susceptible Kentucky bluegrass varieties that should not be used in areas where *Fusarium* blight is a problem.

SUMMARY

The disease *Fusarium* blight appears to be an interaction between nematodes and a fungus in which the nematode is the dominant pathogen. The symptoms of the disease occur during periods of drought stress in warm or cold weather. The disease can be controlled culturally by light, frequent watering during periods of drought stress or chemically with one of the recommended systemic fungicides or nematicides. Check with the turfgrass experts in your area for specific recommendation. CAUTION: Nematicides are exretemly dangerous to human health, and proper clothing and equipment must be worn when applying them. Again, it is advisable to check with an expert in your area before applying nematicides.

Developing Genetic Resistance To Fusarium Blight

by C. Reed Funk

The development of improved levels of a stable, race-nonspecific resistance to *Fusarium* blight should receive high priority in all areas where this disease is a present or potential hazard. This resistance must be combined with other genetic factors involved in the creation of attractive, dependable turfgrass cultivars with good turf-forming properties, tolerance of environmental stress, and good resistance to other important pests. These improved turfgrasses need to be widely adapted and have reduced maintenance requirements.

TYPES OF DISEASE RESISTANCE

Disease resistance in plants has been characterized as either race-specific or race-nonspecific. Race-specific resistance has been widely used in the genetic control of plant disease. It generally is controlled by a single, usually dominant, gene and produces a high degree of resistance to one or more specific races of the disease pathogen. Unfortunately, a variety possessing such resistance may be highly susceptible to other races of the same pathogen. Breeding programs using this race-specific form of disease resistance are frequently faced with the task of continually finding and adding new resistance genes to combat new races of the pathogen. This race-specific resistance has been used extensively in annual crops where new resistant varieties can readily be substituted as resistance in old varieties breaks down. Obviously, it is of much less value in our long-lived perennial turfgrasses.

Race-nonspecific resistance is normally conditioned by the combined action of several genes. It imparts a degree of resistance to all races of the pathogen and is generally relatively stable over long periods of time. In most cases race-nonspecific resistance does not confer the high level of disease resistance normally observed in varieties posessing a race-specific type of resistance. Plant breeding procedures using race-nonspecific resistance are also more difficult. Nevertheless, the development of varieties having the highest possible and most stable forms of race-nonspecific forms of disease resistance should be the primary goal of breeders of perennial species.

PREDISPOSING FACTORS

Observational and experimental evidence suggest that the *Fusarium* blight disease is more serious on turfgrass weakened by one or more environmental stress factors. Factors predisposing the turf to *Fusarium* blight might include the following:

- High temperatures.
- High humidity.
- Recurring drought stress.
- Reduced air circulation.
- Excessive nitrogen.
- Dense, lush growth.
- Thatch.
- Close mowing.
- Nematodes.
- Other diseases.

Varieties better able to tolerate the weakening effects of any of the above factors, which may occur at a critical stage in disease development, are less likely to be seriously damaged by *Fusarium* blight. This might account for much of the variety x test interaction observed in ratings of variety resistance. A variety such as Vantage, which is less tolerant of close mowing than some compace turftypes, may show very little *Fusarium* blight at a 2-inch mowing height but can be weakened by closer mowing to the extent that it becomes moderately susceptible. A variety growing in its area of best adaptation and receiving the management most favorable to its best performance is likely to be damaged less by this disease. The above factors, considered in connection with a highly variable pathogen and our present less than adequate evaluation techniques and information exchange, complicate our understanding of the amount and stability of the genetic resistance available. Nevertheless, we do see substantial variation in the amount of *Fusarium* blight damage to different turfgrass selections. The genetic components of this variation can be used in breeding varieties of improved resistance.

KENTUCKY BLUEGRASS

Kentucky bluegrass, *Poa pratensis* L., is the most important lawn-type turfgrass in the northern half of the United States. It is hardy, attractive, and widely adapted. A number of attractive turf-type bluegrasses with good resistance to the *Helminthosporium* leaf spot and crown rot disease have been developed in recent years. Most of these improved varieties are giving good performance in areas where summer stress conditions are not too severe. Nevertheless, the development of bluegrasses with greater tolerance of the long, hot summers of the transition zone remains a real challenge to the turfgrass breeder. An extensive program to collect and evaluate adapted germplasm from summer stress areas should provide germplasm to produce varieties

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Fusarium Blight

continued

with greatly improved summer performance and dependability.

