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Combating Take-all

of Winter Wheat in Western Oregon

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Take-all disease of wheat is caused by the soilborne fungus *Gaeumannomyces graminis* var. *tritici* (*Ggt*). This disease infects the roots, crown, and basal stem of plants. Take-all is common in western Oregon whenever consecutive crops of wheat are grown. Grain yield may be reduced by as much as 50 percent in second or third crops of winter wheat. In extreme situations, wheat plants may be killed; hence the name "take-all" (Figure 1).

Symptoms are most obvious near heading and include stunting or uneven growth, poor tillering, blackened roots and crowns, premature ripening, and white heads with few kernels. Root systems of severely infected plants may be sparse, brittle, and exhibit black lesions that extend to the crown and basal stem.

Economically effective fungicides are not available, and no wheat varieties exhibit resistance to take-all. Few if any corrective measures are available after identifying a severe take-all infestation.

Figure 1.—Take-all in second-, third-, and fourth-year wheat can reduce the stand, plant vigor, and yield. This photo illustrates severe take-all that killed the wheat plants, leaving only grassy and broadleaf weeds alive.

Where take-all is anticipated, disease control in winter wheat requires specific soil and crop management practices, beginning before planting and extending through early summer. Growers should assess the risk of take-all and adopt a package of management practices to minimize yield losses if the risk of disease is high.

This publication identifies factors that influence the severity of take-all and recommends management practices to minimize losses to the disease in western Oregon. Management suggestions in "Recommendations" (last page) are based on more than 10 years of research and have been successfully implemented by growers. The sections "Disease development" (below) and "Disease management" (page 3) provide data and details about management practices to slow take-all development and minimize yield losses.

Disease development

Roots become infected as they grow through soil near infested debris; they are colonized superficially before being penetrated by the fungus. Infection can occur throughout the growing season and is favored by moist soils having temperatures of 50 to 68°F. These conditions prevail for much of the growing season in western Oregon.

Autumn and early-spring root infections are most likely to progress to the crown. The number of diseased crown roots usually increases exponentially from late February through late May in western Oregon.

Figure 2 (page 2) illustrates this increase in disease severity. It shows that seasonal environment, nitrogen (N) fertilizer source, and number of years in wheat all affect the rate of disease development.

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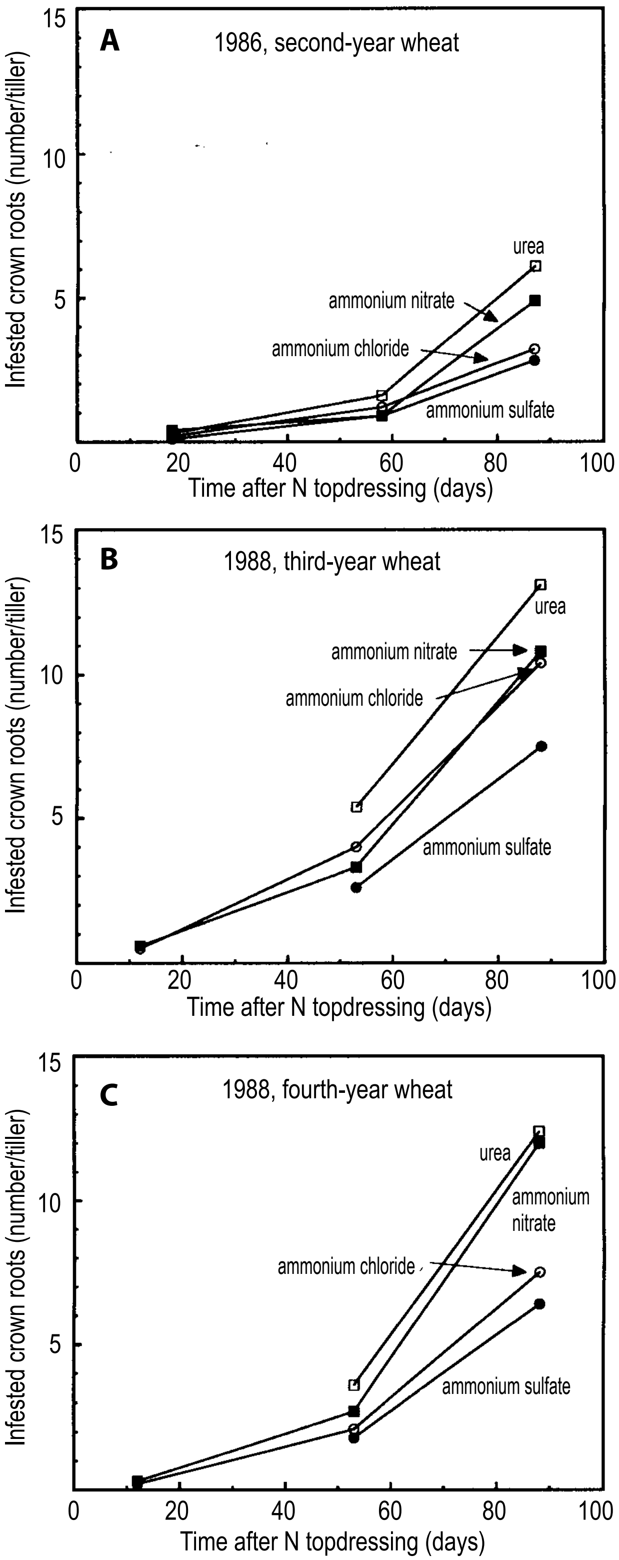

