Incidence and Severity of Take-all of Wheat in Indiana

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ABSTRACT

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The increased awareness of damage from take-all (root and crown rot caused by *Gaeumannomyces graminis* var. *tritici*) following culture of wheat cultivars resistant to Hessian fly (*Mayetiola destructor*) prompted a survey of Indiana wheat fields. Although take-all was present in all major wheat-growing areas, its severity was influenced by seeding date, rotation, and nutritional status of plants. Environmental conditions, especially those favorable for nitrogen loss, predisposed plants to severe take-all damage. Take-all was a major influence on the productivity and variability of wheat yields in Indiana. Statewide yearly losses in grain yield from take-all were about 4% in 1977, and had been as high as 25% of the potential crop in 1973 and 1976. Based on a wheat price of $0.11/kg, this represents an annual loss to Indiana wheat producers of $6.8–50.6 million. Delayed seeding, crop rotation, and nitrogen management can drastically reduce losses from take-all.

Take-all of winter wheat caused by *Gaeumannomyces graminis* (Sacc.) Arx & Oliv. var. *tritici* Walker (= *Ophiobolus graminis* Sacc.) was reported on Indiana wheat in 1919. The northwestern counties of LaPorte and Porter were included in the 1919 take-all quarantine after the disease was found near Wanatah (3). Since that time, take-all has been of varying but limited economic importance. In recent years, stunting, reduced tillering, and early maturity associated with take-all are more prevalent and severe than expected. This increased severity has coincided with the release of new, high-yielding wheat cultivars (Arthur-71 and Abe) resistant to Hessian fly (*Mayetiola destructor* (Say)). Use of these cultivars has encouraged earlier seeding in the fall and other changes in management practices.

I conducted a general survey for take-all and other soilborne diseases of wheat. The survey was begun in 1972 in response to concern over the increased severity of take-all.

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MATERIALS AND METHODS

More than 70 wheat fields were randomly selected each year from 1972 through 1980 in the major wheat production areas of Indiana (Fig. 1). I examined plants in these fields at various times during the growing season and indexed them for the occurrence of take-all. In addition, I examined many fields at the request of growers or county agents. Crop history and information about fertility programs and previous yields were obtained for most of these fields. A history of other cultural and management practices was obtained when possible. Residue from the previous crop was usually present to indicate the cropping sequence in the fields.

An index of 0–5 (0 = no infection and 5 = death before grain formation) was used to indicate disease severity. Yield reductions at various levels of disease severity were estimated on the basis of comparative research studies (Huber, *unpublished*), yields of nearby fields, and weather information for the year being evaluated.

I estimated statewide yields on the basis of severity and frequency of disease and yield reductions in fields surveyed. Planting and harvest data were obtained from the Indiana Annual Crop and Livestock Summary (10). Additional weather and growing conditions are summarized each year in the Indiana small grain performance bulletins (1).

Root and culm tissues were examined under the light microscope for the runner hyphae on the surface that are characteristic of *G. graminis* var. *tritici.* The pathogen was isolated from infected tissues placed on potato-dextrose agar plates for confirmation, and its cultural and mycelial characteristics were studied. Identification was made by comparison with isolates grown from ascospores, isolates of *G. graminis* var. *tritici* obtained from D. Hornby (Rothamsted Experiment Station, England), aminopeptidase profiles of the various organisms (11), and perithecial-forming isolates of *G. graminis* isolated from soybeans by Roy et al (11). Characteristic symptoms of take-all were produced on inoculated wheat plants in the field and greenhouse.

RESULTS AND DISCUSSION

Take-all was present in all wheat-growing areas of Indiana. Fall infection was difficult to detect macroscopically or microscopically, except on early seeded wheat. Early spring root infection appeared as isolated, tan to light brown, necrotic lesions in the cortex that were generally accompanied by typical runner hyphae on the surface. By mechanically slipping or separating the cortex from stellar tissues, I was able to observe vascular occlusions, discoloration, and mycelial involvement not obvious from examining the cortex alone. Symptoms were most obvious at the late boot or early heading stages of development, when plants were under the greatest moisture and nutrient stress. Symptoms appeared as varying degrees of brown to charcoal black lesions on root, crown, or foot tissues; stunting; early maturity or death; and "white" (sterile or partially filled) heads. The disease occurred on individual plants throughout most infested fields, but it was sometimes more severe in specific areas of a field. Fields of wheat infected early had uneven growth because of the erratic occurrence of plants stunted from take-all. Other fields had uniform growth in early stages but failed to develop grain because of moisture and nutrient stress caused by the loss to take-all of root and crown tissues. Seventy percent loss of functional root tissues was common, based on general discoloration or on the location of necrotic lesions and vascular occlusions on roots.

