Soilborne Pathogens on Cereals in a Highland Location of Mexico

D. A. LAWN and K. D. SAYRE, Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), Lisboa 27, Apdo. Postal 6-641, Col. Juarez, Deleg. Cuauhtemoc, 06600 Mexico D.F., Mexico

ABSTRACT

Lawn, D. A., and Sayre, K. D. 1992. Soilborne pathogens on cereals in a highland location of Mexico. Plant Dis. 76:149-154.

Fumigation trials with methyl bromide and dazomet were established in El Batan, Mexico, during 1988 and 1989. Genotypes of triticale (× *Triticosecale*), bread wheat (*Triticum aestivum*), and durum wheat (*Triticum durum*) were evaluated for susceptibility to indigenous soilborne pathogens. The predominant pathogens identified included *Cochliobolus sativus*, *Fusarium* spp., *Gaeumannomyces graminis* var. *tritici*, and *Pratylenchus thornei*. Initial infections on all genotypes were predominantly attributable to *C. sativus*, but when present, *G. g. tritici* was the predominant pathogen on the bread wheat and durum wheat genotypes by a milk stage of development. In 1989, *G. g. tritici* was isolated from 10% of the discolored triticale roots sampled at this stage, compared with 60 and 63% from the discolored bread wheat and durum wheat roots, respectively. Analysis of variance indicated significant fumigation effects on soil populations of *P. thornei* at planting and harvest. Significantly greater reproduction of *P. thornei* occurred on the bread wheat genotypes than on either durum wheat or triticale. Higher tiller numbers were observed throughout the season in both years after fumigation. Fumigation significantly increased the number of spikes per square meter but not vegetative biomass. Because of severe weather, yield data provided no clear indications of the degree of pathogenicity posed by soilborne pathogens.

World awareness of the International Maize and Wheat Improvement Center (CIMMYT) was partially brought about through the publicity given to the high-yielding wheat varieties developed during the 1960s and their role in the "Green Revolution." Breeding for resistance to the major wheat diseases and multilocation testing have played a historical role in this progress (5). Since 1986, the emphasis on research has focused on sustaining the increased yields that directly or indirectly resulted from this "revolution" while conserving the natural resource base of agricultural systems. One related concern is the potential buildup of soilborne, biotic factors that are not easily diagnosed and that may be related to the trend toward increasing cropping intensity throughout the world. As scientists begin to use new breeding and crop management strategies to tackle the sustainability issue, the biotic components of the soil environment must be analyzed as part of an integrated system.

The major cereal root diseases identified at CIMMYT's highland research station (El Batan) in the Valley of Mexico include common root rot, Fusarium foot rot, and take-all (7,11). Of major importance in understanding the literature on Fusarium root rot diseases is recognizing the distinction between common root rot and foot rot. In both, the causal agent(s) include *Fusarium* spp., typically *F. graminearum* Schwabe, *F. culmorum* (W. G. Smith) Sacc., and *F. avenaceum* (Fr.:Fr.) Sacc., but common root rot is a disease complex that also includes *Cochliobolus sativus* (Ito & Kuribayashi) Drechs. ex Dastur (anamorph *Bipolaris sorokiniana* (Sacc.) Shoemaker, syn. *Helminthosporium sativum* Pammel, C. M. King & Bakke). Common root rot occurs on wheat in the form of honey-brown lesions of the crown and subcrown internode, with annual losses in Canada ranging from 2 to 12% (21) and a mean loss of 19% in Brazil (4). Of the two, foot rot is the more insidious disease, causing decay of the crown and basal stem tissue, and has the potential to cause severe yield loss. Development of the more severe foot rot stage from the common root rot stage can occur but depends on very low plant water potential (3). Infections by *Gaeumannomyces graminis* (Sacc.) Arx & D. Oliver var. *tritici* J. Walker, causal organism of take-all, are greatly influenced by soil conditions and the environment, and lesions are typically black. Also, it has been recognized that the incidence of take-all significantly declines after a continuous succession of susceptible cereal crops (16). No data on the historical incidence of take-all at El Batan are available and it is not known whether or not the fields of El Batan depict a similar take-all decline.

In general, studies on wheat/nematode relationships of cereals have been neglected, but recent research efforts are beginning to fill this vacuum (9,10, 13–15). *Pratylenchus thornei* Sher & Allen is one of the most frequently recognized nematodes parasitic to wheat. Yield reductions attributable to this nematode in the Yaqui Valley of Mexico have ranged from 6 to 32% (22) and up to 85% in Queensland, Australia (20). Additional *Pratylenchus* spp. parasitic on wheat in the temperate semiarid regions of the world include *P. neglectus* (Rensch) Filipjev & Schuurmans Stekhoven (syn. *P. minyus* Sher & Allen), *P. penetrans* (Cobb) Chitwood & Oteifa, *P. zeae* Graham, and *P. mediterraneus* Corbett (14,17). The possibility of the presence of plant-parasitic nematodes at El Batan has never been adequately surveyed, although the predominant parasite of wheat appears to be *P. thornei* (D. A. Lawn, *unpublished*).

