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Growing camelina as a second crop in France: A participatory design approach to produce actionable knowledge

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A B S T R A C T

New cropping systems are needed to meet the increasing demand for sustainable feedstock for food, feed, fibre, and fuel. However, the lack of agronomic knowledge has been shown to hinder the introduction of new crops in current cropping systems. In design sciences, the C–K theory, which was developed to model design logics, shows that a design process could be a relevant tool to produce knowledge. In this study, an original participatory design approach combining a multi-actor workshop and on-farm trials was developed to produce actionable knowledge and identify knowledge gaps. The work was based on a case study: the introduction, in the cropping systems of northern France, of a little-known oilseed crop, camelina [*Camelina sativa* (L.) Crantz], to supply a local oilseed biorefinery. During the workshop, farmers, researchers, and industrialists collectively designed eight crop sequences that included camelina as a second crop, and two crop management options, as a relay crop and a double crop. These design activities allowed for the identification of: (i) assessment indicators derived from participants' expectations; and (ii) knowledge gaps about camelina crop functioning, management, and preceding crop effects. After the workshop, four farmers implemented on-farm trials. They autonomously designed and managed thirteen crop management options, and appraised them according to their own indicators. These on-farm trials were monitored through interviews, field tours, and measurements. Eleven criteria used by the farmers to appraise their trials were identified. Four crop management options were considered as conclusive, three as not conclusive, and six as promising. The monitoring of these original on-farm trials allowed for: (i) the identification of farmers' monitoring indicators; (ii) the formulation of decision rules for camelina management; (iii) a better understanding of camelina crop functioning; and (iv) the identification of farmers' questions, revealing knowledge gaps to be fulfilled to enhance camelina areas. In this study, we demonstrated that participatory design could be used to: (i) support, at a low cost, the production of actionable knowledge on a little-known crop; and (ii) pursue the identification of relevant topics lines for research-action programs. We also showed that the combination of a multi-actor workshop and new kinds of on-farm trials is relevant to reach these objectives. In conclusion, this approach could be an interesting way to support the design of diversified cropping systems, including little-known crops such as camelina, and to help in the setting of research priorities for these crops.

1. Introduction

Over the past decade, there has been a growing demand for sustainable feedstock to produce food, feed, fibre, and fuel (Cherubini, 2010; Ghatak, 2011; Jong et al., 2009). The introduction of new food and non-food crops in cropping systems has been recognized as a lever to meet this challenge. More than ten minor oilseed crops have already been identified as good candidates, owing to their agronomic and industrial characteristics (Aresta et al., 2012; Carlsson, 2009; Vollmann and Laimer, 2013). For example, *Brassica carinata* has been investigated in Italy to produce biodiesel (Cardone et al., 2003; Lazzeri et al., 2009), while the production of Cuphea (*Cuphea sp.*, Lythraceae) was studied in the Northern Corn Belt for industrial uses (Gesch et al., 2006). Camelina (*Camelina sativa* (L.) Crantz) and Crambe (*Crambe abyssinica*) were also described as industrial crops suitable to various European environments (Righini et al., 2016; Zanetti et al., 2016, 2017). However, the total surface area under these oil crops is currently very small. Lack of agronomic knowledge, along with technological and socio-economic lock-in, have been identified as obstacles to the development of these diversification crops (Magrini et al., 2016; Meynard et al., 2013).

Camelina is an oilseed crop with specific fatty acid and protein profiles, and consequently with multiple potential food and non-food

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uses (Righini et al., 2016; Zubr, 1997). It is well suited to a wide range of environments, as shown by trials in Chile (Berti et al., 2011), Australia (Campbell et al., 2013), the United States (Gesch et al., 2017), Canada (Gugel and Falk, 2006) and Europe (Vollman et al., 2007). Because of its short cycle, around 1200 °-days with a 5 °C base temperature (Gesch, 2014), camelina can be grown as a second crop: either as a double crop, sown after the harvest of the first crop, or as relay crop, sown in an already established first crop (Berti et al., 2015; Dobre et al., 2014). In the US Corn Belt, winter camelina is considered as an alternative crop to produce fuel and food when double or relay cropped in the fallow-wheat or soybean-maize crop sequences (Berti et al., 2017; Chen et al., 2015). In Europe, camelina is mostly grown as a spring crop on organic farms to produce oil and press cake for animal feed. In these cropping systems, camelina is often mixed with legumes to avoid weed competition and to enhance nitrogen supply (Paulsen, 2007; Saucke and Ackermann, 2006). With the development of oilseed biorefineries in Europe, new opportunities are emerging for the camelina market (Zanetti et al., 2013). Hence, to meet future demand, new camelina-based cropping systems are needed.

In order to design sustainable cropping systems, the combination of empirical and scientific knowledge is essential (Girard and Navarrete, 2005; Malézieux, 2012; Toffolini et al., 2016a).