Figure 2.—Severity of take-all as influenced by time after spring topdressing with urea, ammonium nitrate, ammonium chloride, or ammonium sulfate: (a) second-year wheat in 1986; (b) third-year wheat in 1988; (c) fourth-year wheat in 1988. Nitrogen fertilizers were topdressed on March 1, + or - 7 days.

These results demonstrate the importance of adopting take-all control management practices far in advance of symptom development. At the optimal time for topdressing spring N fertilizer (Feekes Stage 5; approximately March 1), few if any crown roots are infected, and a prediction whether take-all will be mild (e.g., 1986) or severe (e.g., 1988) cannot be made.

Figure 2 also illustrates that the late-February choice of N fertilizer can make nearly a two-fold difference in the severity of take-all in late May. For example, 88 days after spring fertilization in 1988, plants fertilized with urea or ammonium nitrate had an average of 12 infected crown roots per tiller as compared to an average of 7 for plants fertilized with ammonium chloride or ammonium sulfate (Figure 2c). Year-to-year rainfall and temperature differences and the choice of N fertilizer generally have greater effects on take-all severity than does the number of years wheat has been grown. N fertilization is discussed below under “Fertilizer management” (page 5) and “N fertilizer source and soil pH effects on soil N” (page 7).

Yield loss to take-all

In western Oregon, the extent of crown–root infection at anthesis or flowering (late May) establishes the potential for take-all yield loss. Soils are generally dry enough by early June to slow disease development. Consequently, yield losses in any given year depend on take-all severity at anthesis, weather conditions in June and July, and whether a chloride (Cl^-)-containing fertilizer was applied in the spring.

These effects can be seen in Figure 3 (page 3), illustrating the overall relationship between grain yield and disease severity at anthesis. Figure 3 also shows this relationship for several growing seasons and N fertilizer materials topdressed in late February or early March.

Figure 3a shows that for each take-all-infested crown root per tiller, grain yield was reduced by 2.9 bu/a on average. Thirty-five percent of the variability in grain yield in seven experiments over 4 crop years was explained by the number of take-all-infested crown roots at anthesis.

Up to 59 percent of the variability in grain yield was explained by seasonal variability (Figure 3b) and N fertilizer source (Figure 3c). Maximum take-all severity was less in 1986 and 1987 than in 1984 and 1988 (Figure 3b). Despite the similarity in maximum disease severity in 1986 and 1987, grain yield losses to take-all were much greater in 1987 (–3.8 bu/a per infected root) than in 1986 (–1.5 bu/a per infected root), probably because of higher summer temperatures and greater water stress on plants in 1987.

Figure 3c shows that take-all severity was greater with urea and ammonium nitrate fertilizers than with ammonium chloride and ammonium sulfate fertilizers.