Many of the fields at the El Batan station have been planted continuously with cereals during the summer season for more than 20 yr. This intense planting of cereals with minimal crop rotation has created a unique environment that may simulate similar intensive cereal cropping systems in areas with limited crop rotation options. The present study will provide more basic information into the ecology and population dynamics of soilborne pathogens present in this highland location of Mexico. This information, in turn, may serve as an indicator of potential threats to a sustainable agricultural system in this environment. In addition, the results can serve as a database of these pathogens at this CIMMYT station for future studies on disease control that are appropriate to the developing world.

MATERIALS AND METHODS

Trials were conducted in different locations during 1988 and 1989 at CIMMYT's El Batan research station, where the average temperature is 16.6 C and rainfall averages 480 mm during the growing season from May to September. Soils are a clay loam, pH 6.0, with a 1.5% organic matter content. Land preparation included incorporation of the winter cover crop, *Vicia sativa* L., as a green manure, by a disk plow followed by two disk-harrowings and land planing. Before the second disk harrow, nitrogen was applied as urea (75 kg/ha). Approximately 4 wk after planting, the herbicides Illoxan (diclofop-methyl) and Brominal (bromoxynil) were applied at 0.85 and 0.44 kg a.i./ha, respectively. Timely applications of the fungicide Bayleton (triadimefon) were made at 0.13

Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by CIMMYT and does not imply its approval to the exclusion of other products that may also be suitable.

Accepted for publication 11 August 1991 (submitted for electronic processing).

kg a.i./ha for the control of leaf rust. Supplemental irrigations were applied as needed to prevent plant stress.

The experimental design was a split-plot with four replications. Fumigation treatments were main plots and crop/genotypes were subplots. Root rot and nematode population data were analyzed as a split-split-plot with sampling dates as sub-subplots. Root rot incidence was transformed using the square root of the percentage of plants infected + 0.5 or an arcsine transformation was performed on the square root of the percentage. Main plots were fumigated with Basamid (dazomet) at the rate of 387.5 kg a.i./ha or Fumigran (methyl bromide) at 565 kg a.i./ha in 1988, both chemicals at 454 kg a.i./ha in 1989, or were not fumigated. The dazomet was broadcast, incorporated by disking to approximately 15 cm, and the soil surface of the treated area was compacted and sprinkle-irrigated to enhance and activate the fumigant. The plots fumigated with methyl bromide were covered with polyethylene before releasing the fumigant at equally spaced intervals at a 10-cm depth. The polyethylene was removed after 72 hr, and 3 wk after applying both treatments, all plots were disked. Subplots were six rows, 5 m long with 30 cm between rows in 1988 and in 1989 were three 5-m long beds with 75-cm bed width and two rows per bed (20 cm between rows). The following crop/genotypes were hand-planted at the corresponding rates: triticale (× *Triticosecale* Wittmack) genotypes Rhino"S" and Eronga 83, 110 kg/ha; bread wheat (*Triticum aestivum* L.) genotypes Seri M82 and Galvez 87, 120 kg/ha; durum wheat (*T. durum* Desf.) genotypes Altar 84 and Sula//WLS/DWL 5023, 130 kg/ha.

Yield parameters were determined by harvesting the central 4 m of the two center rows of each subplot, and the remaining border rows were used for root samples. Infections of plants by soilborne fungi were assessed by uprooting 10 plants at random with a trowel from these border rows at 4 wk after planting (tillering, Feekes scale = 3–4) and 8 wk (booting, Feekes scale = 10) in both years and at 12 wk (milk, Feekes scale = 11.1) in 1989. Root systems were washed thoroughly, the number of tillers per plant was counted, and crown, subcrown internode, and secondary roots were assessed microscopically for discoloration and decay on a scale of 1–5 (19). Fungi were isolated from one to three subsamples from each diseased plant, depending on the amount of infection present. Each section of diseased root tissue tested was cut in two sections and surface-disinfested in 0.6% NaOCl for 1–2 min. After rinsing in distilled water, one section was plated on potato-dextrose agar (PDA) amended with 100 μg/L of sterile streptomycin sulfate and 50 μg/L of rose bengal, and the second section was plated on Nash and Snyder's PCNB medium (12). Plates were held for 7 days in an incubator set with alternating 12-hr cycles of 25 C with light and 20 C without light. Colonies of *C. sativus* were identified from the PDA/rose bengal, whereas fungal isolates from the PCNB medium were transferred to PDA amended with 100 μg/L of sterile streptomycin sulfate for identification. When *G. g. tritici* was suspected (black lesions), a third section of root tissue was cut, surface-disinfested in 1% $AgNO_3$ for 20 s, and rinsed once in 5% NaCl and twice in distilled water (18). Plant tissue was then placed on PDA and incubated at 20 C with 12 hr of alternating light and dark. Percentages of fungi isolated from diseased tissue were grouped by fumigation treatment and crop.

