A Preliminary Evaluation of Rumex Rust as a Biological Control Agent for Curly Dock

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ABSTRACT

Effects of infection by *Rumex* rust, *Uromyces rumicis* (Schum.) Wint., on seed production and rootstock vigor of curly dock, *Rumex crispus* L., were studied under natural conditions. Comparisons were made between rusted (inoculated or naturally infected) plants and plants protected from infection with a fungicide. Average seed yields from healthy samples were greater in total sample weight and seed number than from rusted samples, but differences were not significant. Distribution of seed weights in samples was shifted toward lighter weights by infection.

In rusted field plots, 43% of the plants resumed growth the following spring, as compared to 95% in fungicide-treated (nonrusted) plots. Dry weight of roots from fungicide-treated, potted plants was 85% greater than that from potted, rusted plants.

The 36 crop selections inoculated with urediospores were immune to infection. Of 12 weedy, experimental polygonaceous hosts, only *Rumex maritimus* was susceptible. Attempts to infect the alternate host, *Ranunculus ficaria* L., and ornamental ranunculaceous selections by teliospore inoculations were unsuccessful. Phytopathology 61:102-107.

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Weedy pests of croplands can in most cases be satisfactorily controlled by conventional methods. On agricultural lands of marginal profit status (grazing lands, watersheds, etc.), however, the low financial returns often do not justify the costs of herbicide applications. In such situations, biological control agents may be useful in controlling specific weeds providing that agents with a high order of host specificity can be found which cause sufficient damage to the target weed. Thus, an effective control agent would reduce the vigor and reproductive capacity of the target weed below the critical level without damaging other plant species, and would be capable of maintaining itself in the target area following its release, eliminating the need for periodic applications. A salient feature of biological control is the elimination of chemical residue complications, an especially significant consideration in watershed areas.

Biological weed control has largely involved the use of phytophagous insects, and in several instances remarkable success has been achieved (2). The use of plant pathogens is encouraged by these results because of the similarity of the two approaches. Both approaches involve searches for likely candidate organisms, study of etiology, host-parasite relations and host range, and eventual release in selected target areas. Interest in phytopathogenic weed control is increasing (7), but plant pathogens have not as yet been widely sought or tested as control agents.

The USDA, Crops Protection Research Branch, began in 1965 to sponsor a study of the feasibility of controlling specific weeds in the United States with plant pathogens. The intent was to search for and collect likely pathogens on selected weeds or their close relatives, to determine the effects of infection on the target weed, and to delineate the pathogens' host range as regarded both wild and cultivated plants. On the supposition that pathogens excluded from the United States by natural barriers would offer greater promise as control agents than those already present, only nonresident pathogens were considered. Because of the danger of importing alien pathogens for tests, preliminary testing was conducted overseas. With the permission and cooperation of the Italian Ministry of Agriculture and Forests, a research base was established at the Istituto Sperimentale per la Patologia Vegetale, Rome, Italy, where temporary quarantine facilities (4) were constructed to test pathogens collected outside Italy.

Early in these studies, the perennial polygonaceous weed curly dock, *Rumex crispus* L., was chosen as an experimental target weed on the basis of its common occurrence, its importance as a pasture weed in certain southern states, and because it was severely attacked in parts of Europe by the rust fungus, *Uromyces rumicis* (Schum.) Wint. This macrocyclic, heteroecious rust is not listed by Arthur & Cummins (1) as occurring in the United States, although three collections on *R. crispus* were reported early in the century from the San Francisco Bay area. The rust is not reported from any other part of the country, and is presumed absent. Information available on the biology of *Uromyces rumicis* has been reported by Inman (5).

This paper describes research conducted to evaluate *Rumex* rust as a biological control agent for curly dock in the United States. Objectives were to determine the effects of the rust on host vigor and seed production under natural conditions in Italy, and to screen selected crop plants and weedy relatives of curly dock for disease susceptibility under greenhouse conditions. On the basis of these preliminary studies, a decision was to be made as to whether to import the rust fungus for release and further field trials in the United States.

