THE INFLUENCE OF DISEASE INCIDENCE AND HOST TOLERANCE ON OAT YIELDS'

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Abstract

Field comparisons over a three-year period have indicated that oat varieties differ in their tolerance to such diseases as stem and crown rust and the septoria disease. Tolerance could be important in areas and years where these diseases are not initiated too early. However, when they develop early and severely, yields of all varieties are considerably reduced. This situation would not occur frequently. Strains from the current Ontario oat-breeding program showed more tolerance than did introduced material accumulated at Ottawa. More emphasis should be placed on early selection for high yield in developing improved cereal varieties, keeping in mind the possible value of host tolerance.

Introduction

In most oat-growing areas the crop is subjected to numerous diseases that often reduce yields. The diseases of major concern in Eastern Canada include stem rust, Puccinia graminis Pers. f. sp. avenae Erikss. & Henn., crown rust Puccinia coronata Cda., septoria leaf blotch, Septoria avenae Frank f. sp. avenae and barley yellow dwarf virus. The production of resistant varieties is the logical means of controlling these and other cereal diseases and, over the years, pathologists and breeders have had considerable success in producing such varieties (6). This has been especially true for diseases like the rusts (9, 10). These varieties, however, have provided only temporary control as they have not retained their resistance for any length of time. Furthermore, recently licensed oat varieties have shown no improvement in resistance over earlier-released varieties (11). In practically all instances, resistant varieties have been developed with genes specific for certain rust races and new races, to which these varieties were not resistant, have subsequently appeared. This problem has been extremely critical in areas where the varieties have been grown in close proximity to the alternate hosts of the oat rusts, because in these areas new races have been produced continually. Even in areas where the alternate hosts have been eradicated the problem is almost as acute. Moore (5) recently reviewed the oat stem rust situation in the north central United States and concluded that it was extremely critical. Because of shifts in rust race populations in recent years, all oat varieties being grown in that area were susceptible. Furthermore, there were only a few possible sources of resistance available and these would probably be attacked by new races in the near future. He suggested that control measures other than major gene resistance have to be considered.

In recent years more attention has been paid to the possible development of varieties with generalized resistance. Polygenic resistance, minor gene resistance, field resistance and tolerance (4, 5, 6, 7) have been included in this category. These types of resistance have been referred to as "horizontal" resistance by Van der Plank (8). Multiline or composite varieties (1), although made up of lines with specific resistance, could be included in this category since they would be expected to be effective against a wide spectrum of races. Tolerance would be expressed by varieties through good yield even though they may be severely diseased. It has been observed that some varieties suffer much less than others when exposed to the same severe levels of infection (6). Varieties with disease tolerance would be very useful in a crop such as oats because of the difficulty in locating resistance to the septoria disease and because of the rapid change in the race picture for both stem and crown rust, especially in Eastern Canada, and the subsequent failure of specific gene resistance to retain its effectiveness for any length of time.

An excellent opportunity to investigate tolerance in oat varieties, especially to the rusts, was available in the Ottawa area because concentrated populations of the alternate hosts of both stem rust (barberry: Berberis vulgaris L.) and crown rust (buckthorn: Rhamnus cathartica L.) occur at Merrickville some 35 miles southwest of Ottawa. These hosts are not found at Ottawa. Numerous varieties were grown in the two areas in combined disease and yield tests in 1962, 1943 and 1964 to determine whether some of them showed more tolerance to diseases than others. This paper summarizes the results obtained.

Materials and methods

All the oat varieties and strains were grown at the Central Experimental Farm, Ottawa and at Merrickville, Ontario. Each entry was planted as a clump of 20 seeds, evenly distributed over an area approximately one foot in diameter. The centres of the clumps were two feet apart. In 1962, a separate test made up of 15 replicates of the check varieties Russell, Garry and Victory, was planted in a randomized block. When yields of replicates were com-

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pared good agreement was obtained indicating that this was a reasonably reliable method of obtaining yield comparisons. At both locations soil variation was kept at a minimum by planting the clumps so that they occupied an area approximately square in shape. Check varieties were arranged so that one of the three was planted at every tenth clump.

Approximately 1300 oat introductions accumulated at Ottawa over the years were planted at Ottawa and Merrickville in 1962. The 48 highest-yielding entries in the Ottawa test were planted in four replicates at both locations in 1963. In addition, one replicate of all of the entries in the 1962 Ontario oat-breeding program, 75 entries from the Eastern Co-operative, Ontario Preliminary and Screening Tests, was planted. In 1964, four replicates of the 20 highest-yielding introductions and of the 20 highest-yielding strains from the breeding material at both Ottawa and Merrickville in 1963 were planted. Each year disease notes were recorded at least twice during the growing season. Harvesting was done over a considerable period of time in 1962 because of the large numbers of and range in maturity of the entries. However, in 1963 and 1964 only minor differences in maturity were evident. Seed yields expressed as grams per clump were obtained and these, as well as the percent increase or decrease in yield obtained at Ottawa, compared with that at Merrickville, were used for comparisons.