Soil samples were collected at planting (postfumigation) and again at harvest. For each experimental unit, eight to 10 subsamples were collected at random within rows using a 2-cm-diameter soil probe to a depth of 20 cm and mixed thoroughly. Nematodes were extracted from a 100-cm^3 aliquant portion of soil by Cobb's gravity sieving technique (2) with 850- and 44-μm pore sieves and the rapid centrifugal-flotation technique (8). Root samples from the previously collected plants, which were not incubated for fungi, were chopped and nematodes were extracted using a 72-hr shaker incubation at room temperature (1). Roots were then dried for 3 days at 75 C and weighed to estimate the number of nematodes per gram of dry root.

RESULTS

At the tillering stage in both years, root rot incidence was lowest after treatment with methyl bromide, and these values were significant in 1988 for the triticale genotypes Rhino"S" and Eronga 83 and the durum wheat Altar 84 (Table 1). By plant booting, root rot incidence appeared to decline in nonfumigated plots during 1988 and the bread wheat Seri M82 depicted a significantly higher incidence after methyl bromide compared with the control. At the booting stage in 1989, root rot incidence was significantly lower in Seri M82, Galvez 87, and Sula//WLS/DWL 5023 fumigated with methyl bromide than in controls. Significant control of root rot incidence with methyl bromide was maintained through the milk stage in Seri M82 and Sula//WLS/DWL 5023. In general, plots treated with dazomet rendered an intermediate control of root rot incidence between methyl bromide-fumigated and nonfumigated controls. In both years, levels of root rot severity indicated that infection was limited to 2–10% of the subcrown internode and secondary root system, except at the milk stage in 1989 when severity levels increased to levels >50%. Root rot severity levels were highest in the fumigated bread wheat subplots at the milk stage in 1989 but were not significantly different from the other treatments.

The predominant fungi identified in both years from diseased tissue at 4 and 8 wk after planting were *C. sativus* and *Fusarium* spp. (Figs. 1 and 2). However in 1989, *G. g. tritici* was isolated at 8 wk and was the predominant pathogen by 12 wk on bread wheat and durum wheat. Of the *Fusarium* spp. identified, *F. oxysporum* Schlechtend.:Fr. and *F. solani* (Mart.) Sacc. predominated,

Table 1. Effects of fumigation on percentage of sampled plants with root rot for triticale, bread wheat, and durum wheat genotypes at 4 and 8 wk after planting in 1988 and 4, 8, and 12 wk in 1989

			Sample date (weeks after planting)				
			1988		1989		
Fumigation	Crop	Genotype	4[x]	8[x]	4[x]	8[x]	12[y]
Methyl bromide	Triticale	Rhino "S"	2.5*[z]	7.5	0.0	2.5	2.5
		Eronga 83	7.5*	0.0	0.0	0.0	7.5
	Bread wheat	Seri M82	15.0	17.5*	0.0	5.0*	15.0*
		Galvez 87	12.5	15.0	5.0	0.0*	20.0
	Durum wheat	Altar 84	12.5*	5.0	0.0	7.5	22.5
		Sula//WLS/DWL 5023	17.5	20.0	5.0	0.0*	2.5*
Dazomet	Triticale	Rhino "S"	12.5	17.5	2.5	7.5	7.5
		Eronga 83	25.0	7.5	0.0	0.0	5.0
	Bread wheat	Seri M82	22.5	5.0	2.5	12.5	25.0*
		Galvez 87	35.0	2.5	7.5	7.5	37.5
	Durum wheat	Altar 84	20.0	17.5	0.0	10.0	22.5
		Sula//WLS/DWL 5023	35.0	15.0	0.0	5.0*	17.5*
Nonfumigated	Triticale	Rhino "S"	27.5	5.0	10.0	10.0	10.0
		Eronga 83	27.5	2.5	5.0	2.5	5.0
	Bread wheat	Seri M82	25.0	2.5	5.0	25.0	45.0
		Galvez 87	25.0	12.5	5.0	20.0	35.0
	Durum wheat	Altar 84	42.5	12.5	0.0	12.5	30.0
		Sula//WLS/DWL 5023	35.0	12.5	2.5	20.0	35.0

[x]Analyzed following the transformation: $\sqrt{\%} + 0.5$.
[y]Analyzed following the transformation: arcsine $\sqrt{\%}$.
[z]Significantly different from the nonfumigated control by LSD (0.05).

whereas *F. graminearum* was sporadically isolated.