MATERIALS AND METHODS.—Field tests were conducted during the 1968 and 1969 growing seasons. The 1968 tests utilized Italian specimens of curly dock of undetermined ages lifted from their natural habitats and transplanted in field plots. The 1969 tests used 1.5-year-old plants originating from seed collected near Thorp, Wisc. Since it was not advisable to deliberately introduce the U.S. host selection into Italy by planting in open field plots, these plants were grown in 14-inch pots on the open roof of the Istituto. Screening of experimental hosts was conducted in the quarantine facility at the Istituto and later in USDA research facilities, Plant Industry Station, Beltsville, Md.

The field plots were established during December 1967. Each plot contained nine plants spaced 1 m apart in three rows of three plants each. Treatments were (i) inoculations with urediospores suspended in mineral oil, 1 part spores:20 parts oil; (ii) inoculations with urediospores in talc, 1 part spores:10 parts talc; (iii) weekly sprays with the zineb fungicide, Siaprit (zinc ethylenebisdithiocarbamate, 45%; ethylene thiuram monosulfur monomer, 5%: Societa Italo Americana Prodotti Antiparassitari; Roma, Italia); 125 g/100 liters applied to runoff; and (iv) untreated control. Three plots were assigned to the untreated control, and two plots to each treatment. Urediospores originated solely from collections made initially in the Rome area and increased on curly dock in the greenhouse. Preliminary greenhouse tests showed that the zineb fungicide prevented rust infection and was not phytotoxic to curly dock at recommended doses.

The purpose of the field inoculations was to provide an initial uniform level of infection which would be permitted to increase as governed by prevailing field conditions. Due to the typically unequal distribution of rust between lower and upper leaves as test plants continued to increase in height and to form new leaves, no disease intensity ratings were made throughout the growing season. Oil-spore inoculations were conducted on 27 March, using a large camel's-hair brush. All leaves showing on this date (5-35 leaves/plant) were inoculated. Talc-spore inoculations were conducted on 3 April by dusting, and repeated on 17 April. All field inoculations were completed prior to tiller proliferation and the appearance of natural infection in untreated control plots. The fungicide treatment was initiated 26 March and continued weekly until harvest the first week in July.

Plants for the 1969 rooftop study were grown from seed in the greenhouse. During November 1968, when seedlings were approx 1 year old, they were transplanted to 14-inch pots and transferred to the field to overwinter under natural conditions to assure flowering during the test growing season. All plants were transferred to the rooftop 10 April 1969. Treatments were (i) talc-spore inoculations 1:10; and (ii) the zineb fungicide sprays, 30 plants/treatment. Inoculations were conducted 3 April, while the plants were still in the field, and 17 April. The weekly fungicide applications were initiated 31 March.

Samples for yield analyses for field plot tests consisted of seeds from one tiller randomly selected from each of 7 plants/plot. The entire seed yield of each plant was harvested for the rooftop tests. Seeds from each tiller or plant were treated as individual samples. The dry, bracted seeds were stripped manually from the fruiting stalks, and the seeds were forced from between the bracts by gently grinding between two wood-backed 6×6 inch squares of 15-mesh hardware cloth. Seeds were then separated from the chaff via air fractionation in a Lartschneider table-top air-classifier.

Seeds in each sample were divided into six wt classes via air fractionation, and per cent total sample wt of seeds in each class was determined. The six wt classes were chosen to include the range of seed wt experienced, as designated by index markings on the air-flow regulator of the Lartschneider apparatus. Differences between classes in seeds/g from field plot plants were highly significant, as shown by a statistical analysis of seed numbers in eight 250-mg aliquots per class. Average seed number ranged from 1,179/g in the lightest wt class (Class "45") to 392/g in the heaviest weight class (Class "85+"). Seeds from the rooftop plants were lighter and smaller than from field plants, and consequently required a different range of wt classes.

Average seed number per sample was estimated by combining and mixing samples in each treatment and counting seeds in weighed aliquots. Germinability of field plot seeds was determined in three replicates of 50 seeds each/wt class per treatment. Replicates were averaged and results expressed as average per cent germination per wt class. Germinability of seeds from rooftop plants was not determined.

