GRAY SPECK OF OATS IN WESTERN CANADA[1]

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Attempts are being made to determine if resistance to gray speck caused by manganese deficiency is a necessary characteristic in new varieties of oats being developed for western Canada. The current concern is that certain new varieties of outstanding merit in other respects have been found to yield less than gray-speck resistant varieties on some soils.

It has been found (12, 29, 30, 33) that gray speck of oats may be due to an absolute manganese deficiency or to a deficiency of available manganese because of inorganic chemical fixation or biological fixation. This paper presents previously unpublished results of experiments on the identification and control of manganese deficiency in oats and includes a review of the literature pertaining to the occurrence of gray speck in western Canada and to the appraisal of oat varieties for resistance.

Establishment of the occurrence of gray speck in western Canada

Gray speck symptoms were observed in experimental plots and farmers' field in Manitoba for several years before diagnosis of the condition was confirmed experimentally (14). The determinative work of MacLachlan (25, 26) in Ontario suggested the desirability of similar studies here, and the presence of manganese deficiency in a Manitoba soil was established in 1944. Earlier attempts using field soils in greenhouse tests had failed to evince a response to manganese because of the presence of available manganese in the 6-inch clay pots used in the experiments. However deficiency symptoms were produced when procedures were followed to remove any traces of exchangeable manganese from the pots. They were washed thoroughly, steeped for 18 hr in 0.1 N NaCl followed by four successive steeps of 6, 15.5, 8, and 2 hr in tap water. A test of the last steep failed to show the presence of chlorine, suggesting that no manganese chloride remained in the pots which were then rinsed in running tap water, wiped with clean cheese-cloth and allowed to dry.

In the experiment, two soils were used: Gilbert Sandy Loam (10), (pH 6.8) from a field in which gray speck had been observed in SW 7 Township 25 Range 22 W near Gilbert Plains, Man.; and a potting soil (pH 7.5) containing a mixture of Red River clay and sand; the mixture was believed not to be deficient in available manganese. Later, the Soils Department, University of Manitoba, found the sand loam soil to be deficient in manganese, low in phosphates but not in potash. The potting soil was low in potash but not in phosphate. Unfortunately its manganese content was not determined.

Twelve pots of each soil for each of four treatments were randomized on a greenhouse bench. One treatment had 0.1 g $MnSO_4.4H_2O$ per pot mixed with the soil before sowing and 20 ml of aqueous solutions $MnSO_4.4H_2O$) (0.2 g) added 40 days after sowing. A[2] second treatment had no addition to the soil, but the plants were sprayed with 1% $MnSo_4.4H_2O$ (=0.68 $MnSO_4$) 34 days after sowing; the plants in a third treatment were sprayed with distilled water 34 days after sowing, a fourth treatment was left undisturbed. The pots were sown with seed of the susceptible variety Richland (37) that had been treated for 10 min by immersion in water at 57 C to kill any halo blight bacteria, Pseudomonas coronafaciens (Elliott) Stevens, that might be present. To establish that halo blight was not being confused with gray speck, 34-day-old plants in six pots in each treatment were inoculated with Ps. coronafaciens by pricking the crowns with a flamed and cooled nichrome needle dipped in inoculum. The plants in the remaining six pots of each treatment were wounded in the same fashion but not inoculated. Plants were examined for halo-blight 13 days later. Observations on gray speck were made 62 days after sowing.

The results of the test (Table 1) indicated a marked deficiency of available manganese in the field soil from Gilbert Plains, and a slight deficiency in the potting soil.

In Europe Steenbjerg and Boken (31) in pot experiments with Victory oats established that reducing agents applied to soil on which oats suffered from severe gray speck resulted in improved yields. Consequently a greenhouse pot experiment with soil from Gilbert Plains was done with the reducing agent quinhydrone. Additions of manganese sulfate and manganese chloride were included as treated controls and the effect of sodium as an exchange ion was determined by the inclusion of treatments with sodium sulfate and sodium chloride (Table 2). Four replicates of each treatment were sown with Richland oat seed that had been steeped at 62 C for 1 min then at 57 C for 10 min followed by cooling in cold water to prevent any possible infection by halo blight. The soil was almost neutral (pH 7.6). The pots were randomized on a greenhouse bench, and 4 weeks

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Table 1. Proportion of Richland oat plants developing halo blight and gray speck in a greenhouse test

