between a number of OSR- fields (Veres et al. 2013; With et al., 2002). The lack of significant relationships between abundances of *C. obstrictus* and landscape complexity, could thus be ascribed to the practical measurements targeting this question.

The absence of a significant relationship between *C. obstrictus* and landscape complexity could also explain the same result for abundances and damages by *D. brassicae* since *D. brassicae*, at a point in its lifecycle, is more or less dependent on the presence and abundance *C. obstrictus* (Hughes & Evans, 2003; Åhman, 1987). However, the lack of statistical significance of these relations is perhaps better explained by viewing the high mean percentage of agricultural land within the buffer zones again (*table 19*). *D. brassicae* is a species with low dispersal abilities (Moser et al., 2009 Williams & Cook, 2010; Stephansson & Åhman, 1998; Sylvén, 1970; Zaller et al., 2008b) and, as explained earlier, it oviposits and hibernates in OSR-fields (Alford, Nilsson & Ulber, 2003; Williams & Cook, 2010). It is thus intuitive to think that *D. brassicae* is more dependent on a homogeneous OSR- landscape rather than a patchy landscape with natural or semi- natural land features (Perović et al., 2010). Landscapes with high percentages of non-agricultural areas can thus be expected to have a negative effect, or no effect, on abundance of *D. brassicae* (O'Rourke, Rienzo-Stack & Power, 2011).

However, in contrast to these results, earlier studies have shown a positive relationship between abundance of *D. brassicae* and a landscape with high percentage of woody land types at small spatial scales (Frank et al. 2010; Zaller et al. 2008a; Zaller et al., 2008b). Frank et al. (2010) and Stephansson and Åhman (1998) argued that forested landscapes may positively affect insect pests of OSR through the indirect contribution of such landscapes in providing wind protection, which facilitates the migration of flying insects to the OSR- fields. Another explanation to these contradictory results can surely be ascribed to different methods used in these studies and in this study (Chaplin-Kramer et al., 2011). Nonetheless, the knowledge of landscape effects on *D. brassicae* is currently too limited to be able to further interpret the findings in this study.

4.10.2 Areas of 2017 WOSR- fields

In the regression models where the importance of the proportion of OSR- fields from 2017 to damages by *D. brassicae* and abundances of the study organisms was assessed, the F-statistics of the models summaries did not display any statistical significances (*table 23*). However in the stepwise regression models, the proportion of OSR- fields had statistically significant effects on damages at the field edge outside of the PFCZ within 3000 and 2000 metres buffer zones in late pod set (*table 24* and *figure 32A*, *32B*) and on damages 20m within the PFCZ within the 500 metres buffer zones in late pod set (*table 25* and *figure 33*). Since the proportion of OSR- fields seem to have some positive effect on damages by *D. brassicae* at smaller (500m) spatial scales, these results supports the notion of *D. brassicae* being a poor flyer with a short flight range (Williams & Cook, 2010; Sylvén, 1970). On the contrary, as the proportion of OSR- fields were also positively correlated to damages at both larger (3000m) and medium (2000m) spatial scales as well, this may also indicate that the general quantity of OSR- fields within a region is important for *D. brassicae* and it may possibly be a reflection of a success of this species to spread in a vast agricultural landscape contrary to a landscape with more forested land features.

It is intuitive to think that some of the measures of *D. brassicae*, either abundance or damage, would response positively to the proportion of OSR- fields in the surrounding landscape since *D. brassicae* is known to emerge from the OSR- fields of the previous year and in the following year migrate to the current OSR- fields (Alford, 2003). Generally, the distribution patterns of *D. brassicae* was expected to follow the patterns of areas of OSR- fields of the preceding year, and hence its overwintering sites, since these fields would theoretically have enabled the accumulation of populations that would then disperse among available OSR- fields in the present year (Hokkanen, 2000). The abundance of *D. brassicae* was therefore expected to increase with the area of its host plant, which has indeed also been shown for other insect pests (Perović et al., 2010; Veres et al., 2013) and the result seen in this study was thus also expected. However, at larger spatial scales of 2000m and 3000m, there may be a large number of confounding factors which affect damages and abundances of *D. brassicae*. Hence, as the proportion of OSR-fields was only explained for damages at the field edge outside of the PFCZ and 20m within the PFCZ in late pod set (*table 24*, *25*), and never for damages in early pod set or abundances of midges (*table 23*), these results also show the complexity of assessing landscape effects on *D. brassicae*.

This complexity can be further demonstrated in two other studies. In the first study no relationships between abundance of *D. brassicae* to the previous years' amount of OSR in the landscape were found, instead, a positive correlation was found between abundances and forested areas in scales of 250-1250m radii (Zaller et al., 2008b). Further in the second study, and in contrary to the results in this study, there were a negative relation between OSR- area and damages by *D. brassicae* within 2000m scales (Zaller et al., 2008a). Although OSR-fields from the current year and not from the previous year were used in this study, which adds further complexity of comparing these results with the results in this study, a possible explanation to the negative relations seen in Zaller et al., (2008a) is that second and third generations of *D. brassicae* have been shown to hibernate in stands of Brassicaceae apart from WOSR or SOSR (Åhman, 1987). Hence, if a sufficient amount of wild or cultivated stands of Brassicaceae species apart from WOSR or SOSR are present in the landscape, this may support populations of pod midges without larger areas of WOSR or SOSR in the landscape. As have been suggested earlier, another explanation could be that since abundance of *D. brassicae* displayed a positive response to woody areas also within very short ranges (250m) in Zaller (2008b), and pod midges are known to be weak fliers with dispersal ranges of only a few hundred meters from their emergence sites (Moser et al., 2009; Williams & Cook, 2010; Sylvén, 1970), woody areas at small spatial scales may provide wind protection and thus support migration to OSR- fields (Stephansson & Åhman, 1998).