Rootstock vigor of field plot plants was estimated by the number of plants per treatment which exhibited new growth the year following treatment. Rootstock vigor of the potted rooftop plants was estimated by air-dry root wt. Supplementary tests were conducted under greenhouse conditions (Beltsville) to determine the possible effects of two zineb fungicides on dry root wt of nonrusted plants. Three treatments, including an untreated control, consisting of 30 plants each were compared. The fungicides, Zineb 75 (zinc ethylenebisdithiocarbamate, 75% WP; Miller Chemical and Fertilizer Corp.) and Siaprit Bianco (zinc ethylenebisdithiocarbamate, 45%; ethylene thiuram monosulfur monomer, 5%; sulfur, 5%; Societa Italo Americana Prodotti Antiparassitari) were applied weekly for a period of 9 weeks, beginning when seedlings were 2 months old. Doses containing 0.93 lb./100 gal were applied to runoff. At the end of the treatment period, roots and tops were separated, dried at 180 F for 5 days, and weighed.

Urediospore inocula used in greenhouse pathogenicity tests consisted of a mixture of spores of *U. rumicis* collected in Italy, France, Germany, and South Africa. At least five plants/experimental host were inoculated, except for grape and *Citrus* spp., where two plants each were used. Spores were smeared lightly and evenly over moistened leaf surfaces with a spatula, and plants were then placed overnight in a saturated atmosphere at 17-19 C. Curly dock was used as a control. Disease observations were recorded 2 weeks after inoculation.

For alternate host studies, curly dock leaves bearing telia collected near Rome during May 1969 were used as inoculum. Leaves were pretreated prior to use for a 5.5-month period during fall and winter 1969 in an attempt to break spore dormancy by simulating overwintering conditions. Pretreatments were (i) natural overwintering on the surface of potted soil; (ii) natural overwintering in a nylon-screen bag; (iii) continuous −8 C; (iv) continuous +5 C; and (v) alternating freeze-thaw temp (−8 C for 16 hr, +5 C for 8 hr). Experimental hosts were the ornamental ranunculaceous species, *Ranunculus asiaticus* L. and *Anemone coronaria* L. The recognized alternate host, *Ranunculus ficaria* L., was used as control. For inoculations, pretreated leaves were placed in contact with leaves of young, developing test plants. Plants thus inoculated were either placed in a mist chamber at 19 C each night and moved to the greenhouse bench each day (19 C), or were placed outside the greenhouse under natural winter conditions (February-March, Beltsville, Md.) for 1 month before being removed to the greenhouse.

RESULTS.—*Observations on rust buildup.*—Pustules developed in inoculated field plots (1968 tests) within 1 week following inoculation. Natural infection was observed in untreated control plots 3 weeks after initial inoculations. No rust developed in the fungicide-treated plots throughout the season. Under favorable conditions, infection spread from inoculated lower leaves to upper leaves as tillers developed and new leaves were formed.

During the first 25-day period, sufficient rain and heavy dews provided favorable conditions for infection and spread, and 6:00 AM field temp at lower leaf level averaged 8 C. During the following 30-day period (27 April-27 May) no rainfall occurred, no dew was observed on test plants after 8:00 AM, and 6:00 AM temp averaged 11 C. Disease buildup slowed considerably during this period, as indicated by the meagre amount of infection which developed on newly formed upper leaves. Moreover, the period 20 April-1 June was critical for host development, for during this period plants flowered and set seed, and a major amount of foliage developed. By the time favorable conditions for rust development returned, the critical developmental period for the host had passed.

During the 7-day period beginning 27 May, field plants were continuously wet due to intermittent rains. On 4 June, a large rust buildup was observed to have occurred in inoculated and untreated control plots. The surge in rust intensity was attributed to the immediately preceding period of favorable conditions for infection and the large amount of inoculum already present in the field. A second rainy period occurred 5-7 June. From this date to the time of harvest, major foliage damage was observed, and continuously widening differences in thriftiness were observed between rusted and fungicide-treated plants. Figure 1 represents the prevailing condition of infected and control field plot plants on 25 June. Infected plants were essentially defoliated by this date, whereas protected plants were still leafy and green.

