Crop Damage and Epidemics Associated with 1993 Floods in Iowa

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In 1993, the midwestern United States experienced unprecedented precipitation, triggering widespread flooding along the Mississippi River and most of its major and minor tributaries. Iowa was among the most severely affected states in terms of damage to homes, businesses, livestock, and crops (Fig. 1A). Combined damages were in the billions of dollars in Iowa alone. Direct flood damage to crops and other plants was extensive (Fig. 1B and C), and the extraordinary weather conditions resulted in severe epidemics in major and minor crops as well as in landscape plants. The purpose of this paper is to document plant disease epidemics associated with the floods and to share this experience with other plant pathologists.

Weather and Crop Production in 1993

Annual precipitation in Iowa was above normal for 1990, 1991, and 1992. The period from November 1992 to April 1993 was the second wettest in Iowa history (since records began in 1873), with the greatest snowfall in 10 yr. This set the stage for the devastating effects of the summer 1993 rains. Record-setting precipitation fell on the already saturated soils (Fig. 2) throughout the spring and summer, triggering the worst natural disaster in Iowa history. July's state average 26.7 cm of precipitation set a record for the wettest month in Iowa history, with some parts of the state receiving more than 50 cm. Similarly, the total summer precipitation was the most ever recorded in Iowa (Fig. 3). Rain fell somewhere in Iowa on 84 of the 92 summer days. Percent sunshine was below normal every month during the summer. Mean monthly temperature was also below normal every month except August; September 1993 was the coolest September on record (8).

The effects of the extreme weather on agriculture were devastating. Approximately 1.1 million ha were flooded at some time during the season. Planting was severely delayed for all major crops (7). Tens of thousands of hectares intended for corn were switched to other crops, and more than 200,000 ha intended for corn could not be planted. Approximately 500,000 ha of corn, soybeans, and oats could not be harvested for grain due to flooding or other weather-related factors (9). Some of these hectares were harvested for silage or straw. Cash receipts from crops were reduced by $568.7 million in Iowa compared to 1992 (10). In addition, costs for livestock feeds increased $42.3 million, primarily due to a poor supply of alfalfa hay. Net farm income in the state is estimated at about $2 billion less than 1992 (10).

The combined effects of flooding, disease, and frost damage resulted in some of the lowest yields of the last 50 yr (9). Average corn yield for the state was only 68% of the 10-yr average, 63% of the average for the 4 yr since the 1988 drought, and only 54% of the record-setting 1992 average. Total corn production was diminished to an even greater extent, reaching only 62% of the 10-yr average and 46% of the record 1992 yield (Fig. 4A). This was the smallest corn crop in Iowa since the 1983 drought and the lowest mean yield since 1974. Grain quality in the 1993 crop also was reduced. The immature grain was easily damaged, and test weights were often well below normal, averaging only 87.5% of normal in the north-central part of the state (14).

Average soybean yield was 79% of the 10-yr average, 73% of the average for the 4 yr since the 1988 drought, and 68% of the 1992 average. Total soybean production reached 78% of the 10-yr average and 69% of the record 1992 yield (Fig. 4B). This was the smallest soybean crop since 1976 and the lowest mean yield since 1974 (9).

Iowa's third largest crop, alfalfa, also suffered substantial losses. Yield per hectare and total production were only 69% of the 1992 levels (Fig. 5). Total hay production in the state was the lowest since 1948. Production of oats, the fourth largest Iowa crop, was most severely affected. Oat production in the state was the smallest since records began in 1866, and only 36% of 1992 production (Fig. 5). Average yield was the lowest since 1956 (9).

Epidemics

Aside from the direct effects of flooding, the accompanying wet soils, below-normal temperatures, high humidity, lack of sunlight, and prolonged wetness periods resulted in some of the worst plant disease epidemics in recent Iowa history. Heavy rains and floods, more than any other type of natural disaster, can lead to intense disease problems that linger well after the flood waters have receded.