One explanation to why abundances of *D. brassicae* and *C. obstrictus* were unrelated to area of OSR in this study, could be that the use of chemical treatments mask and impede the effect of host plant area as a dependent factor for abundances. Chemical treatments may be used more extensively in areas where the insect pest have been historically abundant and where its host plant is widely cultivated (Chaplin-Kramer et al., 2011; Ricci et al., 2009). In this case, chemical treatments are only applied to control abundance of *C. obstrictus*, however as explained earlier, they will inevitably regard *D. brassicae* as well as it is often dependent on the pre-piercing of pods by *C. obstrictus* to be able to oviposit (Åhman, 1987). Hence, because the abundance of *C. obstrictus* affect damages by *D. brassicae*, low abundance of *C. obstrictus* due to the use of chemical treatment can be the limiting factor that results in a lack of relationship between OSR area and abundances of *D. brassicae* and damages in early pod set. But again, as damages in late pod set was related to the proportion of OSR- fields, that demonstrates the difficulties in interpreting these results and it shows that more research on this topic is needed to be able to analyse these results further.

A possibly more important reason for these results than the explanations above, is that the study fields were oriented within an extensive and widespread *agricultural landscape* within the study region, and the OSR- fields from last year seem to be rather evenly scattered within this landscape (*figure 30*). If the study design would instead have been arranged to explicitly target the question of effect of OSR area within *different* landscapes in a larger spatial scale (several kilometres), then perhaps the test result would have shown positive correlations for all tests of OSR area and damages by *D. brassicae* in both early- and late pod set at landscape level. In a local perspective however, species density and thus the extent of damages of such a weak flyer as *D. brassicae*, is perhaps more controlled by the distribution of OSR- fields along a dispersal pathway rather than the OSR- area within larger spatial scales (Moser et al., 2009).

4.10.3 Distances to 2017 WOSR- fields

The distance to the nearest WOSR- fields from the season of 2017 could not explain damages by *D. brassicae* or abundances of the study organisms in this study (*table 23*).

Pod midges of *D. brassicae* live only for a few days (Isidoro et al., 1993; Sylvén, 1970), and they have limited abilities for long distance migration (Nilsson, Vimarslund & Gustafson, 2004). OSR crops must therefore be located at a distance within a few kilometres (Sylvén, 1970) in order for the female pod midges to have time to mate, seek an appropriate host field and oviposit, before they die. If the distribution of damages reflect the range of host search and the species capacities to disperse (Kruess & Tscharntke, 1994), a plausible result in an analysis examining the importance of distance is that damages and abundances of *D. brassicae* would correlate negatively to distances. This was thus not expected to be unrelated in these analyses. In a study by Zaller et al. (2008a) where the importance of distances between current OSR- fields to damages by *D. brassicae* was examined, no statistically significant relations could be found either.

The results in this study can perhaps partly be explained by the locations of the sticky traps at the study fields. *D. brassicae* is a weak flyer, hence the dispersals of the pod midges from the overwintering site to the WOSR- fields may depend on wind direction (Moser et al., 2009; Williams & Cook, 2010; Sylvén, 1970; Zaller et al., 2008b). The sticky traps may therefore have to be selectively placed at the specific field edge that is closest to the previous years' WOSR-field in order to properly investigate this study question. Further, wind direction was not considered in this study.

The best explanation, however, to why distances and damages and abundances were unrelated between the study fields in these analyses, is probably that the distances were practically the same for all but one of the study fields, and they were all very short (*figure 31*). Distance has indeed been suggested to be of great importance and beneficial for damages by *D. brassicae* elsewhere (Jordbruksverket, 2016b; Moser et al., 2009; Nilsson, Vimarlund & Gustafsson, 2004; Stephansson & Åhman, 1998; Zaller et al., 2008a). Therefore, a general recommendation for the control of *D. brassicae* is to cultivate WOSR at safe distances between the current fields and the fields sown in the previous season (Stephansson & Åhman, 1998). The result in this study is thus possibly more a matter of measurement design, and an extensive cultivation of OSR- fields in this region, rather than an irrelevance of distances for damages or abundance of *D. brassicae*.

An alternative study design to target this topic could be to selectively choose study fields with markedly different distances to the closest WOSR- field from last year already in the initial planning of the study methodology. By doing so the question of distance is addressed explicitly. However a problem with this approach is that information from the IACS database regarding the previous year WOSR- fields, may not be accessible at the time of the early field work planning. Another issue, which is possibly more important, is that since WOSR have become a very commonly cultivated crop in Skåne this have resulted in shorter distances between OSR- cultivations from last year and the current year (Gunnarsson, 2017a, b). It may thus be difficult to find WOSR- fields at large distances, of e.g. 2km and more, in this region.

5 Summary

The sizes of the trap catches of *C. obstrictus* and *D. brassicae* varied greatly during the crop season, and there were clear trends in declining abundances of both organisms as the season proceeded. Two increases in abundance of *D. brassicae* was detected, these may be reflections of two generations during the season. No relations were found between abundances of the organisms, this was unexpected, however may be explained by the intense drought during the crop season of 2018 which may have contributed to overall lower abundances. Indeed, considerable lower abundances of *C. obstrictus* compared to a study in 2017 was shown. Significantly more males than females were caught in the sticky traps, which could be a reflection of differences in the flight activity between the sexes.

Within-field analyses of damages showed that damages within the pesticide free control zones were generally greater than outside of the zones, and that damages at field edges and further into the field in early- and late pod set were positively correlated within the zones. Furthermore, the regression analyses revealed that insecticides had an effect on damages in early pod set. This data is analysed on the presumptions that all the farmers used insecticide treatments aimed for *C. obstrictus* at least one time during the season and that they were equally careful to not apply chemicals within the PFCZ. However, the answers provided by the farmers in the questionnaires reveal differences in the timing of insecticide application, the number of applications and the specific insecticide used, and sometimes this information was never provided. Naturally this concern complicates any interpretations of effect of insecticides, nevertheless, the results clearly indicated that chemical treatment had some effect on damages by *D. brassicae* in this study.

Abundance of the study organisms had no effect on damages according to the regression models. An explanation to this could be that the sticky trap catches may have failed as an applicable parameter in this analysis if the number of individuals which are trapped on the yellow sticky traps fail to reflect abundances of individuals that are actually reaching the field at the particular sites where the traps are located. It may also be the case that the unusually low temperatures in February and March in 2018 resulted in significant mortalities of hibernating adults of both weevils and midges or that the results would have been different if it were not for the drought that obscured the inventories of damages. Another aspect to these results is the structure of the WOSR stand and spaces between rows of WOSR in the fields which is a factor that may contribute to the length of the period of infestation and therefore also affect any analyses of relationship between abundances of pests and damages.