Soil	Treatment	Plants developing: Halo blight	Plants developing: Gray speck
Field soil	Plants inoculated with *Ps. coronafaciens*		
	Mn applied to soil	16/17	1/17
	Mn sprayed on foliage	16/17	0/17
	Water sprayed on foliage	15/17	7/17
	Untreated	16/16	9/16
	Plants not inoculated		
	Mn applied to soil	0/18	0/18
	Mn sprayed on foliage	0/18	2/18
	Water sprayed on foliage	0/18	16/18
	Untreated	0/18	14/18
	% of plants developing symptoms of gray speck: Mn treated	4	
	untreated	67	
Potting soil	Plants inoculated with *Ps. coronafaciens*		
	Mn applied to soil	11/18	0/18
	Mn sprayed on foliage	18/18	0/18
	Water sprayed on foliage	18/18	0/18
	Untreated	18/18	3/18
	Plants not inoculated		
	Mn applied to soil	0/18	0/18
	Mn sprayed on foliage	0/18	1/18
	Water sprayed on foliage	0/18	1/18
	Untreated	0/18	3/18
	% of plants developing symptoms of gray speck: Mn treated	1	
	untreated	10	

Table 2. Severity of gray speck in plants of Richland oats 4 weeks after sowing in pots of field soil amended with various chemicals

Amendment and rate (g/6-inch pot of soil)		No. of plants in each severity category: Severe	Moderate	Slight	Trace	Nil
$MnSO_4 \cdot H_2O$	0.076	0	0	2	0	10
$MnCl_2 \cdot 4H_2O$	0.089	0	2	2	1	9
$Na_2SO_4 \cdot 10H_2O$	0.156	2	3	3	1	3
NaCl	0.059	2	6	3	0	1
Quinhydrone	1.767	0	0	0	0	12
Nil	0	2	5	4	0	1

after sowing the plants were examined for the presence and severity of gray speck (Table 2).

Dilution plate isolations of bacteria were made from the roots of 10 gray speck affected plants and from the roots of 10 apparently healthy plants. It was noted that the washed root mass of the healthy plants was approximately three times as great as that of the plants showing symptoms of gray speck. In both healthy and diseased plants the colony counts from individual roots ranged from just over 100 to "infinite" and were preponderantly over 500 per root, there being no correlation between bacterial count and treatment.

The same pots of soil were re-sown with Ajax oats and the plants harvested 13 weeks later. The plants were shaken to free the roots of most of the soil, then the above-ground parts of the plants were clipped off at the crown; the roots were allowed to soak for 3 hr in water, then washed in running water and allowed to soak 2 hr more. They

Table 3. Weight of oven-dried roots of Ajax oat plants grown in re-sown pots of field soil that had been amended before seeding a previous crop of oats (Table 2)

Amendment and rate (g/6-inch pot)		Replicates* 1	2	3	4	Total
$MnSO_4 \cdot H_2O$	0.076	0.500	0.615	0.350	0.260	1.725**
$MnCl_2 \cdot 4H_2O$	0.089	0.650	0.475	0.300	0.203[a]	1.628**
$Na_2SO_4 \cdot 10H_2O$	0.156	0.099	0.119	0.324	0.069	0.611
NaCl	0.059	0.237	0.389	0.239	0.225	1.090
Quinhydrone	1.767	0.754	0.600	0.355	0.415	2.124**
None	0	0.305	0.140	0.260	0.185	0.890

* 3 Plants/replicate, except [a] 2 plants adjusted to a 3-plant basis (3/2 x 0.135 = 0.203).

** Significantly different from control (P = <0.01).

were then washed in running water and spread to dry on filter paper placed on a pad of newspaper. After air-drying for 48 hr they were oven-dried at 105 C and weighed. Plants grown in soil amended with manganese sulfate, manganese chloride, and quinhydrone reducing compound all gave significantly higher root weights than the control (Table 3).

In 1945, paired plots of oat strain R.L. 1273 were grown on four farms at Gilbert Plains, Man., and on one farm each at Brokenhead, East Selkirk, Fort Garry, Hazelridge, Meleb, and Oakbank plants in one plot at each location were sprayed with 0.65% $MnSO_4.H_2O$. With the exception of those at Gilbert Plains all of the fields had been considered unproductive for unknown causes by Agricultural Representatives of the Manitoba Department of Agriculture.

At Gilbert Plains on Gilbert Sandy Loam soil, plots in one field showed a yield increase from spraying of 255% (P = < 0.01), but in another field on the same farm (SW 7-25-22) there was no response. In a field at NW 10-26-22, also on Gilbert Sandy Loam soil, the yield increase from spraying was 35% (P = < 0.01), and in a field at SW 8-25-22 on Dutton Clay Loam the yield increase was 16% (P = < 0.01). In a fifth field, at SW 27-25-22, also on Dutton Clay Loam, there was no response to the manganese sulfate spray.