Rust development during the 1969 tests was slower than during the 1968 season, due probably to the location of the plants on the rooftop, approx 50 ft above field level. Dew formation was never observed in this location throughout the test period (no inspections were

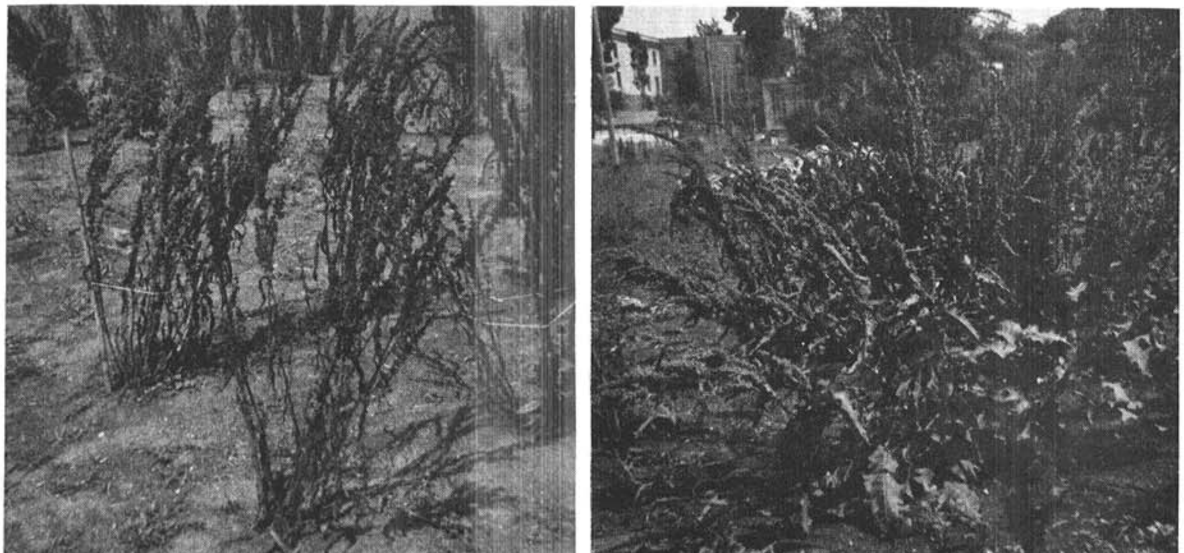

Fig. 1. (Left) Curly dock plants in an inoculated field plot, showing the level of foliar injury evident on 25 June. (Right) Curly dock plant in a fungicide-treated field plot, showing the level of healthy foliage development evident on 25 June.

made prior to 8:00 AM). Symptoms of infection were observed 8 days following the initial inoculation. This infection killed most of the inoculated leaves within 3 weeks, but infection did not spread rapidly to new foliage. Unfavorable moisture conditions for rust development continued generally throughout the season, rust intensity never attained serious proportions, and little difference in thriftiness between rusted and nonrusted plants was apparent until the middle of June.

Seed analyses.—Apparent rust intensities in the three rusted field treatments were equivalent through June. Rusted treatments were therefore combined, and yield comparisons were made between rusted and nonrusted (fungicide-treated) plants. Total seed wt per sample tiller averaged 16.26 g from rusted plants and 18.7 g from nonrusted plants. Seed number from nonrusted tillers averaged 11.6% greater than from rusted tillers. Differences in yield between rusted and nonrusted samples, however, were not significant. Total seed yield varied widely within the 1969 rooftop treatments from 5.92 to 32.86 g/plant in the rusted treatment, and from 6.63 to 44.20 g/plant in the fungicide treatment. The differences between average treatment yields were not significant.

The wt distribution of seeds within rusted field plot samples was significantly higher in the lighter wt classes, and significantly lower in heavier wt classes, than that of seeds in nonrusted samples (Fig. 2). Fifteen per cent by wt of seeds from rusted plants occurred in the light wt class "55", compared with 5% of seeds from nonrusted plants, and 30% compared to 12%, respectively, in class "65". A significant difference also occurred in the heavy wt class "85", where the distribution of seeds from nonrusted plants was 18% greater than from rusted plants. Differences in class "85+", the heaviest wt class, were significant at the .10 level of probability.