The within-field analyses also showed that damages later in the crop season were more extensive at the field edges compared to further into the field and that there was a progression in damages from the field edge towards the field interior. These results indicate that damages at the field edges early in the crop season may be of economic importance later in the season and that the use of chemical treatments could be a legitimate option to prevent considerable damages.

No differences in abundances and damages by *D. brassicae* was found between different geographical locations within the study region. This result may be a question of study design as the methodology was not planned to explicitly target this question. A surprising result was the lack of significant relations between landscape complexity and the abundance of *C. obstrictus* and *D. brassicae* and damage by *D. brassicae*. However, these results may also be a matter of study design as the landscape within each of the buffer zones surrounding the study fields were to the most part characterized by agricultural land and therefore may not have varied enough to be able to answer this study question. It is also possible that the dry climatic conditions at the time of this study confounded the impacts of landscape factors on abundances and damages.

The proportional area of OSR- fields from 2017 had positive effects on damages within large, medium and small spatial scales. However these results were not consistent through early- and late pod set or among damages at the field edge and further within the fields, which could be due to the fact that WOSR has become an extensively cultivated crop in this region and hence there may have been too small variations for these analyses. The distance to the centre point of the nearest WOSR- field from last year to the centre point of the current study fields, was not significantly related to either damages or abundances of the study organisms. This result was not expected, but is possibly explained by the extensive cultivation of WOSR in this region and hence a lack of a variation of distances and larger distances between the fields in the current and previous year.

6 Conclusions

Here follows the main conclusions from this study.

Two increases of abundances of *D. brassicae* during indicates two generations. Males of pod midges were considerably more abundant than females. This may be a result of higher flight activity of males, but it may also be an indication that males follow virgin females to the rapeseed fields and that mating also can take place within the current fields.

Insecticide treatment seemed to have a measurable effect on damages caused by *D. brassicae* early in the WOSR- season. Why these results were not persistent throughout the entire season could be an artefact of the severe drought in 2018. The drought often masked the damages caused by pod midges, and hence, complicated the inventories of damages - especially later in the season.

Relationships between damages and the abundances of weevils and pod midges could not be reported, but several circumstances put a spanner in the works for these analyses. The wet autumn and winter of 2017 and the cold winter at the beginning of 2018 not only affected the amount of acres of WOSR sown and the growth of WOSR, but may also have increased mortalities of hibernating weevils and pod midges. Furthermore, the drought put significant traces in the rape, but this may also have affected abundances of the pests. An indication of this is the significantly lower total number of weevils caught in this study compared to the total catch in a similar study conducted the year before.

Positive correlations between the proportion of WOSR- fields from the previous year and damages was shown. These relations were however not consistent for damages during the early- and late part of the season or for damages at the field edge and at the inner parts of the field. One explanation could be that since WOSR is such a common crop in the region, the variations in the landscape are too insignificant to be able to better investigate the importance of the proportion of the previous year’s WOSR cultivations with the methods used. As a consequence of the dense cultivation of WOSR, the distances between the study fields and the nearest field from the previous year were very short and equal between the fields and could not be associated to abundances of pod midges or damages. A probable cause of this is not an irrelevance of distance to abundance or damages but a difficulty in studying the effect of distance in a landscape with a consistently dense cultivation of WOSR.

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8 References

Aiéro, M., Aldén, L., Andersson, G., Arvidsson, A., Berg, G., Bölenius, E., Dinwiddie, R., Djurberg, A., Eriksson, L., Gerdtsson, A., Holmblad, J., Johansson, C., Johansson, L., Lindgren, A., Mellqvist, E. & Norrlund, L. (2018). *Bekämpningsrekommendationer - Svampar och insekter 2018*. Jönköping: Jordbruksverket. [Brochure]. Available: https://webbutiken.jordbruksverket.se/sv/artiklar/be17.html [Accessed: 2018-10-15].

Alford, D.V. (2003). Chapter 1: The oilseed rape crop. In: David V. Alford (ed.). *Biocontrol of oilseed rape pests*. Oxford: Blackwell Science Ltd. pp. 1-8.

Alford, D.V., Nilsson, C. & Ulber, B. (2003). Insect pests of oilseed rape crops. In: David V. Alford (ed.), *Biocontrol of Oilseed Rape Insect Pests*. Oxford: Blackwell Science Ltd. pp. 9–41.

Axelsen, J. (1992a). The population dynamics and mortalities of the pod gall midge (*Dasyneura brassicae Winn.*) (Dipt. Cecidomyiidae) in winter rape and spring rape (Brassica napus L.) in Denmark. *Journal of Applied Entomology* 114(1-5): 463-471.

Axelsen, J. (1992b). The developmental time of the pod gall midge, *Dasyneura brassicae* Winn. (Dipt., Cecidomyiidae). *Journal of Applied Entomology* 114(1-5): 263-267.

Bañuelos, G. S., Dhillon, K. S. & Banga, S. S. (2013). Oilseed Brassicas. In: Biofuel crops: *Production, physiology and genetics*, pp. 339-368.

Berg, G. (2012) *Vässa växtskyddet för framtidens klimat*. Jönköping: Jordbruksverket (Rapport, 2012:10).

Bianchi, F. J., Booij, C. J. H. & Tscharntke, T. (2006). Sustainable pest regulation in agricultural landscapes: a review on landscape composition, biodiversity and natural pest control. *Proceedings of the Royal Society of London B: Biological Sciences* 273(1595): 1715-1727.

Bouchereau A., Clossais-Besnard N., Bensaoud A., Leport L. & Renard M. Water stress effects on rapeseed quality. *European Journal of Agronomy* 1996(5):19–30.

Cárcamo, H. A., Herle, C. E., Otani, J. & McGinn, S. M. (2009). Cold hardiness and overwintering survival of the cabbage seedpod weevil, *Ceutorhynchus obstrictus*. *Entomologia Experimentalis et Applicata* 133(3): 223-231.

Carré, P. & Pouzet, A. (2014). Rapeseed market, worldwide and in Europe. OCL 21(1): D102.

Champolivier, L. & Merrien, A. (1996). Effects of water stress applied at different growth stages to Brassica napus L. var. oleifera on yield, yield components and seed quality. *European Journal of Agronomy* 5(3-4): 153-160.

