Albugo candida on *Raphanus sativus* in Saskatchewan[1]

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From 1975 to 1983, ***Albugo candida*** (white rust and staghead) was found on a number of occasions in garden plantings of radish ***(Raphanus sativus)*** at Saskatoon. Radish has not been reported previously as a host of ***A. candida*** in Saskatchewan. The symptoms observed are described and illustrated. Eleven cultivars of radish were successfully inoculated. Chinese Rose Winter, Round Black Spanish, and Burpee White exhibited some resistance to white rust. Seed-borne oospores were identified as a possible cause of primary infections. Oospores from hypertrophied radish inflorescences were successfully germinated in the laboratory. The potential significance of radish white rust to rapeseed productian in western Canada is discussed.

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De 1975 à 1983, on a remarqué ***Albugo candida*** à un certain nombre d'occasion dans des semis de radis ***(Raphanus sativus)*** dans des jardins de la region de Saskatoon. C'est la premiere fois qu'on signale en Saskatchewan la presence de ***A. candida*** sur des plants de radis. Les symptômes observes sont décrits et illustrés dans cet article. On a inoculé avec succès onze cultivars de radis et les cultivars Chinese Rose Winter, Round Black Spanish et Burpee White ont montrb une certaine resistance à la rouille blanche. Les oospores transmis par la semence ont été identifies comme une cause possible d'infection primaire. La germination en laboratoire d'oospores provenant d'inflorescences de radis hypertrophies a été effectuée avec succès. On discute de l'importance du danger potentiel de la rouille blanche du radis sur la production du colza dans l'ouest du Canada.

Introduction

Conners (3) listed 26 species of Cruciferae as hosts of *Albugo* candida (Pers. ex Lév.) Ktze. (A. ***cruciferarum*** S.F. Gray) in Canada, including eight commonly cultivated *Brassica* species. Three reports were cited of A. candida on radish ***(Raphanus sativus*** L.) in Manitoba, but there was none from Saskatchewan or Alberta.

By 1971, white rust or staghead was an important disease in commercial crops of turnip rape (***Brassica campestris*** L.) in western Canada (1,2,4). In many fields, substantial yield losses resulted from high incidences of sytemic infections of inflorescences ("stagheads") (4). Following the licensing of the resistant cultivar Tobin in 1981 (7), white rust quickly declined in importance on turnip rape. It is still an important disease of Brown and Oriental condiment mustard ***(Brassica juncea*** (L.) Coss).

White rust can reduce radish seed yields appreciably through destruction of flowers (6). Therefore, although it is of little consequence to gardeners, the disease is of some importance to radish seed producers. In addition, the white rust biotype on *R. sativus* could conceivably infect cultivars or breeding lines of B. ***campesfris*** (10), thus again jeopardizing the canola (rapeseed) industry in western Canada.

From 1975 to 1983, white rust was found on a number of occasions in garden plantings of radish at Saskatoon. This paper describes the symptoms observed, examines the possibility that seed-borne oospores were an important source of primary inoculum, and presents the results of inoculation experiments involving a number of cultivars of ***R. sativus***.

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Materials and methods

In order to determine whether aospores carried with the seed might be responsible for the white rust outbreaks in home gardens at Saskatoon, 25 commercial seed samples of ***R. sativus*** were examined for oospores using a seed washing technique (5) (Table 1). Nine samples were purchased and tested in 1976 seven in 1984, and nine in 1985. In addition, attempts were made to germinate oospores from hypertrophied radish inflorescences collected in 1975 and 1976. Within a year of being collected, ripe hypertrophies were ground to powder by rubbing them on sandpaper. Small quantities of the powder, which consisted largely of oospores, were then washed in sterile tap water in Erlenmeyer flasks on a rotary shaker (9). After this treatment, spores were recorded as unchanged, activated, or fully germinated. A spore was considered to have been activated if the central oil droplet had disappeared and the contents of the spore were coarsely granular. Empty spores were considered to have germinated. One hundred and fifty untreated spores from each original sample were examined to determine whether any spontaneous changes had occurred. Adjustments in the totals in the three categories were made accordingly.

Eleven radish cultivars were inoculated with zoospores from zoosporangia, including two lots each of cultivars Round Black Spanish, Chinese Rose Winter, and Burpee White, from seed from different sources (Table 3). The cultivar Raoula, an oilseed radish introduction, was one of the eleven. Plants were grown, 10 per 9.5 cm pot, in Cornell soilless mix (8) at 21°C under 18 h illumination (17220 lux). There were six replications per cultivar. Zoosporangia were scraped from infected leaves, suspended in deionized water in Petri dishes, and incubated at 10°C for 3-4 h to induce germination. A zoospore suspension containing 25,000 or more spores/ml was sprayed on 10- to 14-day-old plants. Inoculated plants were kept under continuous mist for 18 h in darkness at 20°C. Eight to 10 days after inoculation, the number of infected plants per entry was recorded along with infection severity on the most

heavily infected leaf on each plant. Severity ratings reflected relative number and size of pustules and were: 0 (no sporulation), 1 (trace), 3 (light), 6 (moderate), and 9 (heavy). The mean ratings for diseased plants alone and diseased plus healthy plants were calculated.

