

A Biological Control Agent for Rumex crispus L. 1/

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Phytopathogenic organisms probably are recognized most frequently in the United States for their disastrous effects either on the economy of the nation or on prominent constituents of the native vegetation. Commonly recalled examples are the catastrophic blight of the American chestnut caused by Endothia parasitica (Murr.) P. J. & H. W. Anderson, Dutch elm disease caused by Ceratocystis ulmi (Buismann) C. Moreau, and more recently the southern corn leaf blight Helminthosporium maydis Nisikado & Miyake. In 1967, following a survey on weed pathogens, the U.S. Department of Agriculture decided that an attempt should be made to reap some of the benefits of phytopathogenic organisms. The rust fungus Uromyces rumicis (Schum.) Wint. was selected for study to determine its potential as a biological control of curly dock (Rumex crispus L.) which is a common weed in the United States and other regions of the world. The study was made in Rome under a contract with the Stanford Research Institute of Irvine, California. Dr. Robert E. Inman, the principal investigator, reported on the preliminary phases of the research during the First International Symposium on Biological Control of Weeds (1). This paper is based on the final report of work done under the contract with Stanford Research Institute. 2/

Source of Pathogens and Host Plants

Urediospores of U. rumicis were collected from Cape Town, South Africa; near Rome, Italy; from Verona and Modena, Italy; from Montpellier and Alés, France; and from Offenburg, Germany. The collections were made from several sources in the hope of finding physiological races of rust differing in pathogenicity. It is interesting that no rust was found on R. crispus in Switzerland nor in a large contiguous area of Germany. All of the rust collections made were found to sporulate most freely on R. crispus var. typicus. Consequently, the variety typicus was used as much as possible for inoculations to culture urediospores. Inoculum used in the work was also derived from cultures on synthetic media.

Rumex crispus collected from Brookings, South Dakota; Thorp, Wisconsin; and two locations in California were used as host plants to determine the pathogenicity of U. rumicis to selections originating in the United States. A single selection of R. conglomeratus Murr. from California was also tested for susceptibility to the rust.

Pathogenicity of Uromyces rumicis

Leaf injury caused by rusts collected from South Africa and near Rome was very similar and depended largely on the level of infection. Leaves of R. crispus var. elongatus or typicus supporting heavy infestations were usually dead within a week after symptoms appeared. Moderate infection caused death of the leaves within 18 days. The rust collected near Rome was pathogenic to all host selections from the United States, including the selection of R. conglomeratus. However, the pathogenicity was much more severe to the hosts from Wisconsin and South Dakota, than to the host selections from California. Moderate levels of infection usually killed the leaves within 2 weeks. As was indicated earlier, the pathogenicity of the South African rust was very similar to that of the Rome rust. Rumex from South Dakota was more tolerant than the Wisconsin hosts; however, even the leaves of these plants died within 15 days following high levels of inoculation. The California selections of Rumex, although they supported rust infections, were tolerant of both the Rome and South African rusts.

1/ Presented at The 2nd International Symposium on Biological Control of Weeds. Rome, Italy Oct. 4-7, 1971

2/ Inman, R. E. Investigations to determine pathogenicity of selected pathogens to domestic weed species. Final report to the U.S. Department of Agriculture under Contract No. 12-14-100-9499. March 1970. 105 pp.

The rust collected at Verona was only moderately pathogenic to the Wisconsin selection of Rumex and was not studied extensively. The same was true of the rusts collected at Modena and Montpellier. Virulence of the rust from Alés, France was somewhat less than that of the Rome and South African collections, but more intense than the virulence of rust from other sources. The rust collected at Offenburg, Germany was only slightly less virulent than the Alés rust. Together, the virulence of rusts from Offenburg and Alés lay somewhere between that of the Rome and South African rusts and the rusts from Verona, Modena, and Montpellier.

Variability in Pathogens and Host Reactions

The disease reaction of individual selections of host plants varied when inoculated with a specific rust collection. The difference in reaction was due to variability of the host plants rather than the inoculum. Two types of reaction were distinguished. While the visible disease reaction differed with individual plants, only one type or reaction occurred on a given host. The principal reaction consisted of an enlarging pustule surrounded by a chlorotic area, with sporulation on both leaf surfaces. The less frequent disease reaction consisted of smaller pustules surrounded by light brown, pseudonecrotic areas. The infection area was always less in the latter reaction.

The Rome and South African rust collections were believed to be two distinct physiological races of U. rumicis. Basis for this conclusion was the development of different disease reactions from host plants having a history of predominantly one type of reaction to rust infection. When inoculated with the Rome rust collection, these plants responded primarily with one type of disease reaction. However, when inoculated with the South African rust, the second disease reaction occurred most frequently. Not only were the Rome and South African rusts considered distinct races, but the South African rust itself appeared to be of two different races. The races could be distinguished by size of the pustule produced on the host. When separated, spores from small pustules consistently produced small pustules, and spores from large pustules produced large pustules. This occurred through four generations.

