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# Impacts of break crops and crop rotations on oilseed rape productivity: A review

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ABSTRACT

Over the past decades, the economic benefit has prompted farmers to grow oilseed rape (OSR). Consequently, the global OSR production increased considerably, and today the crop is grown in shorter rotations than ever before. This development is evident for the major growing regions in the European Union, Canada, China, India and Australia. OSR crops usually yield more if grown after other species than when grown after OSR. Based on > 550 comparisons, this review quantifies the yield benefit of OSR growing after a break crop with OSR after OSR as well as OSR growing after two-year and three-year breaks with continuous OSR. The mean yield increase varied with species of break crop and crop break intervals, ranging from 0.22 t ha$^{-1}$ for OSR after barley to 0.46 t ha$^{-1}$ after legumes, with a ranking of: barley < wheat < legumes. The mean yield increase of OSR after barley was consistent over varying yield levels of the following OSR, while it was inconsistent for OSR following wheat and legumes, with a lower yield response of OSR after wheat and a higher yield response of OSR after legumes at high yield levels. The mean additional yield after two successive break crops was 0.53 t ha$^{-1}$, but depended on the yield of the following OSR crop and decreased at higher yield levels. A three-year break demonstrated a consistent yield benefit of 0.47 t ha$^{-1}$ independent of the yield level of the succeeding OSR crop. We discuss the underlying mechanisms how different break crops and break intervals affect the seed yield of OSR, with a particular focus on diseases, pests and weeds. By quantifying the effects of different break crops and break intervals, it is our aim to provide the basis for decision to grow OSR in diverse rotations, to maintain the resources which contributed to the success of the OSR crop over the past decades, to exploit the full yield potential of the crop and to promote more sustainable OSR cropping systems.

## 1. Introduction

The worldwide demand for vegetable oils is predicted to rise further due to a growing food demand associated with an increasing world population as well as a non-food demand, especially as a renewable energy source. Oilseed rape (*Brassica napus* L.) which is also known as canola or rapeseed (for standardization hereinafter referred to as oilseed rape (OSR)) is one of the most important crops for edible oil, fodder and biofuel production on a global scale. Today, OSR is the world's third important oil delivering crop after oil palm and soybean (FAOStat, 2018). Since 1961 the global OSR oil production increased with an annual growth rate of 5.4% per year and currently the production amounts to an entire volume of approximately 69 million tons. Most important production countries are members of the European Union, Canada, China, India, and Australia with an overall contribution of more than 90% to the total world production (FAOStat, 2018) (Fig. 1a).

The large increase of the production is partly due to improved higher yielding and disease resistant varieties and improvements in agronomy. However, it is primarily the result of a great expansion of OSR acreage (Fig. 1b). Globally, the OSR cultivation area has almost doubled since the 1990s and nowadays amounts to an area of 34 million ha, whereas the total area of arable land remains constant in the main production countries (Fig. 1b) (FAOStat, 2018). As a consequence, the proportion of OSR in crop rotations increased noticeably during the past decades and shorter rotation systems were reported by most of the main production countries (Rouxel et al., 2003; Sprague et al., 2006a; Hartman, 2012; Hegewald et al., 2016).

The benefits of crop rotations for land, water resource protection and system productivity have been described extensively in the

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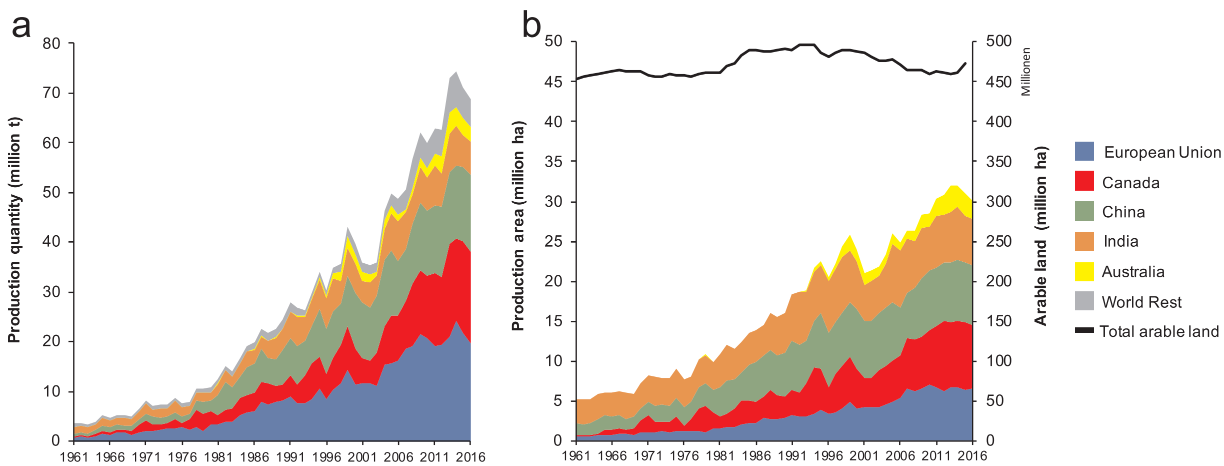


