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Characterization of two rust fungi related to biological control concept in Hungary

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SUMMARY

Weeds cause serious problems in agriculture on a global scale. These plants reduce yield and the quality of crops by competing for water, nutrients and sunlight. The improper or excessive usage of herbicides have led to development of resistance in some weed species while contaminating the environment; therefore, biological control has an increasing role as an alternative method for controlling special weed species.
The aim of this study is to make a brief review of biological control of weeds by pathogens and to characterize two rust fungi (Puccinia lagenophorae and Puccinia xanthii) which are broadly examined recently in a biological control concept and have been found on their hosts, such as common groundsel (Senecio vulgaris L.) and common cocklebur (Xanthium strumarium L.), two common and difficult to manage weeds both in horticultural and agricultural lands also in Hungary.

Keywords*: biocontrol, rust, Xanthium spp., Senecio vulgaris, Puccinia xanthii, Puccinia lagenophorae*

INTRODUCTION

Of the pests which have economic and environmental importance, weeds are one of the most significant (Curtwell McFayden 1998). The improper or excessive usage of herbicides leads to the development of resistance in the target weed species as well as contamination of the environment; therefore, biological control has become an alternative method in the case of controlling a single weed species (Müller-Schärer and Frantzen 1996).

By, definition, the biocontrol of weeds is a deliberate use of living organisms to lower the population density of a weed species below its economic threshold (Radosevich et al. 1997).

Classical biocontrol by using of pathogens has been used in several parts of the world to control exotic weeds (Bruckhart and Hasan 1991, Watson 1991). The concept of this approach is to discover highly host-specific and effective agents from the native geographic range of the problematic weeds, examine their safety and effectiveness by experiments and introduce them into various regions where these (difficult to manage) weeds have been found and require control.

Shortly biological control of weeds can offer alternatives on economically and environmentally safe approach (Curtwell McFayden 1998) to reach sustainable agricultural production.

In biocontrol of weeds 3 main approaches can be distinguished: (1) the classical or inoculative approach which is based on introduction of a non-native control organism from the geographical area of the weed's origin (Watson 1991) released over a small area of a total infestation of the weed; (2) the bioherbicide or inundantive approach based on native pathogens applying in massive dosages of inoculum to the entire weed population like chemical herbicides in intensive agriculture; and (3) augmentative approach based on the application of low amounts of native natural enemies with relying on the reproduction ability of the biological control agent (Charudattan 1988).

Later Müller-Schärer and Frantzen (1996) introduced the system management approach which focuses only on native pathogens without the cautious manipulation of the weed pathosystem like introduction of an exotic control organism or the mass release of inocula. This approach is feasible for controlling weeds where natural enemy cannot be produced in large quantities or the introduction of an exotic natural enemy is not possible for some reasons.

Classical biological control has not been used widely in weed management especially in intensively managed crops due the slowness of its process compares to the short duration of cropping season (Charudattan and Dinoor 2000).

A good example for a successful biological control of weed with a rust fungus is *Puccinia chondrillina* to control *Chondrilla juncea* (skeleton weed) an important weed in Australian cereal crops. After the release and establishment this fungus disseminated widely and rapidly controlled this weed. The estimated cost benefit analysis of this project has resulted of 1:100 ratio (Cullen 1985).

In classical biological control of weeds rust fungi are the most widely used pathogens. That's because of their high level of specificity, they can cause severe damage on plants, and they have got efficient wind dispersal capabilities of spores (anemochory).

Host specificity is one of the most crucial attribute for biocontrol agent, especially if we considered for introduction into a new niche of environment.

Rust fungus are obligate parasites that live and propagate only on living hosts. The successful biological control of weeds by rust fungi involve autoaecious rusts, which complete their life cycles on one host. Heteroaecious rusts require two different host species to complete their life cycles (Dinoor 1981, Dinoor and Eshed 1987).

The success in biological control depends on survival and perpetuation of the pathogen. In this case the propagation of an autoaecious rust is a sure thing, but for heteroaecious rusts it is essential the presence of alternative hosts to serve as primary inocula source at the beginning of the season.

The aim of this study is to make a brief review of biological control of weeds by pathogens and to characterize two rust fungi such as *Puccinia lagenophorae* and *Puccinia xanthii* severally which are broadly examined in a biological control concept on their hosts, common groundsel (*Senecio vulgaris* L.) and common cocklebur (*Xanthium strumarium* L.) and commonly occur in Hungary both in horticultural and arable lands.

Common groundsel (*Senecio vulgaris* L., Asterales) and its pathogenic rust fungus *Puccinia lagenophorae* Cooke

Senecio vulgaris is a short-lived, annual species, originating most probably from southern Europe (Kadereit 1984), but nowadays it can be found all over the world.

It is a troublesome weed mostly in horticultural plantations, when the level of herbicide resistance is high within the weed populations and mechanical control is difficult or not possible to use. So, under these conditions biological weed control might be an alternative to traditional control methods.

Common groundsel occurs in both agricultural and ruderal habitats. In cultivated areas it is considered as an annual weed in horticultural plantations, orchards and plant nurseries.