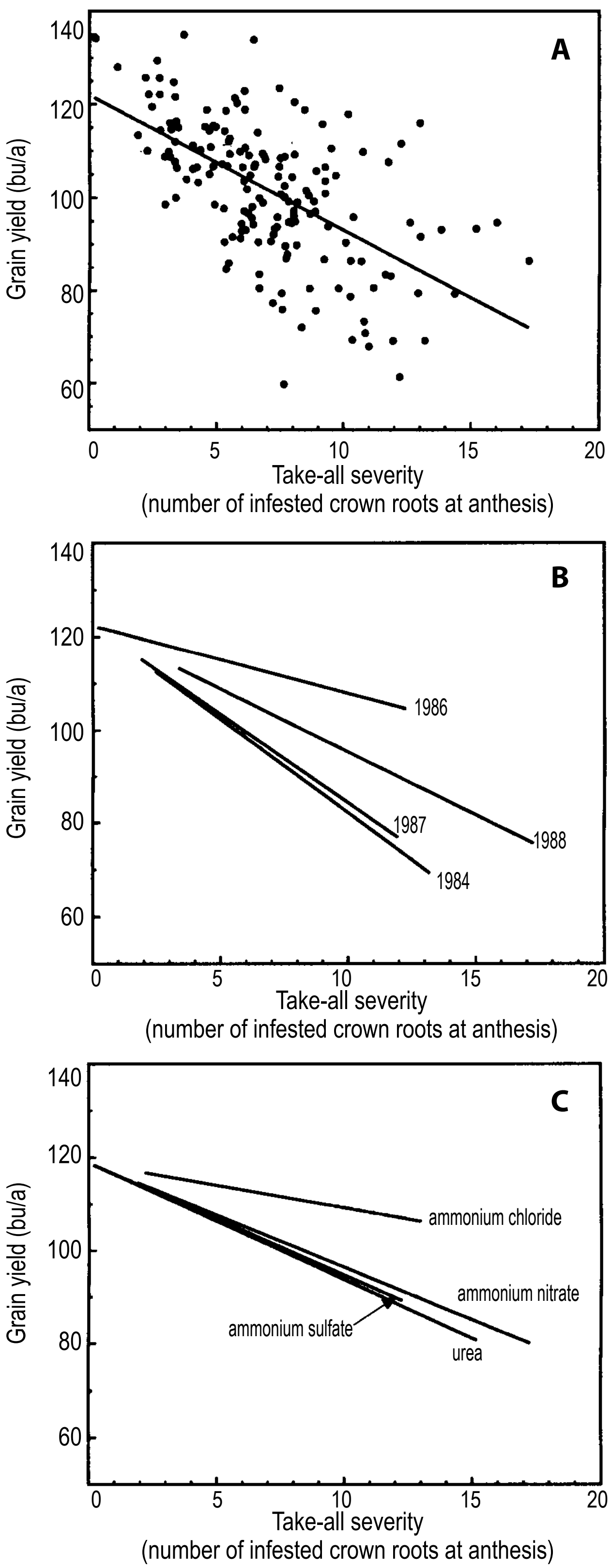

Figure 3.—Winter wheat grain yield as influenced by the number of take-all infested crown roots at anthesis: (a) seven experiments in four seasons; (b) by year; (c) by N fertilizer in 1986–1988.

Figure 3c also shows that yield losses to take-all were less when the crop was topdressed with a chloride-containing fertilizer (–1.0 bu/a per infected root) as compared to N fertilizers without chloride (–2.4 bu/a per infected root). Apparently, chloride-fertilized plants have an increased tolerance to take-all.

Disease management

Soil temperature, soil water content, and soil and crop management practices influence take-all disease and associated yield losses in western Oregon. While weather conditions cannot be controlled, a number of management practices can slow disease development and maintain grain yield. These include cropping history and rotation, weed control, stubble management, planting date, soil pH and liming, fall and spring fertilization, and control of other diseases. Management practices interact with environmental conditions, and with each other, to determine the severity of take-all and the magnitude of yield loss. Predicting which factors will be most important in any given year is impossible.

Cropping history and rotation

Crop rotation is the best way to control take-all. The pathogen persists in infected host debris, which serves as the primary source of inoculum for infection of subsequent wheat crops. Survival of the fungus in the absence of a host is poor. A 1-year break from wheat or barley is usually sufficient to reduce the risk to an insignificant level. Suitable break crops include oats, corn, beans, vegetables, oilseed crops, and annual legumes for seed.