Results and discussion

The prevalent diseases at Ottawa, especially the rusts, appear and develop fairly late and they usually do not influence yields to any extent. At Merrickville, however, where barberry and buckthorn are present, the rusts are initiated early, develop rapidly, reach epidemic proportions, and affect yields considerably. Disease tolerance in varieties would be indicated by those that were able to maintain a reasonable yield of oats when exposed to severe disease conditions, especially if they showed little or no resistance.

The disease picture was similar in the three years of the tests (Table 1). Stem and crown rust and septoria were the diseases of principal concern with barley yellow dwarf virus and manganese deficiency (greyspeck) present in trace amounts. Stem and crown rust were present at both Ottawa and Merrickville but infection was earlier and heavier in the latter area (Table 1). If only the degree of infection at maturity was compared then the difference in rust development at the two locations did not appear too great. However, when the duration of exposure of the crop to these diseases at Ottawa and Merrickville was considered; then the differences became more significant. The overall influence of the rusts on yields would be expected to be considerably greater at Merrickville than Ottawa. No entries were completely free from rust infection in the tests and at Merrickville most were quite susceptible. The septoria disease was present at both locations to about the same degree each year (Table 1). However, because of the heavy rust infection in most cases at Merrickville, there was less leaf area available for the fungus to become established.

Table 1. Kind and prevalence of diseases on oat varieties grown at Ottawa and Merrickville from 1962 to 1964.

	Introductions					
	Stem rust		Crown rust		Septoria	
Year	Ott.	Mer.	Ott.	Mer.	Ott.	Mer.
1962	L*	H	M	H	M-H	M-H
1963	Tr-L	L-M	L	H	M-H	M-H
1964	L-M	M-H	L	M-H	H	H
	Breeding Material					
1962	—**	—	—	—	—	—
1963	M	H	L	M	M-H	M-H
1964	L	M-H	L	M	H	H

* Disease scale Tr - trace, L - light, M - moderate. H - heavy
** Not grown

Table 2. Average yield in grams per plot of varieties of oats grown at Ottawa and Merrickville from 1962 to 1964.

	Introductions	
	Ottawa	Merrickville
1962	87.6*	—**
1963	26.3	6.3
1964	119.7	92.1
	Breeding Material	
1962	—***	—***
1963	31.4	19.3
1964	95.2	82.9

* This figure includes the same entries that were grown in 1963.
** Not harvested
*** Not grown

There were no notable differences in environmental conditions, other than disease severity, between the two locations. Oat yields at Ottawa were reasonably good in 1962 and 1964 (Table 2). However, they were very poor in 1963 because the early part of the growing season was hot and dry and the latter part, cool and wet. The poor yields obtained at Merrickville in 1962 and 1963 (Table 2) resulted mainly from early stem and crown rust infections. The 1962 test was located in an area that limited

early growth. This, combined with the heavy rust infection produced such a poor crop that it was not worth harvesting. In 1963, plant growth was reasonably good but seed yields were poor, particularly from the introductions. Stem and crown rust developed later at Merrickville in 1964 and consequently there was a smaller reduction in yields when compared with those obtained at Ottawa.

It is generally believed that stem rust is responsible for greater reductions in yield than crown rust. Stem rust was heavy on the breeding material at Merrickville in 1963 and light on the introductions. Crown rust was heavy on the introductions and light on the breeding material (Table 1). This suggested that, on the average, the introductions had good resistance to stem rust and the breeding material good resistance to crown rust. However, the 1963 data for Merrickville (Table 2) indicate that the yields of the introductions were reduced considerably more than were those of the breeding material.

No tolerance comparisons could be made between yields at Ottawa and those at Merrickville in 1962. There was, however, awide variation in the yields of the various entries grown at Ottawa. At maturity many of the high yielding ones were heavily infected by the rusts and septoria diseases indicating that these varieties had some degree of tolerance. Comparisons could be made in 1963, although yields at both locations were low. Some of the entries were able to maintain their yield at Merrickville much better than others, although it would appear that, in a year when the rusts are initiated early, yields of all entries are greatly reduced. In general, entries included in the breeding material showed more tolerance than those in the introductions. This fact was substantiated when the yields of the check varieties were compared with those in the two groups. All three checks outyielded any of the introductions at Merrickville in 1963 but several entries in the breeding material outyielded even the best check and none of these entries showed an appreciable degree of resistance, especially to stem rust.

