A Plant Assay of Soil to Assess Potential Damage to Wheat by *Heterodera avenae*

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ABSTRACT

SIMON, A. 1980. A plant assay of soil to assess potential damage to wheat by *Heterodera avenae*. Plant Disease 64:917-919.

A plant assay of soil to predict, before seeding, the potential damage to wheat by cereal cyst nematode (CCN) in soil from individual fields is described, validated, and compared with CCN egg counts of the same soil samples. The relationship between the plant assay of CCN in 17 fields and the yield response to nematicide application was highly significant (r value, 0.65).

The cereal cyst nematode (CCN) or cereal eelworm (*Heterodera avenae* Woll.) is a major soilborne pathogen that limits the production of wheat grown in large areas of Victoria and South Australia (1,5,8,11,14,15). Meagher (9) found CCN in Victoria in 71% of Mallee soils (0.75 million ha sown to cereals in 1962) and 46% of Wimmera soils (0.5 million ha sown to cereals in 1962). CCN occurs in New South Wales (7) and Western Australia (13) but does not cause widespread disease in either state.

Extensive trials in South Australia in 1976–1978 by CSIRO and the South Australian Department of Agriculture showed that CCN causes losses in wheat production of 0.3 to 1 t/ha. Rovira (14) estimated that the annual cost to wheat production due to CCN damage was $15 million in South Australia.

Field trials in Victoria and South Australia have demonstrated that nematicides such as aldicarb increase wheat yields by controlling CCN (3–5,14; King, Rovira, Brown, Brisbane, and Simon, *unpublished*).

The magnitude of the damage caused by CCN and the resulting loss in grain production depend on many factors (eg, CCN population and soil moisture, temperature, and fertility), and hence any estimate of the level of CCN in soil can predict only the potential damage.

With the recent developments in chemical (3–5) and agronomic (12) control of CCN, farmers now have options for combating the disease. Some options such as chemical control are costly, and a test to predict the potential damage from CCN would help farmers. The direct method of predicting potential damage is to sample the soil before seeding and count CCN eggs. However, the use of a susceptible plant such as wheat as an indicator of CCN damage has the advantages of integrating plant growth with the CCN level and other soil factors; the test can also provide valuable information about the levels of other soilborne root pathogens such as the take-all fungus, *Gaeumannomyces graminis* var. *tritici*, and the bare-patch fungus, *Rhizoctonia solani*.

This paper describes a plant assay that I developed and discusses its validation and justification as a method of assessing the potential damage to wheat by CCN.

MATERIALS AND METHODS

Soil sampling. Soil sampling is critical because the CCN population varies at different points within a field.

Soil was sampled in January with at least five replicate samples per field or per major soil type in the field. Each sample was a composite of 10 × 1 kg samples from 0 to 10 cm along each of the lines such as shown in Fig. 1. After samples were sieved (6-mm mesh) and thoroughly mixed, a 1-kg subsample was kept for the assay. Root material to which cysts might be attached were retained after sieving and distributed throughout the soil.

CCN hatching. Each soil was wet to 75% of field capacity and incubated at 15 C for at least 4 wk to maximize hatching (2,10;Rovira and Simon, *unpublished*).

Seeding procedure and growth conditions. Superphosphate was mixed with the moist soil at 200 mg/kg before the sample was divided in two. One portion was seeded but not treated further. The nematicide aldicarb, in a 10% granular formulation, was added at 9 mg/kg to the other portion before seeding to ensure a CCN-free control. Moist soil (400 g) was placed in a tapered pot 11 cm deep and 7 cm in (top) diameter, and five seeds of a susceptible wheat cultivar were planted 1 cm below the surface. Although the diameter of the pot and the number of seeds per pot could be reduced, the depth is necessary for adequate root growth during a 4-wk growth period.

The pots were placed in refrigerated root temperature tanks at 10 C, with the plant tops growing at glasshouse temperature.