Puccinia lagenophorae Cooke an autoaecious rust fungus is native to Australia, where it infects some native *Asteraceae* species. In Europe it was found first time in the early 1960'-s (Wilson et al. 1965). Until today about 80 host plant species of this fungus are known (Farr and Rossmann 2017).

Common groundsel (*Senecio vulgaris* L., Asterids, Asterales) was selected for detailed investigations of the COST project 816 (Biological Control of Weeds in Crops) (Müller-Schärer and Frantzen 1996).

P. lagenophorae is an autoaecious species forming only repeating aecia (stage I.) and telia (stage III.). Orange aeciospores infect leaves, stems and capitula causing severe malformations. The infections decreasing common groundsel biomass by 48% and the survive of the plant by 16% (Müller-Schärer and Rieger 1998).

The infection rate of the rust is higher in autumn than spring, which indicating that this rust fungus may require a period to recover from overwintering (Paul and Ayres 1986).

According to Frantzen and Müller-Schärer (1999) the infections established later in the year have a greater chance of surviving the winter period, because the infected host plants are more likely to live overwinter, thus the following spring can be serve as inoculum source.

In competition experiments common groundsel (*S. vulgaris*) reduced celeriac (*Apium graveolens* L., Asterids, Apiales) and lettuce (*Lactuca sativa* L., Asterales) yields by 28–50% in control pots, but the rust infection of *S. vulgaris* by *Puccinia lagenophorae* eliminated these yield losses (Paul and Ayres 1987, Müller-Schärer and Rieger 1998).

Common cocklebur (*Xanthium strumarium* L., Asterales) and its rust fungus *Puccinia xanthii* Schwein

Common cocklebur is an annual herb, 20–150 cm tall with a tap root, propagating and spreading by seed only. The stem of this weed is erect, ridged, rough hairy and usually branched and spotted with purple (Weaver and Lechowicz 1983). Leaves alternate, triangular-ovate to broadly ovate in shape, between 2–12 cm long, base often cordate, petiole 2 to 8 cm long at the sides irregularly toothed or lobed (Holm et al. 1977).

Resistant populations to imidazolinones of this weed have been reported in the USA (Heap 1997).

Puccinia xanthii is an autoaecious and microcyclic rust which lacking pycnial, aecial and uredinial stages (Parmelee 1969). Economically important *Xanthium* species are highly susceptible to this rust species (Hasan 1974). The host range of *P. xanthii* is relatively restricted. It is occurring and cause infections on *Ambrosia* species (Batra 1981), *Calendula officinalis* L. (Alcorn 1976), *Zinnia tenuiflora* (Alvarez 1976) and researches pointed on that it can be occur on some cultivars of *Helianthus annuus* L., too.

Results of researches showed that *Puccinia xanthii* has a potential biological control agent for the noogoora burr complex (*Xanthium* spp.) in different regions of Australia (Julien et al. 1979, Chippendale 1995). It can severely decrease the growth of this weed but rarely destroy the whole plant (Julien et al. 1979, Morin et al. 1993).

Infected plants mature rapidly than healthy ones and show decreased transpiration, dry weight, bur production and percentage of germination (Hasan 1974).

MATERIALS AND METHODS

Examined specimens

Field material of *Xanthium strumarium* infected with *Puccinia xanthii* was collected from various sites in Hajdúság region (East Hungary) (GPS coordinates: 47 15"59" N 21 29"54" E; 47 24"35.6 "N 21 31"53.3" E; 47 36"17.6" N 21 28"7.5" E). Infected specimens of *Senecio vulgaris* (*Puccinia lagenophorae*) were collected in Debrecen (GPS coordinates: 47 33"7.86" N 21 36"5.84" E). Infected leaves bearing aecia (*P. lagenophorae*) and telia (*P. xanthii*) placed in a professional plant press and kept at adequate conditions during transport.

Some specimens were dried in plant press at room temperature for two weeks before deposited in Plant Pathogen Herbarium of the Plant Protection Institute of University of Debrecen, Faculty of Agriculture, Food Sciences and Environmental Management.

Morphological characteristics

The morphological characters of aecia (*Puccinia lagenophorae*) and telia (*P. xanthii*) were measured on 50 randomly selected aeciospores and teliospores respectively.

Aeciospore length and width, wall thickness, and in case of teliospore length and width, pedicel length and width as well as wall thickness at the apex and at the sides were measured. No statistical analysis was performed on these data due to the relatively low number of samples.

Spores from dried herbarium specimens were examined using a Zeiss AxioImager A1 microscope. Digital images were recorded with an AxioCam MrC5 camera mounted on a Zeiss AxioImager A1 microscope (Zeiss, Germany) and images were processed with the software AxioCam 4.8.

For comparison with *Puccinia lagenophorae* published morphological descriptions were evaluated (Wilson et al. 1965, Scholler 1993, 1997; Littlefield et al. 2005). In case of *Puccinia xanthii* we used the parameters given by Parmalee (1969) and Dávid et al. (2003) to compare and determine the species.