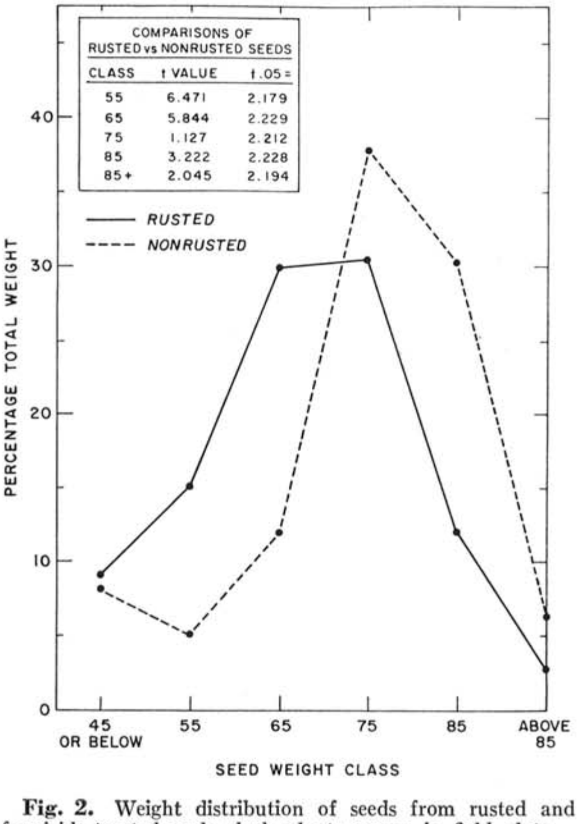

Fig. 2. Weight distribution of seeds from rusted and fungicide-treated curly dock plants grown in field plots.

Seed wt distribution curves for the two rooftop treatments were similar to those shown in Fig. 2 for field treatments. Seeds from rusted plants averaged 812/g as compared to 844/g for nonrusted plants. This relatively small difference was highly significant ($P = < .01$).

Germinability of seeds from field plots was equivalent in seeds of equivalent wt, regardless of whether they had been harvested from rusted or nonrusted plants, and increased with seed class wt. Average germination was 30.5% in class "45", 79.0% in class "55", 90.4% in class "65", 95.7% in class "75", 97% in class "85", and 97.6% in class "85+". Differences in per cent germination were highly significant ($P = < .01$) between classes "45" and "55", between "55" and "65", and significant ($P = < .05$) between classes "65" and "85". The effect of infection in reducing seed wt would be reflected in a lower germination percentage of the total seed crop, resulting in a lower reproductive potential of rusted plants. The extent of this reduction would depend upon the intensity and chronology of infection.

Observations on rootstock vigor.—Any deleterious effect of infection and consequent defoliation on the rootstock vigor of the perennial host might be reflected in the number of rootstocks capable of producing new plants the following season. The number of field plot plants (rusted or nonrusted during 1968) which had resumed growth by the next spring was recorded on 19 March 1969 (Table 1). New growth was usually evident by October of the previous year, and plants overwintered in the green rosette stage. Rosettes generally began expanding again in February. Of the 63 plants that had been heavily rusted and had suffered severe foliar damage by 25 June 1968, only 27 (43%) showed any evidence of new growth on 19 March 1969. Of the

TABLE 1. Survival of rusted and nonrusted curly dock plants from 1968 to 1969 in field plots

		No. plants[a]		
Treatment	Treated	Rusted 1968	Survived[b] 1969	% Survival/treatment
Inoculated, oil-spore suspension	18	18	6	33.3
Inoculated, talc-spore mixture	18	18	9	50.0
Control, natural infection	27	27	12	44.4
Control, fungicide-treated	18	0	17	94.4

[a] Values based on three 9-plant replicates for the natural infection control treatment, and on two 9-plant replicates for each of the other treatments.

[b] As observed 19 March 1969.

18 fungicide-treated plants, however, 17 (94%) had resumed growth. The lone mortality among the fungicide plots was a plant which had persisted throughout the previous growing season in a decidedly unthrifty condition. Moreover, the new growth of surviving plants was much more luxuriant in the fungicide treatment than in the rusted treatments.

The survival percentage of potted rooftop plants (1969 tests) could not be assessed due to termination of the project prior to spring, 1970, so root wt were used to estimate the effect of infection on rootstock vigor. Air-dry wt of roots from the fungicide treatment averaged 51.3 g/plant, as compared to 27.7 g/rusted plant; an average difference of 85%. Under greenhouse conditions, dry root wt of plants treated with zineb 75% WP were 10% greater than either those from healthy, untreated controls or those treated with the Italian zineb fungicide, Siaprit Bianco. Although this difference was statistically significant, it was not sufficient to account for the difference observed in the 1969 rooftop studies. Hence, the differences in rootstock vigor parameters between rusted and healthy plants may be ascribed to the deleterious effects of infection rather than to any nutritive benefits afforded to healthy plants by the fungicide. The conclusion that rootstock vigor in curly dock is adversely affected by infection with *U. rumicis* is compatible with the extent of foliar injury shown in Fig. 1, left.