Chaplin-Kramer, R., O'Rourke, M. E., Blitzer, E. J. & Kremen, C. (2011). A meta-analysis of crop pest and natural enemy response to landscape complexity. *Ecology letters* 14(9): 922-932.

Chen, M., & Shelton, A. M. (2007). Impact of soil type, moisture, and depth on swede midge (Diptera: Cecidomyiidae) pupation and emergence. *Environmental Entomology* 36(6): 1349-1355.

Čuljak, T. G., Pernar, R., Juran, I., Ančić, M. & Bažok, R. (2016). Impact of oilseed rape crop management systems on the spatial distribution of *Brassicogethes aeneus* (Fabricius 1775): implications for integrated pest management. *Crop protection* 89: 129-138.

Depotter, J. R., Deketelaere, S., Inderbitzin, P., Tiedemann, A. V., Höfte, M., Subbarao, K. V., Wood, T. A. & Thomma, B. P. (2016). Verticillium longisporum, the invisible threat to oilseed rape and other brassicaceous plant hosts. *Molecular plant pathology* 17(7): 1004-1016.

Dosdall, L. & Moisey, D. (2004). Developmental biology of the cabbage seedpod weevil, Ceutorhynchus obstrictus (Coleoptera : Curculionidae), in spring canola, Brassica napus, in western Canada. *Annals Of The Entomological Society Of America 97*(3): 458-465.

Dosdall, L. M. & Mason, P. G. (2010). Key pests and parasitoids of oilseed rape or canola in North America and the importance of parasitoids in integrated management. In: Williams, I. (ed.). *Biocontrol-based integrated management of oilseed rape pests*. Dordrecht: Springer, 167-213.

Dosdall, L. M., Ulmer, B. J., Gibson, G. A. P. & Cárcamo, H. A. (2006). The spatio-temporal distribution dynamics of the cabbage seedpod weevil, *Ceutorhynchus obstrictus* (Coleoptera: Curculionidae), and its larval parasitoids in canola in western Canada. *Biocontrol Science and Technology* 16(10): 987-1006.

Dosdall, L. M., Weiss, R. M., Olfert, O., & Cárcamo, H. A. (2002). Temporal and geographical distribution patterns of cabbage seedpod weevil (Coleoptera: Curculionidae) in canola. *The Canadian Entomologist* 134(3): 403-418.

Ekbom, B. (2010). Pests and their enemies in spring oilseed rape in Europe and challenges to integrated pest management. In: William, I. H. *Biocontrol-based integrated management of oilseed rape pests*. Dordrecht: Springer, pp. 151-165.

Ferguson, A. W., Campbell, J. M., Warner, D. J., Watts, N. P., Schmidt, J. E. & Williams, I. H. (2004). Phenology and spatial distributions of *Dasineura brassicae* and its parasitoids in a crop of winter oilseed rape: Implications for integrated pest management. *IOBC/wprs Bull* 27(10): 243-252.

Ferguson, A. W., Klukowski, Z., Walczak, B., Clark, S. J., Mugglestone, M. A., Perry, J. N. & Williams, I. H. (2003). Spatial distribution of pest insects in oilseed rape: implications for integrated pest management. *Agriculture, ecosystems & environment* 95(2-3): 509-521.

Ferguson, A. W., Klukowski, Z., Walczak, B., Perry, J. N., Mugglestone, M. A., Clark, S. J. & Williams, I. H. (2000). The spatio-temporal distribution of adult Ceutorhynchus assimilis in a crop of winter oilseed rape in relation to the distribution of their larvae and that of the parasitoid *Trichomalus perfectus*. *Entomologia Experimentalis et Applicata* 95(2): 161-171.

Ferguson, A.W., Ziesmann, J., Blight, M.M., Williams, I.H., Wadhams, L.J., Clark, S.J., Woodcock, C.M. & Mudd, A. (1999). Perception of oviposition-deterring pheromone by cabbage seed weevil (*Ceutorhynchus assimilis*). *Journal of Chemical Ecology* 25(7): 1655-1670.

Ghasemi, A. & Zahediasl, S. (2012). Normality tests for statistical analysis: a guide for non-statisticians. *International journal of endocrinology and metabolism* 10(2): 486.

Graora, D., Sivčev, I., Sivčev, L., Bьchs, W., Tomić, V., Dudić, B. & Gotlin-Čuljak, T. (2015). Biology and harmfulness of Brassica pod midge (*Dasineura brassicae Winn.*) in winter oilseed rape. *Pesticidi i fitomedicina* 30(2): 85-90.

Gunnarsson, A. (2016a) *Blygrå vivel krattar manegen åt skidgallmyggan*. Klågerup: Svensk frötidning. [Brochure]. Available: http://www.svenskraps.se/kunskap/pdf/01903.pdf [2018-10-12].

Gunnarsson, A. (2016b). *Torka och insekter plundrade höstrapsen 2016*. Klågerup: Svensk frötidning. [Brochure]. Available: http://www.svenskraps.se/kunskap/pdf/01891.pdf [2018-12-03].

Gunnarsson, A. (2016c). *Nya trösklar för blygrå rapsvivel och skidgallmygga 2016*. Klågerup: Svensk frötidning. [Brochure]. Available: http://www.svenskraps.se/kunskap/pdf/01864.pdf [2019-01-11].

Gunnarsson, A. (2016d). *Bekämpning av blågrå rapsvivlar och skidgallmyggor*. [Brochure]. Available: https://www.svenskraps.se/kunskap/pdf/01927_2016_hostraps-blygra-rapsvivlar-skidgallmygga_rapport.pdf [2019-01-11].

Gunnarsson, A. (2017a). *Bekämpning av blygrå rapsvivel i höstraps*. Report/Hushållningssällskapet. Skara: Hushållningssällskapet.

Gunnarson, A. (2017b). *Steklar håller skidgallmyggan i schack*. Klågerup: Svensk Frötidning. [Broschure]. Available: http://www.svenskraps.se/kunskap/pdf/01917.pdf [2019-01-31].