CCN disease assessment. After 4 wk the roots were washed free of soil, and the level of CCN infestation was assessed either by a visual rating of 0–5 (Fig. 2) or by the mean depth to which 90% of the roots had grown in soil with and without CCN, expressed as "percent reduction in rooting depth."

Validation of the plant assay. To check the validity of the plant assay as an

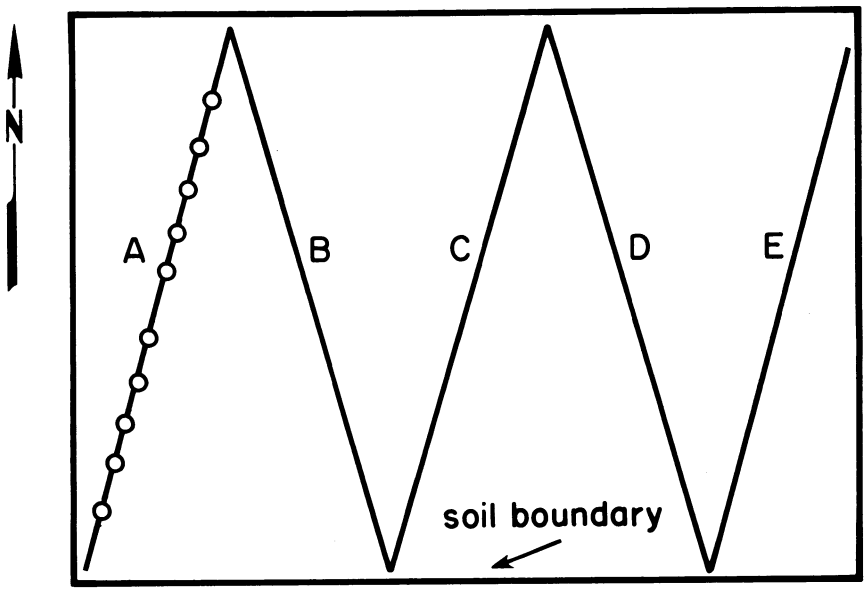

Fig. 1. Plant assay of soil to determine potential damage to wheat by *Heterodera avenae*: suggested pattern for obtaining five replicate samples (A–E), each sample being a composite of 10 subsamples. o = 1-kg sample.

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Table 1. *Heterodera avenae* egg counts, plant assay and field disease ratings, and yield response to application of aldicarb in wheat fields in the Coonalpyn District of South Australia in 1978

Site[a]	Egg counts		Plant assay			Field disease rating (0–5)[c]	△ Yield (t/ha)[d]
	Eggs in soil[b] (no./200 g)	Coefficient of variation (%)	Disease rating (0–5)[b]	Coefficient of variation (%)	% Reduction in rooting depth[b]		
1	0	...	0	...	0	1	0
2	50	232.6	0.1	230.0	1	0	0
3	330	156.9	0.7	64.3	3	2	0.06
4	65	185.2	0.8	32.5	0	1	0.20
5	440	186.4	0.9	24.4	3	2	0
6	440	115.8	0.9	24.4	11	3	1.02
7	640	118.2	1.1	20.0	8	1	0.51
8	170	116.7	1.2	22.5	17	4	0.80
9	980	49.6	1.3	34.6	26	4	0.57
10	1,100	46.8	1.4	20.0	20	3	0.66
11	610	75.1	1.6	26.3	29	2	0.39
12	1,210	20.8	2.3	11.7	23	4	0.38
13	1,290	37.5	2.3	19.6	35	4	0.73
14	900	35.5	2.6	15.8	26	4	0.98
15	510	95.3	2.8	32.5	45	4	0.45
16	1,070	38.8	3.0	14.3	45	3	0.53
17	1,700	20.7	3.5	24.9	36	3	1.37

[a] Determinations on three of the 20 sites were omitted from this table; two had severe *Rhizoctonia* damage and the other had damage to the mature crop by emus.
[b] Mean of duplicate determinations on each of five replicate soil samples.
[c] Field disease rating (0–5) made on wheat plants collected in August from the 20 experimental field sites.
[d] △ Yield (t/ha): Yield response in wheat to application of aldicarb at 0.6 kg/ha; ie, △ yield (t/ha) = (mean yield [t/ha] of duplicate plots with aldicarb) − (mean yield [t/ha] of duplicate plots without aldicarb).

