Europ. J. Agronomy 77 (2016) 81–89

Contents lists available at ScienceDirect

European Journal of Agronomy

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

The influence of crop sequence on fungicide and herbicide use intensities in North German arable farming

Sabine Andert[a,*], Jana Bürger[b], Susanne Stein[c], Bärbel Gerowitt[a]

[a] Crop Health, Faculty of Agricultural and Environmental Sciences, University of Rostock, Satower Straße 48, D-18051 Rostock, Germany
[b] Grassland and Fodder Sciences, Faculty of Agricultural and Environmental Sciences, University of Rostock, Justus-von-Liebig-Weg 6, D-18051 Rostock, Germany
[c] Georg-August-Universität Göttingen, Centre for Biodiversity and Sustainable Land Use, Grisebachstrasse 6, D-37077 Göttingen, Germany

ARTICLE INFO

Article history:
Received 5 January 2016
Received in revised form 26 March 2016
Accepted 8 April 2016
Available online 16 April 2016

Keywords:
Pesticide use intensity
Crop rotation
Treatment Frequency Index (TFI)
On-farm data
Germany
Tillage
Riskiness

ABSTRACT

The reduction of pesticide use intensity is a societal and political ambition. Crop rotation is one important method to control pests and diseases in arable farming. We investigated the contribution of crop rotation to the variability of herbicide and fungicide use of 60 farms in four regions of Northern Germany. Our study aimed at answering the question: do diverse crop sequences lead to reduced herbicide and fungicide use in arable farming?

Ten-year data on chemical plant protection measures and field management were examined for six field crops. We classified crop sequences (triplets of three succeeding crops) according to their susceptibility for weeds and diseases (= 'riskiness'). The Treatment Frequency Index (TFI) of the last crop in the triplet was set in relation to the crop triplet riskiness, additionally also in combination with tillage.

In general, herbicide and fungicide use intensities were smaller in more diverse crop sequences. Diversified cereal sequences, involving roots and tubers, maize or spring cereals were less dependent on herbicides. Cultivation of maize in three subsequent years increased herbicide use. Crop sequences including high proportion of winter cereals increased fungicide use in cereals, while roots and tubers, winter oilseed rape and set-aside in the crop sequence decreased it. In winter oilseed rape, sequences with roots and tubers also increased fungicide use. In sugar beets, sequences with maize or a high concentration of sugar beets led to increasing fungicide use. If farmers chose riskier crop sequences tillage by plough decreased the need for herbicide and fungicide use.

To reduce herbicide and fungicide use intensities we recommend increasing the diversity of crop rotations, including a higher number of crops per rotation together with ploughing. Simplifying both crop sequence diversity and tillage intensity implies higher use of herbicides and fungicides. Results will be useful for convincing farmers to diversify crop sequences.

1. Introduction

One of the major objectives in order to improve sustainability of agricultural systems is to reduce inputs into crop production. In Europe, farmers are obliged to reduce pesticide use by adopting the principles of Integrated Pest Management (IPM) (European Directive 2009/128/EC on sustainable use of pesticides).

Looking back into the history of agriculture, crop rotations arose as one of the first sustainable agricultural practices (White, 1970; Howard, 1996). Even today, crop rotations drive many aspects of agricultural management, for example nutrient supply (Smith et al., 2008), nutrient leaching (Broussard and Turner, 2009) and type and technique of soil tillage. Thus, diversified crop rotations can enhance crop productivity in cropping systems (Smith et al., 2008). Howden et al. (2007) reported that diverse and regionally adjusted crop rotations can split and lower the farm risks due to weather-related extreme events.

Moreover, diversification of crop rotations is often presented as an efficient management tool for controlling pests and thereby, improving agricultural sustainability (Umaerus, 1992; Bailey and Lazarovits, 2003; Chikowo et al., 2009; Davis et al., 2012; Lawes and Renton, 2015). In rotations with cereals, break crops such as a legume or oilseed rape should help the following cereal to grow in an environment with lower levels of weeds and diseases (Brennan et al., 2013). Crop selection can reduce the abundance of dominant weed species (Liebmann and Dycke, 1993) and improve the man-

* Corresponding author.
E-mail address: sabine.andert@uni-rostock.de (S. Andert).

