Statistical approach to predict abundances of oilseed rape volunteers

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Abstract

Harvest losses of oilseed rape (OSR) often emerge as volunteers in future crops after several years of soil persistence. Especially, GM (genetically modified) OSR volunteers can harm the quality of subsequent or adjacent OSR crops and complicate weed management. Several factors were identified affecting volunteer abundances under controlled conditions (laboratory, experimental station). Crucial factors are the cropping frequency, the management of OSR post-harvest stubble tillage and variety selection.

In 2009/10 and 2010/11, a survey was conducted concerning OSR volunteer abundances on 103 agricultural fields. The objective was to check the findings from previous studies under on-farm conditions, thereby developing a prediction model for OSR volunteers.

To derive a prediction model, a regression tree was built. The regression tree revealed that OSR volunteer abundances depend on long-term factors like location and OSR frequency in crop rotations. By that 48.2% of the total variation was explained. In contrast to previous findings, stubble tillage as short-term factor was not detected by the regression tree.

Another significant factor known from previous studies, variety selection, was partly unveiled by molecular genotypic identification of OSR volunteers. In rotations with intermediate or low OSR frequencies most volunteers could be assigned to open pollinated varieties with high secondary dormancy.

Introduction

Harvest losses of rapeseed often emerge after several years of persistence in the soil and occur as volunteers in subsequent crops.

At present, there are several issues concerning conventional OSR volunteers. Quality losses can be caused by volunteers (e.g. high erucic acid volunteers in double low varieties; double low quality in varieties with special fatty acid composition). In addition, OSR volunteers can increase herbicide use in sugar beet, because OSR is integrated increasingly in sugar beet rotations.

Also, the expected introduction of *Clearfield®* OSR (*CL*, conventionally bred herbicide resistance) raises concerns in Germany, as *CL* volunteers are no longer sensitive to many ALS inhibitor herbicides applied in cereals and sugar beet. Therefore, volunteer control may also become more expensive.

If genetically modified (GM) oilseed rape (OSR) is cultivated in the European Union (EU), volunteers can cause undesirable admixtures in subsequent OSR crops and pollen-mediated gene flow to non-GM OSR crops (Messéan et al., 2007). Exceeding the threshold of 0.9% GM admixture in agricultural raw products for food and feed in the EU, requires the labeling of products as GM.

Therefore, a survey was carried out to gain knowledge about the long-term factors affecting OSR volunteer abundances under conditions of agricultural fields (on-farm). In previous studies carried out in laboratory and experimental station, several factors of land management were identified affecting OSR volunteer abundances. Cultivation practice affects volunteers through crop sequence (Devos et al. 2004), stubble tillage operations (Gruber et al. 2010) and variety selection (Gulden et al. 2004). It was investigated if findings from previous studies could be confirmed under on-farm conditions. The final aim was to derive a prediction model for OSR volunteers.

Material and methods

In the growing seasons 2009/10 and 2010/11, volunteers were counted on 103 fields in North and East Germany. Volunteer abundances were surveyed by two methods: in fall 2009 and 2010, volunteers per m² were counted in artificial gaps of OSR crop stands, while in spring 2010, OSR plants protruding a semi-dwarf hybrid variety were classified as volunteers.

To derive a prediction model and to test factors influencing volunteer abundances, a classification and regression tree analysis was carried out. This analysis can explain the variation of a single response variable (volunteer abundance) with multiple explanatory variables. As in our case, multiple explanatory variables add to the complexity of analysis through higher-order interactions, missing data and lack of balance (De´ath and Fabricius, 2000). Classification and regression tree analysis makes complexity manageable and transparent.

To gather information about influencing factors, farmers filled in questionnaires reflecting the cropping history of fields. Factors were characterized as follows.

- Location: subdivision of fields in soil-climate-areas with relatively homogeneous site conditions (Graf et al. 2009)
- Crop sequence (1997 to present): low (<20%), medium (20-25%) and high (>25%) intensity of previous OSR cultivation
- Primary tillage (in typical rotation OSR – winter wheat – winter barley): typically, drilling was prepared by inverting soils (moldboard plow) previous to each crop. Alternatively, several intermediate stages occurred up to consequent non-inversion or conservation tillage.
- Stubble tillage: temporal interval (weeks) between OSR harvest and first tillage operation
- Harvest conditions: presence or absence of extreme seed loss events (hail, lodging or drought)
- Herbicide application: annual season with at least one herbicide ingredient applied in the crop subsequent to OSR, leading to successful volunteer control (fall, spring, fall and spring, annually fluctuating).
- OSR variety selection: omitted

Data exploration showed that classification of OSR variety selection was not feasible because field histories differed individually with regard to numbers and temporal successions of cultivated varieties. As an alternative, we investigated the genotypic origin of OSR volunteers by molecular methods (ISSR-PCR).

