Europ. J. Agronomy 60 (2014) 33–40

Contents lists available at ScienceDirect

European Journal of Agronomy

journal homepage: www.elsevier.com/locate/eja

Emergence and performance of volunteer oilseed rape (*Brassica napus*) in different crops

Ernst Albrecht Weber*, Sabine Gruber, Wilhelm Claupein

University of Hohenheim, Institute of Crop Science, Fruwirthstr. 23, 70599 Stuttgart, Germany

ARTICLE INFO

Article history:
Received 10 January 2014
Received in revised form 27 June 2014
Accepted 31 July 2014

Keywords:
Oilseed rape
Dormancy
Volunteers
Gene dispersal
Soil seed bank
Crop rotation

ABSTRACT

Volunteer oilseed rape (OSR, *Brassica napus* L.) causes various agronomic problems in crop rotations and can contribute to gene dispersal by pollen and by seed admixture. A 4-year field experiment (2008–2011) was set up in south-west Germany to investigate the performance of volunteers derived from two OSR cultivars with different levels of seed dormancy. Volunteers of a high-dormancy (HD) and a low-dormancy (LD) OSR cultivar were deliberately generated by spreading 10,000 seeds m^{-2} on a field in August 2008 and 2009. Four different crops were grown on that area in the first year following the seed rain: winter wheat (*Triticum aestivum* L.), winter turnip rape (*Brassica rapa* L.), spring barley (*Hordeum vulgare* L.) and field pea (*Pisum sativum* L.). In the second year, maize (*Zea mays* L.) was sown uniformly across all plots. Numbers of OSR seedlings emerging in early autumn shortly after seed rain were not connected with the size of the soil seed bank in early spring of the following year. The seeds of the HD-cultivar formed a much greater soil seed bank (up to 14% of the initially spread seed number) compared with the LD-cultivar (up to 1.3%) in the soil layer of 0 to 30 cm in early spring 2009 and 2010). Across all crops, considerably more volunteers of the HD-cultivar than of the LD-cultivar were present at several survey dates in the first year following seed rain. The highest number of volunteers originated from the HD-cultivar with up to 11 volunteers m^{-2} in winter turnip rape compared with a maximum of 0.48 plants m^{-2} in the other crops. Cultivar-specific differences in volunteer density were observed as well in maize two years after OSR seed rain. Flowering and seed setting volunteers were only present in 2010 and the flowering time was crucially overlapping with that of sown winter OSR. The reproductive ability (seeds produced m^{-2}) of the LD-volunteers was five times lower in winter turnip rape than of the HD-volunteer; a similar trend was observed for the OSR volunteers in the other host crops.

Strategies to definitely reduce unwanted effects of OSR volunteers, such as gene flow, should include the use of LD-cultivars with a low potential to form a soil seed bank, particularly if selective herbicides are not available, for instance in broad-leaved crops, or if the volunteers are herbicide-tolerant.

1. Introduction

Today's modern oilseed rape (*Brassica napus* L.; OSR) cultivars still exhibit some wild plant characteristics such as low shatter resistance of the mature pods and the ability of the seeds to acquire secondary dormancy under unfavourable germination conditions (Pekrun et al., 1997a). Seeds that get lost right before or during harvest can enter the soil seed bank, persist in the soil for up to 10 or more years (Lutman et al., 2003) and emerge as volunteers in following crops.