Signs of take-all included runner hyphae on roots, mycelial mats under leaf sheaths, and (sometimes) perithecia. Microscopic examination indicated that small lateral roots were frequently infected through the root cap, because extensive mycelial ramification was apparent between stellar and cortical tissues without the presence of superficial mycelium or visible evidence of cortical necrosis. Vascular tissue in these small roots was discolored, occluded, and apparently nonfunctional. *G. graminis* var. *tritici* was isolated from infected tissues and demonstrated to be virulent by the inoculation of Arthur-71 or Abe wheat seedlings in the greenhouse. Only a few of the many isolates obtained from the field were induced to produce perithecia in culture.

The cultural conditions in the field having the greatest influence on disease severity are date of seeding, crop sequence, and nutrient availability (4,5). Take-all is also more severe when a long cool and wet period in the spring leads to nitrogen loss and subsequent plant stress (8).

Date of seeding, as manifested in the amount of fall growth, was a primary determinant of disease severity, with the most severe take-all observed on wheat seeded before the "fly-free" date (Hessian fly) (Fig. 1). Because it is not the actual date of seeding so much as the stage of growth before winter dormancy that is important, prolonged growing conditions

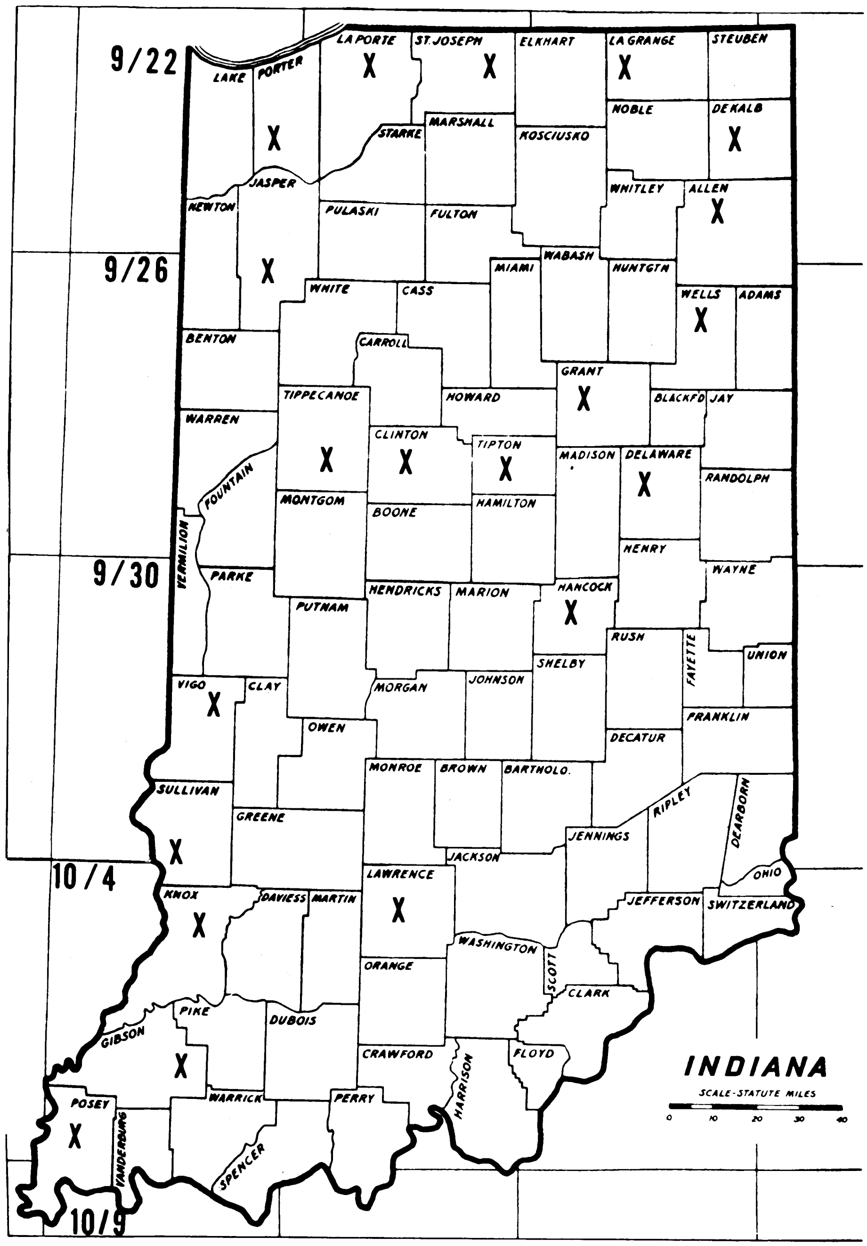

Fig. 1. Primary survey locations (X) and dates free of Hessian fly in the wheat production areas of Indiana.

in the fall favor early infection and severe disease expression. The fly-free date had been established as the date of seeding that would produce the best yields in the various wheat-growing areas of the state (2). It was assumed that Hessian fly was the primary factor reducing yields of early seeded wheat.