Gunnarsson, A. (2017c). *Stora variationer i höstraps 2017*. Klågerup: Svensk Frötidning. [Broschure]. Available: https://www.svenskraps.se/kunskap/pdf/01982.pdf [2019-01-31]

Hatzig, S. V., Nuppenau J-N., Snowdon, R. J. & Schieß, S. V. (2018). Drought stress has transgenerational effects on seeds and seedlings in winter oilseed rape (*Brassica napus* L.). *BMC Plant Biology* 297: 1-13.

Hausammann, A. (1996). Strip-management in rape crop: is winter rape endangered by negative impacts of sown weed strips? *Journal of applied entomology* 120(1-5): 505-512.

Haye, T., Mason, P. G., Dosdall, L. M. & Kuhlmann, U. (2010). Mortality factors affecting the cabbage seedpod weevil, *Ceutorhynchus obstrictus* (Marsham), in its area of origin: A life table analysis. *Biological Control* 54(3): 331-341.

Hokkanen, H. M. (2000). The making of a pest: recruitment of *Meligethes aeneus* onto oilseed Brassicas. *Entomologia experimentalis et applicata* 95(2): 141-149.

Holmblad, J., Gerdtsson, A., Bölenius, E., Berg, G., Söderlind, C. & Benediktsson, A. (2017) *Växtskyddsåret 2017 Halland Skåne och Blekinge län*. Jordbruksinformation 5-2017. Tillgänglig: https://webbutiken.jordbruksverket.se/sv/artiklar/jo175.html [Accessed 2018-12-06].

Hughes, J. M. & Evans, K. A. (2003). Lygid bug damage as a pod access mechanism for Dasineura brassicae (Dipt., Cecidomyiidae) oviposition. *Journal of applied entomology* 127(2): 116-118.

Isidoro, N., Williams, I. H., Solinas, M. & Martin, A. (1993). Mating behaviour and identification of the female sex pheromone gland in the brassica pod midge (*Dasineura brassicae* Winn.: Cecidomyiidae, Diptera). *Bollettino dell'Istituto di Entomologia Guido Grandi'della Università degli Studi di Bologna* (47): 27-48.

Jonsson, M., Straub, C. S., Didham, R. K., Buckley, H. L., Case, B. S., Hale, R. J., Gratton, C. & Wratten, S. D. (2015). Experimental evidence that the effectiveness of conservation biological control depends on landscape complexity. *Journal of Applied Ecology* 52(5): 1274-1282.

Jordbruksverket. (2014). *Växtskyddsåret 2014, Hallands, Skånes och Blekinge län*. Jönköping: Jordbruksverket. [Brochure] Available: https://webbutiken.jordbruksverket.se/sv/artiklar/jo1415.html [Accessed 2018-11-12].

Jordbruksverket. (2015). *Växtskyddsåret 2015, Hallands, Skånes och Blekinge län*. Jönköping: Jordbruksverket. [Brochure] Available: https://webbutiken.jordbruksverket.se/sv/artiklar/jo1520.html [2018-11-12].

Jordbruksverket. (2016a). *Höstraps - skidgallmygga och kålmal*. Alnarp: Jordbruksverket. [Brochure]. Available: http://www.anpdm.com/newsletter/3721955/44425D447843435A4A71 [Accessed 2018-10-16].

Jordbruksverket. (2016b). *Var restriktiv med insektsbekämpning i blommande höstraps*. Alnarp: Jordbruksverket. [Brochure]. Available: http://www.anpdm.com/newsletter/3618061/44425D447843435A4A71 [Accessed 2018-10-16].

Jordbruksverket. (2016c). *Växtskyddsåret 2016, Hallands, Skånes och Blekinge län*. Jönköping: Jordbruksverket. [Brochure] Available: http://webbutiken.jordbruksverket.se/sv/artiklar/jo1620.html [Accessed 2018-11-12].

Jordbruksverket. (2017a). *Växtskyddsåret 2017, Hallands, Skånes och Blekinge län*. Jönköping: Jordbruksverket. [Brochure] Available: https://webbutiken.jordbruksverket.se/sv/artiklar/jo175.html [Accessed 2018-11-12].

Jordbruksverket. (2017b). *Höstsådda arealer 2017*. Available: https://www.jordbruksverket.se/webdav/files/SJV/Amnesomraden/Statistik,%20fakta/Areaaler/JO18/JO18SM1701/JO18SM1701.pdf [Accessed 2019-01-20].

Jordbruksverket. (2018). *Skörd av spannmål, trindsäd och oljeväxter 2018*. Available: http://www.jordbruksverket.se/webdav/files/SJV/Amnesomraden/Statistik,%20fakta/Vegetabilieproduktion/JO19/JO19SM1801/JO19SM1801_ikortadrag.htm [Accessed 2018-12-11].

Kania, J., Mączyńska, A., Głazek, M., Krawczyk, T. & Gillner, D. M. (2018). The influence of chosen fungicides on the activity of aminopeptidases in winter oilseed rape during pods development. *Pesticide biochemistry and physiology* 148: 166-174.

Korotyaev, B. A. (2008). Geographical distribution of the weevil subfamily Ceutorhynchinae (Coleoptera , Curculionidae). *Entomological Review* 88(8): 928- 947.

Kovács, G., Kaasik, R., Metspalu, L., Williams, I. H., Luik, A. & Veromann, E. (2013). Could Brassica rapa, Brassica juncea and Sinapis alba facilitate the control of the cabbage seed weevil in oilseed rape crops? *Biological control* 65(1): 124-129.

Kruess, A. & Tscharntke, T. (1994). Habitat fragmentation, species loss, and biological control. *Science* 264(5165): 1581-1584.

Laffin, R. D., Dosdall, L. M. & Sperling, F. A. H. (2005). Population structure of the cabbage seedpod weevil, Ceutorhynchus obstrictus (Marsham)(Coleoptera Curculionidae): origins of North American introductions. *Environmental entomology* 34(2): 504-510.

Lanchashire, P. D., Bleiholder, H., Boom, T. V. D., Langelüddeke, P., Stauss, R., Weber, E. & Witzenberger, A. (1991). A uniform decimal code for growth stages of crops and weeds. *Annals of applied Biology* 119(3): 561-601.

Mazzi, D. & Dorn, S. (2012). Movement of insect pests in agricultural landscapes. *Annals of Applied Biology* 160(2): 97-113.