Detailed examination of old turfgrass stands and variety trials located in summer stress areas of the Middle Atlantic region is providing us with valuable insights into different types of Kentucky bluegrass. Under conditions of moderately low nitrogen fertility and high, infrequent mowing, the tall, erect-growing, narrow-leafed common types such as Kenblue dominate. However, old turf areas that have been mowed regularly have very few bluegrasses of the erect, narrow-leaf common type. The narrow-leafed common types have apparently been weakened by leaf spot and replaced by large patches of a broader leafed, more prostrate, moderately open type with extensive deep rhizomes. These might be referred to as a Middle Atlantic common. Vantage, PS2, and P-154 are selections of this type. This Middle Atlantic common type of bluegrass with its deep rhizomes, somewhat greater intrinsic tolerance of heat, greater summer food reserves, deeper roots, and somewhat open growth is well suited to survive summer stress, especially if not overfertilized or mowed too closely.

Many of the very attractive, dense, lower-growing turf-type bluegrasses selected from cooler summer climates of Northern Europe and from other breeding and evaluation trials in less severe environments are often disappointing in southern trials. Their dense, attractive turf is the result of a very high population of tillers per unit area. This results in increased competition between each tiller for light, water, carbon dioxide, and nutrients. Each tiller has a smaller percentage of the root system for support and is more subject to drought stress. A higher humidity develops in this dense turf. Excessive thatch accumulation is more likely to occur. This favors many disease organisms, including *Fusarium*. Kentucky bluegrass is best able to tolerate the frequent close mowing, high fertility, and other factors associated with the production of dense, compact turf desired on golf course fairways and similar turf areas in regions of high light intensity, cool temperature, and low to moderate humidity. As we go into less favorable climates, we must compensate with improved varieties and better management.

There may be a fourth type of bluegrass, which we might refer to as a southern turftype, that is widely adapted, pest resistant, and tolerant of heat and drought. This type has the ability to produce an attractive, compact, dense, disease-free turf in favorable environments. It also has the phenotypic plasticity to produce the deeper roots and rhizomes and the more open growth habit of the middle Atlantic common type in areas of severe and prolonged summer stress. It has good heat tolerance and the ability to maintain higher levels of carbohydrate reserves through prolonged periods of hot weather. A few of our very best bluegrasses are approaching this description. Further improvements in heat tolerance and pest resistance, including better resistance to *Fusarium* blight, will be most helpful in meeting the challenge of the transition zone. For commercial success these varieties also have to be economical seed producers. Expanded efforts should be made to develop and identify these grasses.

New Brunswick Trials

Turf trials at New Brunswick, New Jersey, show that bluegrass varieties exhibit a wide variation in resistance to *Fusarium* blight under the conditions of our evaluation program (Table 1). We have had very little damage from *Fusarium* blight on most test fields. High levels of earthworm activity and perhaps other factors have virtually eliminated any thatch buildup except on fields treated with tricalcium arsenate or chlordane.

Three bluegrass tests on fields treated with tricalcium arsenate all show considerable thatch buildup

Table 1. Fusarium Blight Incidence on Kentucky Bluegrass Varieties, Blends, and Mixtures Grown at New Brunswick, New Jersey, 1975[a]

Variety	Percent diseased	Variety	Percent diseased
Enmundi	1	Merion	15
Windsor	1	Park	16
Adelphi	1	Victa	18
P-59	1	Baron	18
Parade	1	Cheri	21
Sydsport	3	Merion-Pennstar	23
Bonnieblue	4	Merion-Kenblue	24
Adelphi-Kenblue	4	Fylking-C26	27
Adelphi-Nugget	5	Nugget	29
Sodco	5	Nugget-Pennstar	29
Glade-Nugget	6	Fylking	31
Vantage	7	Pennstar	31
Glade	7	Delft	37
Adelphi-Fylking	8	Fylking-Pennlawn	37
Touchdown	8	Nugget-Park	38
Majestic	8	Fylking-Jamestown	45
Glade-Adelphi	10	Modena	52
Vantage-Victa	10	Enita	59

