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What are the traits of *Phelipanche ramosa* (L.) Pomel that contribute to the success of its biological cycle on its host *Brassica napus* L.?

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ABSTRACT

In France, the fact that the holoparasitic plant *Phelipanche ramosa* has adapted to oilseed rape over the past two decades is deeply worrying, as it can cause over 80% yield losses. Its distribution area and the range of its host plants, whether they are cultivated plants or weeds, are expanding dramatically. As no natural regression of the infestation has been recorded so far, we undertook a detailed study of the different steps of the biological cycle of the *P. ramosa*/oilseed rape pathosystem to determine the adaptive traits that favour the parasite's success. We combined experimental approaches involving controlled conditions with *in vitro* and in pot co-cultivation on the one hand and a field trial on the other hand. These experiments allowed us to determine a 4-mm zone around host roots within which oilseed rape root exudates stimulate the germination of *P. ramosa*, the early action of host root exudates and the rapid fixation of the parasite on host roots. We also unveiled that *P. ramosa* was able to tune its biological cycle to that of oilseed rape. The important trophic relationships between the parasite and its host induced phenotypic (dwarfism, leaf chlorosis, silique abortion) as well as agronomical (90% yield losses) consequences on oilseed rape. Our results can constitute a relevant basis for further experimental studies. The research perspectives they open will focus on key-processes of the host–parasite relationship, and more particularly on the trophic relationships that are set up as far as carbon assimilates and minerals such as nitrogen are concerned.

Introduction

Among crop bioagressors, the *Phelipanche* and *Orobanche* genera are obligate parasites of dicotyledonous roots and are considered as one of the main biotic constraints on economically important crops. They are also known to be the cause of crop losses ranging from 5 to 100% (Joel et al., 2007; Musselman, 1980; Parker and Riches, 1993; Press and Graves, 1995; Press and Phoenix, 2005; Schneeweiss, 2007). *Phelipanche ramosa* (L.) Pomel (Joel, 2009) is most devastating and has by far the widest range of hosts, among which Solanaceae, Brassicaceae and legumes are prominent (Buschmann et al., 2005; Haidar et al., 2003; Joel et al., 2007; Parker and Riches, 1993). In France, *P. ramosa* got remarkably adapted to oilseed rape, causing deeply worrying losses of about 80%, but also to hemp and tobacco. So far the adaptation of *P. ramosa* to oilseed rape seems to have remained limited to the French territory. The distribution area of the parasite and the range of its host plants appear to have dramatically expanded lately, with more than 70 weed species as new hosts (Boulet et al., 2007; Brault et al., 2007; Gibot-Leclerc et al., 2003, 2006, 2009).

The biological cycle of epirhizal parasites is usually composed of two distinct phases (Bouwmeester et al., 2003; Joel et al., 2007; Keyes et al., 2001; Parker and Riches, 1993; Rubiales, 2003; Sauerborn, 1991; Yoder, 2001). Underground, the first phase is initiated by seed germination and goes on with the fixation on host roots and the penetration into host tissues along with the development of an absorption system called a haustorium. Aboveground, the second phase starts with the emergence and then the growth of floral scapes and ends with flowering and fructification. In recent years several authors (Buschmann et al., 2005; Echevarría-Zomeño et al., 2006; Goldwasser et al., 2001; Haidar et al., 2003; Kogan, 1994; Lu et al., 2000; Pérez de Luque et al., 2004; Sallé et al., 2000) have insisted on the need to increase our knowledge about parasitic plant biology in order to make it easier to develop suitable protocols for an efficient control. The knowledge acquired about broomrape so far deals with the biology of the main broomrape/host pathosystems, *i.e. Orobanche cernua*/sunflower, *O. crenata*/faba bean, *O. cumana*/sunflower, *Phelipanche ramosa*/potato, *P. ramosa*/tobacco,

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P. ramosa/tomato. However, a detailed study of the biological cycle of the *P. ramosa*/oilseed rape pathosystem has never been performed. Acquiring knowledge about the biology of the *P. ramosa*/oilseed rape pathosystem is all the more crucial as recent molecular biology works have proved that there exist at least two different *P. ramosa* pathovars with clearcut host specificities, which makes culture management in severely infested plots even more complicated.