Seedling diseases. The cold, wet soil provided ideal conditions for seedling pathogens and delayed seedling emergence, prolonging the opportunity for infection. Seedling blights caused by *Pythium*, *Fusarium*, or *Rhizoctonia* were widespread in all crops. We conducted a statewide survey in which diseased soybean seedlings from 44 locations were sampled. Isolation results showed that the causal agents included *Pythium*, *Rhizoctonia*, *Phytophthora*, and *Fusarium*, but *Pythium* and *Phytophthora* were very predominant (16). Traditionally, most growers in Iowa do not treat soybean seeds with fungicides, but in 1993 seed treatment was used on a greater proportion of the soybean acreage because of the poor planting conditions. In many fields that were planted too wet, a hard soil crust formed and slowed or greatly weakened the seedlings, resulting in increased seedling blights (Fig. 6A and B). A telephone survey indicated that an average of 10% of soybean fields had serious stand reduction problems. Some soybean fields were planted three times and still failed to establish an acceptable stand. Wet conditions prevented replanting of many poor stands. Marginal soybean stands that normally might have provided acceptable yields did not compensate well because of slow growth early in the season.

No-till acreage in Iowa has increased quickly in recent years because no-till production can save costs and high-residue systems will be a mandatory federal requirement on some soils by 1995. Higher residue in no-till fields can result in increased overwintering of seedling pathogens (1) and cooler, wetter soil conditions. Agronomists, research farm managers, and university extension specialists reported that there were more seedling disease problems in Iowa no-

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till fields than in tilled fields in 1993, which agreed with our observations. In one field we examined, a first-time no-till farmer in Chickasaw County planted soybeans the third week of May with a no-till drill planter. Damping-off resulted in fewer than 20 plants per square meter over his two 10-ha fields. Manure applied to half of each field resulted in more severe stand reduction than in the half without manure. The grower subsequently plowed both fields and replanted.

Foliar diseases of corn and soybeans. Foliar diseases were much more prevalent than normal in all major crops, as wet, humid conditions persisted throughout most of the growing season.

Common rust (*Puccinia sorghi* Schwein.) was by far the most serious foliar disease on corn in 1993 in Iowa and neighboring states (Fig. 7A and B). This disease was more severe than it had been during the past 20 yr or more (C. Martinson, *personal communication*). Rust occurs annually in Iowa but usually does not cause losses in hybrid dent corn. Most dent corn hybrids have adequate partial resistance, and a few carry *Rp* genes for resistance to *P. sorghi*. During most years, this resistance is sufficient to prevent losses. In sweet corn production and on dent corn inbreds grown in seed production, some losses occur each year because of inadequate resistance

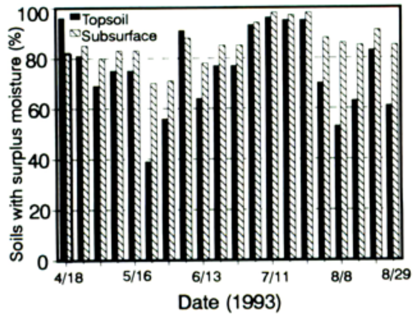


Fig. 2. Percentage of soils in Iowa with surplus moisture, 18 April through 29 August 1993.

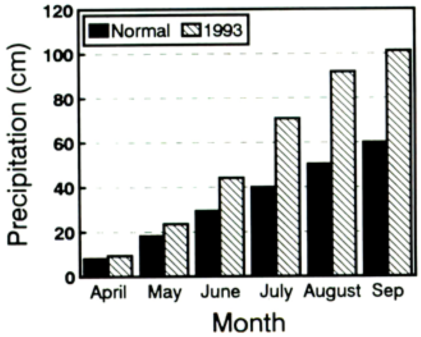


Fig. 3. Cumulative mean monthly precipitation in Iowa, April through September 1993 vs. normal.

Fig. 1. (A) Fields in every Iowa county were inundated with flood waters during 1993. **(B)** Rushing flood waters were responsible for substantial crop damage. **(C)** Flood damage was compounded by extensive hail damage in some parts of the state.