[a]*Test planted April, 1972. Half of each plot received tricalcium arsenate treatment, which produced a four-fold increase in Fusarium blight. Plots were mowed at ¾-inch height with moderately high fertility.*

and substantial damage from *Fusarium* blight. One half of each plot on the 1972 regional bluegrass test was treated with 4.8 pounds of tricalcium arsenate in both the spring and the fall of 1973. Thatch buildup has occurred on the treated half but not on the untreated half. The treated half shows four times as much damage from *Fusarium* blight as the untreated half. At our Adelphia location we have seen considerable *Fusarium* blight disease in fields not treated with tricalcium arsenate. Areas of these fields having reduced air circulation show substantially more from *Fusarium* blight.

THE FINE FESCUES

Fine fescues are generally tolerant of acid soils, low fertility, and shade. They perform best in cool climates and during cool seasons. They are intolerant of higher levels of nitrogen fertilizer and poor drainage during hot weather. The fine fescues currently showing the greatest potential for turf use can be classified into five types. Dr. Robert W. Duell, who is working closely with the fine fescues at Rutgers, refers to them as the Chewings, Creeping, Spreading, Hard, and Sheeps fescues. The Chewings, Creeping, and Spreading fescues are currently included in one species, *Festuca rubra* L. However, these three types are very different in appearance, growth habit, management requirements, adaptation, breeding behavior, and cytological characteristics. They should be classified as separate species.

The **Chewings type,** *F. rubra* L. subsp. *commutata* Gaud., is a fine-leafed, lower growing grass without rhizomes. Under mowing, these plants spread slowly by basal tillering. Where summers are cool, they will tolerate rather close mowing and will produce attractive dense turf requiring less fertilizer and less mowing than needed for a good bluegrass turf. A number of very attractive varieties of Chewings fescue have been developed in recent years by breeders in the United States and Europe. 'Jamestown,' 'Banner,' 'Koket,' and 'Highlight' are representative of the improved varieties within this group. Their dense growth habit can make them much more competitive and persistent in mixtures with Kentucky bluegrass than fescue varieties formerly available. This can be either an advantage or a disadvantage.

The **Creeping type,** *F. rubra L.* subsp. *Trichophylla* Gaud., is represented by European varieties such as 'Cumberland Marsh,' 'Dawson,' 'Golfrood,' and 'Oasis.' They are fine-leafed, low-growing varieties with short, thin rhizomes. Under mowing, they develop a turf similar in appearance to the improved Chewings type fescues. Some varieties within this group have demonstrated good salt tolerance. Currently available Creeping types are highly susceptible to dollar spot and are generally low seed producers. These factors limit the potential use of the Creeping types. It is hoped that improvements can be made in these characteristics, for some of our most leafspot-resistant germplasm is found within this group.

The **Spreading type,** *F. rubra* L. subsp. *rubra* Hack, is represented by varieties such as 'Fortress' and 'Ruby.' Spreading fescues have 56 chromosomes while Chewings and Creeping fescues have 42 chromosomes. Spreading fescues have somewhat wider leaves, longer and thicker rhizomes, and better seedling vigor than other fine fescues. They are less tolerant of close mowing, have a lower turf density, and produce less thatch than the Creeping and Chewings types. In trials in New Jersey and Maryland the Spreading types have shown considerably less damage from *Fusarium* blight than the Chewings types. Improved selections of Spreading fescues would appear to be more compatible with Kentucky bluegrass and would have greater seedling vigor, better performance under low maintenance, and possible better shade tolerance. Increased breeding efforts should be made to improve the Spreading fescues, especially in areas of severe summer stress.

The **Hard fescues,** *F. longifolia* Thuil., are receiving considerable attention since the development and release of 'Biljart' hard fescue (Scotts C-26) in Holland. The improved Hard fescues produce a turf comparable in texture and growth habit with the better varieties of the Chewings type fescue but with a somewhat slower rate of vertical growth, better resistance to some hot-weather diseases, and better adaptation to some poor soil conditions. Spring dormancy, slow recovery from injury, and costly seed production are problems that need improvement.