Infectivity tests on experimental hosts.—All experimental hosts outside the genus *Rumex* proved immune to infection when inoculated with urediospores of *U. rumicis*. Curly dock controls become heavily rusted in all tests. The plants tested (Table 2) included 36 crop selections, of which rhubarb and buckwheat were in the same family (Polygonaceae) as curly dock; and 12 polygonaceous weeds, most of which have value as wildlife food. The only experimental host which was susceptible to *U. rumicis* was *Rumex maritimus* L., a close relative of curly dock and a member of the same subgenus, *Lapathum*. *Rumex acetosella* L. (red sorrel), of the subgenus *Acetosella*, was immune.

The crops which were immune as primary hosts from infection with *U. rumicis* were alfalfa (*Medicago sativa* L.), barley (*Hordeum vulgare* L. 'Atlas' and 'Blue Mariot'), bean (*Phaseolus vulgaris* L. 'Pinto'), garden beet (*Beta vulgaris* L. 'Early Wonder Green Top'), sugar beet (*B. vulgaris* L. 'HH 5'), bluegrass (*Poa pratensis* L.), broccoli (*Brassica oleracea* L. var. *botrytic*), buckwheat (*Fagopyrum esculentum* Moench.), carrot (*Daucus carota* L. var. *sativa* DC. 'Imperator'), celery (*Apium graveolens* L. var. *dulce* DC.), crimson clover (*Trifolium incarnatum* L.), Egyptian clover (*T. alexandrinum* L)., red clover (*T. pratense* L.), white clover (*T. repens* L.), field corn (*Zea mays* L. 'KY7A Hybrid'), sweet corn (*Z. mays* L. 'NK 1304 Hybrid'), cotton (*Gossypium hirsutum* L. 'Acala'), grape (*Vitis vinifera* L. 'Kober 5BB'), lemon (*Citrus limon* [L.] Burm. 'Santa Teresa'), lettuce (*Lactuca sativa* L. 'Great Lakes R-200'), oak (*Avena sativa* L. 'Kanota' and 'Sierra'), orange (*Citrus sinensis* [L.] Osbeck 'Biondo Comune'), potato (*Solanum tuberosum* L.), rhubarb (*Rheum rhaponticum* L. 'Myatts Victoria'), paddy rice (*Oryza sativa* L. 'Earlirose'), safflower (*Carthamus tinctorius* L. 'Gila'), sorghum (*Sorghum vulgare* Pers. 'NK 222 Hybrid'), soybean (*Glycine max* L. 'Hawkeye'), spinach (*Spinacia oleracea* L. 'Andalus'), sweet clover (*Meliotus indica* [L.] All. 'White Standard'), tangerine (*Citrus nobilis* var. *deliciosa* [Ten.] Swingle 'Ajana'), tobacco (*Nicotiana tabacum* L.), tomato (*Lycopersicon esculentum* Mill. 'Globe WR-7'), wheat (*Triticum aestivum* L. 'Federation'), and wind flower (*Anemome coronaria* L. 'St. Brigid').

Species of polygonaceous weeds immune from infection were *Rumex acetosella* L., *Polygonum convolvulus* L., *P. natans* (Michx.) Eat., *P. coccineum* Muhl, *P. punctatum* Ell. var. *robustius* (Small) Fern., *P. hydropiper* L., *P. lapathifolium* L., *P. hydropiperoides* Michx., *Eriogonum umbellatum* Torr., *E. nudum* Torr., and *E. deflexum* Dougl.

The recognized alternate host of *U. rumicis* is the wild buttercup, *Ranunculus ficaria* L. Attempts to induce pycnial and aecial infections via teliospore inoculations on the ornamental ranunculaceous species, *R. asiaticus* L. and *Anemone coronaria* L., were unsuccessful. Tests were inconclusive, however, because no infection was obtained on the *R. ficaria* controls. Five pretreatments of teliospores were unsuccessful in stimulating germination.

DISCUSSION.—Two types of injury may occur on curly dock under natural conditions as a result of infection: reduction of seed yield in terms of average seed wt and total seed number, and reduction of rootstock vigor exemplified by decreased root wt and rootstock reproductive potential, although significant differences in seed yields could not be demonstrated due to high levels of variation within treatments. Unfortunately, from a research viewpoint, high levels of variation are characteristic of wild populations, and greater sample numbers are needed to verify differences.