Table 1. Extent of infestation by oospores of ***Albugo candida*** of commercial radish seed samples purchased and tested in 1976, 1984 and 1985.

Cultivar	Year tested and number oospores per gram of seed 1976	1984**	1985
Cherry Belle			5.4
Comet		+	0.0
Champion	0.0	0	8.6
French Breakfast	0.0	0	0.2
Sparkler	0.3		0.2
White Icicle	0.0		0.4
Chinese White Winter		+	
Burpee White		+	0.4
Chinese Rose Winter			0.0
Round Black Spanish		0	0.8
Crimson Giant	1.7		
Scarlet Globe 1	13.0		
Scarlet Globe 2	0.3		
Scarlet turnip white tip sparkler	3.4		
Scarlet white tip	0.0	+	
Mean spores/g seed	2.1		1.8
Mean % samples infested	55.6	57.1	77.8

** Ten 50X microscope fields examined per slide per sample. + = oospores present at <1 per field, 0 = oospores not seen. Oospore numbers in 1976 and 1985 samples were determined by counting all oospores present on cleared filtration discs (5).

Results

Symptoms observed on radish in Saskatoon collections. Abundant infections usually were observed on radish staring in mid-July. They consisted of sporangial pustules on the leaves, spindle-shaped stem galls, floral hypertrophies, hypertrophy of entire inflorescences or terminal parts of inflorescences, and pod infections (Figs. 1 and 2). Zoosporangial pustules frequently covered hypertrophied floral organs.

Presence of oospores in commercial seed samples of radish. Oospores were recovered from 16 of the 25 samples (64%) (Table 1). They were found in 55.6% of the samples purchased in 1976, 57.1% of those from 1980, and 77.8% of those from 1985. However, the number of oospores per seed sample was small with no more than a few recovered per gram of seed.

Germination of oospores from radish. Changes occurred in over 50% of the spores in both samples (Table 2). Spores in the 1975 sample germinated more slowly than those from 1976. Only 4.6% of the former germinated completely in six days, as opposed to 48% of the latter. However, 50% of the 1975 spores exhibited internal changes in six days, which indicated that the germination process had been initiated. Germination was largely by the sessile vesicular method, one of three different modes of germination previously noted in ***A. candida*** from rapeseed (9).

Inoculation of radish cultivars. The cultivars Chinese Rose Winter and Round Black Spanish had substantial numbers of "clean" plants, whereas the other cultivars had none or very few (Table 3). The overall white rust severity ratings for these two cultivars were therefore the lowest, followed by the ratings for Burpee White. However, although white rust incidence was high on Burpee White, infected plants of this cultivar were less severely diseased than infected plants of all other cultivars in that the rust pustules were generally smaller.

Discussion

Radish seed sown in western Canada is imported from the United States. The results show that oospores of white rust are continually reintroduced into Canada on seed. Although circumstantial evidence points to this as a source of primary infections in this country, the levels of oospore infestation were low. Also, the inoculum threshold required for infection by oospores is unknown.

Table 2. Germination of oospores of ***Albugo candida*** from ***Raphanussativus*** following washing in sterile tap water.[1]

Year Oospores Collected	Number Counted	Percentage of oospores Unchanged	Activated[2]	Fully Germinated
1975	150	45.4	50.0	4.6
1976	100	42.0	10.0	48.0