Three genera of plant-parasitic nematodes were identified—*Scutellonema*, *Tylenchorhynchus*, and *Pratylenchus*. Negligible levels of the *Scutellonema* sp. and *Tylenchorhynchus* sp. were extracted from soil at planting and harvest, whereas high populations of *P. thornei* were extracted (Figs. 3 and 4). A significant fumigation effect was detected for initial soil populations of *P. thornei*, but no differences were found among crop/genotypes. Significantly lower at-planting populations occurred in all crop/genotypes after fumigation with methyl bromide. Dazomet treatment resulted in a significant reduction in soil populations of *P. thornei* compared with nonfumigated controls. However, only in 1989 was this reduction statistically similar to that achieved with methyl bromide. Root populations of *P. thornei* were reduced significantly at tillering in both years in plots fumigated with methyl bromide (Table 2). Root populations of *P. thornei* in the dazomet plots were not statistically lower than the untreated plots at tillering in the genotypes Rhino"S", Eronga 83, and Galvez 87 in 1988 and Rhino"S" in 1989. Significant fumigation effects, genotype, and a genotype × fumigation interaction were found for final soil population levels at harvest. Significantly lower final soil populations occurred in all genotypes fumigated with methyl bromide, but only in 1989 were dazomet-treated Rhino"S" and Seri M82 significantly less than those in the nonfumigated controls. Significantly higher final soil populations were found on bread wheat genotype Seri M82 than on triticale or durum wheat in dazomet-treated and nonfumigated plots during both years. Similarly, final soil populations for Galvez 87 were significantly greater in 1988 but limited to dazomet-treated plots in 1989. No significant differences were found between the triticale or durum wheat genotypes, except in 1989 when Sula//WLS/DWL 5023 had less than Rhino"S" in nonfumigated plots.

Tiller number was higher in fumigated than in nonfumigated plots in all samples of 1988 and 1989 (Table 3). The number was greater with methyl bromide than dazomet, and the difference in number of tillers between plots fumigated with methyl bromide and nonfumigated subplots at 4 wk after planting was significant for all genotypes except the triticale Rhino"S" in 1989. Some plant yellowing, apparently associated with methyl bromide fumigation, was observed with Galvez 87 and Sula//WLS/DWL 5023 during grain filling, which confounded grain yield data. In addition, early frost and severe weather in both years rendered grain yield data unreliable. Plant lodging was significantly greater in fumigated vs. nonfumigated plots with the exception of triticale subplots, where all plots were lodged because of their tall stature. Fumigation increased the number of spikes per square meter and occasionally decreased vegetative biomass (Table 4). In both years, the main treatment effect (fumigation) was significant on spikes per square meter but not significant on vegetative biomass. In 1989, there was a significant fumigation × genotype interaction on vegetative biomass.

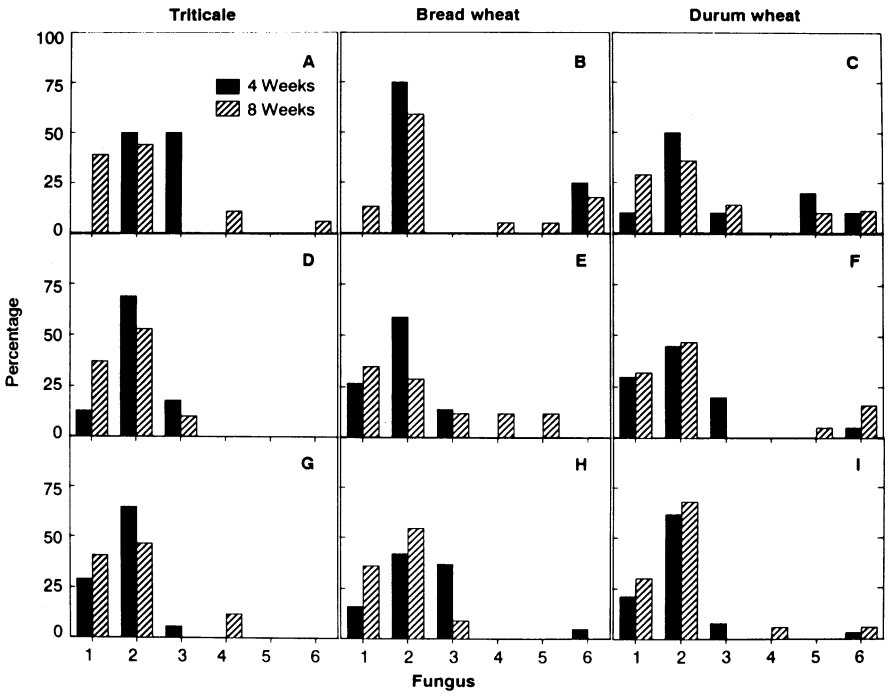

Fig. 1. Percentages of fungi isolated in 1988 from necrotic tissue of triticale, bread wheat, and durum wheat at 4 and 8 wk after planting, following fumigation with **(A-C)** methyl bromide, **(D-F)** dazomet, and **(G-I)** nonfumigated. Fungus: 1 = *Cochliobolus sativus*, 2 = *Fusarium oxysporum*, 3 = *F. solani*, 4 = *F. graminearum*, 5 = *F. equiseti*, and 6 = *Rhizoctonia* sp.