Volunteer OSR can cause various agronomic problems in a crop rotation: they reduce yields due to competition with the sown crop (Krato and Petersen, 2012); they act as a link for pests and diseases (Hwang et al., 2012); they reduce frost tolerance of a sown OSR crop due to increased crop density before winter and they can spoil the quality of sown OSR by seed admixture (Baux et al., 2011). Moreover, long-term seed persistence and the occurrence of volunteer OSR within a crop rotation is a serious issue of concern in the debate about genetically modified (GM) OSR, as volunteers can contribute to gene dispersal by pollen flow or by seed admixture (Hüsken and Dietz-Pfeilstetter, 2007; Messéan et al., 2007). A density of only 0.6 GM volunteers m^{-2} can result in seed admixture in conventional seed lots that exceeds the European labelling threshold for GM batches of 0.9% (Gruber and Claupein, 2007). Thus, there is virtually a very narrow range of tolerance for GM OSR volunteers. New concern about OSR volunteers arose in Europe in the

* Corresponding author. Tel.: +49 711-45922374; fax: +49 711 45922297.
E-mail addresses: Ernst.Albrecht.Weber@uni-hohenheim.de (E.A. Weber), Sabine.Gruber@uni-hohenheim.de (S. Gruber), Wilhelm.Claupein@uni-hohenheim.de (W. Claupein).

http://dx.doi.org/10.1016/j.eja.2014.07.004
1161-0301/

context of the introduction of imidazolinone tolerant oilseed rape because of the volunteers' expected tolerance to this specific group of herbicides.

An on-farm research conducted on 23 farmers' fields in southwest Germany in 2008 revealed a mean seed loss of 4700 seeds m^{-2} at OSR harvest, which is about one hundredfold of the seed density of sown OSR (Weber et al., 2009). Other studies from the United States and Europe reported comparable harvest losses of approximately 4000–7000 seeds m^{-2} (Thomas et al., 1991; Brown et al., 1995; Pekrun et al., 1998; Gruber et al., 2007). While a considerable number of OSR seeds already germinates before or shortly after first post-harvest tillage, a certain percentage of the seeds is buried in the soil by tillage and enters the soil seed bank. According to studies of Gruber et al. (2010) up to 17% of OSR seeds of the initial seed rain can be found in the soil seed bank one year after seed rain, and up to 1.6% of the seed rain can still exist four years after OSR harvesting, depending on OSR cultivar and the mode of soil tillage.

There is clear evidence that the potential to develop secondary dormancy is affected by the OSR genotype (Gruber et al., 2008, 2012; Schatzki et al., 2013). Four QTL could be identified, which together explained 35% of the phenotypic dormancy (Schatzki et al., 2013). Other studies showed that the genotypic predisposition to develop secondary dormancy correlates well with the ability of OSR seeds to persist in the soil (Momoh et al., 2002; Gulden et al., 2004; Gruber et al., 2009, 2010).

Once a soil seed bank has been established, by unfavourable soil tillage and/or by growing high dormancy varieties, the decline of seed numbers in the soil takes time (Gruber et al., 2010; Lutman et al., 2003).

However, the emergence and performance of volunteer OSR in crops of a crop sequence and the potential for gene transfer by pollen and by seed is affected by the competitive ability of crops towards OSR volunteers and by chemical control of volunteers (Gruber and Claupein, 2008). The competitive capacity of crops towards weeds is generally determined by the sowing time, seed/plant density, earliness, plant morphology and shading capacity (Gower et al., 2002; Efthimiadou and Efthimiadis, 2009). Indirect volunteer control by crop–volunteer interactions and by crop rotations become more important, because (i) chemical control of OSR volunteers is difficult in broad-leaved crops, (ii) herbicide applications are sometimes reduced to save money or due to ecological motivations, (iii) herbicides cannot always be applied in time, and (iv) herbicide-tolerant volunteers can emerge from new, herbicide tolerant cultivars (e.g. in the Clearfield® system).

Earlier studies about volunteer OSR/canola either focused on the role of cultivar for the built up of a soil seed bank and emergence in the following crop (Gulden et al., 2003; Gruber et al., 2004a) or on the effect of some selected following crops for the fitness of OSR volunteers from only one experimental year (Gruber and Claupein, 2008). But up to now information is missing about possible interactions between the genotypic predisposition of OSR cultivars to exhibit dormancy and the species of the following crop (with its generic sowing date and plant density) on volunteer density and vigour. The genotypic predisposition to acquire dormancy could possibly affect time and number of volunteer emergence but different following crops may alter volunteer development due to differences in their competitive capacity. Therefore, a two-year field trial was set-up in two approaches (2008–2010 and 2009–2011) to study the fate of two OSR cultivars with low or high seed dormancy and the performance of their volunteers in following crops (two winter and two spring crops) in a tight temporal pattern.

