BIOLOGICAL CHARACTERISTICS OF SOME PARASITIC FLOWERING PLANTS

Milan Blagojević, Branko Konstantinović, Nataša Samardžić, Milena Popov, Bojan Konstantinović*
University of Novi Sad, Faculty of Agriculture Novi Sad, Serbia
*Corresponding author: bojank@polj.uns.ac.rs

Abstract

Evolutionary conditions may favor development of parasitism in practice. Orobanche spp. (broomrape) is holoparasitic flowering plant at the root of a large number of crops that greatly reduce the yield in dry, warm, temperate and semi-arid regions. The problem of pathogenic organisms is focused primarily on fungi, nematodes, bacteria and viruses. These organisms certainly cause economically significant damages on plants, and the fact that parasitic flowering plants are economically significant pathogens can be surprising. Roots of parasitic plants develop primarily on annual plants on which parasitic seedlings form haustoria and thus gain a functional root system. In order to create connection between the host and the parasite, some kind of stimulus is needed. The substance for stimulation of connecting the host and the parasite is highly unstable, so the distance between the parasite seed and the root of the host plays a vital role in creating a contact. Cuscuta campestris Yuncker – field dodder has always been known as a plant without root and chlorophyll, i.e. parasitic plant that is completely dependent upon the host. It is generally accepted that water and inorganic nutrients are absorbed through the xylem between the host and the parasite, and organic compounds are transported through the phloem of the host, so that the parasite adapts it by phloem connections. This view has been accepted by almost all reference works and textbooks. The research has proved the existence of chlorophyll A and B in very small quantities in Cuscuta campestris in relation 2.5:1.

Keywords: parasitic flowering plants, Orobanche, Cuscuta, holoparasites, hemiparasites.

Introduction

The first association problem of pathogenic organisms is directed to fungi, nematodes, bacteria and viruses. These organisms certainly lead
to economically significant damages of plants, and the fact that parasitic flowering plants are also economically significant pathogens can be surprising. Parasitic plants are angiosperms (flowering plants) that are directly linked to other plants by haustoria. Haustoria are root modifications that form morphological and physiological bonds between the parasite and the host. Parasitic plants (originating from Greek word *para* - beside and *zitos* – guard oneself) are organisms that cause parasitic plant diseases. These are predominantly heterotrophic organisms, because they feed by ready to eat food that they take from either living cells or dead organic matter. Only a limited number of autotrophic organisms adapted to parasitic way of life.

Between parasites and saprophytes (*sapro* - rot, *phyton* - plant), there is a great number of transitional forms, and among them there are no clear boundaries. Some authors use this name to mark any agent of plant diseases, either of parasitic or non-parasitic nature. Therefore, it would be a broader concept in relation to parasite which is of biotic nature. However, phytopathologists often use the term pathogen, mainly for parasitic organisms. If the symptoms of disease are created on the host, then it is pathogen, as well as parasite. Until now, great number of parasitic organisms was identified on plants. For example, so far in North America there are about 8.000 parasitic fungi, 300 bacteria, 500 viruses, 75 species of organisms that look like mycoplasma and about 3.000 described parasitic flowering plants. Parasitic weed species, known as broomrape - *Orobanche cumana* Wallr. is one of limiting factors in sunflower production, as well as in other world countries. Genetic resistance in combination with herbicides is the best manner for control of this weed species (Eizenberg *et al*., 2006; Rubiales *et al*., 2009; Fernandez-Martinez *et al*., 2010). Even beside possible control, there is significant increase of infected areas. This parasitic weed originates from Russia, and nowadays is widely spread in Eurasia, including Black Sea region (Antonova *et al*., 2009). In Serbia, presence of broomrape has also been confirmed (Maširević and Medić-Pap, 2009), as well as on the territory of Romania (Pricop *et al*., 2011), Turkey (Demirci and Kaya, 2009), Spain (Fernandez-Martinez *et al*., 2009), Israel (Eizenberg *et al*., 2003), and it has recently been also discovered in Africa (Amri *et al*., 2012). Certainly that intensive exchange of sunflower seeds between countries in the world, as well as small broomrape seed enable fast spread of this weed species. High genetic resistance of commercial sunflower hybrids to this weed species in Argentina could be potential answer to high distribution of this weed species (Cantamutto *et al*., 2012).

Parasitic flowering plants, such as species of the genus *Cuscuta* L. (dod-
der) and *Orobanche* L. (broomrape), quantitatively do not have significant number in relation to total weedy vegetation of Serbia that numbers 1,009 species (Kojić and Vrbničanin, 1998). *Cuscuta* genus includes over 100 species, distributed in moderate and warmer regions of the world. In vegetation Serbia, represented are only 10 species of this genus (Kojić and Vrbničanin, 2000).