Molnár, B. P., Boddum, T., Hill, S. R., Hansson, B. S., Hillbur, Y. & Birgersson, G. (2018). Ecological and phylogenetic relationships shape the peripheral olfactory systems of highly specialized gall midges (Cecidomiiydae). *Frontiers in physiology* 9: 323.

Moser, D., Drapela, T., Zaller, J. G. & Frank, T. (2009). Interacting effects of wind direction and resource distribution on insect pest densities. *Basic and applied ecology* 10(3): 208-215.

Murchie, A. K. & Hume, K. D. (2003). Evidence for monogeny in the brassica pod midge *Dasineura brassicae*. *Entomologia experimentalis et applicata* 107(3): 237-241.

Murchie, A. K., Burn, D. J., Kirk, W. D. J. & Williams, I. H. (2001). A novel mechanism for time-sorting insect catches, and its use to derive the diel flight periodicity of brassica pod midge *Dasineura brassicae* (Diptera: Cecidomyiidae). *Bulletin of entomological research* 91(3): 199-203.

Murchie, A. K., Smart, L. E. & Williams, I. H. (1997). Responses of *Dasineura brassicae* and its parasitoids Platygaster subuliformis and Omphale clypealis to field traps baited with organic isothiocyanates. *Journal of Chemical Ecology 23*(4): 917-926.

Murchie, A. K., Williams, I. H. & Perry, J. N. (1999). Edge distributions of Ceutorhynchus assimilis and its parasitoid Trichomalus perfectus in a crop of winter oilseed rape (*Brassica napus*). *Biocontrol* 44(4): 379-390.

Naturvårdsverket. (2014). *Svenska marktäckedata*. Report/Naturvårdsverket: 1.2. Stockholm: Naturvårdsverket.

Nilsson, C. (2009). *Ligg lågt med myggan*. Klågerup: Svensk Frötidning, nr 2. [Broschure]. Accessible: http://www.svenskraps.se/kunskap/pdf/01030.pdf [2019-01-01].

Nilsson, C., Buechs, W., Klukowski, Z., Luik, A., Ulber, B. & Williams, I. H. (2015). Integrated crop and pest management of winter oilseed rape (*Brassica napus* L.). *Zemdirbyste-Agriculture* 102(3): 325-334.

Nilsson, U. & Ullvén, K. (2014). Gynna nyttiga insekter med blommande växter. Alnarp: Sveriges lantbruksuniversitet. [Broschure]. Accessible: https://pub.epsilon.slu.se/11947/7/nilsson_u_ulven_k_150227.pdf [2019-01-12].

Nilsson, C., Vimarlund, L. & Gustafsson, G. (2004). Long term survival of Brassica Pod Midge (*Dasineura brassicae*) populations. *IOBC/WPRS* 27(10): 297-302.

O'Rourke, M. E., Rienzo-Stack, K. & Power, A. G. (2011). A multi-scale, landscape approach to predicting insect populations in agroecosystems. *Ecological Applications* 21(5): 1782-1791.

Pavela R., Kazda J., Herda G. (2007). Influence of application term on effectiveness of some insecticides against brassica pod midge (*Dasineura brassicae Winn.*). *Plant Protection Science* 43: 57–62.

Pavela, R., Kazda, J. & Herda, G. (2009). Effectiveness of Neem (*Azadirachta indica*) insecticides against Brassica pod midge (*Dasineura brassicae* Winn.). *Journal of Pest Science* 82(3): 235-240.

Perović, D. J., Gurr, G. M., Raman, A. & Nicol, H. I. (2010). Effect of landscape composition and arrangement on biological control agents in a simplified agricultural system: a cost–distance approach. *Biological Control* 52(3): 263-270.

R Core Team. (2018). R: A language and environment for statistical computing. R foundation for Statistical Computing. Vienna, Australia.

Ricci, B., Franck, P., Toubon, J. F., Bouvier, J. C., Sauphanor, B. & Lavigne, C. (2009). The influence of landscape on insect pest dynamics: a case study in southeastern France. *Landscape Ecology* 24: 337–349.

Robinson, C. & Schumacker, R. E. (2009). Interaction effects: centering, variance inflation factor, and interpretation issues. *Multiple Linear Regression Viewpoints* 35(1): 6-11.

Rösvik, A. (2017). Landscape and within-field factors affecting the damages of the brassica pod midge (*Dasineura brassicae*) in Swedish winter oilseed rape cultivation. *Unpublished*. Alnarp: Sveriges lantbruksuniversitet.

SCB. (2017). *Jordbruksstatistisk sammanställning 2017*. Örebro: SCB. [Brochure] Available: http://www.scb.se/publikation/31475 [2018-11-26].

SCB. (2016). *Jordbruksstatistisk sammanställning 2016*. Örebro: SCB. [Brochure]. Available: https://webbutiken.jordbruksverket.se/sv/artiklar/jordbruksstatistisk-sammanstallning-2016-med-data-om-livsmedel-tabeller.html [2018-11-26].

SCB. (2018). *Jordbruksstatistsk sammanställning 2018*. Örebro: SCB. [Brochure]. Available: https://webbutiken.jordbruksverket.se/sv/artiklar/js2018-2.html [Accessed 2018-07-28].

Sivčev, I. L., Sivčev, L. I., Pešić, S., Graora, D., Tomić, V. & Dudić, B. (2015). Weevils of the genus Ceutorhynchus Germ associated with oilseed rape in northern Serbia. *Pesticidi i fitomedicina* 30(3): 155-159.

Smart, L. E., Blight, M. M. & Hick, A. J. (1997). Effect of visual cues and a mixture of isothiocyanates on trap capture of cabbage seed weevil, Ceutorhynchus assimilis. *Journal of Chemical Ecology* 23(4): 889-902.

SMHI. (2016a). *Skånes klimat*. Available: https://www.smhi.se/kunskapsbanken/meteorologi/skanes-klimat-1.4827 [Accessed 2018-11-27].

SMHI. (2017a). *Oktober 2017 - Blött med nya nederbördsrekord*. Available: https://www.smhi.se/klimat/klimatet-da-och-nu/manadens-vader-och-vatten-sverige/manadens-vader-i-sverige/oktober-2017-meteorologi-1.125743?l=null [Accessed 2019-02-20].