There was again evidence of tolerance in a number of the entries compared in 1964 (Fig. 1) and, as before, primarily in the breeding material. The rusts developed later than usual and as a result five of the entries showed slightly higher yields at Merrickville than at Ottawa. The introductions outyielded the breeding material at both locations (Table 2). The average percent reduction in yield at Merrickville was greater for the introductions (27.6) than for the breeding material (12.3). The introductions, therefore, as a group had the potential at Ottawa to outyield the breeding material but they did not have the disease tolerance to maintain their superiority in yield at Merrickville. Six of the introductions showed less than a 10 percent increase or decrease in yield at Ottawa when compared with Merrickville. but 15 of the entries in the breeding material could be included in this category (Fig. 1). The two top yielding entries in the breeding material were included in this group and, in both cases, they were quite susceptible to stem rust at Merrickville. A general observation was made that entries in both groups that gave high yields were susceptible to the rusts and those that gave low yields showed some resistance. This would indicate that resistance and high yields are negatively associated and that continual selection for resistance would favor low yields.

Date of maturity may have had an influence on the yield of some of the entries as early maturing strains would be expected to have an advantage as they would suffer less from severe disease infections. In 1963 and 1964 yield comparisons of the individual varieties at the two locations were used to show the presence of tolerance and entries that were early or late maturing at Ottawa were also early or late maturing at Merrickville. However, in these two years the range in maturity was relatively small amounting to a difference of approximately one week. Maturity did not appear to be an important factor in these tests as both early and late maturing entries showed varying degrees of tolerance. In 1964, entries 'OA 90-3', 'OA 94-1', 'OA 18-28' and 'Dorval' in the breeding material group (Fig. 1) were moderately late to late in maturity and showed good tolerance while 'OA 34-9' was early but showed poor tolerance. The same picture was true in the group of introduced varieties. The introduced varieties were, on the average, earlier in maturity than the breeding material and this might account for their high yield in 1964 compared to the breeding material (Table 2) since diseases were not as severe that year.

The development of oat varieties with good tolerance to the rusts and septoria is feasible and the presence of this character should considerably increase yields in oat-growing areas in most years. The results presented here were obtained in an area where stem and crown rust occurvery early and are severe every year. Similar epidemics would be found consistently only in areas where the alternate hosts of the rusts are present to the same extent. It has been noted previously (2) that oat varieties show a considerable range in tolerance to ascosporic inoculum of the fungus causing the septoria disease. The increased yields obtained with the recently released variety Russell (10) is thought to be due to the fact that this variety has shown better tolerance to septoria disease than those developed previously (3).

The fact that entries from the current Ontario oat breeding program have more tolerance than the introduced varieties is not surprising. These entries have been selected for many factors including high yields, often under reasonably severe disease epidemics, hence those with tolerance would be retained automatically. The introduced varieties nt. doubt have not been subjected to such intensive selective processes. Most breeding programs involved in the search for improved varieties of cereals have as their primary objective the finding of genes for disease resistance and selection for improved yields usually takes place in advanced generations. By the time yield selections are made, lines with genes