**Species of parasitic plants**

Unlike ordinary weeds, parasitic plants are heterogeneous plant organisms that are not able to synthetize sufficient nutrients need for their development, due to which they lodge to other, host plant out of which they extract nutrients through structures called haustoria that anatomically connect binding channels of two plants (Konstantinović, 1999).

There are two basic types of parasitic plants that can be distinguished: parasites of stem and parasites of root. Stem parasites occurred in several families, and pathogens are some mistletoe and field dodder (*Cas-sitha* and *Cuscuta*). Stem parasites are more frequent and are found in different taxonomic groups. Some of economically important stem pathogens belong to the family of flowering plants, *Orobanchaceae*. Holoparasite and hemiparasite species differ according to the degree of dependence of parasites on the host plant. Hemiparasites can be obligatory and facultative parasites. Optional (facultative or semi-) parasitic weeds contain chlorophyll and can survive without host. Facultative parasites or necrotrophs held mostly on dead organic matter (saprophytic phase), and only a part of development cycle they spend on plants (parasitic phase). From the other hand, complete (obligatory or parasitic) weeds, demand host for survival. Obligatory parasites can develop only on alive tissues of the host plant. Hemiparazites contain chlorophyll during their growth, thus being photosynthetically active, and uptake water by binding with the host by haustoria. Holoparazites lack chlorophyll i.e. they are photosynthetically inactive and therefore they must rely on the host xylem and phloem content. All holoparasites are obligatory parasites. Although these definitions imply absolute and partial categorization, some parasitic plants are intermediators between hemi- and holoparasitic plants, e.g. *Cuscuta* (dodder).

**Morphological characteristics.** On some stem parasites such as *Cassitha* (mistletoe) and *Cuscuta* (dodder), vegetative part consists exclusively from stem and rudimentary leaves. Opposite to this, numerous photosynthetic hemiparasites of root will not be accepted as parasites because they are green with completely formed leaves. As the level of parasitic
dependence grows (evolution from hemiparasites to holoparasites), great changes occurred in morphology of parasitic plants. The best example of evolutionary phase from hemi- to holoparasites can be seen between different representatives of the family of flowering plants (*Orobanchaceae*).

**Orobanchaceae (flowering plants)**

This family includes the greatest number of genus (90) and species (about 1800) of all families of parasitic flowering plants. In Serbia there are 26 different broomrape species, 56 varieties and 226 forms that make total of 308 taxa (Maširević and Medić-Pap, 2009). In the past hemiparasitic members of this family have been classified as a part of *Scrophulariaceae* family, while holoparasitic members have been included in *Orobanchaceae* family. The most recent molecular phylogenetic studies that have included both hemi- and holoparasites show that *Orobanchaceae* are monophyletic – i.e. they originate from a common ancestor, and that evolutionary line is offspring of non-parasitic *Scrophulariaceae*. In further text, two economically most important genus, *Striga* and *Orobanche* are described separately, with similarities and differences of their life cycles.

**Orobanche L.**

The genus *Orobanche* contains about 150 species of holoparasites that attack the root of the host. These plants are known for their English names “broomrape”, because it was thought to grow as tubers (“rapum”) from broom (the common name for legumes *Cytisus*). This genus reaches its greatest diversity in Mediterranean climate and north Asia. The majority of economically significant pathogenic species are of ancient origin. Molecular proves suggest that *Orobanche* is not monophyletic, so that other generic terms can eventually be applied. The main families of host for parasitic *Orobanche* are legumes, nightshades (eggplant, tomato, tobacco, potato, but not paprika), then squires (carrot, parsley, celery), brassicas (cabbage, cauliflower) and composites (lettuce, sunflower). Control is difficult due to seed dormancy in the soil (more than five decades), tiny seeds (smaller than width of the human hair), fertility (thousands of seeds per plant), as well as due to underground phases (seed germination) under soil and lives as parasite host before it emerges and becomes evident. Populations that naturally occur in red clover (*Trifolium pratense*) and carrot (*Daucus carota* subsp. Gummifer), show different host specificities, indicating possibilities of fast adaptation. There are numerous studies on hosts that attack *Orobanche* species. It has been shown that *O. ramosa* L. can
parasitize plants in 11 different dicotyledonous families, in fact, on several different hosts than any other flowering plants. Related species of *O. aegyptiaca* cause especially heavy damages of melon in Central Asia, where flowering plants not only reduce yield, but also encourage production of toxins within melons that become commercially unusable. For example, there are no reports of parasitism in soybean by any flowering plant, although *O. crenata* Forsk. is soybean parasite in a pot. However, pot assays are valuable, for potential hosts can be identified on the bases of specificity of domestic parasite strains that can be identified. In general, *Orobanche* is the parasite of colder climates, and germination temperature is between 10 to 20 °C, alternately with temperatures of 5 °C. This can explain why *O. ramosa* represents a problem in the river Nile valley in Sudan only in winter, and the fact why *O. cernua* Loefl. attacks tobacco in India, and it does not represent a problem in sunflower (*Helianthus annuus*) grown in the same region during summer. *Orobanche* noticeably weaken roots of its host. The longest dormancy of *Orobanche* seed in the soil was documented in Bulgaria in 1956 due to severe *Orobanche* infection, in tobacco fields of Tobacco Research Institute near Plovdiv, was planted a vineyard. In 1991 vineyards were removed and tobacco was sown again. Great number of *O. ramosa* occurred probably out of seed that were dispersed during previous tobacco cropping in 1956. *O. ramosa* imported in California makes a problem on tomato. Despite efforts to eradicate it, the parasite keeps surviving. It is highly probable that parasite seed was imported by the crop, by either infected plant or contaminated tomato seed. More recent of tomato in Chile should be used as a warning that *O. ramosa* infection can be expected wherever there is a convenient host.