In the case of camelina, cultivation areas are still limited in Europe compared to major oilseed crops. Farmers therefore have little empirical knowledge and expertise on this crop. The interest for this crop has increased this last decade, leading to an increase number of scientific publications. Even though, numerous scientific knowledge gaps on camelina genetics, breeding, ecophysiology, management, and uses remain (Berti et al., 2016). Many studies looked up at the effect of various camelina management techniques, such as sowing date, rate and/or depth (Schillinger et al., 2012; Urbaniak et al., 2008), soil tillage (Gesch and Cermak, 2011), nitrogen and sulphur fertilisation (Jiang et al., 2013; Mohammed et al., 2017; Wysocki et al., 2013), or irrigation (Hergert et al., 2016; Hunsaker et al., 2013), on camelina physiology, growth and/or production. All these results might support the design of camelina management. However, they are difficult to be mobilized by farmers for their technical action. For instance, the emphasis of response curves of camelina to nitrogen is a scientific knowledge that justifies for nitrogen inputs, but it does not support farmers to design a nitrogen fertilisation strategy suited to their own environment (i.e. mineral nitrogen content in the soil, weather conditions) and objectives. Hence, there is a need to produce actionable knowledge on camelina, which means knowledge mobilized in and for the design and the implementation of cropping systems.

In agronomy, various methods to produce and capitalize knowledge have been developed to support agricultural change (Doré et al., 2011). Historically, experiments are the most common way to produce agronomic knowledge but they are time- and labour-consuming, and are often thought by researchers only. More recently, expert elicitation (Cornelissen et al., 2003) or on-farm innovations tracking (Salembier et al., 2016) have been proposed as alternative methods to valorise empirical knowledge. Finally, meta-analysis has been used to synthesize available scientific knowledge (Philibert et al., 2012). All these methods require deep expertise or a sound scientific background, neither of which yet exists for camelina.

In design sciences, the C–K theory has been developed by (Hatchuel and Weil, 2003) to model design logics. In this theory, innovative design, which could be helpful to address new issues in agriculture (Berthet et al., 2016; Prost et al., 2016), is defined as a joint expansion of a space of concepts (C) and a space of knowledge (K). More precisely, it means that the exploration of new concepts, i.e. objects to be designed, depends on existing knowledge but also leads to the expansion of knowledge. Thus, a design process generally results in the production of new knowledge or at least in the identification of knowledge to be produced. Until now this theory has been used primarily to support innovative design processes in industry (Hatchuel and Weil, 2009; Potier et al., 2015). Some applications in agriculture can nevertheless be found with the design of agroecosystems (Berthet et al., 2014), the characterization of the knowledge produced during a design process (Prost, 2008) or the identification of knowledge gaps hindering the design (Ravier et al., 2017a,b).

Our study aimed to: (i) identify knowledge gaps that hamper the development of camelina-based cropping systems in northern France; and (ii) produce actionable knowledge, defined here as any knowledge mobilized for the design and the implementation of cropping systems. With the aim of producing knowledge on the introduction of a new crop in current cropping systems, a participatory design approach combining a multi-actor workshop and on-farm trials was developed.

2. Material and methods

2.1. The case study: background and characteristics of the study area

A new company (SAS PIVERT, https://sas-pivert.com/) undertook a project in 2012 to develop the basis of an oilseed biorefinery in northern France. The future supply area of the biorefinery corresponded to a fifty-kilometre radius around the city of Compiègne (F.Valter, personal communication, 11 November 2016). The climate of this supply area is oceanic, with a mean annual temperature and rainfall respectively equal to 11 °C and 681 mm, over the 1981–2010 period. The three main types of soil in the area are: (i) deep loamy soil (120 cm) characterized by a high maximum available soil water content (ASW = 175–200 mm); (ii) moderately-deep sandy loamy soil (90 cm; ASW = 150–155 mm); and (iii) shallow limestone soil (60 cm; ASW = 120 mm) (Begon et al., 1977).

This study area is characterised by a diversity of crops, such as winter wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), maize (*Zea mays* L.), sugarbeet (*Beta vulgaris* L.), potato (*Solanum tuberosum* L.), carrot (*Daucus carota* L.), French bean (*Phaseolus vulgaris* L.), rapeseed (*Brassica napus* L.), and pea (*Pisum sativum* L.). In the supply basin as a whole, twenty-nine typical crop sequences were identified and then classified in three types: (i) short crop sequences with cereals and oilseed crops (3 or 4 years); (ii) medium crop sequences with sugarbeet (minimum 4 years); and (iii) long crop sequences with sugarbeet and/or potato and/or vegetables (maximum 8 years). The spatial distribution of these crop sequences is mainly linked to soil characteristics, with long crop sequences located in the most fertile soils.

2.2. General frame of the participatory design approach

A participatory design approach combining a multi-actor workshop and on-farm trials designed, managed and appraised by farmers was developed. At each step, some of the outputs were used to support the global design process (Fig. 1).

The objective of the multi-actor workshop was to identify: (i) assessment indicators for camelina and camelina-based cropping systems; and (ii) knowledge gaps hampering the design and implementation of these cropping systems. The workshop involved farmers from the study area, interested in the introduction of camelina and motivated to set up experiments on their own farms, and actors with skills concerning crop management, camelina and oilseed crop processing, or biorefinery processes. Twenty-two individuals attended the workshop: seven farmers, two local advisors from agricultural extension services, one representative of a French technical centre for oilseed and legume crops, Terres Inovia, two researchers specialized in oilseed crops extraction and processing, from the university of Compiègne, two members of oilseed industrial groups (Lesieur and Avril), and two representatives of the company SAS PIVERT. Lastly, four researchers involved in the research project were either facilitators or observers. The workshop was organized in three phases to support design activities. Observers were focused on the participants' questions and