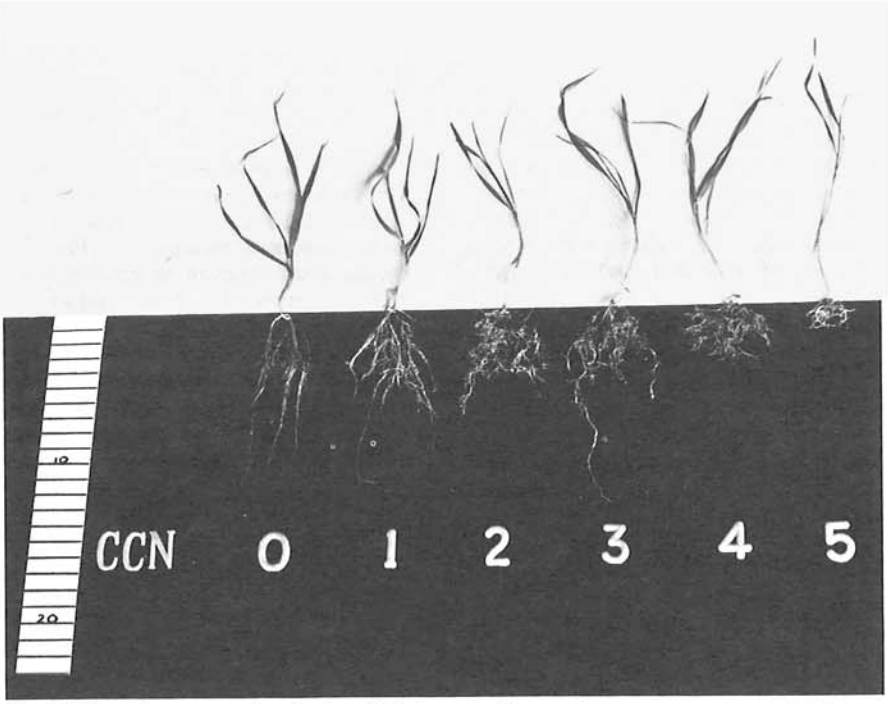

Fig. 2. *Heterodera avenae* visual rating (0–5): 0 = no evidence of cereal cyst nematode (CCN); 1 = 1–5 CCN galls per root system, no reduction in root length; 2 = 5–25 CCN galls per root system, 20% reduction in root length; 3 = 25–50 CCN galls per root system, 40% reduction in root length; 4 = more than 50 CCN galls per root system, 60% reduction in root length, top growth reduced by 25%; 5 = roots very knotted, 80% reduction in root length, top growth reduced by 50%.

indicator of potential CCN damage, a relationship was established between the plant assay results and egg counts on the same 100 soil samples from the Coonalpyn district of South Australia.

The 100 soil samples collected in January 1978 were from 20 fields on 11 farms and represent a range of soil types and soil fertility levels. Each site was divided into 10 parts; five samples, each a composite of 10 subsamples (one from each part), were collected. The farms and fields were selected without prior knowledge of CCN levels and could be taken as representative of the district.

The egg counts and plant assays were conducted on the soil samples between January and March 1978. In June the 20 sites were sown to wheat (cv. Condor) in plots with and without aldicarb. Between August and September the actual damage to the wheat seedlings by CCN was assessed by a 0–5 rating similar to that used in the plant assay. Yield losses to CCN were assessed by the increase in grain yield in response to aldicarb applied in the drill rows at 0.6 kg/ha.

RESULTS

The results in Table 1 show that at most sites, the field disease rating was higher than the plant assay disease rating, possibly because plants growing in the glasshouse, unlike those in the field, do not experience stresses of water and temperature.