1 Five days on shaker and one day in still culture.
2 Central oil droplet gone and contents coarsely granular.

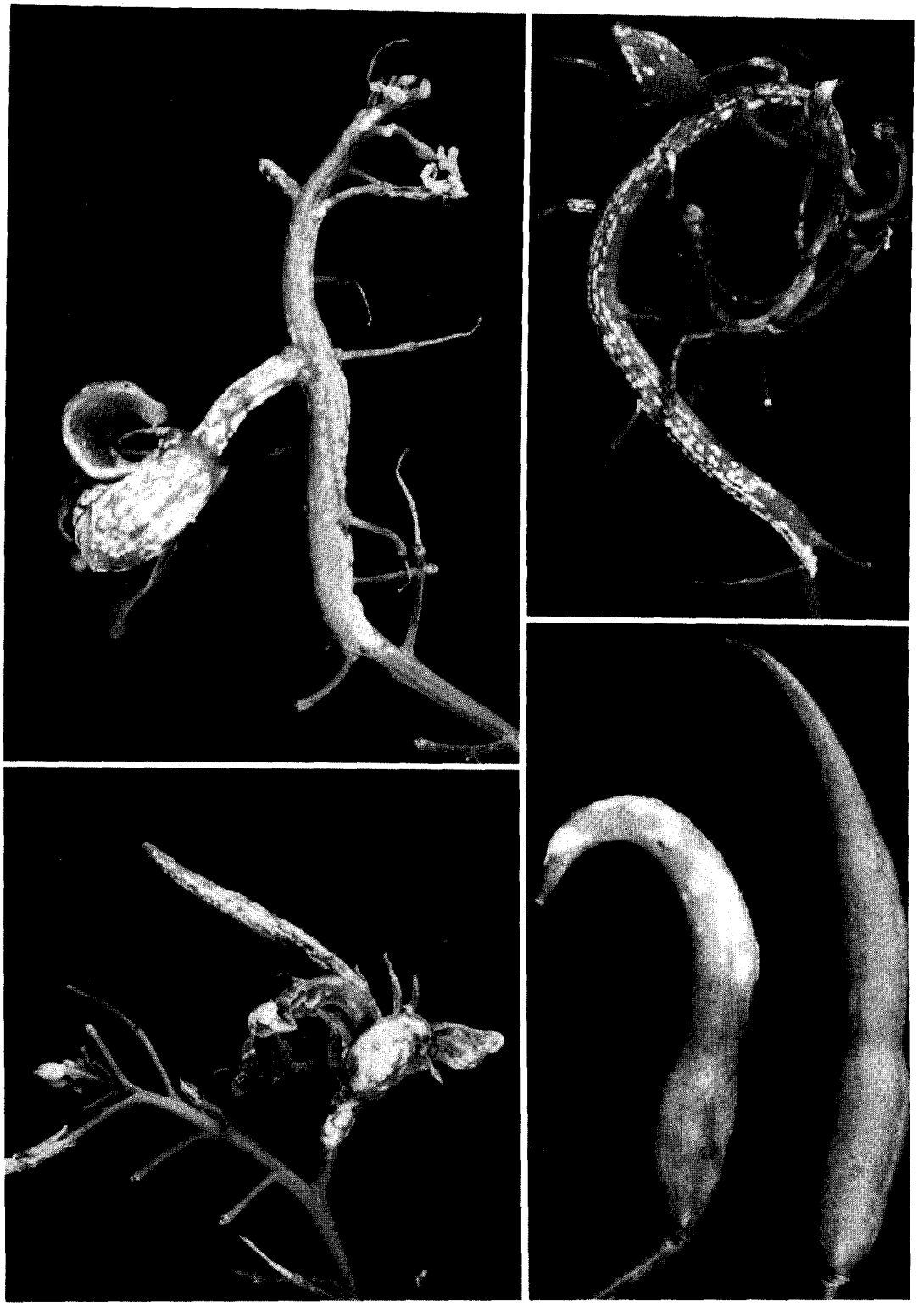

Figure 1. *Albugo candida* on *Raphanus sativus*. Top: two systemically infected peduncles; Bottom right: infected (left) and healthy pods; Bottom left: infection of an individual flower. Note white sporangial pustules on the surfaces of infected parts.