The software used for classification and regression tree analysis was the package *rpart,* Version3.-46 (recursive partitioning) within the *R* statistical system (Version 2.11.1). Because of the numeric character of the response variable “OSR volunteer abundance”, a regression tree was built. Tree building was checked by cross validation.

Results and discussion

In regression tree analysis, “soil-climate-area” and “crop sequence” were identified as explanatory variables for volunteer abundance (total variation explained: 48.2 %). These factors explain the long-term element of OSR soil seed bank incline.

The soil-climate area “East hilly lands in Schleswig-Holstein” is characterized by earliest, highly intensive OSR rotations compared to other regions of Germany. Therefore, it seems reasonable that the highest median volunteer abundance (11 plants per m²) occurred in this region (10 fields). Also, we can distinguish volunteer abundances between areas in former East and West Germany. In West Germany in areas favorable for OSR cultivation, comparatively small farms concentrated on rotations with fewer crops than in East Germany. So, OSR cultivation was only limited by rotation-specific demands. In most regions of East Germany, however, especially in naturally less favorable areas, OSR was only grown after the introduction of crop-specific subsidies in 1992 (MacSharry reforms). Before that time, wider rotations were fixed by governmental authorities. However, from 1992 to 2001 the economic attraction of OSR cultivation was limited by thresholds for OSR acreage supported by subsidies (Blair House Agreement). In addition, in East German farms wider rotations were often kept after 1990 in order to decrease average labor and machinery costs. So in 27 fields of the central east loess soils , only 1 plant per m² (median) occurred in contrast to favorable regions of West Germany (11 fields on loamy soils northwest: 3 plants/m²; 7 fields on marshlands: 3 plants/m², 7 fields in central/west uplands: 4 plants/m²). One exception is the northeast glacial soils, where the maritime climate is generally more favorable for OSR cultivation. Therefore, OSR cultivation was more intensive (volunteers: 3.5 plants per m²). In less favorable soil-climate-regions (11 fields on weathered soils southeast: 1.0 plants/m², 11 fields on glacial soils southeast: 0 plant/m², 5 fields in Brandenburg northwest: 0.5 plant/m²), OSR is the most important break crop, but rotations were not intensified because of problems with OSR pathogens (sandy soils, continental climate).

The importance of other factors was shown in studies under controlled conditions (laboratory, experimental station). In case of stubble tillage, it is known that delaying operations results in substantially less volunteer abundances than immediate tillage after OSR harvest (Gruber et al. 2010). But in our study, stubble tillage did not explain the variation of volunteer numbers in the regression tree because the exact time delay of stubble tillage in past years was unknown. So, farmers very often estimated the average time delay. Also, conditions of stubble treatment (depth of tillage, soil moisture conditions, precipitation events etc.) were usually not documented. The relevance of primary tillage was negligible in previous studies (Gruber et al. 2010). This is supported by our findings in regression tree analysis. Plowing shifts OSR seeds to deeper soil layers, thereby reducing volunteer number in the subsequent crop, mostly winter wheat, but the emergence of dormant seeds is only shifted to the future. So, delaying and reducing of stubble tillage is most advantageous (Gruber et al. 2010).

Also, variety selection affects seed persistence in the soil by the genotypic impact on secondary dormancy (Gruber et al. 2009; Gulden et al. 2004). Therefore, we aimed to identify the genotypic origin of OSR volunteers by PCR-based methods (data not published). For fields with high OSR intensity, the genotypic origin of volunteer plants could often not be revealed. This is most likely due to intra-specific hybridizations and in case of hybrid varieties, due to segregation in the F_2 generation. But in rotations with intermediate and low intensity, high proportions of volunteers could be identified as originating from varieties with known high secondary dormancy potential. Taken together, our results from agricultural fields complement previous findings.

Conclusions

The prediction of OSR volunteers based on plant abundances on 103 agricultural fields is based on factors indicating the long term character of the soil seed bank structure. Volunteer abundance can be characterized by location and frequency of OSR cultivation. Regarding these factors, the farmer has either no choice (location) or little choice (crop rotation) for decision making. This is true especially in West German region with high rents for land (economic pressure). So, this prediction model cannot support short-term decisions of farmers.

Alternatively, farmers can adapt tillage operations by delaying and reducing the intensity of stubble tillage after OSR harvest. Variety selection is another effective tool to control OSR volunteer abundance, although information about the dormancy potential of OSR varieties is not generally available.

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