SMHI. (2017b). *September 2017 - Nytt svenskt lufttrycksrekord för månaden och extremt solfattigt*. Available: https://www.smhi.se/klimat/klimatet-da-och-nu/manadens-vader-och-vatten-sverige/manadens-vader-i-sverige/september-2017-meteorologi-1.124774?l=null [Accessed 2019-02-20].

SMHI. (2018a). *Sommaren 2018 - Extremt varm och solig*. Available: https://www.smhi.se/klimat/klimatet-da-och-nu/arets-vader/sommaren-2018-extremt-varm-och-solig-1.138134 [Accessed 2018-12-11].

SMHI. (2018b). *Maj 2018 - Sommarväder med rekordvärme*. Available: https://www.smhi.se/klimat/klimatet-da-och-nu/manadens-vader-och-vatten-sverige/manadens-vader-i-sverige/maj-2018-sommarvader-med-rekordvarme-1.134781 [Accessed 2018-12-11].

SMHI. (2018c). *April 2018 - Årets första vårmånad*. Available: https://www.smhi.se/klimat/klimatet-da-och-nu/manadens-vader-och-vatten-sverige/manadens-vader-i-sverige/april-2018-arets-forsta-varmanad-1.133032 [Accessed 2019-01-10].

SMHI. (2018d). *Vintern 2018 - Mycket snörik i norr*. Available: https://www.smhi.se/klimat/klimatet-da-och-nu/arets-vader/vintern-2018-mycket-snorik-i-norr-1.130588 [Accessed 2019-01-10].

SMHI. (2018e). *Mars 2018 - Kallt i hela Sverige*. Available: https://www.smhi.se/klimat/klimatet-da-och-nu/manadens-vader-och-vatten-sverige/manadens-vader-i-sverige/mars-2018-kallt-i-hela-sverige-1.131750 [Accessed 2019-01-10].

Steffan-Dewenter, I. & Tscharntke, T. (2000). Butterfly community structure in fragmented habitats. *Ecology Letters* 3(5): 449-456.

Stephansson, D., Åhman, I. (1998). *Blygrå rapsvivel och skidgallmygga*. Uppsala: Jordbruksverket. [Brochure]. Available: https://www.slu.se/globalassets/ew/org/inst/ekol/faktablad/faktablad-vaxtskydd/faktablad_om_vaxtskydd_57j.pdf [Accessed 2018-10-13].

Sylvén, E. (1970). Field movement of radioactively labelled adults of *Dasyneura brassicae* Winn. (Dipt., Cecidomyiidae). *Insect Systematics & Evolution* 1(3): 161-187.

Takashima, N. E., Rondanini, D. P., Puhl, L. E. & Miralles, D. J. (2013). Environmental factors affecting yield variability in spring and winter rapeseed genotypes cultivated in the southeastern Argentine Pampas. *European Journal of Agronomy* 48: 88-100.

Tamburini, G., De Simone, S., Sigura, M., Boscutti, F. & Marini, L. (2016). Conservation tillage mitigates the negative effect of landscape simplification on biological control. *Journal of Applied Ecology* 53(1): 233-241.

Tansey, J. A., Dosdall, L. M., Keddie, A. & Olfert, O. (2010). Flight activity and dispersal of the cabbage seedpod weevil (Coleoptera: Curculionidae) are related to atmospheric conditions. *Environmental entomology* 39(4): 1092-1100.

Tansey, J. A., Dosdall, L. M., Keddie, A., Fletcher, R. S. & Kott, L. S. (2010b). Responses of *Ceutorhynchus obstrictus* (Marsham) (Coleoptera: Curculionidae) to olfactory cues associated with novel genotypes developed by *Sinapis alba* L.× *Brassica napus* L. *Arthropod-Plant Interactions* 4(2): 95-106.

Tansey, J. A., Dosdall, L. M., Keddie, B. A. & Noble, S. D. (2010a). Contributions of visual cues to cabbage seedpod weevil, *Ceutorhynchus obstrictus* (Marsham) (Coleoptera: Curculionidae), resistance in novel host genotypes. *Crop protection* 29(5): 476-481.

Thies, C., Haenke, S., Scherber, C., Bengtsson, J., Bommarco, R., Clement, L.W., Ceryngier, P., Dennis, C., Emmerson, M., Gagic, V. & Hawro, V. (2011). The relationship between agricultural intensification and biological control: experimental tests across Europe. *Ecological Applications* 21(6): 2187-2196.

Thies, C., Steffan-Dewenter, I. & Tscharntke, T. (2003). Effects of landscape context on herbivory and parasitism at different spatial scales. *Oikos* 101(1): 18-25.

Tscharntke, T., Steffan-Dewenter, I., Kruess, A. & Thies, C. (2002). Characteristics of insect populations on habitat fragments: a mini review. *Ecological research* 17(2): 229-239.

Ulber, B., Klukowski, Z. & Williams, I. H. (2010). Impact of insecticides on parasitoids of oilseed rape pests. In: William, I. H. *Biocontrol-based integrated management of oilseed rape pests*. Dordrecht: Springer, pp. 337-355.

Ulmer, B. & Dosdall, L. (2006). Spring emergence biology of the cabbage seedpod weevil (Coleoptera: Curculionidae). *Annals of the Entomological Society of America* 99(1): 64-69.

Unal, H., Sincik, M. & Izli, N. (2009). Comparison of some engineering properties of rapeseed cultivars. *Industrial Crops and Products* 30(1): 131-136.

Vaitelyte, B., Petraitiene, E., Smatas, R., & Brazauskiene, I. (2011). Control of *Meligethes aeneus*, *Ceutorhynchus assimilis* and *Dasineura brassicae* in winter oilseed rape (*Brassica napus* L.). *Zemdirbyste-Agriculture* 98(2): 175-182.

Warner, D. J., Allen-Williams, L. J., Ferguson, A. W. & Williams, I. H. (2000). Pest–predator spatial relationships in winter rape: implications for integrated crop management. *Pest management science* 56(11): 977-982.

Veres, A., Petit, S., Conord, C. & Lavigne, C. (2013). Does landscape composition affect pest abundance and their control by natural enemies? A review. *Agriculture, Ecosystems & Environment* 166: 110-117.