*Orobanche cernua* is widely distributed in East Europe and Middle East, with heavy invasions in South India and sporadical occurrences in North Africa, China and East Europe. Its primary hosts are crops from *Solanaceae* family and sunflower. Sunflower is the most important oil plant in some parts of East Europe, and *O. cernua* is a major constraint for production, especially in Bulgaria in which sunflower oil is a national brand. Infected plants are stunted and have smaller heads and lower oil quality. Between 1947 and 1950, *Orobanche* created a problem that in Bulgaria became so serious that it threatened further sunflower existence. Tobacco can be seriously damaged by *O. cernua*; however, tobacco was not attacked in Bulgaria, even in regions near heavily infected sunflower fields. In India in which tobacco is heavily damaged, situation is inverted and sunflower was not attacked. It has been proved that *O. cernua* devel-
ops on hosts from family Solanaceae and that it will not attack sunflower. Russian breeders studied O. cernua development for many years. Their data should be studied and proved by new genetic methods (PCR). Given the size of the area under sunflower, more awareness on this pathogen is needed. Yet another of the species from Orobanche genus is O. crenata. Main hosts of this species are ordinary beans, lentils, forage legumes, carrot, parsley, celery and etc.

The other two genus of Orochanaceae family, Aeginetia and Christisonia, can be considered smaller problem on monocotyledonous plants. In agro-ecological region of Serbia, broomrape on sunflower in greater or lesser extent occurs almost annually and can cause significant damages. One of the most efficient and the most economical ways of control of these parasitic flowering plants is certainly sowing of resistant hybrids. For studies on hybrid resistance to broomrape it is very important to have broomrape seed of good rate of emergence. Trifender is biological product based Trichoderma asperellum. Broomrape rate of emergence is the lowest on medium with trifender; thus, the effect of this biological product for seed germination should be studied in more detail (Maširević et al., 2011).

Orobanche cumana Wallr., as well as other parasitic plants from the family Orobanhaceae, demand presence of chemical compounds from the environment as stimulus for germination. In the study of Plakhine et al. (2009) showed that seed germination of O. cumana is improved due to influence of synthetic nijmegen-1 strigolactone applied directly to dry seed. Studies directed toward development of PCR methods for detection of seed abundance of two parasitic plants Phelipanche ramosa and Orobanche cumana, as well as related species are used during harvest of rapeseed and sunflower. The method is based upon design of the starting probing. The method is based on the design of initial probing that is set for each parasitic plant with determination of transcribed space sequences for quantitative PCR determination. Together with the proposed DNA protocol, this diagnostic method allows a faster, high-throughput and accurate assessment of contaminated rapeseed, without complex purification steps and identification under a binocular microscope. TaqMan assay is highly specific, since it is not possible to detect plant impurities that are present in a given crops seed. The results of this test can be presented via the number of parasite seeds per kilogram of crops seed, which can contribute to improved sales of crops seed (Rodriguez et al., 2010). It is known that a new specific bioassays lead to the discovery of new classes of biologically active compounds (Yoneyama, 2010).
Cuscuta L.