Under conditions favorable to rust buildup during the critical host growth period, meaningful reductions in seed production could be expected. Although critical requirements have not been determined, rust buildup in the field appears to be favored by prolonged cool, wet periods. Following the preliminary stages of growth resumption and tiller proliferation during the late winter and early spring, the critical host growth period in the Rome area occurs between 20 April and 1 June. Heading occurs generally toward the end of April, and flowering and seed-set during May. In both the 1968 and 1969 test seasons, conditions during this critical period were unfavorable for rapid rust increase. Precipitation essentially did not occur, and dews were light in the field and were not observed at the rooftop site. The rapid increase of the rust, with the return of favorable conditions in June, reached severe proportions in the field plots, resulting in the essential defoliation of rusted plants by 25 June. This event, although in all probability responsible for the observed reduction in rootstock vigor, did not have a proportionately large effect on the production of seeds, which were set and maturing well before infection reached damaging levels.

Likewise, during the 1969 rooftop tests, the pathogen developed on inoculated leaves but did not spread upward to newly developing tissues. Thus, seed production was not significantly affected.

The extent of reduction in rootstock vigor as suggested by these preliminary results is encouraging from a control viewpoint. If the observed results were due to rust infection as indicated, *U. rumicis* must be regarded as a promising candidate control agent. A limited degree of curly dock control by *U. rumicis* apparently occurs in the Rome area. The persistence of the weed in spite of this infection pressure, however, may be due to the relatively dry conditions and low rust levels occurring during the critical host growth period, and the subsequent production of near-normal seed crops. In regions with more frequent late spring rains and similar temp, a greater degree of control might be expected in terms of reduced seed production as well as decreased vigor. Certain target areas under consideration in the southern states have year-round temp conditions similar to Rome's and more than twice the average late spring rainfall.

Other factors in addition to climate will affect the control level achieved in a given target area. Primary among these are host variability in disease resistance within populations, variability within the released inoculum, and the chance of eventual development of resistant populations from resistant individuals. Hence, the utility of the pathogen as a control agent, and the influence of climatic and host factors on control levels, can only be ascertained after the pathogen has been released in selected target areas and accurate assessments have been made of its accumulative effects through consecutive seasons.

It is doubtful that *U. rumicis* is currently present in the United States, despite the three reported collections for the San Francisco Bay area early in the century. A survey conducted by California quarantine officials in the Bay area in summer 1969 failed to find the rust. Moreover, some doubt exists as to the identity of the California collections, for teliospores were reportedly not observed in herbarium material, and closer examination of the specimens revealed the host to be *R. occidentalis*, not *R. crispus*. (G. B. Cummins, Purdue Univ., *personal communication.*)

The risk that *Rumex* rust may attack desirable plants as primary hosts in the target area was essentially dispelled by the results of screening tests. All of the crop selections tested, including representatives of the family Polygonaceae, were immune, as were 11 of 12 polygonaceous weeds screened. It appears that the uredial host range of the pathogen may be restricted to the subgenus, *Lapathum,* although *Rumex* spp. outside this subgenus have been recorded as hosts (6). Attempts by Gäumann (3) to infect four of these reported hosts outside *Lapathum* were unsuccessful, however. The present research also confirmed Gäumann's findings on the immunity of *R. acetosella.*

Because of the inability of teliospores to germinate, studies were unsuccessful in confirming the restriction of the alternate host range of *Rumex* rust to *Ranunculus ficaria,* as previously determined by Gäumann (3). Hence, little can be stated concerning the risk of infecting commercial *Ranunculus* spp. as alternate hosts. Gäumann, however, while successful in infecting *R. ficaria* with teliospores, obtained no infection on *R. bulbosis* or *R. steveni,* suggesting that the alternate host range may indeed be restricted to the single host.

On the basis of the studies described, it is believed that sufficient potential of *U. rumicis* as a candidate control agent for curly dock has been demonstrated to justify introduction into the United States for further trials. It is also felt that the risks of infecting economic plants as primary hosts, as indicated by results of screening tests, are sufficiently low to be considered as reasonable and acceptable.

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