The statistical significances of the relationships that are important in assessing the accuracy and reliability of the plant assay to predict the potential damage to wheat by CCN are presented in Table 2. The correlation between egg count and visual disease rating in the plant assay was highly significant (0.84, $P = 0.001$). The prediction of damage to the wheat crop in the field was better when based on the plant assay than on the egg count. The correlation between yield reponse to aldicarb and the CCN disease rating as assessed by the plant assay was highly significant (0.65, $P = 0.01$); the correlation between yield response to aldicarb and egg counts was similar.

DISCUSSION

The plant assay disease rating cannot be expected to correlate very closely with yield because yield depends on many interacting soil and climatic factors. Despite these limitations, there was a significant correlation of 0.65 ($P = 0.01$) between the plant assay disease rating and the yield

Table 2. Significance of relationships between factors used to assess potential damage and those used to assess actual damage to wheat by cereal cyst nematodes

Factors predicting potential damage (x)	Other (y)	Correlation coefficient (r)	Proportion of variation described by correlation r^2	Equation of straight line (y = a + bx)	Significance (P =)
Plant assay disease rating	Egg count	0.80	0.64	y = 68.49 + 393.99x	0.001
Egg count	Field disease rating	0.59	0.35	y = 1.59 + 0.0016x	0.02
Plant assay disease rating	Field disease rating	0.67	0.45	y = 1.29 + 0.87x	0.01
Egg count	△ Yield[a]	0.64	0.41	y = 0.17 + 0.0005x	0.01
Plant assay disease rating	△ Yield	0.65	0.42	y = 0.12 + 0.25x	0.01
Field disease rating	△ Yield	0.61	0.37	y = 0.03 + 0.18x	0.01

[a] △ Yield = (Yield [t/ha] in plots with aldicarb at 0.6 kg/ha) − (Yield [t/ha] in plots without aldicarb).

response when CCN was controlled with aldicarb.

The population of CCN varies widely in a field (6), and a soil sample must be representative of the field to assess potential CCN damage to wheat reliably by egg counts or a plant assay. A reliable sample can be obtained by pooling subsamples, as I have suggested. Although egg counts remain the most direct method of estimating potential damage to wheat by CCN, the plant assay compares favorably with egg counts because it does not require a high level of training in nematology and varies less than egg counts (Table 1).

Possible reasons for the lower variability are that: (1) More soil is used for the plant assay than can be treated practicably for an egg count. The variability could be decreased further by incubating a larger sample of moist soil than was done in this study and by conducting the assay on a subsample. (2) CCN eggs are aggregated inside a few cysts, whereas the plant assay depends on dispersed, hatched larvae.

Other advantages of the plant assay are that it assesses damage due to the CCN larvae that have hatched, albeit under conditions that promote maximum hatching. This assessment may indicate what occurs in the field better than an egg count, which estimates the number of larvae that could hatch in the forthcoming season. The plant assay also integrates soil factors such as fertility with damage due to CCN.

The plant assay has been used to screen chemicals such as geofos, terbufos, and oxamyl for their ability to protect wheat from CCN. Results are obtained within 8 wk, compared with field trials that take 6–9 mo. The plant assay takes 60–75 min to conduct per soil sample, regardless of soil type; an egg count takes 1–2 hr per soil sample, depending on the soil type.

I suggest that the assay be given the name SIRONEM test.

ACKNOWLEDGMENTS

I thank A. D. Rovira and P. G. Brisbane for encouragement and valuable discussions. I also thank R. H. Brown, Leanne Clarkson, and Damien O'Rourke (Victorian Department of Agriculture) for egg counts and Union Carbide Australia Ltd. and Cyanamid Australia Pty. Ltd. for providing technical assistance and chemicals. The field ratings were conducted by P. M. King, South Australian Department of Agriculture, as part of the joint study with CSIRO Division of Soils in the Coonalpyn District of South Australia.

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