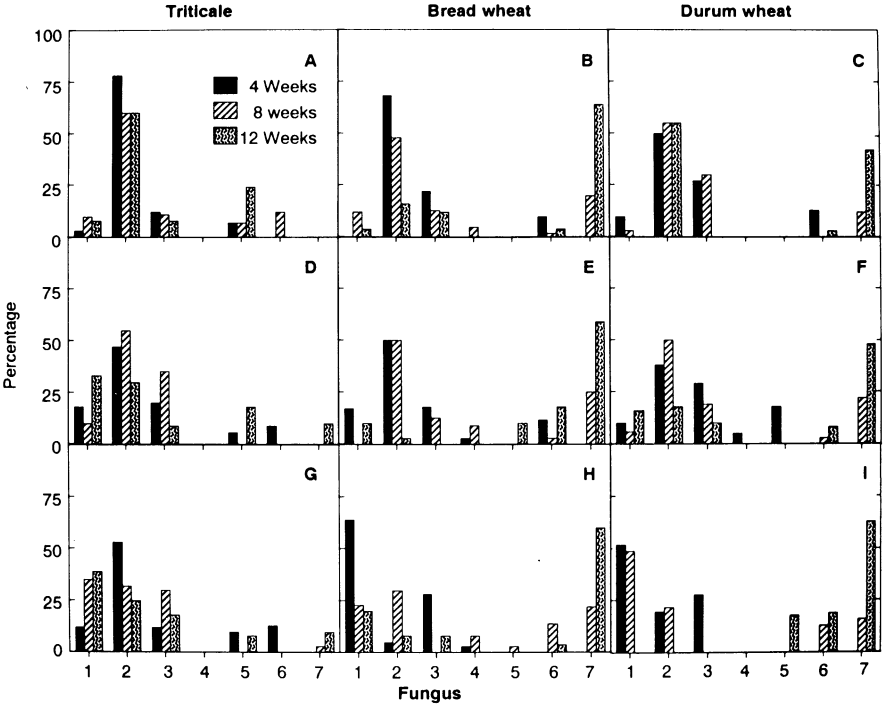

Fig. 2. Percentages of fungi isolated in 1989 from necrotic tissue of triticale, bread wheat, and durum wheat at 4, 8, and 12 wk after planting, following fumigation with **(A-C)** methyl bromide, **(D-F)** dazomet, and **(G-I)** nonfumigated. Fungus: 1 = *Cochliobolus sativus*, 2 = *Fusarium oxysporum*, 3 = *F. solani*, 4 = *F. graminearum*, 5 = *F. equiseti*, 6 = *Rhizoctonia* sp., and 7 = *Gaeumannomyces graminis* var. *tritici*.

DISCUSSION

Root rot incidence at tillering in nonfumigated plots was greater in 1988 than 1989, but in 1988, incidence levels had decreased by the booting stage. This was probably a reflection of including superficial root discoloration in the early disease ratings. In contrast, 1989 root rot incidence increased by plant booting, particularly among the bread wheat genotypes. By the milk stage of development, root rot incidence had increased less on the triticale genotypes than on the bread and durum wheats, regardless of fumigation treatment.

In both years, initial root infections were caused by *C. sativus* and the *Fusarium* spp. These fungi, pathogens in the common root rot complex, are known to decrease the tillering potential of cereals (6), and such a response was observed in the present study. Although the severity of yield loss attributable to common root rot at El Batan could not be determined from this study, decreased plant tillering was observed. This decrease may confound estimations of genetic yield potentials in the El Batan environment. The adequate soil fertility and timely irrigations may minimize damage from common root rot, but the presence of take-all, identified at later plant development stages, is a potential threat to germ plasm evaluation. Compared with the bread wheat and durum wheat, the lower incidence of disease caused by *G. g. tritici* among the triticale genotypes used, which have a complete set of seven rye chromosomes, supports the previous report that intermediate resistance between wheat and rye is inherited in certain triticale lines (23). Although no significant differences in severity levels were detected, observation of the highest levels in fumigated bread wheat subplots, when *G. g. tritici* was the predominant pathogen, suggests that soil microflora at El Batan may play a role in the biological control of take-all. Future studies on the epidemiology of take-all at El Batan are needed to confirm the presence of take-all decline.