'The development of improved levels of a stable, race-nonspecific resistance to Fusarium blight should receive high priority' — Funk

The **Sheeps fescues,** *F. ovina* L., collected from old turf areas of the Northeast look interesting in our turf evaluation plots. Most selections appear "grainy" under mowing but have shown excellent persistance under severe summer stress conditions. They have good shade tolerance and good adaptation to poor soils.

TALL FESCUE

Tall fescue, *Festuca arundinacea* Schreb., is used extensively for pasture, hay, general-purpose turf, and erosion control throughout the summer heat stress zone of the United States. It has the ability to tolerate summer heat and drought stress in areas where other cool season grasses perform poorly. There would appear to be considerable potential for the plant breeder to make substantial improvements in the appearance and turf performance of this interesting grass even though breeding efforts to date have met with only limited success. Dense, attractive, fine-textured lower growing types currently available in our breeding collection need further improvements in pest resistance and tolerance of temperature extremes. Recent work in central Alabama show that nematodes can seriously limit rooting depth, drought tolerance, persistence, and productivity of tall fescue and other cool-season grasses. Well-organized and adequately supported team efforts by pathologists, nematologists, physiologists, and plant breeders might well produce tall fescue varieties of considerable value for areas where *Fusarium* blight is prevalent.

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Fusarium Blight

continued

PERENNIAL RYEGRASS

The development of improved turf-type perennial ryegrass (*Lolium perenne* L.) varieties such as 'Manhattan,' 'Pennfine,' 'Citation,' 'NK200,' 'Eton,' 'Derby,' 'Yorktown,' 'Diplomat,' and 'Omega' has made this species of considerable usefulness to the turf industry. These improved ryegrasses are substantially superior to common perennial ryegrass for many turf purposes. Like all ryegrasses, the new turf-types are quick and easy to establish and are adapted to a wide range of soil types and uses. When properly managed in their area of adaptation, these ryegrasses can be durable, persistent, and attractive. Instances have been reported where turf-type ryegrasses have given good performance on turf areas where Kentucky bluegrass has been seriously damaged by *Fusarium* blight. The turf-type ryegrasses appear to produce much less thatch than bentgrass, Kentucky bluegrass, and the Chewings-type fescues. A number of golf course superintendents in summer heat stress areas such as Washington, D.C., are having very promising success with overseeding established bermudagrass with blends of improved turf-type ryegrasses such as Manhattan, Pennfine, and Citation. Continued breeding efforts should lead to further improvements in mowing quality, summer performance, winter hardiness, and resistance to crown rust *(Puccinia coronata)*, brown patch *(Rhizoctonia solani)*, and leaf spot *(Helminthosporium siccans)*. Improved resistance to *Pythium* is also needed for good summer performance of ryegrass in the humid summer heat stress region.

Techniques for Determination of Fusarium Blight Susceptibility In Kentucky Bluegrass

by William A. Meyer
and Frank H. Berns

Fusarium blight is now recognized as a major disease problem of Kentucky bluegrasses and some other cool-season turfgrasses in the northeastern and midwestern sections of the United States (1,6) and in California (2) *Fusarium roseum* and *F. tricinctum* are the two species of fungi found by Couch and Bedford (1) to be the incitants of this disease.

Disease symptoms seldom appear until a turf stand is two or more years old. Occasionally, symptoms may appear during the first year of turf establishment. The severity of this disease may vary greatly from year to year, depending upon such environmental factors as heat and moisture stress. It is usually very difficult to get a uniform distribution of *Fusarium* blight throughout a replicated turf plot area. In the development of new Kentucky bluegrass varieties, it is important to establish their degree of susceptibility to *Fusarium* blight as well as other major diseases before they are released. Because of the time required for this disease to develop consistently in turf plots, rapid screening techniques are needed. The following paper will describe techniques which were developed to aid in the screening of Kentucky bluegrass cultivars for *Fusarium* blight susceptibility.