Experimental Hosts

An important phase of the research was the screening of various agricultural crops for susceptibility to infection by U. rumicis. A total of 38 experimental hosts was tested (Table 1). Seventeen were inoculated with both the Rome and South African rust collections in separate tests, one was inoculated with the Rome rust only, and 20 were inoculated with a mixture of spores from the seven rust-collection sites. None of the experimental crop hosts became infected and it appeared that the host range of U. rumicis is restricted to the genus Rumex, and the subgenus Lapathum. This group of hosts includes R. crispus, R. obtusifolius, R. conglomeratus, R. pulcher, and several other species.

Plot Tests

Plot tests were made to determine the effects of rust infection on plant growth and seed production under natural conditions, and to test the effectiveness of artificial field inoculations in increasing the intensity of rust infection over that of natural infection. Fifteen plots were divided into two sections of 9 and 6 plots each. The larger section was used for artificial inoculation experiments and controls, while the smaller section of 6 plots was used as additional checks for natural infection. Inoculations were made by an oil-spore suspension, and by a talcum-spore mixture. Oil inoculations were made the latter part of March, while the talc inoculations were made April 3. Control plants were treated weekly with zinc ethylenebis(dithiocarbamate) (zineb) to control the rust. Infection in the talcum-spore mixture inoculated plots was much heavier and more uniform than infections from the oil-spore suspension. The zineb treatment to prevent rust infection was singularly successful. The treated plants retained a full complement of leaves during the vegetative and reproductive stages of growth.

Infection of the host plants by artificial inoculation preceded natural infection by

several weeks. Unfortunately, there was no rainfall from April 28 to May 27, and rust development was greatly retarded. Beginning May 27, a 7-day wet period occurred with a rapid development of the rust infection. However, much of the growth of the host plants occurred during the month-long dry spell which probably accounted for the larger than anticipated size of the infected plants. By June 13, considerable leaf kill was evident on the oil-spore inoculated plants. By June 25, plants inoculated with the talcum-spore mixture were completely defoliated and maturity and drying of fruits were well advanced. Natural infection of untreated plants was delayed until several days following the wet period which began on May 27.

Seed Production

The attempt to determine the effects of infection by *U. rumicis* on seed production, seed size, and germinability was unsuccessful. Differences in numbers of seed produced by infected and noninfected plants were not significant. Although weights of seeds from inoculated plants were lower, germinability of the seeds was not effected. The major development of rust, following the dry period that coincided with the period of flowering and initial seed development, did not seriously impair seed production.

Survival of Rust-Infected Plants

Following harvest of the plants for seed analysis, it was noted that zineb-treated plants soon resumed growth and produced a number of new tillers while infected plants remained inactive. This was the first evidence of the deleterious effect of infection on vigor of the rootstocks of rusted plants. This effect was also evident when the plants began the fall growth phase typical of this species. The number of infected plants showing growth, and the amount of growth could be correlated with the degree of infection observed. Survival of rust-infected plants from fall to spring was 43%; while survival of zineb-protected plants was 95%. Mortality of the infected plants was presumed due to a decrease in rootstock vigor. This presumption was supported by other studies which showed the weight of roots from healthy plants to be approximately twice that of roots from infected plants.

Alternate Host of *Uromyces rumicis*

Ranunculus ficaria L. has been implicated in the pycnial and aecial stages of *U. rumicis*. Infectivity tests conducted by Gaumann confirmed this species as the alternate host. An attempt was made with little success to determine the role of *R. ficaria* in the rust's life cycle. All attempts to germinate teliospores either on glass slides or on *R. ficaria* itself were unsuccessful. Extensive surveys of *R. ficaria* resulted in finding a few plants, having a total of four aecia, near Lago Bracciano, Italy. Comparative infectivity tests appeared to confirm that the pathogen was *U. rumicis*.

The observation of the uredial stage of the rust throughout the winter, and the almost complete failure to observe pycnial and aecial stages of the rust on the alternate host, suggest strongly that *U. rumicis* overwinters, at least in the Rome area, mainly as uredia or vegetative mycelia on the primary host. Primary infection in the spring is by urediospores rather than aeciospores from the alternate host.

Further studies on alternate hosts of *U. rumicis* were conducted in the United States. Inoculations were made on the recognized alternate host of the rust, as well as on the two ornamental selections, *Ranunculus asiaticus* L. and *Anemone coronaria* L. Despite various pretreatments to break the teliospore dormancy, all efforts to infect these species were unsuccessful.

Supplemental Host Specificity Studies

Although the greatest risk in introducing exotic pathogens is the danger of infecting economic crops, there is considerable concern that the pathogens may attack wild species that are beneficial to wildlife, or are desirable for other reasons. Tests conducted in Rome demonstrated the safety of the pathogen with respect to numerous crops. (Table 1).