The highest risk of take-all occurs when wheat is planted in consecutive years (Figure 4). Disease severity

Figure 4.—Influence of rotation on severity of take-all. This field of second-year wheat has severe take-all everywhere except where wheat did not grow the previous year. The tan-colored plants are wheat plants that survived to head and mature; they are growing in field corners skipped by the planting drill the previous year. The green plants are grassy weeds growing where wheat grew the previous year.

and yield loss can be substantial in second, third, and fourth wheat crops, with the worst take-all usually occurring in the third consecutive crop. Take-all becomes less severe, and yields usually increase, with the fifth or sixth successive wheat crop. This occurs because of a natural increase in soil microorganisms antagonistic to the pathogen—a phenomenon known as "take-all decline," which persists only so long as wheat is grown continuously.

Some growers have been caught off-guard by crop rotations that appear to be low-risk and yet unexpectedly develop severe take-all. One such rotation is winter wheat–sweet corn–winter wheat, in which volunteer wheat from the first crop is allowed to overwinter as a cover crop. The 5-month break when corn is grown is insufficient to reduce the inoculum potential of the infested residue. The severity of take-all in the second crop of wheat can be comparable to that seen in second or third crops of continuous wheat.

Weed control and stubble management

The take-all fungus (*Ggt*) invades wheatgrass and quackgrass (*Agropyron* spp.), bromegrass (*Bromus* spp.), and bentgrass (*Agrostis* spp.), as well as wheat and barley. Like volunteer wheat or barley, these weeds can harbor the pathogen. They may contribute to unexpected disease outbreaks when first-year wheat follows a legume crop infested with host grasses.

Killing grassy hosts with tillage or herbicides within a few months of planting wheat may not reduce the risk of take-all since *Ggt* persists in host debris. We recommend advance, long-term control of grassy hosts for rotations including wheat.

Chopping stubble followed by plowing to a depth of 8 inches buries and reduces host crop residues that serve as the primary inoculum source for subsequent crops. This delays or minimizes seedling infection and increases the probability that other control measures will slow disease progress.

Data from other regions suggest a higher risk of take-all when wheat follows wheat in reduced tillage systems. Experience in western Oregon has shown that the risk of take-all is low when winter wheat is sown directly (no-till planting) into herbicide-killed sod of annual ryegrass (*Lolium multiflorum* L.), perennial ryegrass (*Lolium perenne* L.), or tall fescue (*Festuca arundinacea* Schreb.).

Planting date

On well-drained valley-floor soils, delaying planting until late October can reduce early take-all infection of seedlings and increase grain yield, especially if other disease control measures are practiced (Table 1). Be cautious, however, as fall rains can reduce stand development. *Do not* delay planting on valley-floor soils with reduced drainage or on hill soils. A survey of 126 growers reporting results from 495 fields revealed that planting after October 12 reduced yield by 14 to 26 bu/a on hill or poorly drained soils.

Soil pH and liming

Increasing the pH of moderately acid soils through liming generally increases the severity of take-all and reduces grain yield (Table 2). Other management practices, such as application of ammonium-N (NH_4^+) plus chloride in the spring, are more effective in controlling take-all when soil pH is near 5.5.

Table 1.—*Planting date and N source effects on winter wheat grain yield on two well-drained soils with a high risk of take-all.*

	Planting date[1]		Planting date[2]	
	Oct. 4	**Oct. 27**	**Oct. 15**	**Oct. 25**
Spring N source	Wheat grain yield (bu/a)			
Ammonium sulfate	43	65	58	60
Ammonium chloride	56	76	67	80
LSD (P=0.05)	8	4	9	9

[1] 'Hyslop' winter wheat planted on Willamette silt loam topdressed with 120 lb N/a in spring of 1978.

[2] 'Stephens' winter wheat planted on Woodburn silt loam topdressed with 120 lb N/a on March 16, 1981.

Table 2.—*Liming (soil pH) and N fertilizer effects on winter wheat grain yield on moderately acid soils with high risk of take-all.*

	Soil pH[1]			Soil pH[2]		Soil pH[3]	
	5.5	**6.0**	**6.2**	**5.5**	**6.5**	**5.5**	**6.0**
Spring N source	Wheat grain yield (bu/a)						
Ammonium nitrate	—	—	—	—	—	93	70
Ammonium sulfate	67	60	61	52	57	112	94
Ammonium chloride	85	75	65	70	56	114	96
LSD (P=0.05)		10		9		5	

[1] 'Hyslop' planted October 27, 1977 on Willamette soil topdressed with 120 lb N/a in spring 1978.