The release of new wheat cultivars resistant to Hessian fly encouraged growers to seed earlier to minimize soil erosion, winter heaving damage to seedling plants, and conflicts with corn or soybean harvest. However, the predisposition to severe take-all damage nullified these benefits, because wheat seeded after the fly-free date was generally less severely damaged by take-all. I found no evidence that the new cultivars were more susceptible to *G. graminis* var. *tritici*. The correlation of increased take-all damage with their introduction was apparently related to the earlier seeding.

Crop sequence influences the date of seeding, and it is not always possible to distinguish between their effects on disease expression. In general, take-all was more severe on wheat following wheat than other crops in the rotation; however, most of the early seeded wheat followed a previous wheat crop. The third consecutive wheat crop was usually more severely infected than the second crop unless a subsequent crop was seeded late. Corn and soybean harvests were late enough to preclude early seeding of a subsequent wheat crop. The exceptions occurred in 1971 and 1973, years with a long fall growing season, when wheat seeded after soybeans was as severely damaged as the second or third consecutive wheat crop.

Increased severity of take-all following soybeans was associated with applications of lime to adjust the soil pH to 6.3 or higher for soybeans. Liming is well recognized as a predisposing factor for take-all (8,12). The disease was not generally increased when corn preceded wheat in the rotation, but Fusarium root rot and scab (*F. graminearum* Schwabe) frequently were. *Pseudocercosporella herpotrichoides* (Fron) Shaw (the cause of eyespot), *Rhizoctonia solani* Kuehn (the cause of sharp eyespot), and Fusarium root rot were most severe on early seeded wheat recropped to wheat. *F. graminearum* and *P. herpotrichoides* were not generally present on wheat following soybeans.

Early seeded wheat grown on light, sandy soils was consistently different in the amount of tissue destroyed by take-all when compared with wheat grown on heavier soils. The greater yield losses of wheat grown on sandy soils resulted from the disproportionate increase in moisture and nutrient stress associated with the loss of roots. This conclusion is supported by the large reduction in disease severity with nitrogen fertilization, which was especially noticeable on coarse-textured soils having little residual or mineralizable nitrogen. Because most nitrogen is applied to wheat during the winter or early spring, early seeded fall wheat may be predisposed to take-all because of nitrogen deficiency. Application of nitrogen in the fall is not a common practice, as severe leaching and denitrification occur over the winter. Nitrogen top-dressed during the winter months on frozen ground may run off and be unavailable for plant growth in the spring (9).

Regardless of soil type, unfertilized areas in a field were more severely damaged by take-all than fertilized areas, even though a difference in growth was not always noticed. Spring top-dressings of nitrogen reduced take-all but sometimes increased foot rot caused by *R. solani* and *P. herpotrichoides*. When nitrogen is applied at more than 44 kg/ha, increased severity of *P. herpotrichoides* tends to nullify the nutritional benefits of the fertilizer (4).

An example of yield loss due to take-all is the 538 kg of wheat per hectare harvested from a severely infected, early seeded, recropped field of Arthur-71 wheat in Knox County in 1974. This represents a 90% reduction in yield from the year before, when the field produced 5,389 kg/ha from the same cultivar. Also in 1974, an adjacent field of late seeded Arthur-71 wheat planted after corn yielded 6,265 kg/ha. The greater severity of take-all in the southern half of the state was correlated with earlier seeding and greater nitrogen stress.

Before the high yield average of 3,300 kg/ha in 1980, the Indiana record was the 1972 crop at 3,230 kg/ha. Most of the wheat planted in 1972 followed other crops in the rotation. Thus, even though the long fall growing season intensified damage from barley yellow dwarf virus and snow mold, the extreme severity of take-all was limited to fields recropped to wheat or early seeded fields following soybeans. Several of these fields were not harvested because of take-all damage (Table 1). Growers did not harvest areas where the yield was too low to justify harvest expenses. Take-all was a major, but not the only, contributor to this situation. Most of the abandoned nectares in 1977 (6%) and 1978 (9%) reflected losses due to Rhizoctonia spring blight (winter kill) (6).