**Fig. 1.** Change in (a) global production quantity and (b) production area of oilseed rape and total arable land for the major growing countries from 1961 until 2016. Source: FAOstat 2018.

literature (Karlen et al., 1994). Primarily, these positive effects are related to an improved nitrogen availability and reduced N losses, a generally improved nutrient supply, a better water use efficiency, the control of diseases, weeds and insect pests as well as allelopathic control functions. Despite the knowledge of the beneficial effects of crop rotations there is a worldwide trend to produce crops in shorter rotations or even in monoculture (Bennett et al., 2012). Principally responsible for this development are market trends, technological advances, government incentives, and retailer and consumer demands. Moreover, this trend will continue further in the future, since breeding and chemical companies are increasingly merging and tend to focus on the most profitable crops with a large acreage.

Nevertheless, it remains questionable to produce in short rotations with only the short-term economic benefit in mind. There are some recent results which give cause for concern (Sprague et al., 2006a; Harker et al., 2015a; Peng et al., 2015; Heap, 2017). Sprague et al. (2006a) have shown the loss of resistance against blackleg within a few years of intensive cultivation of Rlm 1 resistance harboring cultivars in France and Australia, associated with severe yield limitations. The investigations of Harker et al. (2015a) and Peng et al. (2015) in Canada indicated limited yields of OSR produced in shorter rotations due to blackleg and clubroot disease although the cultivars were considered as resistant. Furthermore, there is a growing problem with herbicide resistant weeds across the world (Heap, 2017), which could restrict modern crop production systems. Similarly, intensive and improper use of fungicides could result in insensitivity to these products in pathogen populations and several studies have shown fungicide resistant isolates for the pathogens *Leptosphaeria maculans* (Van De Wouw et al., 2017), *Sclerotinia sclerotiorum* (Gossen et al., 2001; Penaud and Walker, 2015; Xu et al., 2015) and *Pyrenopeziza brassicae* (Carter et al., 2014) which may pose a threat to the OSR production.

The effects of different break crops or rotations have been observed in numerous experiments and are well-known for cereal production systems, especially for wheat. Extensive overviews on the impact of different break crops and the responses of wheat were given by Kirkegaard et al. (2008) and more recently by Angus et al. (2015) for a wide range of experiments in order to determine the underlying causes. Both studies showed that OSR is an excellent break crop for cereal based production systems due to breaking the disease cycle of cereal pathogens, biofumigation and high amounts of residual N as well as more efficient N recovery. However, there are fewer studies that investigated the impact of different break crops or rotations on the yield of OSR, although this crop plays an important role in many cropping systems worldwide.

Hence, this review aims to summarize a variety of experiments that concentrate on the impact of different preceding crops or crop rotations on OSR by firstly reviewing the yield data of OSR following different break crops or crop rotations. Afterwards, the efficiency of break crops and crop rotations in controlling diseases, pests and weed infestation are outlined. This review concludes with a discussion of the principle factors, which restrict seed yield of OSR depending on the cropping system.

## 2. Material and methods

This review is primarily based on data collected from published reports on the effects of preceding crops or different crop rotations on OSR seed yield. In comparison with studies that focused on the effect of different break crops or crop rotations on wheat, the amount of such data for OSR is limited. However, we were able to collect data from 35 field studies across the major growing countries. The majority of the experiments were conducted in North America (18) and Europe (10), and a limited set of data was collected by Asian (2) and Australian experiments (2). A total number of 20 studies could be found, which investigated the break crop or rotation effect in relation to a continuous OSR or an OSR-OSR control treatment which is why these studies were included in our data analysis. A detailed overview of all studies with regard to the experimental location, the experimental period, the cultivated break crops and the control sequence is given in Table 1.

Basically, our data analysis was carried out according to the methodology of Angus et al. (2015) with some minor amendments for our dataset. As a more limited set of data was available for OSR, we had to create a selection criterion for the data to achieve a higher number of comparisons. Therefore, we considered an alternate wheat-OSR rotation as a single break crop experiment as categorized by Angus et al. (2015). Furthermore, when a rotation consists of more than two crops, it is not possible to conclude whether the whole sequence of preceding crops is needed to provide a yield benefit to the target crop, or whether a part of the sequence is responsible for the benefit. In the case of OSR following legumes in cropping sequences, we assumed for the purpose of this analysis that the yield benefit was brought by the preceding legume crop regardless of the pre-preceding crop. Based on these assumptions a higher number of comparisons for wheat and grain legumes as preceding crops for OSR with OSR-OSR were achieved in this analysis. Besides wheat and grain legumes we found a limited set of data for barley as a single break crop for the analysis. As the availability for other crops was even more scarce, we could not find reliable data for other single break crops. As a result, we analyzed the yield benefit of OSR following a two-year break and following a three-year break when the studies investigated a continuous OSR control for three or four years in the same experiment.