In plots at Oakbank, Man. (SW 7-25-22) on Marquette Clay to Heavy Clay Loam soil, a yield increase of 101% (P = < 0.01) was obtained, while at Brokenhead, East Selkirk, Fort Garry, Hazelridge, and Meleb there was no response to spraying with manganese sulfate.

Wherever a substantial increase in yield was obtained a noticeable improvement was observed in the vigor and height of the plants treated with manganese sulfate.

Also in 1945, a seed steep with 23% manganese sulfate for 20 min followed by covering for 6 hr (moist) gave a yield increase of 55% in the field (P = < 0.05) at Gilbert Plains, Man. (16). Later Berkenkamp and McBeath (4) obtained some control of gray speck by pelleting seed with manganese phosphate.

In July 1945, Mr. B. Peturson drew to my attention 12 plots of Tama oats affected by gray speck at the University of Manitoba in Fort Garry. The plants were 18 inches tall and had reached the early shotblade stage, considered a late stage for a response to Mn spray. However one guard row of each plot of Tama was sprayed with 1% $MnSO_4$, the other left unsprayed. Spraying resulted in a mean increase in yield of 30% (P = < 0.01). This experiment demonstrated that a deficiency of available manganese occured in the soil type on which the moderately resistant variety Exeter was selected.

Varietal resistance

Although manganese appears to be an essential element for all oat varieties, differences in varietal resistance to gray speck have been reported by several investigators (1,2,9,11,28,32,37,38) but not always consistently. Inconsistencies may be due in part to differences in the standards used by different investigators and in part to soil heterogeneity with respect to manganese availability. It is not unusual to find the same variety with widely different severities of gray speck in different replicates of the same test. For this reason, the maximum severity found may be more reliable than the mean of all readings. Perhaps an even more reliable indication would be dry weight of roots produced in carefully controlled comparisons of different varieties grown in a uniformly-mixed soil deficient in available manganese. Dry weight of roots appeared to be a useful criterion in determining the effect of quinhydrone and might prove useful in varietal comparisons.

The original plot-by-plot data gathered at Oakbank on percentage of leaf area destroyed by gray speck and on reduced vigor, and summarized in part previously (37 Table 1), were re-examined. Of 44 varieties tested 2 years or more during 1947, 1948, and 1949, 8, (Bambu, Benton, Exeter, Landhafer, Larain, Nakota, Santa Fe, and Sixty Day) had maximum single-plot ratings of 30% or less, and 2 of these (Landhafer and Santa Fe) had maximum single-plot ratings of 15%.

Table 4. Chemical content, basis dry matter, of varieties differing in degree of gray speck development when grown on a neutral Red River clay soil deficient in available manganese at Oakbank, Man., 1945

Variety	Gray speck (%)	Ash (%)	K (%)	Ca (%)	Mg (%)	P (%)	Fe (ppm)	Mn (ppm)
Black Mesdag	6.0	10.4	3.34	0.34	0.25	0.26	160	9.5
Ajax	7.3	8.3	2.68	0.26	0.18	0.30	130	9.5
Beaver	18.3	11.6	4.29	0.37	0.32	0.39	140	10.0
Gopher	20.0	11.5	3.95	0.38	0.35	0.40	160	8.0
Tama	31.7	11.6	3.34	0.38	0.30	0.30	205	10.5
Trispernia	76.7	14.4	4.30	0.29	0.33	0.36	160	11.0

Chemical content of oat tissues

In the 1945 varietal test of resistance to gray speck reported by Welsh et al. (37), samples of plant material from two resistant, two intermediate, and two susceptible varieties were submitted for analysis to Division of Chemistry, Science Service, CDA, Ottawa, Ontario. Only minor differences in manganese content were found (F. B. Johnston, personal communication) even though there were very marked differences in the field readings for gray speck (Table 4). These data suggest that plants resistant to gray speck do not accumulate a high content of manganese. More recent data (R. I. H. McKenzie, personal communication) indicate that the manganese content of oat plants varies widely in different soils regardless of variety (Table 5 and 6) and tends to be low in fields suspected of gray speck proneness, such as those at Glenlea, Man. Low manganese content appeared both in a resistant variety, Rodney, and a susceptible variety, O. T. 187 (Tables 5, 6). A low content of manganese was also found by Leach et al. (24) in several samples of Tama oats grown at Oakbank by W. A. F. Hagborg. It seems quite possible that plant sampling for manganese content may be a useful method of surveying for gray speck-prone soils.