Higher yields and the availability of two new cultivars resistant to Hessian fly prompted earlier seeding in the fall of 1972 and 1973. Although the state area planted to the 1973 wheat crop was only 300,000 ha, much of this followed wheat in the rotation. Take-all was extremely severe in these fields, and yields varied in proportion to take-all severity. Leaf blight caused by *Septoria tritici* was also severe during 1973, reducing yields significantly. The fall of 1973 was wet and cool, and the 1974 crop was also severely damaged by take-all.

After the severe disease conditions of 1973 and 1974, many growers responded to recommendations to delay seeding the 1975 crop until after the fly-free date and to practice crop rotation and optimal nitrogen fertilization. Take-all incidence was less than previously observed, and average yields increased. Some of the increased acreage for the 1975 and 1976 crops was taken out of pasture. Take-all became very severe on wheat planted after pasture or alfalfa. Expected price incentives and government encouragement to increase wheat production in 1976 encouraged growers to plant more acreage. Wheat was seeded earlier for the 1976 crop than for the 1975 crop, and take-all increased. Spring remained cool and wet for a period, followed by a long dry period in the southern two-thirds of the state. This delayed fertilization, intensified nitrogen losses, and predisposed plants to *G. graminis* var. *tritici*.

The wheat crop planted during the fall of 1976 (1977 crop) was seeded 10–14 days later than the established fly-free dates in most areas. Temperatures were

Table 1. Estimated reductions in yield and income caused by take-all disease of wheat in Indiana (1972–1980)

Crop year	Date of seeding[a]	Hectares ($\times 10^3$)[b] Planted	Harvested	Not harvested[c]	Yield (kg/ha)[b]	Yield reduction (%)	Dollar loss ($\times 10^6$)[d]
1971	Normal	297	281	17	3,099	...	...
1972	2 wk late	361	334	26	3,233	8	10.276
1973	Normal	300	285	15	2,358	25	23.067
1974	3 days early	583	506	77	2,526	20	33.300
1975	Normal	632	567	65	2,964	18	39.251
1976	1 wk early	676	607	69	2,425	25	50.625
1977	10 days late	547	512	35	2,897	4	6.788
1978	Normal	364	330	34	2,627	6	6.318
1979	3 days late	405	383	22	3,166	6	8.460
1980	Normal	466	445	21	3,300	5	8.452

[a] Based on floating average of the previous 5 yr; normal date of planting is currently September 30.
[b] Indiana annual crop and livestock summary, H74-1 and A77-1, Agric. Statistics Dept., Purdue Univ., W. Lafayette 47907.
[c] Expected yields did not justify harvest expenses.
[d] Based on wheat price of $0.11/kg.

lower than normal during the fall and winter months, and much of the wheat emerged during the winter or early spring. This resulted in a late functional seeding date, and take-all was greatly reduced. Also, only a small portion of the wheat was planted after a wheat crop.

The prolonged wet, cool spring following heavy snow cover in 1977 and 1978 on unfrozen ground predisposed wheat to Rhizoctonia infections (spring blight) (6,7), and large areas were not harvested. This disease was especially severe after nitrogen top-dressing in late winter or early spring. Excessive amounts of nitrogen applied in early spring were lost; however, much of the wheat was fertilized late because of wet soil conditions, and this late fertilization improved plant growth and reduced the incidence of take-all.

Most of the 1979 wheat crop was seeded after the fly-free date. The relatively dry fall and spring conserved nitrogen, and severe take-all was limited to fields seeded early or low in nitrogen. Wet winter and spring soil conditions in 1980 intensified nitrogen losses in the southern wheat areas and predisposed wheat to severe take-all. Most of the other wheat areas were drier, seeded later, and more adequately nourished, allowing the state to achieve the new yield average of 3,300 kg/ha.

Each year, I have been able to locate severely diseased fields (yields of <1,000 kg/ha) in close proximity to healthy fields (>5,000 kg/ha). The most obvious differences between the fields were seeding date, available nitrogen, and disease severity. These observations suggest that new cultivars are not generally more susceptible to take-all, but that cultural and management practices play an important role in determining the severity of the disease. Take-all is a major contributor to yield variability and low productivity. Late seeding, crop rotation, and nitrogen fertilization can greatly reduce the economic losses attributed to take-all. The fly-free date is a good median time for seeding that will minimize potential problems while avoiding adverse environmental conditions.

Based on the known yield potential of wheat cultivars grown in Indiana and the soil and environmental conditions there, a statewide average yield of more than 4,000 kg/ha should be attainable. Many diseases reduce this potential, and take-all has been a major cause of reduced yields in recent years.

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