High populations of the root lesion nematode, *P. thornei*, were found in the soil and in the plant roots, but the degree of damage to the plants is unknown. Differences were noted among crops and genotypes in susceptibility, however, no information is available on their tolerance under the test conditions. Previously, at El Batan, positive yield responses did not occur when Temik 15G (aldicarb) was applied at 2.25 kg a.i./ha (D. A. Lawn, *unpublished*). The use of broad-spectrum fumigants in the present work largely precluded differentiation of host genotype-pathogen interactions. Nematode invasions, however, likely predispose the plants to infection by other soilborne pathogens. The differences among the crops in susceptibility to *P. thornei*, therefore, are important regardless of the extent of direct damage. Quantifying this susceptibility/resistance may well play a role in an integrated pest management approach to control *P. thornei*.

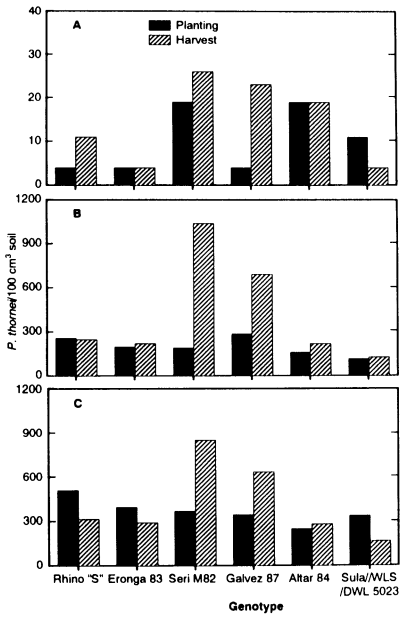

Fig. 3. Soil populations of *Pratylenchus thornei* at planting and harvest in 1988 on triticale, bread wheat, and durum wheat genotypes after fumigation with **(A)** methyl bromide, **(B)** dazomet, and **(C)** nonfumigated. Least significant difference (0.05) at planting = 233 and at harvest = 275.

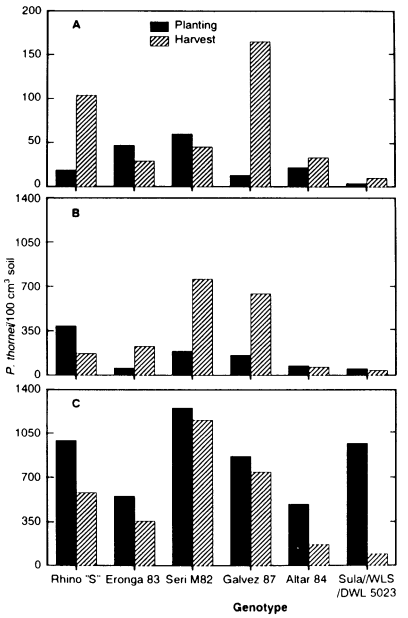

Fig. 4. Soil populations of *Pratylenchus thornei* at planting and harvest in 1989 on triticale, bread wheat, and durum wheat genotypes after fumigation with **(A)** methyl bromide, **(B)** dazomet, and **(C)** nonfumigated. Least significant difference (0.05) at planting = 544 and at harvest = 273.

Table 2. Effects of fumigation on *Pratylenchus thornei* per gram of dry root for triticale, bread wheat, and durum wheat genotypes at 4 and 8 wk after planting in 1988 and 4, 8, and 12 wk in 1989

			Sample date (weeks after planting)				
			1988		1989		
Fumigation	**Crop**	**Genotype**	**4**	**8**	**4**	**8**	**12**
Methyl bromide	Triticale	Rhino "S"	25*[z]	84*	604*	251	280
		Eronga 83	45*	52*	382*	68	33*
	Bread wheat	Seri M82	32*	108*	168*	99*	467*
		Galvez 87	28*	129*	218*	83	200*
	Durum wheat	Altar 84	25*	63*	207*	163	253*
		Sula//WLS/DWL 5023	40*	20*	361*	63	53
Dazomet	Triticale	Rhino "S"	1,292	893	1,395	135	350
		Eronga 83	530	486	742*	167	90*
	Bread wheat	Seri M82	552*	702*	1,115*	633	840
		Galvez 87	1,055	1,116	893*	257	410*
	Durum wheat	Altar 84	1,714*	189	387*	100	270
		Sula//WLS/DWL 5023	1,294*	182	503*	75	70
Nonfumigated	Triticale	Rhino "S"	1,176	782	1,970	527	700
		Eronga 83	872	761	2,423	417	713
	Bread wheat	Seri M82	4,956	2,322	4,401	888	1,267
		Galvez 87	1,152	984	4,732	398	1,013
	Durum wheat	Altar 84	3,163	460	2,430	413	793
		Sula//WLS/DWL 5023	4,522	236	2,888	139	280

[z] Significantly different from the nonfumigated control by LSD (0.05).