[2] 'Hill 81' planted November 3, 1982 on Woodburn soil topdressed with 120 lb N/a on March 15, 1983.

[3] 'Hill 81' planted October 20, 1983 on Woodburn soil topdressed with 160 lb N/a on March 6, 1984.

In contrast, soils with pH 5.2 or less, especially those with low phosphorus (P) soil tests, may respond favorably to liming. Liming an acid, low-P Nonpareil soil (pH 5.2, 12 ppm P) increased yield of third-year wheat from 30 to 64 bu/a and decreased the percentage of whiteheads (a symptom of take-all) from 63 to 14 percent. When crops requiring high soil pH, such as sweet corn, garlic, or red clover are grown in rotation with 2 or more years of wheat, apply lime after the last wheat crop is harvested.

Fertilizer management

Fall

Nutrient deficiencies at any time during the growing season will increase the severity of take-all. Ensuring that N, P, sulfur (S), and potassium (K) are adequate at planting is especially important. Band N-P-S or N-P-K-S fertilizers with the seed when the risk of take-all is high.

When take-all is present, banded P fertilizer will increase wheat yield on soils where no yield increase would be expected in the absence of take-all. For example, grain yield increased from 56 to 65 bu/a (LSD @ 5% = 7.3) when P was banded with the seed on a Willamette soil testing 125 ppm P. Routinely apply P since P-deficient plants are more susceptible to take-all, and infected seedlings have poorly functioning root systems.

Sulfur is more often deficient for wheat in western Oregon than is K and should be applied at planting.

Fall-applied N should be in the NH_4^+-N form to minimize take-all development and leaching loss of NO_3^--N.

Spring

Use the mineralizable N (Nmin) soil test to determine spring N rate; take a soil sample from the top foot in mid- to late January and have it analyzed for ammonium-N, nitrate-N, and mineralizable-N. OSU Extension publication FS 334-E, *Using the Nitrogen Mineralization Soil Test to Predict Spring Fertilizer N Rate* provides spring N rates based on the mineralizable N soil test.

Figure 5.—Comparison of fertilizer treatments illustrating the importance of fertilizer management to combat take-all. Shorter plants on the left received ammonium nitrate and yielded less. Plants on the right received ammonium chloride and are more vigorous, even though both treatments are infested with take-all.

As Figures 2c and 3c show, spring topdressed N fertilizers can influence the severity of take-all and, thus, grain yield (Table 3). Yields are generally higher with ammonium chloride than with ammonium nitrate (34-0-0), urea (45-0-0), or ammonium sulfate (Figure 5). On average, grain yield with ammonium nitrate or urea was slightly less than with ammonium sulfate. Fertilization with ammonium chloride, as compared to ammonium sulfate, significantly increased grain yield in seven of nine growing seasons.

These data compare favorably with results of a survey of 126 growers who reported average responses to chloride of 12 bu/a. In research trials, test weight of wheat fertilized with ammonium chloride (59.7 lb/bu) was consistently higher than test weight of wheat fertilized with other N fertilizers (58.7 lb/bu).

Table 3.—*Spring topdressed N fertilizer effects on grain yield in 19 experiments.*

	Year of harvest (number of experiments)								
	1978 (2)	1980 (3)	1981 (3)	1982 (1)	1983 (1)	1984 (4)	1986 (2)	1988 (2)	1989 (1)
Spring N source[1]	Wheat grain yield (bu/a)[2]								
Urea	—	—	—	—	—	111a	93a	86a	144ab
Ammonium nitrate	—	—	—	—	85a	109b	94ab	93b	141ab
Ammonium sulfate	54a	88a	66a	52a	106b	111a	99b	98b	138a
Ammonium chloride[3]	66b	107b	80b	70b	106b	111a	107c	116c	151b

[1] Topdressed at rates of 120 (1978, 1980, 1981, 1982), 125 (1983), or 160 lb N/a (1984–1989) by Feekes Stages 4 to 7.

[2] Within-column means followed by the same letter are not significantly different at P = 0.05. (For instance, 138a and 151b are not significantly different from 141ab, but they are significantly different from each other.)

