Yield Loss by Brassica campestris and B. napus from Systemic Stem Infection by Albugo cruciferarum

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ABSTRACT

In a field experiment with crops sown at different dates, the relationship between yield of *Brassica campestris* 'Span' and severity of the systemic stem infection phase of white rust (staghead) caused by *Albugo cruciferarum* was expressed by the equation $Y = 100 - 0.952X$, where Y was yield expressed as percent of potential and X was percent of stems systemically infected. The equation

$$\text{Yield loss (\%)} = 100 \times \frac{\text{Number of stems systemically infected}}{\text{Total number of stems examined}}$$

is suggested for use in disease loss assessment. *Brassica napus* 'Oro' showed no symptoms of infection by the biotype of *A. cruciferarum* that attacked Span.

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Production of Polish or turnip rape (*Brassica campestris* L.) and rape or Argentine rape (*B. napus* L.) on the Canadian prairies increased from 711 thousand acres in 1961 to 5.6 million acres in 1971 (2, 4). Rape thus became Canada's most important oilseed crop.

White rust, caused by *Albugo cruciferarum* S. F. Gray, occurs as discrete pustules on leaves and stems of many cruciferous hosts (3). On rape and mustard, the fungus may become systemic in developing stems and pods causing hypertrophy, distortion, and sterility of the affected part. This phase of the disease is commonly referred to as "staghead."

Little has been done to determine the loss caused by white rust, even though it affects a number of economically important crucifers. European workers have reported that white rust caused little loss in cruciferous oilseed crops (8, 9). In Canada, the staghead phase occurs frequently (1, 10, 11). Petrie and Vanterpool reported that systemic stem infection caused an average reduction of 60% in seed yield of individual plants (11). This study was undertaken to determine the relationship between severity of systemic infection of stems by *A. cruciferarum* and seed yield of rape, and to develop an equation for assessing yield loss in the field.

MATERIALS AND METHODS.—A six-replicate, randomized block, date-of-sowing experiment with plots 6×42 m was laid out on summerfallowed silty clay loam at the Canada Department of Agriculture Research Station at Lethbridge, Alberta in 1971. 'Span,' a low erucic acid cultivar of *B. campestris,* and 'Oro,' a low erucic acid cultivar of *B. napus,* were sown at the rate of 4.5 kg/hectare (ha) every 7 days from April 29 to June 10. Total precipitation was 19.91 mm and mean temp was 16.3 C for the period May 1 to August 31, compared to the 60-yr average of 21.44 mm and 15.0 C (5, 7). Plots were harvested when the testae of the seeds in one-third of the pods had assumed their normal, mature, brown color.

White rust developed in the experimental plots from an unknown inoculum source. Flea beetle (*Phyllotreta* spp.) occurred in large numbers in mid-August, causing severe damage to the late-sown crops as they matured.

At harvest, all the plants of Span in a 4.87 m^2 area of

TABLE 1. Yield, stand, and percentage infection by *Albugo cruciferarum* of *Brassica campestris* cultivar 'Span' sown at different dates in 1971[y]

Date sown	Yield[z] (kg/ha)	Plant stand (Thousands/ha)		Stems/ plant (no.)	Infected	
		Plants	Stems		Plants (%)	Stems (%)
April 29	813 b	213 d	1,052 e	4.94	34.9	9.9
May 6	1,068 a	536 cd	1,812 cd	3.38	25.9	11.4
May 13	781 b	417 d	1,524 de	3.65	25.5	10.5
May 20	757 b	786 c	2,140 bc	2.72	13.6	6.1
May 27	856 b	1,801 a	3,352 a	1.86	5.7	3.5
June 3	741 b	1,319 b	2,612 b	1.98	1.6	1.0
June 10	337 c	1,345 b	2,581 b	1.92	10.0	6.1

[y]Means of six replicates, except those for the June 3 sowing, which are means of two replicates.
[z]Means in the same column followed by the same letter do not differ at $P = 0.01$.

each plot were lifted. The number of stems systemically infected and the total number of stems were recorded for each plant. Plants from each plot were segregated into disease categories for yield determination. These categories were: healthy, slight, moderate, and severe, and represented 0, 1 to 25, 26 to 50, and over 50% of stems systemically infected, respectively. This classification ignored the occurrence of pustules on leaves and stems and of systemically infected, discrete pods.

Analysis of variance and Duncan's multiple range test were applied to appropriate data. Covariance analysis was used to determine the relationship between seed yield and degree of stem infection. Probability values for analyses involving disease categories were considered to be approximations because a nonuniform variance was associated with large differences in population size among the categories; transformation of the data did not entirely compensate for this.

RESULTS.—Span was susceptible to infection by *A. cruciferarum*. The stems and pods were systemically infected, and localized pustules developed on leaves and stems. The leaves, stems, and pods of Oro remained free from symptoms of white rust throughout the growing season.

Span rape sown April 29, May 13, May 20, May 27, and June 3 differed little in yield of seed (Table 1). Rape sown May 6 yielded more, and that sown June 10 yielded less, than that sown on the other dates.

There was no definite relationship between the percentage of plants or stems with systemic infection by *A. cruciferarum* and the yield of Span rape sown at the different dates. However, when yields of plants in the four disease categories were compared for each date separately, healthy plants were found to have outyielded plants with moderate or severe systemic infection for each date of sowing (Fig. 1). In contrast, the slightly infected plants outyielded the healthy plants at all dates except the first. The slightly and moderately infected plants also bore more stems than the healthy and severely infected ones. When yields of stems in the four disease categories were compared, the differences among categories in number of stems per plant was avoided and there was a gradual decrease in yield as the degree of stem infection increased.