Environmental conditions at El Batan, together with genotypes susceptible to plant lodging, prevented the detection of yield losses attributable to diseases caused by soilborne pathogens. The increased lodging in fumigated plots was likely a result of the significant increase in spikes per square meter after fumigation. Results in 1989 indicated an increase in vegetative biomass associated with fumigation, with the exception of Galvez 87 and Sula//WLS/DWL 5023. This discrepancy, which probably resulted in the significant fumigation × genotype interaction, is likely attributable to the physiological sensitivity of these genotypes to the effects of methyl bromide. In addition, the later maturity of Sula//WLS/DWL 5023 may have resulted in detrimental environmental interactions. The effects on tillering by early infections attributable to soilborne organisms, together with later take-all infections, may be detrimental to germ plasm assessment in CIMMYT's breeding programs.

The implications of the results from this type of study on CIMMYT's crop management and breeding programs may be broad ranged. The maintenance of high disease potential of a diverse number of pathogens may provide a useful environment for evaluating the effects of crop management strategies on soilborne pathogens and for selection of disease resistant materials. From the present study, it becomes clear that screening germ plasm for resistance to common root rot at El Batan is possible at the late tillering or booting stages of development, before infections by *G. g. tritici*, which may confound disease severity ratings.

As new and traditional farming technologies are implemented in the developing world, their impact on incidence of soilborne pathogens should be considered. The present study is as an example of treating the biotic constituents of the soil as an integrated unit. Such an approach may serve as one quantifiable factor, which may be associated with declining wheat yields.

Table 3. Effects of fumigation on number of tillers for triticale, bread wheat, and durum wheat genotypes at 4 and 8 wk after planting in 1988 and 4, 8, and 12 wk in 1989

			Sample date (weeks after planting)				
			1988		1989		
Fumigation	Crop	Genotype	4	8	4	8	12
Methyl bromide	Triticale	Rhino "S"	5.1*[z]	3.8	3.6	5.2	3.9
		Eronga 83	6.3*	4.3*	6.0*	6.7	3.6
	Bread wheat	Seri M82	6.0*	4.5*	4.1*	7.5*	5.7
		Galvez 87	6.0*	4.0*	4.4*	6.3	5.1
	Durum wheat	Altar 84	6.8*	4.8*	5.2*	8.6*	6.5
		Sula//WLS/DWL 5023	8.0*	4.4	6.0*	6.9	5.3
Dazomet	Triticale	Rhino "S"	5.2*	3.6	3.8	4.5	3.7
		Eronga 83	5.4	3.4	4.0	5.7	3.9
	Bread wheat	Seri M82	5.0*	4.2*	3.3	6.4	4.7
		Galvez 87	4.7	3.8	3.5	6.2	5.0
	Durum wheat	Altar 84	6.1	4.3	5.1	7.4	4.9
		Sula//WLS/DWL 5023	6.5	4.0	5.0	6.4	4.7
Nonfumigated	Triticale	Rhino "S"	4.0	3.1	3.6	4.3	3.7
		Eronga 83	4.8	3.6	3.2	5.6	4.7
	Bread wheat	Seri M82	4.5	3.2	3.5	6.2	3.5
		Galvez 87	5.1	3.2	3.1	6.1	4.1
	Durum wheat	Altar 84	5.5	3.8	4.2	6.9	4.8
		Sula//WLS/DWL 5023	6.3	3.7	4.7	6.2	3.5

[z] Significantly different from the nonfumigated control by LSD (0.05).

Table 4. Vegetative biomass and spikes per square meter for triticale, bread wheat, and durum wheat genotypes after fumigation with methyl bromide (MB) or dazomet (DAZ) and nonfumigated (O) in 1988 and 1989

			Vegetative biomass			Spikes/m^2		
Year	Crop	Genotype	MS	DAZ	O	MB	DAZ	O
1988	Triticale	Rhino "S"	12,509	13,777	14,235	394*[z]	319	307
		Eronga 83	11,950	12,548	12,974	297	279	276
	Bread wheat	Seri M82	9,705	9,919	8,392	480*	340	295
		Galvez 87	6,972*	11,580	10,727	448*	404*	336
	Durum wheat	Altar 84	10,288	12,008	10,393	489*	396	408
		Sula//WLS/DWL 5023	9,948	12,524	11,689	544*	422	399
1989	Triticale	Rhino "S"	13,713*	13,616*	11,095	408*	372	318
		Eronga 83	15,567	16,101	15,245	326	326	278
	Bread wheat	Seri M82	8,917*	9,133*	6,567	503*	418*	277
		Galvez 87	8,500*	9,389	10,731	527*	479*	404
	Durum wheat	Altar 84	12,727	12,953*	10,785	597*	544*	445
		Sula//WLS/DWL 5023	9,925*	10,945	11,950	500*	466*	348

[z] Significantly different from the nonfumigated control by LSD (0.05).