TILLER-PUNCTURE TECHNIQUE

With the tiller-puncture technique (4), 14 Kentucky bluegrass varieties were propagated from individual tillers and grown in 2-inch pots in the greenhouse for 50 to 75 days. They were then transferred to a growth chamber (14-hour day at 29° C, 24° C night; 4,000 foot candles; and 70 percent relative humidity) for three days prior to inoculation. A small sound (2 mm long) penetrating to the youngest enclosed leaf was made in each of two healthy tillers per pot between the crown area and third leaf. Mycelium pieces of *Fusarium trincinctum* isolate MSU1 or of *F. roseum* isolates U12 or KC1 were then placed in the wounds. Wet sterile peat moss was used to cover the wounded area of each inoculated tiller. Other tillers were wounded but noninoculated to serve as controls. In all, 60 tillers of each variety were inoculated with the MSU1 isolate, 36 tillers with the UI2 isolate, and 12 tillers with the KC1 isolate. All pots were then returned to the growth chamber and the peat moss was kept moist.

Foliar lesions could be seen on the emerging leaf two to three days after inoculation. In many tillers the initial fungal infections in the new and old leaves would advance down into the crown area of the plant and eventually cause death. Some tillers were killed within seven days on the most susceptible varieties. After two weeks all pots were removed from the chamber and rated for severity of infection. The MSU1 isolate was the most virulent isolate followed by UI2 and KC1. Leaf and crown lesions caused by the three isolates were similar on all of the varietiies. The experimental variety WTN-I-13 had the smallest percentage of crown-rotted and dead plants. Eighteen percent of the WTN-I-13 tillers were crown rotted or dead with the MSU1 isolate, 8 percent with UI2, and none with KC1. WTN-I-2 and Belturf were ranked next with slightly higher percentages of dead or diseased plants. The varieties P104, WTN-J79, and Fylking were the most severely affected.

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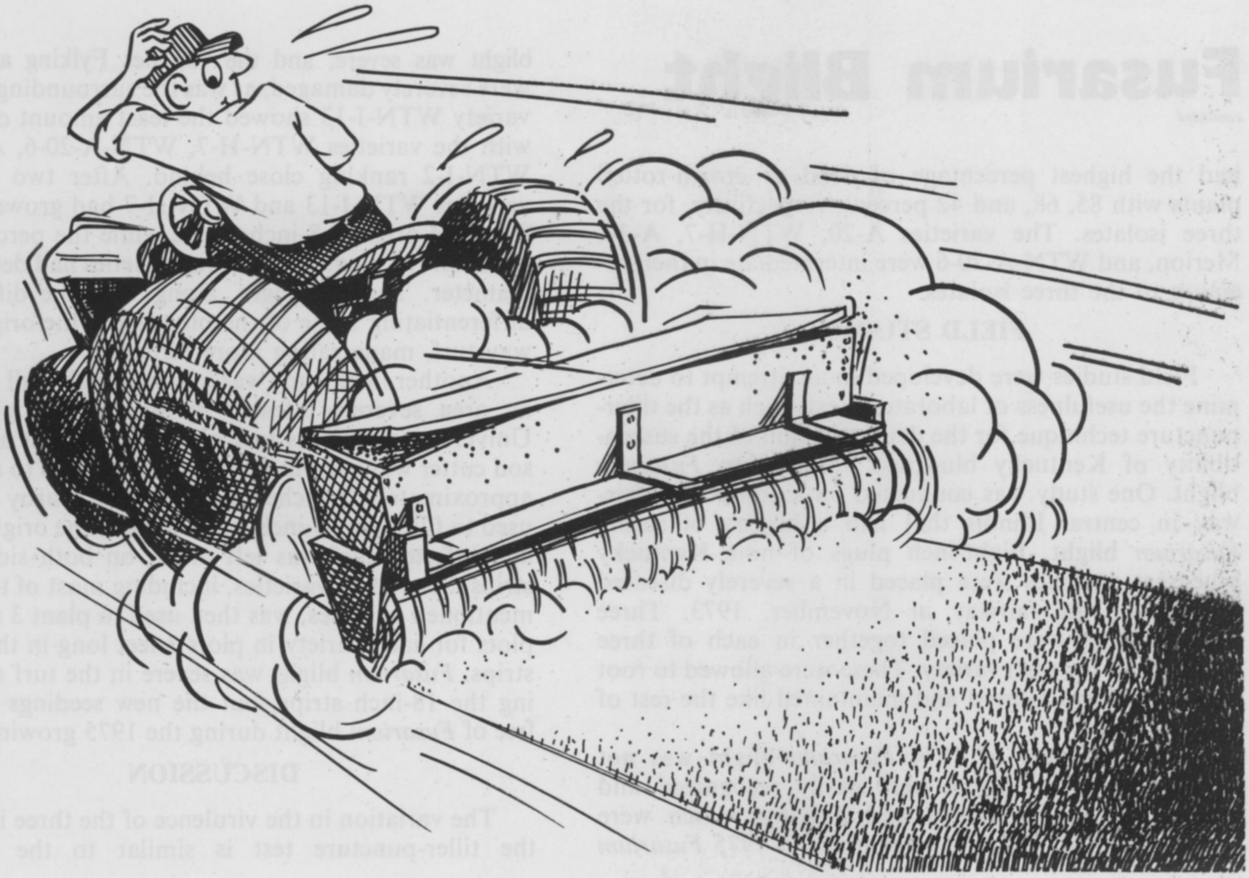