http://dx.doi.org/10.1016/j.eja.2016.04.003
1161-0301/

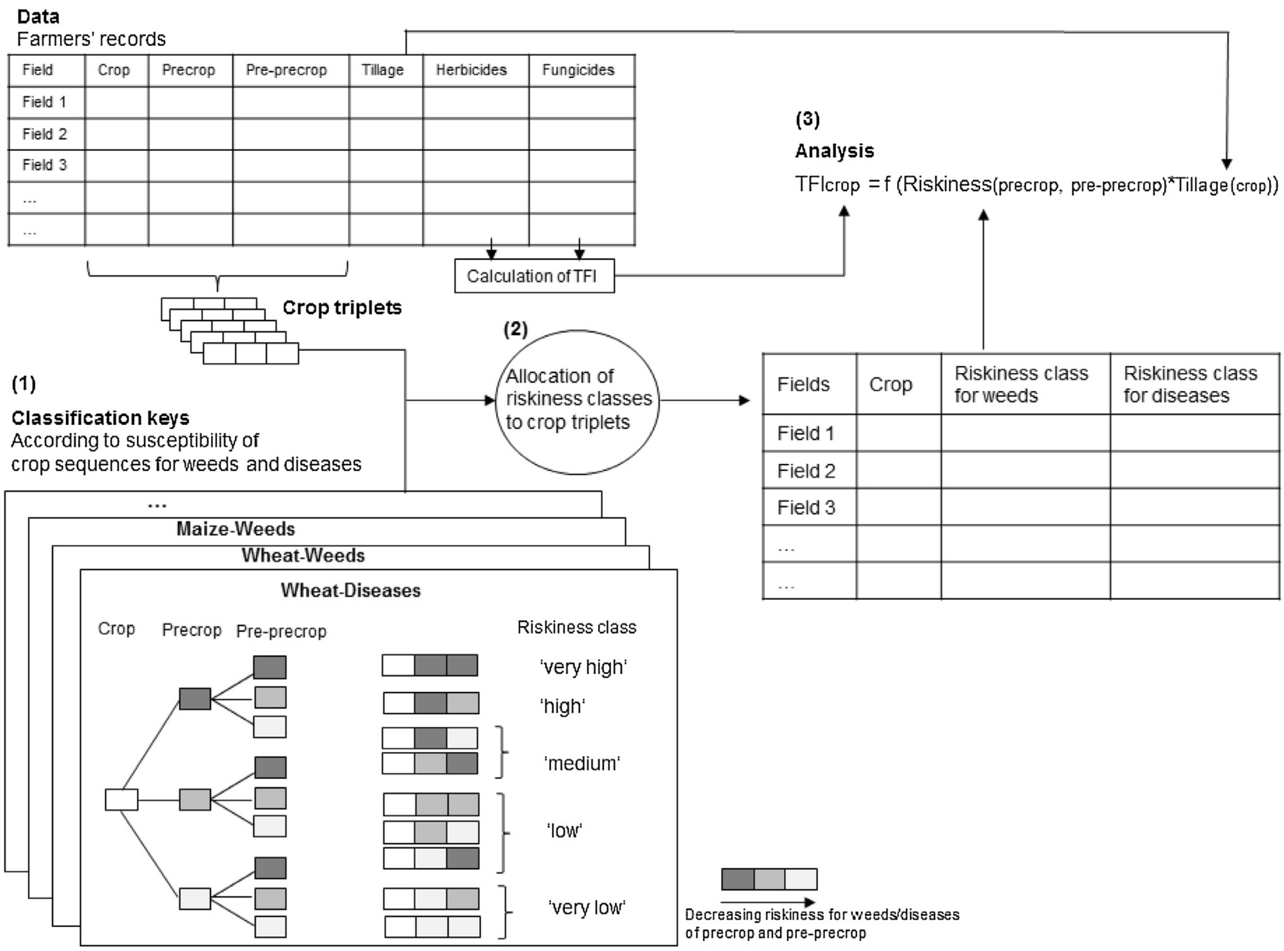

Fig. 1. An overview of the connections between data (farmersírecords), crop-specific classifications keys for weeds and diseases and analysis of TFI_{crop} (Treatment Frequency Index).

agement of plant diseases through interruption of disease cycles (Krupinsky et al., 2004).

A number of plant diseases can be managed effectively by rotations especially when combined with intensive tillage (Bockus, 1998; Krupinsky et al., 2002; Jørgensen and Olsen, 2007; Krupinsky et al., 2007; Ronis et al., 2009; Bankina et al., 2015). A well-planned crop-sequence system helps farmers avoiding many of the problems associated with conservation tillage, such as perennial weeds (Roth, 1996), and lead to lower herbicide use (Sarani et al., 2014).

Despite the many beneficial effects, classical crop rotation has become fragmented and simplified during the last decades (Rabbinge and van Diepen, 2000). Why do farmers use rotations less? Modern intensive farming management with high amounts of agro-chemical inputs has reduced the reliance on rotations for weed and disease control. Reduction of the rotation length and limitation of the number of crops are characteristic trends of present-day agriculture. Farmers often consider short-term profitability when determining crop choices using information on likely future commodity prices (Fraser, 2006; Melander et al., 2013) or grow crops that receive special support by national agricultural policy. In Europe, this resulted in an intensive cropping of some major crops such as wheat and maize (Leteinturier and Herman, 2006; Melander et al., 2013; Steinmann and Dobers, 2013; Aouadi et al., 2015).

Some studies have proposed the term "crop sequence" to cover both fixed rotations and flexible sequences of crops (Bohan et al., 2011; Steinmann and Dobers, 2013). In this study we use the term crop sequence to distinguish between the more dominant break crop effect and a probably less dominant rotation effect (Kirkegaard et al., 2008).

Several field experimental studies have proven that crop sequence is an important management tool to control weeds and diseases in arable farming (Christen et al., 1992; Christen and Sieling, 1993; Sieling et al., 2007; Davis et al., 2012; Winter, 2014). However, field experiments are often spatially and temporally limited. If, on the other hand, studies use a large number of on-farm data they often face the challenge to extract meaningful groups of crop sequences out of the multitude of possible crop combinations. Sometimes crop proportions in a rotation are used as classification measure or the analysis is based on a limited number of fixed rotation patterns. This usually leads to rather general results on the effect of rotations (Leteinturier and Herman, 2006; Melander et al., 2013; Steinmann and Dobers, 2013; Aouadi et al., 2015). Approaches are lacking to make the analysis of crop sequence effects in large or diverse data sets more operational without losing information through too tight rotation categories.

Here, we report on the analysis of a large-scale 10-year dataset (2005–2014) examining the impact of 3-year crop sequences and tillage on herbicide and fungicide use in North German arable farming. We used linear mixed models to estimate the relationship between the management variables and the treatment intensity. The models were complemented with random effects of geographical region, farm and year whose impact on pesticide use had already been demonstrated (Andert et al., 2015).

In this paper we present three steps of analysis: (i) Development of keys to classify crop sequences according to their susceptibility