The relationship between percentage of stems infected and yield (expressed as percent of potential) (Fig. 2) is as follows:

(i) Yield = 100 − 0.952X, where X = percent of stems with systemic infection. The regression coefficient and standard error for the following dates of sowing were: April 29, −1.394 and 0.0041; May 6, −1.063 and 0.0010; May 13, −0.961 and 0.0006; May 20, −0.962 and 0.0004; May 27, −1.019 and 0.0002; June 3, −0.911 and 0.0005; and June 10, −0.987 and 0.0005. There was little variation in the relationship between the percentage of systemic stem infection and yield, except in plants of the first date of sowing.

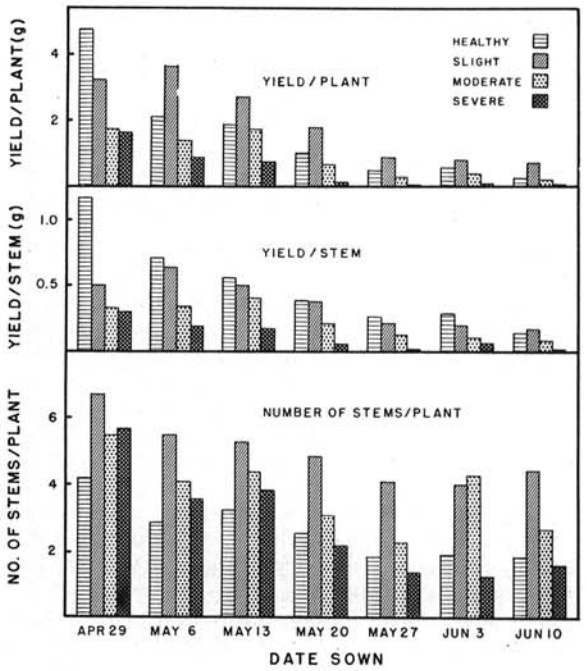

Fig. 1. Seed yield/plant, seed yield/stem, and number of stems/plant of 'Span' rape sown at several dates and differing in percentage of stems systemically infected by *Albugo cruciferarum* as follows: healthy = none, slight = 1 to 25%, moderate = 26 to 50%, and severe = over 50%.

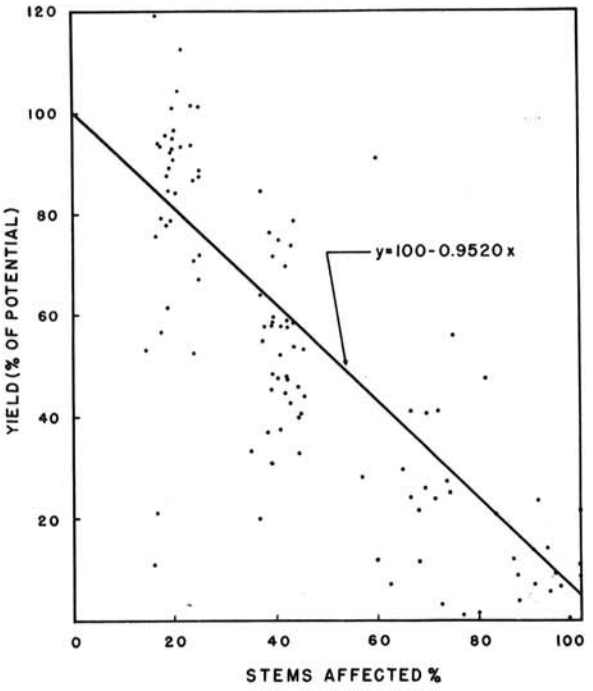

Fig. 2. Seed yield of 'Span' rape (expressed as percent of potential) in relation to percentage of stems systemically infected by *Albugo cruciferarum*.

The relationship between systemic infection of stems by *A. cruciferarum* and yield loss of rape can be stated as follows:

(ii) Yield loss (%) = 0.952 × (percent stems systemically infected). For estimating yield loss in commercial crops the coefficient can be rounded to unity.

DISCUSSION.—The loss in yield from systemic infection of stems by *A. cruciferarum* was clearly demonstrated when yield and disease severity were compared for plants harvested from a single plot. This method of comparing yield of diseased and healthy populations eliminates the confounding influences that can occur when populations are separated by time or space or when fungicides, for example, are used to attain differences in disease severity. Except for the earliest-sown crop, there was a marked uniformity in the relationship between disease severity and yield. Possibly there were too few plants in the first sowing date to produce additional flowering stems to compensate for those converted to stagheads.

The larger number of stems on the slightly and moderately diseased plants than on the healthy and the severely diseased plants is accounted for by the definition of the categories themselves. The plants categorized as slightly diseased must have at least four stems and those in the moderately diseased category must have at least two stems, whereas those in the healthy and severe categories can have any number of stems.

Field results indicated that Oro rape may be immune to the strain of the pathogen that attacked Span in 1971. However, pathogenic races of *A. cruciferarum* have been recognized (6, 12). More work is needed to characterize the pathogenic biotypes of the fungus on genera, species, varieties, and cultivars of the Cruciferae to determine the importance of this instance of apparent immunity.

The simple equation, yield loss (%) = percent stems systemically infected, is suggested for converting severity of white rust to loss in yield of rape. The equation estimated the loss to within ±10% in crops that varied in stand from 417,000 to 1.8 million plants/ha, in yield from 387 to 1,068 kg/ha, and in stems infected from 1.0 to 11.4%. This variation was considered to be a reasonable sample of that likely to occur in commercial rape production. The accuracy of yield loss estimates based on this equation will depend largely on the adequacy of the sampling procedures used to estimate the percentage of systemically infected stems in the population under study.

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