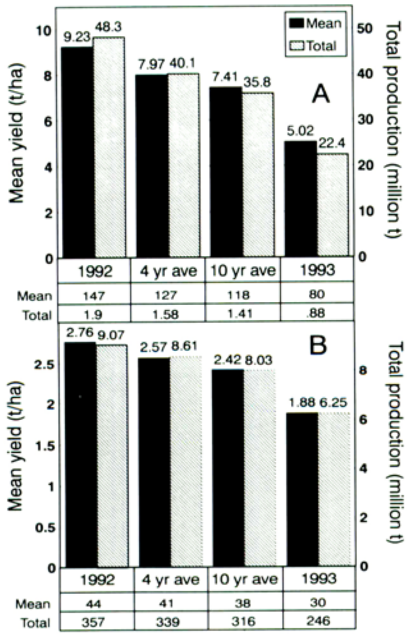


Fig. 4. (A) Mean yield (t/ha) and total production of corn (million t) in Iowa in 1993 compared to 1992, the 4-yr average since the 1988 drought (1989–1992), and the 10-yr average (1983–1992). **(B)** Mean yield (t/ha) and total production of soybeans (million t) in Iowa in 1993 compared to 1992, the 4-yr average since the 1988 drought (1989–1992), and the 10-yr average (1983–1992). Values in the data tables are bu/acre and million bu.

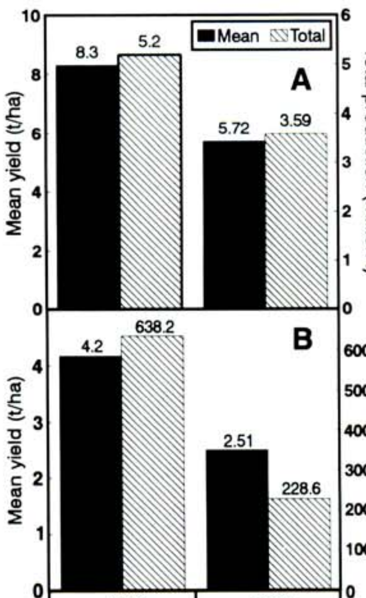
(15). In 1993, rust pustules on seed corn first appeared about 2 wk earlier than normal, and severity increased rapidly. Many susceptible dent corn inbreds and sweet corn varieties were killed by mid-August, resulting in a total crop loss. In Iowa State University fungicide trials on seed corn, yield reductions due to rust ranged from 20% to more than 50%. Sweet corn suffered similar levels of infection and damage. The use of fungicides (primarily mancozeb, propiconazole, and chlorothalonil) on seed corn increased substantially in 1993. After a brief survey by Iowa State University plant pathologists, a crisis exemption was approved for the use of propiconazole on seed corn. Seed producers reported that for some inbreds, fungicide use resulted in a 10-fold increase in yield of marketable seed. Rust was less severe on hybrid field corn, but in some hybrids, affected leaf area exceeded 40% by the time of tasseling. Because of the early arrival of rust spores and delayed host development, the more susceptible younger leaves (6) were available for infection for a much longer time than in a normal season. Consistently favorable night temperatures (5) and high humidity provided an ideal environment for infection and sporulation. Heavy infection by southern rust (*Puccinia polysora* Underw.) occurred on a much smaller scale, primarily in southeastern Iowa.

Other foliar diseases were prevalent earlier in the season. Anthracnose leaf blight (*Colletotrichum graminicola* (Ces.) G.W. Wils.) was notable in late May and early June. Plants were growing slowly and suffering stress due to lack of sunlight. Severe anthracnose occurred on the lower leaves, causing defoliation, particularly in fields where corn followed corn. The disease became less prevalent as the season progressed. Eyespot (*Aureobasidium zeae* (Narita & Hiratsuka) J.M. Dingley) also was common early in the season where corn followed corn. Like anthracnose leaf blight, this disease did not persist into the middle of the growing season.