In order to determine the adaptive traits that favour the parasite's success, we characterized the biological cycle of the *P. ramosa*/oilseed rape pathosystem. More precisely, we determined (1) the extent of the zone where oilseed rape root exudates stimulate *P. ramosa* seed germination; (2) the success rate of the first fixation steps of *P. ramosa* on host roots following its germination; (3) how the different phases of the *P. ramosa* development cycle tune in with the oilseed rape cycle; (4) the phenotypic and agronomical consequences of the parasitism of *P. ramosa* on oilseed rape. In order to make it easier to study the early development steps of *P. ramosa*, we decided to work with *in vitro* and sandwich co-cultivation methods. In parallel, a field trial was

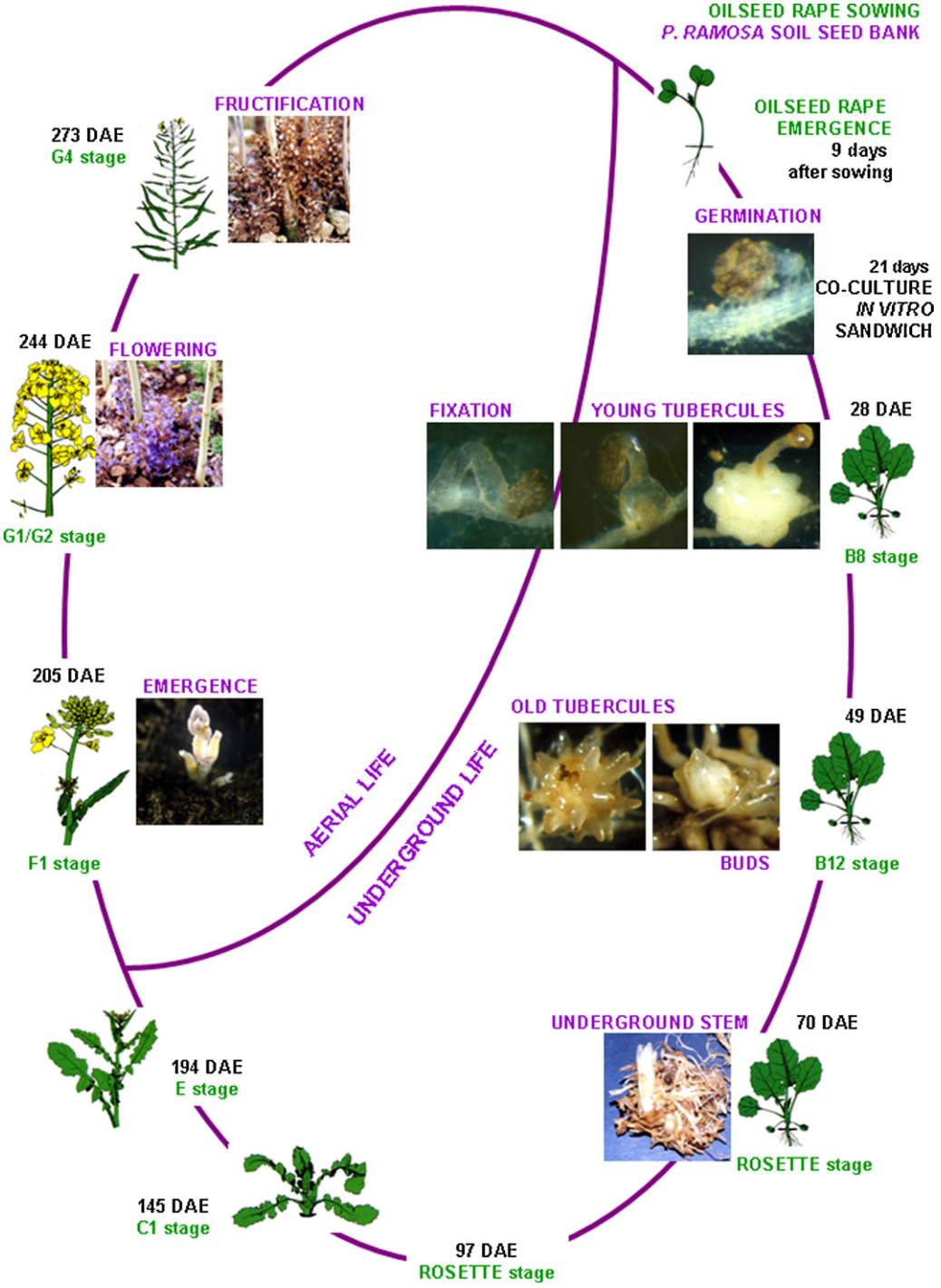

Fig. 1. Development cycle of the *Phelipanche ramosa*/oilseed rape pathosystem in Charente-Maritime (France).