Table 5. Manganese content* (ppm), basis dry matter, in flag leaves of oat plants collected at 3 locations in Manitoba in 1972

Variety	Glenlea	Portage la Prairie	Brandon
Rodney	13.0	96.2	117.0
		86.8	84.0
O.T. 186	8.2		
O.T. 187	8.0	53.5	56.0
	8.0	47.2	96.1
	15.3		
	8.0		
Frazer		110.0	79.1
		92.6	80.1

* Determinations by G. Racz, Soil Science Department, University of Manitoba, by atomic absorption spectrometry (Perkin-Elmer Model 303).

Summary of reports of gray speck in western Canada

Gray speck was first reported in western Canada by Hagborg (13,14,16) at Winnipeg and Gilbert Plains in Manitoba. Later it was found at Swan River, Ethelbert, Erickson, and Oakbank (15), Portage la Prairie and Elm

Table 6. Manganese content* (ppm) in seed samples of two lines of oats grown in the Co-operative Oat Test in 1972

Variety	Glenlea, Man.	Portage la Prairie, Man.	Brandon, Man.	Indian Head, Sask.	Edmonton, Alta.
Rodney	16.2	43.0	39.0	53.5	31.2
O.T. 187	4.7	32.0	36.5	42.5	19.7

* Determinations by R.E. Smith, Soils Section, CDA Research Station, Winnipeg, Man., by atomic absorption spectrometry (Perkin-Elmer, Model 303).

Creek (23), St. Norbert (17), Balmoral, Mesieres, and Prawda (35), Starbuck and Oak Bluff (18), and Glenlea (20). A sample of typical gray speck was also received from the Peguis Indian Reserve, Hodgson, Man. in 1969.

Vanterpool (34) in 1949 first reported gray speck in Saskatchewan at Spalding and confirmed the response of oats to manganese treatment on soil from that location. Subsequently Vanterpool and Samborski (36) reported work with Mn amendments to the same soil. In 1953 and 1962 Vanterpool (36, 8) again reported gray speck at Spalding. Manganese deficiency in soils at Kinistino, Sask., was evidenced by the discovery of marsh spot in peas (Pisum sativum L.) (19). Samples of peas with the marsh spot syndrome were also received from Aylesham, Sask., and Sperling, Man.

Henry (23) first reported gray speck in Alberta in 1951 at Edmonton and in the Peace River District. In 1959 Campbell (5) reported it from 29 of 76 fields of oats surveyed in the northern part of the province. Two years later Campbell and Horricks (6) reported it in 26 fields in the north, central, and foot-hill areas of the province and, also in 1961, Campbell and Skoropad (7) confirmed that manganese deficiency was the cause of the disease and reported evidence of some factors influencing the availability of manganese in Alberta soils. Still later the disease was also found at High Prairie, McGrath, and in southern Alberta (8), Lacombe and Red Deer (3), Crooked Creek (22), La Crete, Fluffton and Two Hills (21), and Thorhild and Redwater (20).

Although gray speck is evidently widespread in Manitoba and Alberta, its importance is diminished by the fact that it occurs in patches even at the many known locations.

Discussion

Whether the abundant data on varietal reaction to the Scolecotrichum or gray speck disease reported by Nilsson-Ehle (27) in 1908 applies to our presently known gray speck disease is somewhat uncertain. It was not until 1928 that Samuel and Piper (29) showed that gray speck was a manganese-deficiency disease due probably to a deficiency of available manganese in soil. They pointed out that some kinds of plants either require less manganese or else have a greater ability to absorb manganese. They did not mention varietal differences within the cereals but stressed the difference between rye (resistant) and the other cereals. Gray-speck resistant oat varieties do not have a lower manganese content than susceptible varieties grown on the same soil (Table 4), so there should be no fear by nutritionists that widespread use of gray-speck resistant varieties would fail to supply sufficient manganese. Susceptible varieties are also low in manganese when grown on soils low in available manganese.

The question of whether or not strains of oats developed for release as commercial varieties in western Canada should have gray-speck resistance is a matter requiring the appraisal of several factors. Obviously resistance is a desirable character, but lack of gray-speck resistance may not be sufficiently important to prevent the release of new varieties with other desirable characteristics such as resistance to stem rust.

From the data reviewed in this paper it is obvious that soils lacking available manganese are widespread in Manitoba and Alberta and are present locally in Saskatchewan. To date there is insufficient data from the prairie provinces on gray speck to arrive at a firm conclusion as to the need for resistance to it in a new variety. It would appear that a thorough survey, possibly in cooperation with Agricultural Representatives, in which tissue samples are collected and analyzed by atomic absorption spectrophotometry would provide the required data for estimating the extent of the problem and the probable monetary loss associated with releasing a variety lacking resistance to gray speck. Comparisons could then be made with potential losses from susceptibility to other diseases such as stem rust.

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