Cuscuta species, commonly known as dodder, is among the best known parasitic plants, and is one of the most invasive weeds in the world. Species of Cuscuta, known as field dodder, is among the best known parasitic plants, and it is one of the most invasive weeds in the world (Lowe et al., 2001). Field dodders have a wide spectrum of hosts, although they favour less monocotyledonous species. Genus Cuscuta contains three sub-genuses. Members of subgenus monogina are robust vines that attack and destroy fruit trees, while the species in subgenus Cuscuta represents a problem for hosts of the herbaceous plants, as well as subgenus Grammica. Infected plants weaken; vegetative luxuriance is reduced, as well as their fertility (Koskela et al., 2001; Fathoulla and Duhoky, 2008). In moderate climate, field dodder is maybe the most important parasitic weed of legumes. C. campestris in alfalfa (Medicago sativa) is of special importance. Alfalfa and field dodder seed are alike by size, and by alfalfa sowing the parasites spreads with the host. The most efficient control measure is sowing of pure seed. Due to bumpy surface of field dodder seed, it retains, and cylindrical seed of alfalfa passes. Genus Cuscuta belongs to the family Convolvulaceae, although some authors think that it belongs to the other family (Cuscutaceae). Many species that are hardly recognizable and are able to parasite numerous shrubby and woody species belong to this genus. Although the results of the mitochondrial genome analysis confirmed a link between the family Convolvulaceae (McNeal & DePamphilis, 2000), some studies also show that Cuscuta phylogenetically belongs to the family Convolvulaceae (Stefanovic et al., 2002; Stefanovic & Olmstead, 2004).

The most widespread species in our country is Cuscuta campestris, that is considered holoparasitic for it does not have pigments for photosynthesis. Performed assays showed that it contains chlorophyll (a or b), during its whole vital cycle, although in much smaller quantities than other green plants. Presence of this pigment varies depending on plant development stage and reaches maximum during flowering. In it are present chloroplasts that function during whole plant life cycles that are able to perform photosynthesis by chlorophyll, although to a lesser extent, which forces it into heterophyl nutrition. Cuscuta campestris is extremely difficult to control, due to its well coated seeds, as well as its natural joining in host-parasite association. Making part of “seed bank”, Cuscuta seed in the soil maintains rate of emergence for long time, and it can survive at least 10 years in the field and up to 50 years in dry warehouses, depending
upon the species (Dawson et al., 1984). Chickpeas are very susceptible to *C. campestris*. However, there are several efficient selective products that are used in control of this parasite in chickpeas crops. After studies of several genotypes of Israeli varieties that are resistant to *C. campestris*, genotypes ICCV 95333 and Hazera 4 showed high resistance in more than 80% of the studied chickpeas (Goldwasser et al., 2012).

Seeds of *C. campestris* are different in size and usually germinate in the following year, creating radicle rich in nutrients and a stem. Radicle first penetrates slowly into the soil, but later it degenerates and decays so that the plant loses all connection with land. The stem is able to grow up to a month until it meets the host plant on which it fastens. It is in the form of a thread, with varying looks, yellow-whitish in colour, with no leaves and it is able to hold onto the host plant due to hooks, or papillae. The flowers are white, small and produce many seeds. The most frequent host plants of *Cuscuta campestris* are medicinal plants from family *Fabaceae*, as well as sugar beet crop. Control of this parasite is performed primarily by preventive measures, in order to inhibit seed germination. If the parasitic plant has already spread, herbicide application that acts on cell division is efficient. Field dodder is certainly great problem in cultivation of cranberry and other fruit trees shrubs (Sandler, 2010). With the aim of field dodder control, treatment is made in alfalfa 1-3 trifoliate leaf stage, or after first cutting with some of the following herbicides: imazethapyr, clethodim, propyzamid, diquat and fluazifop-p-butyl (Konstantinović et al., 2004). Use of *Cuscuta* species in control of invasive weed species is a new approach that is being developed in China in last years (Yu et al., 2011; Shen et al., 2011).

Conclusions

Even though 270 genera and 4400 species of flowering parasites are parasites, only about 25 genera have negative impact to cultivated plants and thus are considered pathogenic. Among them, two genera are the most harmful - *Orobanche* (broomrape) and *Cuscuta* (field dodder). Parasitic flowering plants are particularly harmful on legumes and crops belonging to family *Solanaceae*, primarily genus *Orobanche*. It produces thousands of tiny seeds that survive in the soil “seed bank” that makes control very difficult. However, as an integral part of every ecosystem that is compatible with its hosts, control is the only way for control of this parasite. Knowledge of the complex biology of parasitic flowering plants requires simultaneous studies of the host and parasitic flowering plant.
Literature


MAŠIREVIĆ, S., S. MEDIĆ-PAP, B. KONSTANTINOVIĆ, A. TERZIĆ, 2011: Germination of broomrape seed on different nutritive media. *11th World Congress on Parasitic Plants*. 7-12 June, Martina Franca, Italy.


SANDLER HILARY, A., 2010: Managing *Cuscuta gronovii* (Swamp Dodder) in Cranberry Requires an Integrated Approach. Cranberry Station, University of Massachusetts-Amherst, P.O. Box 569, East Wareham, MA 02538, USA.