LITERATURE CITED

1. Chapman, R. A. 1957. The effects of aeration and temperature on the emergence of species of *Pratylenchus* from roots. Plant Dis. Rep. 41:836-841.
2. Cobb, N. A. 1918. Estimating the nema population of soil. U.S. Dep. Agric. Technol. Circ. 1. U.S. Government Printing Office, Washington, DC.
3. Cook, R. J. 1981. *Fusarium* diseases of wheat and other small grains in North America. Pages 39-52 in: *Fusarium*: Diseases, Biology and Taxonomy. P. E. Nelson, T. A. Toussoun, and R. J. Cook eds. Pennsylvania State University Press, University Park, PA.
4. Diehl, J. A., Tinline, R. P., Kochhann, R. A., Shipton, P. J., and Rovira, A. D. 1982. The effect of fallow periods on common root rot of wheat in Rio Grande do Sul, Brazil. Phytopathology 72:1297-1301.
5. Dubin, H. J., and Rajaram, S. 1982. The CIMMYT's international approach to breeding disease-resistant wheat. Plant Dis. 66:967-971.
6. Duczek, L. J. 1989. Relationship between common root rot [*Cochliobolus sativus*] and tillering in spring wheat. Can. J. Plant Pathol. 11:39-44.
7. International Maize and Wheat Improvement Center. 1977. CIMMYT Rep. Maize Wheat Improve. 1977. El Batan, Mexico. 245 pp.
8. Jenkins, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Dis. Rep. 48:692.
9. Johnson, A. W., and Motsinger, R. E. 1989. Suitability of small grains as hosts of *Meloidogyne* species. Ann. Appl. Nematol. 4S:650-653. (J. Nematol. Vol. 21.)
10. Kimpinski, J., Anderson, R. V., Johnston, H. W., and Martin, R. A. 1989. Nematodes and fungal diseases in barley and wheat on Prince Edward Island. Crop Prot. 8:412-416.
11. Lawn, D. A., and Sayre, K. D. 1989. Effects of crop rotation, tillage and straw management on common root rot of wheat. (Abstr.) Phytopathology 79:1142.
12. Nash, S. M., and Snyder, W. C. 1961. Quantitative estimations by plate counts of propagules of the bean root rot Fusarium in field soils. Phytopathology 52:567-572.
13. Orion, D., Amir, J., and Krikun, J. 1984. Field observations on *Pratylenchus thornei* and its effects on wheat under arid conditions. Rev. Nematol. 7:341-345.
14. Orion, D., and Shlevin, E. 1989. Nematicide seed dressing for cyst and lesion nematode control in wheat. Ann. Appl. Nematol. 4S:629-631. (J. Nematol. Vol. 21.)
15. Robbins, R. T., Riggs, R. T., and Von Steen, D. 1989. Phytoparasitic nematode surveys of Arkansas wheat fields 1986-88. Ann. Appl. Nematol. 4S:624-628. (J. Nematol. Vol. 21.)
16. Rovira, A. D., and Wildermuth, G. B. 1981. The nature and mechanisms of suppression. Pages 385-415 in: Biology and Control of Take-All. M. J. C. Asher and P. J. Shipton, eds. Academic Press, New York.
17. Sikora, R. A. 1987. Plant parasitic nematodes of wheat and barley in temperate and temperate semiarid regions—A comparative analysis. Pages 46-68 in: Nematodes Parasitic to Cereals and Legumes in Temperate and Semi-arid Regions. Proc. Workshop Int. Cent. Agric. Res. Dry Areas, Aleppo, Syria.
18. Slope, D. B., Salt, G. A., Broom, E. W., and Gutteridge, R. J. 1978. Occurrence of *Phialophora radicicola* var. *graminicola* and *Gaeumannomyces graminis* var. *tritici* on roots of wheat in field crops. Ann. Appl. Biol. 88:239-246.
19. Sumner, D. R., and Csinos, A. S. 1986. Assaying populations and evaluating fungicides for control of soilborne pathogenic fungi. Pages 277-280 in: Methods for Evaluating Pesticides for Control of Plant Pathogens. K. D. Hickey, ed. American Phytopathological Society, St.

Paul, MN.
20. Thompson, J. P. 1991. Root-lesion nematodes. Chapter 12 in: Soilborne diseases of wheat in the Australian environment. L. W. Burgess and B. Summerall, eds. Academic Press, Sydney, Australia. In press.
21. Tinline, R. D., and Ledingham, R. J. 1979. Yield losses in wheat and barley cultivars from common root rot in field tests. Can. J. Plant Sci. 59:313-320.
22. Van Gundy, S. D., Perez B. J. G., Stolzy, L. H., and Thomason, I. J. 1974. A pest management approach to the control of *Pratylenchus thornei* on wheat in Mexico. J. Nematol. 6:107-116.
23. Wallwork, H. 1989. Screening for resistance to take-all in wheat, triticale, and wheat-triticale hybrid lines. Euphytica 40:103-109.