Bacterial blight (*Pseudomonas syringae* pv. *glycinea*) and brown spot (*Septoria glycines* Hemmi) of soybean were widespread in Iowa in 1993. Severe bacterial blight was reported from different parts of the state by extension field specialists during July. Both diseases occurred at least 2 wk earlier than normal despite the fact that many soybean fields were planted 2 wk late due to the excessive rain. A survey by Iowa State University plant pathologists indicated that these diseases were present in almost every field in the state. Ample rain provided rapid means of spread for both diseases. Poor root development of plants may have contributed to earlier senescence, which increased susceptibility to brown spot. While bacterial blight symptoms did not persist into the late season, an epidemic of brown spot caused statewide premature defoliation during the fall. In many soybean fields, plants were completely defoliated while all pods were still green (growth stage R5-R6) (Fig. 7C and D). There was some concern by growers that the rapid defoliation of soybean plants might be due to soybean sudden death syndrome (SDS), which previously had not been reported in Iowa. Descriptions of "mysterious" soybean sudden death by the press also compounded concern by growers.

Confusion over this issue continued when SDS (caused by *Fusarium solani*) was identified for the first time in the state later in the 1993 season (20). The disease was detected in a few locations but did not appear to cause extensive damage. The extremely wet conditions in 1993 apparently were responsible for increased symptom expression. Growers' diagnosis of the diseases causing early death of soybeans was aided by Iowa State University Extension and other publications (17,19). SDS appeared in additional Iowa locations in 1994 (*unpublished*).

Root, stem, and grain diseases of corn and soybean. Root and stalk diseases of corn were a major cause of the poor



	1992	1993
Mean	67.0	40.0
Total	25.1	9.0

Fig. 5. (A) Mean yield (t/ha) and total production of alfalfa hay (million t) in Iowa in 1993 compared to 1992. **(B)** Mean yield (t/ha) and total production of oats (thousand t) in Iowa in 1993 compared to 1992. Values in the data table are bu/acre and million bu.

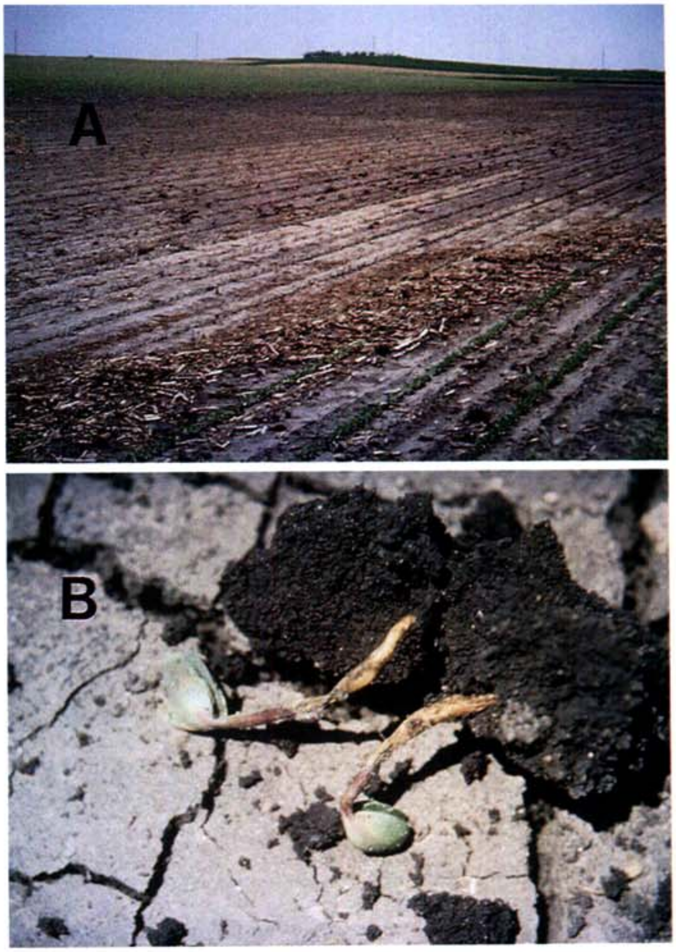


Fig. 6. (A) Soybean seedlings killed by flooding. **(B)** Damping-off of soybeans associated with soil crusting effect after the flood.

yields. The extremely poor growing conditions were very conducive to root rots and probably predisposed corn plants to severe stalk rot.