[3] Experimentally equivalent to ammonium sulfate (21-0-0) plus KCl (0-0-60) to supply at least 100 lb Cl/a.

Because ammonium chloride is no longer available in western Oregon, use ammonium sulfate *plus* potassium chloride (KCl) to supply ammonium-N and chloride. Topdress sufficient KCl with ammonium sulfate to supply at least 100 lb Cl/a. Apply ammonium-N and chloride by Feekes Stage 5 if you are making a single fertilizer application.

See *Nutrient Management Guide for Soft White Winter Wheat in Western Oregon*, EM 8963-E, for more information about fertilization of winter wheat.

Control of other diseases

The effectiveness of crop and soil management to minimize yield losses to take-all is reduced when other plant diseases threaten the wheat crop. Common diseases that may need further control measures include strawbreaker foot rot, caused by *Pseudocercosporella herpotrichoides,* and septoria leaf and glume blotches, caused by *Septoria tritici* and *S. nodorum*. Plants infested with take-all are commonly much more susceptible to septoria.

For more information

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Further reading

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The authors acknowledge the contributions of the late Thomas L. Jackson. For more than 30 years, Dr. Jackson promoted Oregon agriculture through practical scientific endeavors as professor of soil science at Oregon State University. In 1976, Dr. Jackson observed that wheat plots fertilized with ammonium chloride were less affected by take-all than were plots fertilized with other N sources. This observation was the starting point for research that developed the management program described in this publication.

N fertilizer source and soil pH effects on soil N

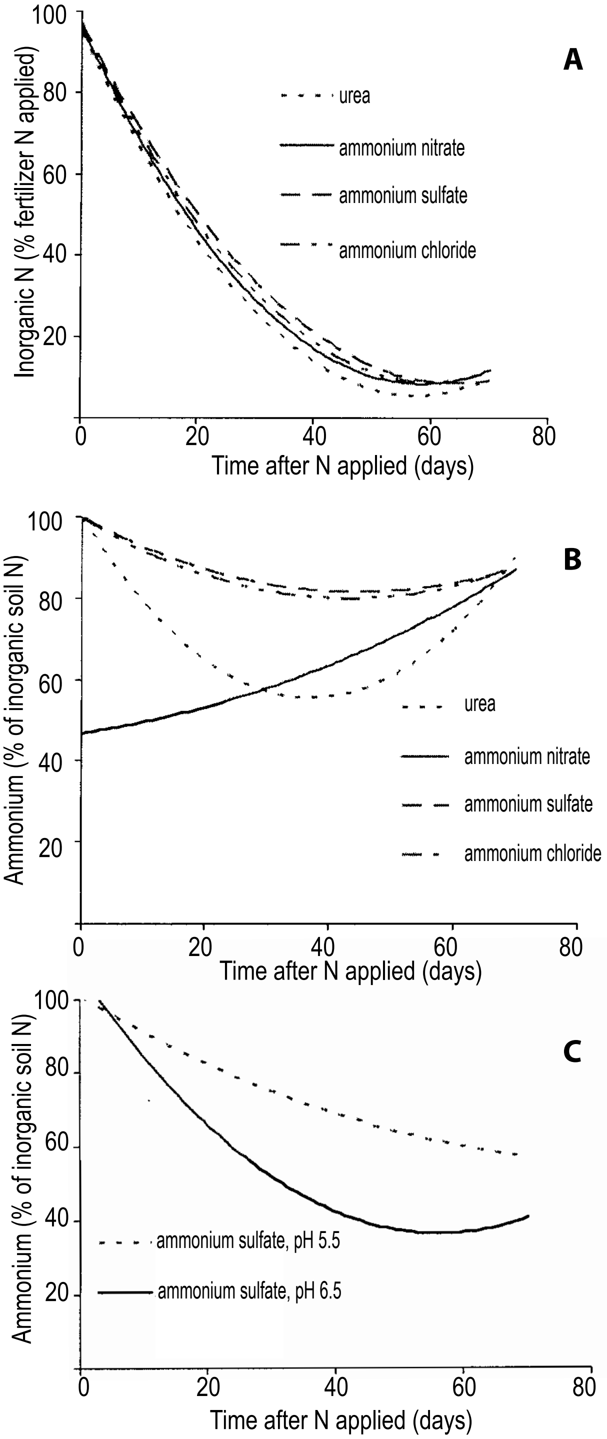

Figure 6.—Effect of N fertilizer source and soil pH on inorganic soil N: (a) amount of inorganic soil N (ammonium-N plus nitrate-N) by N source; (b) ammonium-N as percent of inorganic N by N source; (c) ammonium-N as percent of inorganic N as influenced by soil pH. N was applied at Feekes Stages 2 to 3 (early March).