The underlying questions of this study were: (i) How does the predisposition of OSR cultivars to exhibit dormancy affect the occurrence of volunteers and the soil seed bank in different following crops? (ii) Is the number of emerging volunteers in autumn a useful measure to predict the size of the OSR seed bank and the number of volunteers in the next year? (iii) Does the time of volunteer emergence (before or after winter) affect their potential to flower and to set seed? (iv) How do the specific environments, typically provided by different crops, affect the occurrence of OSR volunteers and their potential to flower and set seeds depending on OSR cultivar?

Results were expected to help develop concepts for indirect volunteer control.

2. Materials and methods

2.1. Site description and experimental design

The field experiment was carried out at the experimental station Ihinger Hof (48°44′N, 8°56′E, 478 m a.s.l., Ø 8.1 °C, Ø 693 mm) of the University of Hohenheim from August 2008 to June 2011. The study region is characterized by a temperate climate with a peak of precipitation in summer, and with moderate frost in winter.

The field experiment comprised two approaches with each lasting over two following crops, i.e. the first approach started in summer of 2008 and ended in summer of 2010, and the second approach started in 2009 and ended in 2011. Soil texture at the experimental site was loamy clay for approach 1 and loam for approach 2. There has been grown no OSR on the experimental area for at least 10 years.

The experiment was arranged in a two-factorial split-plot design in four replicates with crop species as the main-plot factor and volunteer OSR cultivar as the sub-plot factor (plot size of the subplot was 4.0 × 6 m). Following crop species – two winter crops and two spring crops – were grown after OSR seed rain: winter wheat (*Triticum aestivum* L. cv. Dekan), winter turnip rape (*Brassica rapa* L. cv. Buko), spring barley (*Hordeum vulgare* L. cv. Quench) and field pea (*Pisum sativum* L. cv. Hardy). Turnip rape was used to simulate conditions of an oilseed rape crop with the option to identify OSR volunteers by several botanical details. The following OSR cultivars were used as volunteers: Express—low seed dormancy; in the following referred to as LD-cultivar, Smart high seed dormancy; in the following referred to as HD-cultivar).

2.2. Experimental performance

Freshly harvested seeds of the OSR cultivars Express (LD) and Smart (HD) were used. Dormancy levels of the OSR seed lots were determined according to the Hohenheim Standard Dormancy Test (Weber et al., 2010) just before the seeds were deliberately broadcast on the field to simulate a high seed rain during oilseed rape harvest. In the dormancy test, seeds in petri dishes (100 seeds per replicate, four replicates) are first exposed to osmotic stress under exclusion of light by using polyethylene glycol solution (354.37 g in 1 l water), to create an osmotic potential corresponding to the permanent wilting point of −15 bar. After 14 days of dormancy induction, seeds are transferred to petri dishes and water is added to allow the seeds to germinate. During the following days germinated seedlings are counted and removed. After 14 days, all remaining intact non-germinated potentially dormant seeds undergo a viability test to break dormancy by exposing them to alternating light and temperature conditions. Finally, dormancy is calculated as the percentage of dormant seeds from the total number of viable seeds.

The dormancy levels determined by the Hohenheim Standard Dormancy Test of the LD-cultivar was 15% (August 2008) and 18% (August 2009), while that of the HD-cultivar was 95% and 75% (2008, 2009). Each of the seed lots had a high viability of 99% and 100% (LD Express) and 99.3% and 95.6% (HD Smart), respectively.