In addition to this, supplemental screening was done in the United States to test the pathogenicity of the rust to representative relatives of R. crispus that are recognized as valuable sources of food for wildlife. The species tested were:

R. maritimus var. fueginus (Phil.) Dusen.
Polygonum natans (P. amphibium L.)
P. coccineum Muhl.
P. punctatum var. robustius (Small) Fern.
P. hydropiper L.
P. lapathifolium L.
P. hydropiperoides Michx.

and

Eriogonum umbellatum Torr.
E. nudum Torr.
E. deflexum Dougl.

Of the 10 experimental hosts, only R. maritimus was susceptible to infection. All species of Eriogonum and Polygonum were immune.

Because of the inability to gain more positive knowledge concerning the alternate hosts of U. rumicis, release of the organism in the United States has not been approved. Hopefully this information will be obtained and the potential of this pathogen utilized in control of curly dock.

Table 1. Experimental Hosts Immune to Infection by Various Inocula of Rumex Rust.

Host	Variety	Inocula ^a /
Alfalfa	---	3
Anemone	Anemone coronaria var. St. Brigid	3
Barley	Atlas	1,2
Barley	Blue Mariot	1,2
Bean (field)	Pinto	1,2
Beet (garden)	Early Wonder Green Top	1
Beet (sugar)	HH 5	3
Blue grass	---	3
Buckwheat	---	1,2
Broccoli	---	3
Carrot	Imperator	3
Celery	---	3
Clover	Crimson	3
Clover	Egyptian	3
Clover	Red	3
Clover	White	3
Corn (field)	KY 7A hybrid	1,2
Corn (sweet)	NK 1304 hybrid	1,2
Cotton	Acala	1,2
Grape	Kober 5 BB	3
Lemon	Santa Teresa	3
Lettuce	Great Lakes R-200	3
Oat	Kanota	1,2
Oat	Sierra	1,2
Orange (sweet)	Biondo Comune	3
Potato	---	3
Rhubarb	Myatts Victoria	1,2
Rice (paddy)	Earlirose	1,2

Safflower	Gila	1,2
Sheep sorrel	(Wild collection, Thorp, Wisconsin)	1,2
Sorghum	NK 222 hybrid	1,2
Soybean	Hawkeye	3
Sweet clover	White Standard	3
Tangerine	Ajana	3
Tobacco	---	3
Tomato	Globe WR-7	1,2
Wheat	Federation	1,2
Wild buckwheat	(Wild collection, Brookings, South Dakota)	1,2

^a/1=Italian rust, 2=South African rust, 3=mixture of rusts from all 7 locations.

Literature Cited

- (1) Inman, R. E. 1969. Control of Rumex crispus L. with the rust fungus, Uromyces rumicis (Schum.) Wint. Preliminary investigations. Proc. First Int. Sym. on Contr. of Weeds.

DISCUSSION

CAVERS Our group might be appropriate for further work on Rumex crispus since I have worked on this species for the past 12 years. With regard to varietal names I believe that variety arvensis is applied to the usual form and variety elongatus would be the form with the non-crisped or non-curved leaves. I have not heard of variety typicus before.

FRANK I don't know where the variety typicus came from, perhaps other people can help you on that.

CAVERS Did you look at rhubarb as an alternate host?

FRANK Yes, rhubarb was among the non-susceptible crops tested.

CAVERS There are also a number of species of Rumex in the sub-genus Lapathum which are North American in origin and which are apparently very important as food for wild fowl, e.g. Rumex verticillatus, Rumex orbiculatus. Dr. Inman didn't say that these have been tested and I presume they haven't been considered. I would also suspect that they would be susceptible to the fungus.

FRANK All I can say is that several of these species are listed followed by a group designated as "others". So among the "others" may be some of those you are speaking of.

CAVERS There is a considerable difference in the whole biology of Rumex crispus from the southeastern United States where it is very common through to the places you've mentioned. For example, in the southeastern states it is typically an annual plant. It grows very quickly there and will flower within 16 weeks. I wonder if plants from that area might be useful for testing?

FRANK There is no mention of this in the work that Dr. Inman did other than his description of Rumex crispus as a perennial weed.

CAVERS The normal plant from the northern U.S.A. or Canada would be quite different in that it has to go through a winter experience before it flowers.

LITTLE Did you say, Dr. Frank that you can inoculate these Rumex as seedlings or can you only inoculate them when they are relatively mature.

FRANK The Rumex can be inoculated and become infected any time that the spores are present and the weather conditions are suitable. It's the teliospore inoculation and germination on the alternate host that we haven't been able to obtain.

LITTLE What I want to find out is, can you inoculate when the plant is a seedling? Can you prevent it seeding altogether or does it go on through to these big seed heads we saw?

FRANK Dr. Inman's work suggests that seedlings can be inoculated and infected. However, the seed of Rumex probably germinates and the seedling makes a good deal of growth during autumn and early spring when conditions are not favorable for massive infection and growth of the rust. He concluded that the final size of his test plants was due in large part to the dry weather which prevented rust development but did not retard the growth of Rumex.

END OF DISCUSSION

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