RESULTS AND DISCUSSION

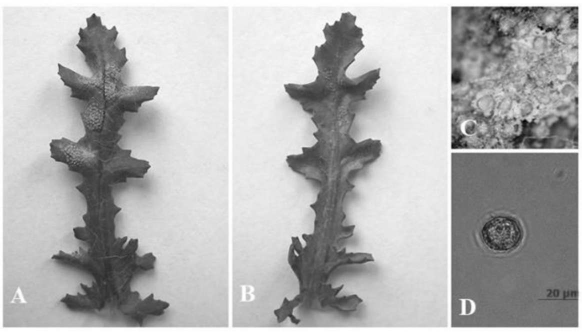
Morphological characterization of *Puccinia lagenophorae* Cooke

Aecia cupulate both on leaves, stems and floral pedicels surface. Aecia are amphigenous, situated in groups. The colour of the aecia varies from orange to yellow, peridium present and each aecia surrounded by it.

Aeciospores usually dispersed in the mounting fluid, without the fluid sometimes in chains of five to eight cells.

The shape of aeciospores is subglobose or ellipsoidal, in initial stages of development sometimes angularly compressed, yellow to orange coloured, 11–17.5×10.5–16 µm, the wall is thick (0.5 µm) and densely echinulate or finely verrucose with refractile granules (*Figure 1*). There were no telia found on examined material.

Figure 1: ***Puccinia lagenophorae*** **on common groundsel (*Senecio vulgaris* L.) – amphigenous, orange aecia on the leaf surface (A), undersurface of the aecia (B), close-up aecia from dried herbarium (C), and a thick walled, subglobose and echinulate aeciospore (D)**



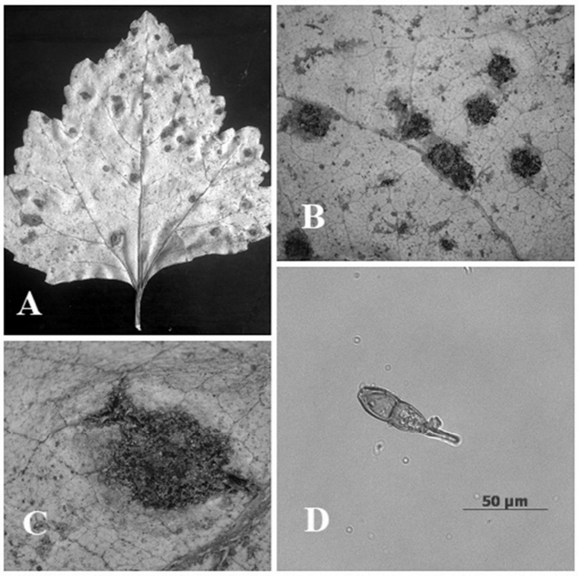
Source: Tóth (2017)

Morphological characterization of *Puccinia xanthii* Schwein.

Telia (~4 mm in diameter) mostly find on abaxial leaf surface in close groups of various sizes. The sori often confluent, the layer of spores is dark brown, sori lighter (chocolate) brown. It is compact, and from germination becoming gray coloured.

Two-celled teliospores are highly variable in shape and size (32–57×14–22 µm), sometimes narrowly obovoid, narrowly ellipsoid or nearly cylindrical. The wall at sides 1–1.5 µm thick, 5–10 µm at apex, golden brown. At the apex the colour of spore slightly paler, smooth surfaced. Pedicel is pale brown, rarely 50 µm long, but usually much shorter (*Figure 2*).

Figure 2: ***Puccinia xanthii*** **on common cocklebur (*Xanthium strumarium* L.) – telia in various sizes on abaxial leaf surface (A), chocolate brown sori (B), close-up picture from sori (C), and a golden brown narrowly ellipsoid teliospore (D)**



Source: Tóth (2017)

CONCLUSIONS

The successful biological control of weeds by rust fungi involves autoaecious rusts, which complete their life cycles on one host. Both *Puccinia lagenophorae* and *P. xanthii* meet these requirements, and experiments demonstrated that these species can cause severe malformations and can contribute to suppress growth and propagation of their host plants.

Restrictions of weed biocontrol by plant pathogens are the following: limited commercial interest in these weed control approaches and markets for bioagents are usually small and highly specialized, thus it is seemingly too small to be in interest for the traditional pesticide industry.

The complexities in production and the relatively low or restricted efficacy as well as shelf-life of the inocula are also crucial.

Both *Puccinia lagenophorae* and *P. xanthii* are obligate parasites, therefore, it is difficult to produce inocula in sufficient quantities for usage in inundative mycoherbicides. However, local applications particularly in herbicide-resistant populations of potential host plant can be reasonable. This can be promoted by precision and local applications by drone sprayer technology, as future drone tech is currently undergoing groundbreaking progressive improvement (Greenwood 2016, Joshi 2017).

Despite of these points, if we examine the number of successful cases and their cost-benefit ratios we can understand that biological control is a good option to keep in mind, and it is worth further investigation with these rust species.

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