An understanding of soil N dynamics helps explain the reason N fertilizer source and soil pH influence take-all development and grain yield losses to the disease. Four N sources were applied to three fields of second-year wheat (soil pH 5.7 to 6.3), and inorganic soil N was measured repeatedly for 70 days after fertilizer application. Inorganic soil N disappeared rapidly as a result of N uptake by the wheat crop and by soil microorganisms (Figure 6a). Figure 6a shows that N uptake by plants and microorganisms was similar for all N fertilizer sources, despite the fact that ammonium nitrate initially supplied one-half of the N as ammonium (NH_4^+-N) and one-half as nitrate (NO_3^--N), while the other three fertilizers initially supplied all of the N as NH_4^+-N (Figure 6b).

Although the total quantity of inorganic soil N was similar for all N sources, the form of N (NH_4^+-N or NO_3^--N) available to wheat plants differed markedly among N sources throughout the 70-day period (Figure 6b). With ammonium sulfate or ammonium chloride, more than 80 percent of the N was available as NH_4^+-N. In contrast, 30 days after application, ammonium nitrate and urea provided less than 60 percent of the N in the NH_4^+-N form.

Nitrogen fertilizer source is not the only factor influencing NH_4^+-N supply to wheat plants. Soil pH influences the relative amounts of NH_4^+-N and NO_3^--N in soil by influencing the rate of nitrification. Figure 6c illustrates that more inorganic soil N remained in the NH_4^+-N form when the soil pH was 5.5 than when the soil pH was 6.5.

Uptake of more NH_4^+-N than NO_3^--N by wheat plants reduces the pH around the roots. The reduction in soil pH favors the growth of microorganisms antagonistic to the take-all fungus and is the reason that take-all is less severe and yield losses are minimized when soil pH and N fertilizer sources are managed to maintain inorganic soil N in the NH_4^+-N form (Figure 7).

Figure 7.—Take-all-infested roots illustrating the effect of spring N source on take-all severity. Wheat plants on the left received ammonium nitrate, and plants on the right received ammonium chloride.

Recommendations

Preplant management

Liming	A soil pH of 5.5 is desirable for combating take-all. Apply lime only if the soil pH is 5.2 or less.
Stubble	Chop stubble and plow deeply to bury the inoculum.

Planting

Planting date	On well-drained valley-floor soils, delay planting until late October if possible. *Do not* delay planting beyond mid-October on hill soils or valley-floor soils with reduced drainage. For more information on wheat production on poorly drained soils, see FS 269, *Growing Winter Wheat on Poorly Drained Soil*.
Fertilization	Band 20 to 30 lb N/a in ammonium form, 30 to 50 lb P_2O_5/a, and 10 to 15 lb S/a. Apply 25 to 30 lb K_2O/a if a soil test indicates the need for K.

Growing season

Fertilization	Use the Nmin soil test to determine spring N rate. For more information about the Nmin soil test, see *Using the Nitrogen Mineralization Soil Test to Predict Spring Fertilizer N Rate*, FS 334-E. Apply N as ammonium sulfate plus 100 lb Cl/a as KCl before Feekes Stage 5. Alternatively, apply 40 lb N/a and 100 lb Cl/a at late tillering (Feekes 4; mid-February) and the remaining N within 3 to 4 weeks, but before jointing (Feekes 6). For more information on spring fertilization of wheat, see EM 8963-E, *Nutrient Management Guide for Soft White Winter Wheat in Western Oregon*.
Weed control	Control weeds to minimize competition with wheat for nutrients and moisture.
Disease control	Control leaf diseases such as septoria and other root diseases by using resistant cultivars or fungicides to ensure maximum benefit from other aspects of this management plan to reduce yield loss from take-all. Read and follow fungicide label directions.

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