During September, premature senescence of entire cornfields was widespread (Fig. 8A), cutting short the growing season and reducing yields substantially. Anthracnose stalk rot (*C. graminicola*) was identified as the major cause of this problem (Fig. 8B), but other stalk rots and root rots were involved in some cases. In many fields showing premature senescence, more than 99% of stalks had severe symptoms of anthracnose stalk rot. Traditionally, anthracnose has not been a major disease in Iowa, but its occurrence is increasing. Neighboring states also reported very severe anthracnose stalk rot in 1993. The levels of infested corn residue are now high throughout Iowa, increasing the risk of recurrence of severe anthracnose (11). Because of anthracnose, many corn producers increased tillage activities after the 1993 season.

Prolonged saturation of soils resulted in poor root growth and rapid root decay in corn. We observed many fields exhibiting stunting and chlorosis due to these conditions (Fig. 8C). No single root rot pathogen was identified as a widespread problem, but root rots due to *Pythium* and *Fusarium* spp. were common.

Soybean brown stem rot (BSR), caused by the fungus *Phialophora gregata* (Allington & D.W. Chamberlain) W. Gams, is an endemic disease infesting 95% of Iowa soybean fields (18). The disease develops quickly in cool, rainy weather (18). In 1993, it caused premature defoliation (Fig. 8D and E) in many fields. Severe defoliation was found frequently in no-till soybean fields. The pathogen can survive on soybean residues for 3 yr (18) and therefore is a greater threat in no-till fields.

The experience of one farm we visited at Gilman, Iowa, is illustrative. The grower has been no-till farming for 8 yr. In 1993, more than 120 ha of his soybean fields were heavily infested with *P. gregata.* A 22-ha field that normally yields 3.76 t/ha (60 bu/a) started to defoliate in late August, with 100% incidence of BSR. The yield of this field was only 2.70 t/ha (43 bu/a) in 1993. A 2-day survey conducted in that area found that 100% of the fields were infested and more than 40% of fields had early defoliation.

The importance of BSR, previously unknown by many growers, was recognized widely in 1993. Infested soybean residue from 1993 could have an impact