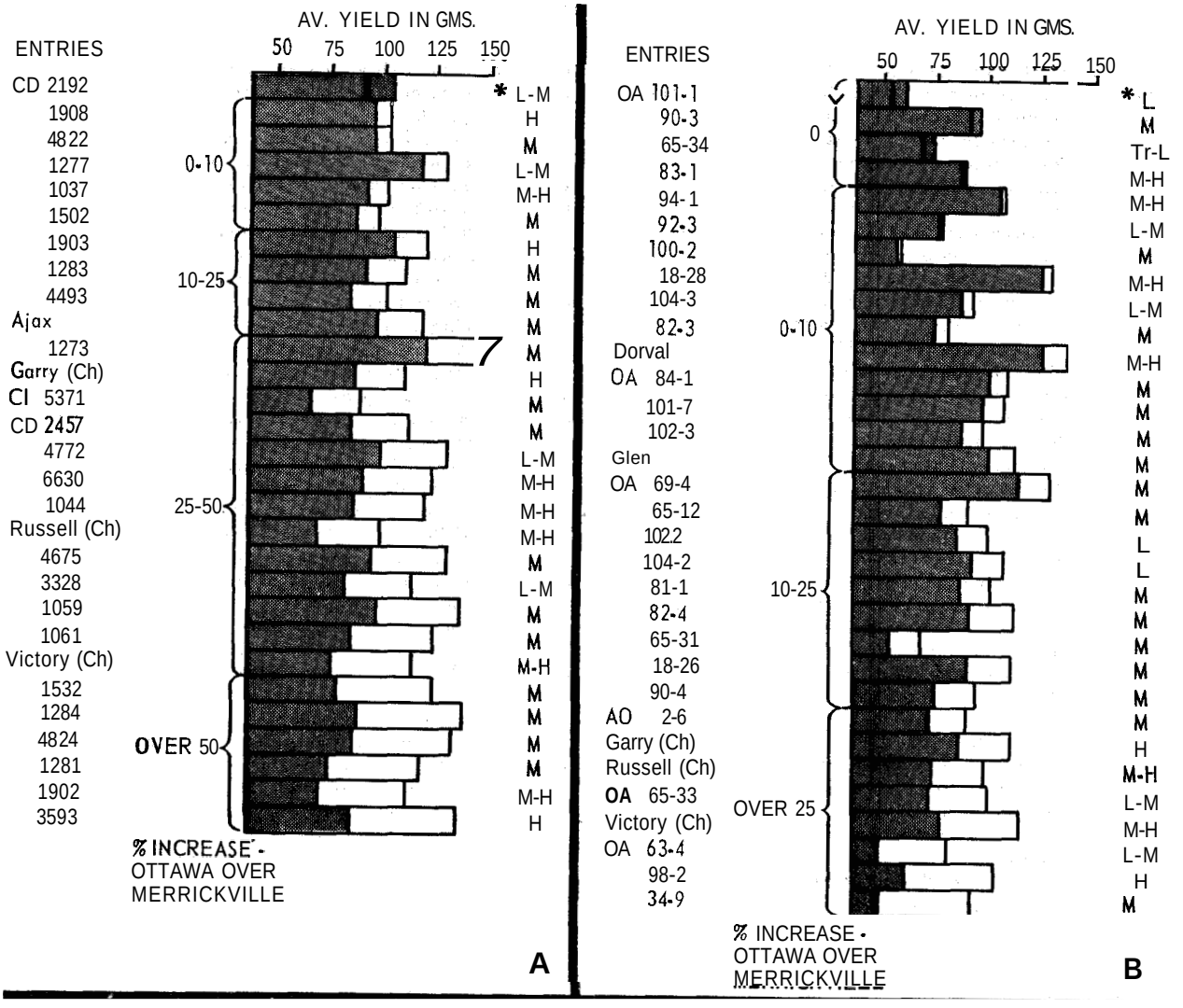

Figure 1. The average yield in grams per plot of varieties of oats grown at Ottawa and Merrickville, Ontario, in 1964. (A) Introduced varieties. (B) Ontario Breeding program Material. Entries in both groups arranged according to the percent increase in yield at Ottawa over Merrickville.

that would improve yield may have been discarded because of susceptibility to diseases. A more advantageous approach might be to have improved yields as the primary objective of the breeding program. Disease resistant lines could possibly be selected from or genes for resistance could be added to advanced generations. In this way the high-yielding ability of certain lines would not be lost. Host tolerance could be used to provide protection under disease conditions.

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Literature cited

1. Borlaug, N. E. 1958. 11. The impact of agricultural research on Mexican wheat production. Trans. N.Y. Acad. Sci. 20: 278-295.
2. Clark, R.V. and F.J. Zillinsky. 1960. Varietal reaction of oats to the septoria disease under field and greenhouse conditions. Can. Plant Dis. Survey 40: 1-9.
3. Clark, R. V. and F. J. Zillinsky. 1962. The influence of several fungicidal treatments on yields of oats infected by septoria. Can, J. Plant Sci. 42: 620-627.
4. Hodgson, W. A. 1960. Field resistance to potato late blight. Proc. Can. Phytopathological Soc. 27: 13.
5. Moore, M. B. 1964. New threats from stem rust of oats. Minn. Farm & Home Sci. 22: 15-16.
6. Stakman, E. C. and J. F. Christensen. 1960. The problem of breeding resistant varieties. In J. G. Horsfall and A. E. Dimond (Editors). Plant Pathology, An Advanced Treatise, Vol. III Academic Press, New York pp. 567-624.
7. Van der Plank, J. E., 1963. Plant Diseases: Epidemics and Control. Academic Press, New York, 349 pp.
8. Van der Plank, J. E. 1966. Horizontal (polygenic) and vertical (oligogenic) resistance against blight. Amer. Potato J. 43: 43-52, 1966.
9. Welsh, J. N., R. B. Carson, W. J. Cherewick, W. A. F. Hagborg, B. Peturson and H.A.H. Wallace, 1953. Oat varieties - past and present. Can. Dept. Agr. Pub, 891.
10. Welsh, J. N 1957. Garry and Rodney oats. Agric. Inst. Rev. 12 (4): 13-15.
11. Zillinsky, J. F. 1961. Note on Russell oats. Can. J. Plant Sci. 41: 683-684.