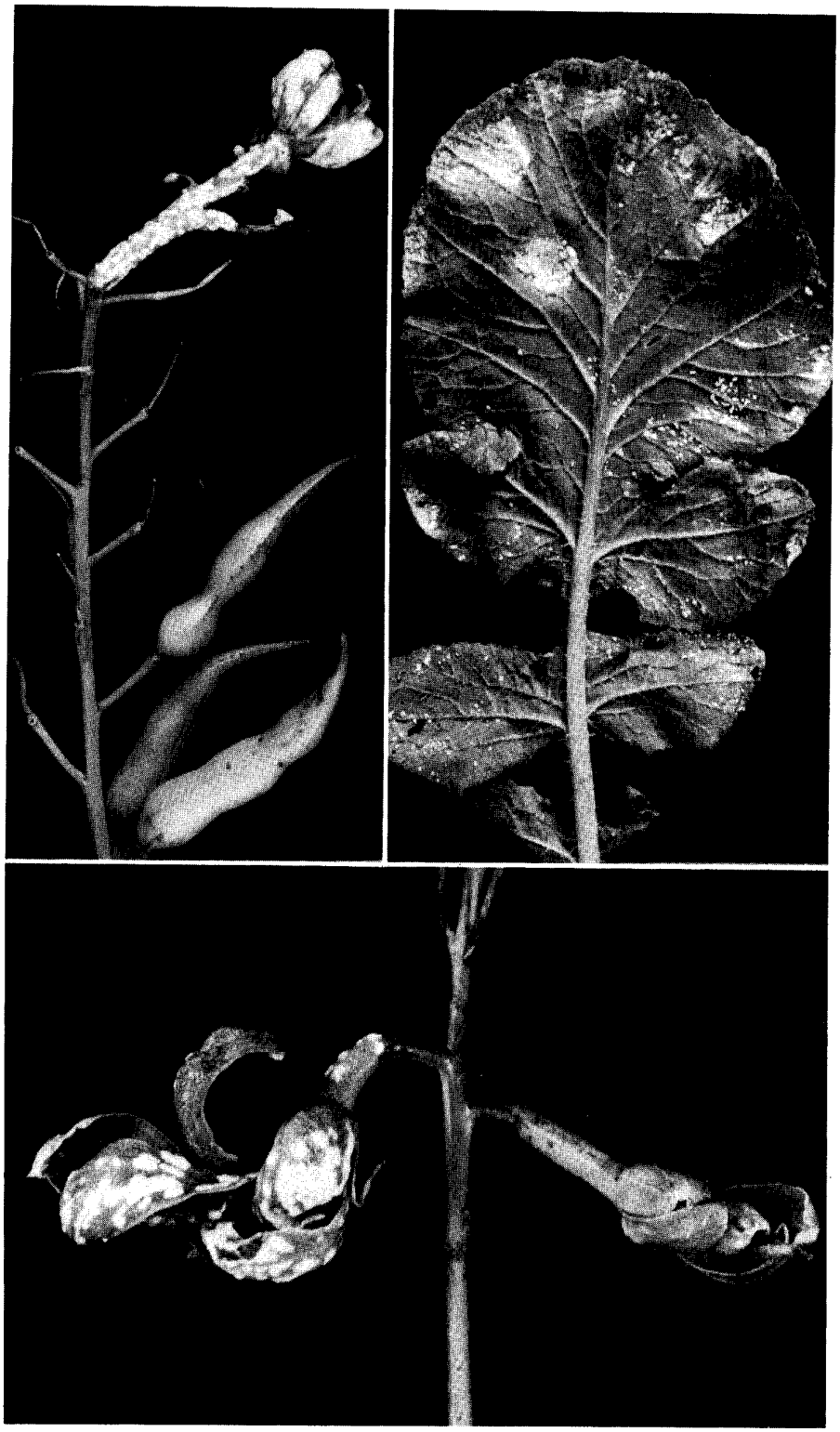

Figure 2. *Albugo candida* **on** *Raphanus sativus.* **Clockwise from upper left: systemic infection of the upper part of a peduncle; sporangial pustules on a leaf; two infected flowers.**

Table 3. Incidence and severity of white rust on eleven radish cultivars in an inoculated test.

Cultivar	Mean number[1] plants/10 infected	Mean severity[1] rating (0-9) all plants	Mean severity rating (0-9) infected plants
Cherry Belle	10.0 a	5.95 a	5.95
Comet	10.0 a	5.95 a	5.95
Champion	10.0 a	5.90 a	5.90
French Breakfast	10.0 a	5.75 a	5.75
Sparkler	10.0 a	5.55 a	5.55
Raoula	10.0 a	5.55 a	5.55
White Icicle	10.0 a	5.23 ab	5.23
Chinese White Winter	9.5 a	4.80 abc	4.88
Burpee White (S)[1]	10.0 a	4.17 bc	4.17
Burpee White (E)[1]	9.8 a	3.80 cd	3.87
Chinese Rose Winter (E)	5.7 b	2.75 de	4.92
Chinese Rose Winter (S)	5.8 b	2.68 e	4.68
Round Black Spanish (S)	4.7 bc	2.50 e	5.45
Round Black Spanish (E)	3.8 c	2.08 e	5.07

[1] (S) and (E) denote different seed sources.
[2] Means followed by the same letter within a column do not differ significantly according to Duncan's Multiple Range Test (P = 0.01)

Germination of A. candida oospores from radish has not been reported previously. It confirms earlier findings (9) that high percentages of oospores in many collections of A. candida germinate in a relatively short time when leached in water. The results of inoculation trials are in general agreement with an earlier study (11) which also reported that the cultivars Round Black Spanish and China Rose Winter contained a proportion of resistant plants.

As severe natural infections were observed only on radish which had been allowed to go to seed, white rust normally would be of no practical significance on this minor garden crop in Saskatchewan. It could, however, become important if susceptible introductions of *B. campestris* (10) were used in canola breeding programs. Care should be taken to guard against this occurring. Host specialization of collections of white rust from Saskatchewan, including that from radish, will be considered in another paper.

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