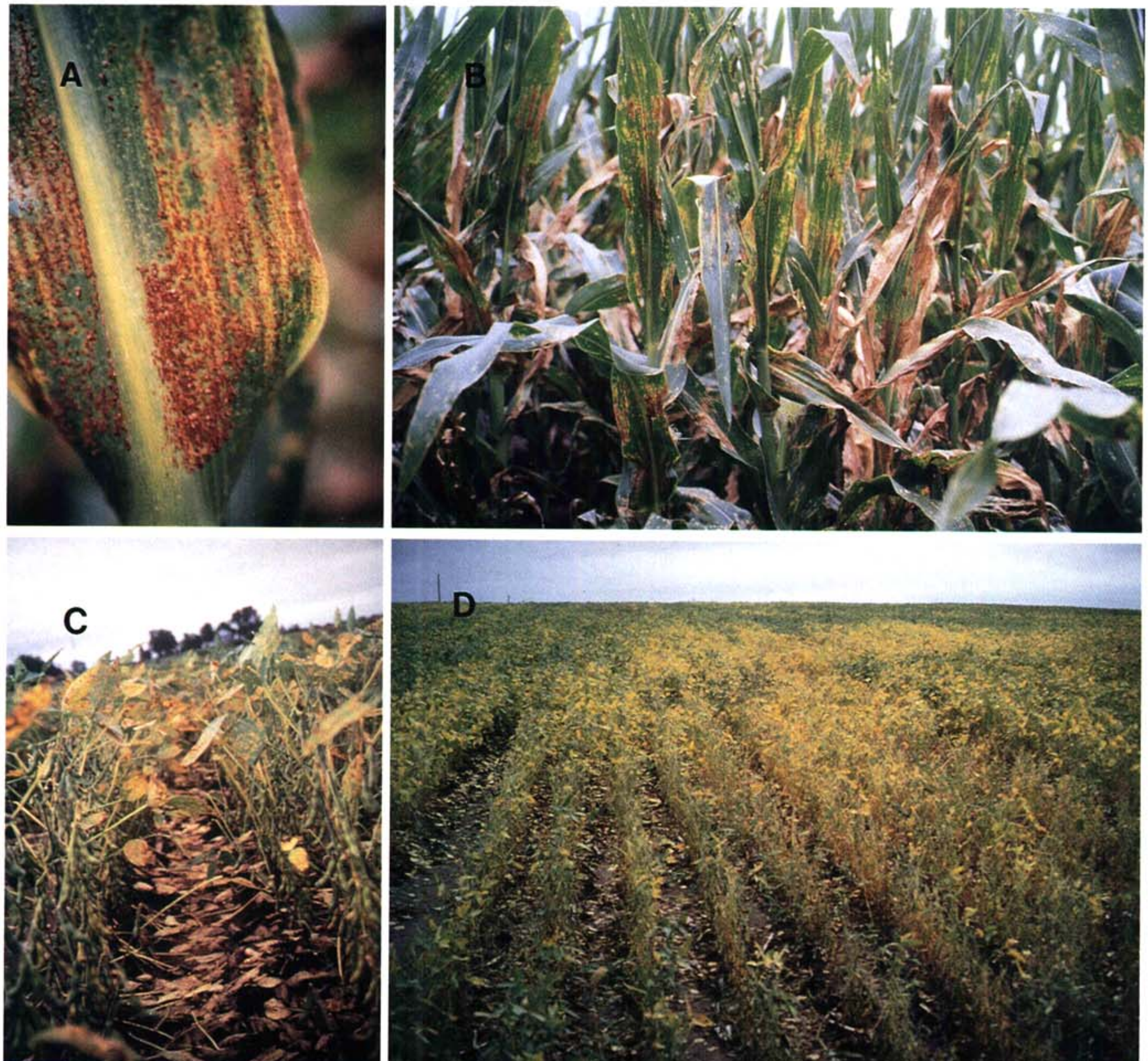


Fig. 7. Foliar diseases of corn and soybeans. **(A)** and **(B)** Common rust of corn. **(C)** and **(D)** Defoliation of soybeans due to brown spot.

Fig. 8. (A) Premature senescence of corn hybrid at right due to anthracnose. **(B)** Cornstalk rotted by *Colletotrichum graminicola.* **(C)** Stunting and chlorosis of corn due to soil saturation and root rot. **(D)** Deterioration of soybean stem caused by *Phialophora gregata.* **(E)** Premature senescence of soybeans due to brown stem rot. **(F)** Diplodia ear rot of corn. **(G)** Gibberella ear rot of corn.

on BSR occurrence during the next 2 yr. Rotation of soybeans with corn for 1994 followed by the use of BSR-resistant cultivars for 1995 was suggested. As a result of epidemics, the demand for available seed of resistant cultivars increased dramatically in many parts of Iowa.

Severe ear rot problems, primarily due to *Gibberella zeae* (Schwein.) Petch (Fig. 8G), appeared in some areas during September. In the north-central part of the state, Gibberella ear rot was detected in more than 40% of fields (14). More than 50 corn samples submitted to the Iowa State University Plant Disease Clinic or Veterinary Diagnostic Laboratory had levels of deoxynivalenol (a mycotoxin produced by *G. zeae*) exceeding 1 ppm, which is considered the safe limit in feed for swine (13). In a statewide survey (14), more than 65% of samples had detectable deoxynivalenol, and 10% of the samples had levels exceeding 1 ppm. These factors indicated a high risk for mycotoxin problems in livestock, but widespread problems were not reported. There were only scattered reports of feed refusal or illness in livestock due to mycotoxins. Dry weather finally arrived in September and October. This facilitated a quick harvest and probably arrested mycotoxin development. Locally severe outbreaks of Diplodia ear rot (*Diplodia maydis* (Berk.) Sacc.) also occurred (Fig. 8F), but this disease was not widespread. Fusarium ear rots (*F. subglutinans* (Wollenweb. & Reinking) P.E. Nelson, T.A. Toussoun, & Marasas, *F. moniliforme* J. Sheld., *F. proliferatum* (T. Matsushima) Nirenberg, and others) were common but not usually severe (14). The survey indicated that about 45% of asymptomatic corn kernels were infected by *Fusarium* spp. Their presence in combination with the generally poor condition of the 1993 crop resulted in reduced storability of this grain.