Veromann, E., Luik, E., Metspalu, L. & Williams, I. (2006). Key pests and their parasitoids on spring and winter oilseed rape in Estonia. *Entomologica Fennica* 17(4): 400-404.

Weisberg, S. (2005). *Applied linear regression* (Vol. 528). New Jersey: John Wiley & Sons.

Wickham, H. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York, 2016.

Williams, I. H. & Cook, S. M. (2010). Crop location by oilseed rape pests and host location by their parasitoids. In I. Williams (ed.) *Biocontrol-based integrated management of oilseed rape pests*. Dordrecht, Netherlands: Springer, 215-244.

Williams, I. H. & Ferguson, A. W. (2010). Spatio-Temporal Distributions of Pests and Their Parasitoids on the Oilseed Rape Crop. In: Williams, I. H. (Ed.). *Biocontrol-based integrated management of oilseed rape pests*. Dordrecht: Springer, pp 245-273.

Williams, I. H. (2010). The major insect pests of oilseed rape in Europe and their management: an overview. In I. Williams (ed.) *Biocontrol-Based Integrated Management of Oilseed Rape Pests*. Dordrecht, Netherlands: Springer, 1-43.

With, K. A., Pavuk, D. M., Worchuck, J. L., Oates, R. K. & Fisher, J. L. (2002). Threshold effects of landscape structure on biological control in agroecosystems. *Ecological Applications* 12(1): 52-65.

Zajac, T., Klimek-Kopyra, A., Oleksy, A., Lorenc-Kozik, A. & Ratajczak, K. (2016). Analysis of yield and plant traits of oilseed rape (*Brassica napus* L.) cultivated in temperate region in light of the possibilities of sowing in arid areas. *Acta Agrobotanica* 69(4): 2-13.

Zaller, J. G., Moser, D., Drapela, T., Schmöger, C. & Frank, T. (2008a). Effect of within-field and landscape factors on insect damage in winter oilseed rape. *Agriculture, ecosystems & environment* 123(1-3): 233-238.

Zaller, J. G., Moser, D., Drapela, T., Schmöger, C. & Frank, T. (2008b). Insect pests in winter oilseed rape affected by field and landscape characteristics. *Basic and applied ecology* 9(6): 682-690.

Åhman, I. (1985). Oviposition behaviour of *Dasineura brassicae* on a high-versus a low-quality Brassica host. *Entomologia experimentalis et applicata* 39(3): 247-253.

Åhman, I. (1987). Oviposition site characteristics of Dasineura brassicae Winn. (Dipt., Cecidomyiidae). *Journal of Applied Entomology* 104(1-5): 85-91.

Åhman, I. (1988). Wild and cultivated crucifers as hosts for Dasineura brassicae Winn.(Dipt., Cecidomyiidae). *Journal of Applied Entomology* 105(1-5): 420-424.

Östrand, F. (2011). Jämförelse av gulskål och frihåvning för att fånga blombesökande insekter: vilka faktorer kan påverka fångsten i gulskålar? *Entomologisk tidskrift* 132(3): 141-152.

Appendix 1.

Questionnaire to the WOSR farmers.

Frågeformulär

Information

Ditt namn, eller gårdens namn: ______________________ Datum: ____________

Frågor

Fråga 1: Hur gick du tillväga för att kolla efter blygrå rapsvivel i rapsen i början av rapssäsongen?

Svar:

Fråga 2: Hur upplevde du mängden blygrå rapsvivel i år jämfört med tidigare år?

Svar:

Fråga 3: Vad avgjorde för dig när, och om, det var dags för besprutning? Låg din bedömning utefter några allmänna rekommendationer kring besprutning (i så fall, vilka rekommendationer?) eller gjorde du en annan bedömning av skaderisken på rapsen?

Svar:

Fråga 4: När (Ungefärligt datum/tidpunkt), och hur många gånger besprutade du rapsfältet i år och med vilket/vilka besprutningsmedel?

Svar:

Fråga 5: Vilken är din uppfattning kring mängden blygrå rapsvivel i rapsen i år jämfört med tidigare år?

Svar:

Fråga 6: Vilken är din uppfattning kring mängden skador på rapsen orsakade av blygrå rapsvivel och skidgallmygga i år jämfört tidigare år?

Svar:

Fråga 7: När skördades rapsen i år? Skedde det ungefär vid samma tidpunkt som tidigare år eller avvek tidpunkten från tidigare år?

Svar:

Fråga 8: Blev längden på rapssäsongen i år lika lång som tidigare år, eller kortare/längre?

Svar:

Fråga 9: Som bekant var sommaren 2018 osedvanligt varm och hade en väldigt låg nederbördsmängd som resulterade i svår torka på många håll, märkte du av detta i rapsen? På vilket sätt i så fall?

Svar:

Fråga 10: Övrig kommentar kring rapssäsongen och rapsskörden i år:

Stort tack för din medverkan!

Table, appendix 1. The table contain information derived from the questionnaire to the farmers. Field area, chemical treatment, number of treatments, type of insecticide used and treatment time is included. Empty cells indicate that no information was acquired from the farmer.

Study field (numbered)	Field area (ha)	Chemical treatment	Number of treatments	Type of insecticide	Treatment time
1	30.1				
2	67.3				
3	12.8	Yes	1	Biscaya	2018-05-05
4	35.1	Yes	1		
5	3.4	Yes	1	Biscaya	2018-05-15
6	6.0				
7	50.5	Yes	1		In full bloom
8	54.3	Yes	1	Cantus & Fastac	In full bloom
9	61.2				
10	14.1	Yes	2	Biscaya	2018-05-17, 2018-05-24
11	7.4	No	0		
12	10.5	Yes	1	Biscaya	2018-05-15
13	41.7	Yes	1	Biscaya	2018-05-19
14	45.9	Yes	1	Biscaya	2018-05-20
15	27.7				
16	9.7	Yes	1		2018-05-20
17	18.1	Yes	3	Bor 150, Mangan 235, Nova Balance, Propulse SE250, Biscaya, Mavrik & Cantus	2018-05-04, 2018-05-14, 2018-05-24
18	11.7	Yes	3	Bor 150, Mangan 235, Nova Balance, Propulse SE250, Biscaya, Mavrik & Cantus	2018-05-04, 2018-05-14, 2018-05-24