Diseases on other crops. In alfalfa, the third largest Iowa crop, the wet fall of 1992 resulted in extensive root rots and poor hardening off. In some areas, as much as 50% of established alfalfa stands did not survive the winter (12), and new seeding was hampered by the spring weather. After the extensive winter injury (Fig. 9A), alfalfa was plagued with severe foliar diseases and root rots throughout the 1993 season. Many stands that barely survived the winter continued to deteriorate due to disease pressure and saturated soils. Spring black stem (*Phoma medicaginis* Malbr. & Roum. in Roum.) and Leptosphaerulina leaf spot (*Leptosphaerulina briosiana* (Pollacci) J.H. Graham & Luttrell) were notably severe. These leaf diseases, which normally decrease in midsummer, persisted throughout the season (Fig. 9B). Early cutting was recommended to reduce defoliation in these fields, but it was not possible because the growth of alfalfa was so poor and most stands did not recover well from cutting. Phytophthora root rot (*Phytophthora medicaginis* Hansen & Maxwell) was a common cause of poor growth and decline of stands. Crown rots, a perennial problem in alfalfa, also contributed to the decline of many stands. While the poor growing conditions very likely predisposed plants to crown rots, crown rot severity did not noticeably increase in 1993. However, during the spring of 1994, many stands showed lingering effects of the severe weather with increased root rots and crown rots (Fig. 9C).

Oat crown rust (*Puccinia coronata* Corda) was very severe in some areas. Late-planted oats were heavily infected early in their development, resulting in extremely stunted growth (Fig. 9D). Poor growth and heavy disease pressure resulted in a drop in hectares of oats to be harvested for grain from 151,000 in 1992 to 91,000 in 1993, a 39.7% reduction (9).

The horticultural crops and landscape plants also suffered severe damage. The wet conditions resulted in severe leaf and fruit diseases on fruit and vegetable crops. The tomato crop suffered from an early-season epidemic of Septoria leaf

Fig. 9. (A) Alfalfa winter injury. **(B)** Leptosphaerulina leaf spot of alfalfa. **(C)** Crown rot of alfalfa. **(D)** Oat crown rust telia.

spot (*Septoria lycopersici* Speg.), followed by severe anthracnose (*Colletotrichum coccodes* (Wallr.) S.J. Hughes). Apples were infected with severe scab (*Venturia inaequalis* (Cooke) G. Wint.) (4). Woody and herbaceous landscape plants suffered from extensive root rots caused by *Pythium* and *Phytophthora* species. Stress to woody plants caused by prolonged flooding may have lasting effects. Decline of flooded trees has continued well into 1994 (P. H. Flynn, *personal communication*). Foliar diseases of landscape trees, such as ash, maple, and sycamore anthracnose, and scab of ornamental crabapple caused widespread defoliation (2). Sphaeropsis tip blight and Dothistroma needle blight of landscape pines were also severe (3).

Summary

The interactions of plant disease with environmental conditions and stresses make it difficult to estimate the proportion of losses attributable to disease in Iowa in 1993. Nevertheless, it is clear that diseases comprised a large component of these losses. The effects of the 1993 diseases likely will continue in many areas due to inoculum buildup and chronic effects on some perennial plants. Monitoring these long-term effects should provide some unique information.

The economic effects of crop losses in 1993 continue to be felt by the agriculture industry and the entire state. Many Midwest farmers now face critical financial situations, as recovery from the financial crises of the 1980s is not complete. Federal disaster assistance has alleviated some of the pressure. Late in 1993, Iowa State University Extension launched a comprehensive program addressing many agronomic, economic, and social aspects of recovering from the floods. This program included the establishment of eight flood recovery centers throughout the state, as well as statewide conferences, local meetings, and development of published materials. Recovery will not be a quick process, and much depends on the success of the 1994 crop year.

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