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Fusarium Blight

continued

had the highest percentage of dead or crown-rotted plants with 85, 68, and 42 percent, respectively, for the three isolates. The varieties A-20, WTN-H-7, A-34, Merion, and WTN-A-20-6 were intermediate in their reaction to the three isolates.

FIELD STUDIES

Field studies were developed in an attempt to determine the usefulness of laboratory tests such as the tiller-puncture technique for the determination of the susceptibility of Kentucky bluegrass varieties to *Fusarium* blight. One study was conducted on a golf course fairway in central Illinois that had a history of severe *Fusarium* blight. Eight-inch plugs of nine Kentucky bluegrass varieties were placed in a severely diseased portion of the fairway in November, 1973. Three healthy plugs were placed together in each of three replications for each variety. These were allowed to root down and were mowed and maintained like the rest of the fairway.

In the summer of 1974 *Fusarium* blight was not severe; all of the plugs were easily recognized and healthy except for Baron and Fylking, which were slightly thinned. During the summer of 1975 *Fusarium* blight was severe, and the varieties Fylking and Baron were severely damaged, as was the surrounding turf. The variety WTN-I-13 showed the least amount of damage with the varieties WTN-H-7, WTN-A-20-6, A-20, and WTN-I-2 ranking close behind. After two years the varieties WTN-I-13 and WTN-H-7 had grown laterally from the original 8-inch plugs, while the percentage of cover on the plugs of the other varieties had decreased in diameter. These changes, along with the difficulty in differentiating some of the plugs from the original fairway turf, made rating more difficult.

Another field study was initiated in the fall of 1974 in an area severely infested by *Fusarium* blight at the University of Illinois turf plots. In this test an 18-inch sod cutter was used to remove diseased sod to a depth of approximately 2 inches. Soil from a nearby field was used to fill these 18-inch strips back to the original grade and infested turf was left intact on both sides of the strips. Seed of 32 varieties, including most of the above-mentioned varieties, was then used to plant 3 replicated plots for each variety in plots 3 feet long in the 18-inch strips. *Fusarium* blight was severe in the turf surrounding the 18-inch strips, but the new seedings remained free of *Fusarium* blight during the 1975 growing season.

DISCUSSION

The variation in the virulence of the three isolates in the tiller-puncture test is similar to the variation reported by other workers (3) with different *Fusarium* isolates. A limitation with the tiller-puncture test is that each inoculation is made with a single strain of the pathogen. Since the *F. roseum* and *tricinctum* species vary greatly in nature, a larger number of isolates need to be included in tests to increase their validity.

None of the varieties in the tiller-puncture test remained completely healthy. WTN-I-13 was the least severely affected variety in both the tiller-puncture and the field study. Other tests are needed in different locations with this variety to verify its degree of susceptibility to *Fusarium* blight. Some of the varieties that ranked intermediate in the laboratory tests also ranked intermediate in the field test. It should be noted that Merion was not the most susceptible variety in the test. The high degree of susceptibility of Fylking to *Fusarium* blight has been reported in different locations (5). The susceptibility of the variety WTN-J-79 at a level similar to Fylking is an indication that this variety may perform poorly in areas where *Fusarium* blight is severe. The tiller-puncture test with a limited number of isolates may be most useful as a method to detect a high degree of susceptibility in a variety before it is released. Many experimental and commercial Kentucky bluegrass varieties besides the 14 reported in this paper have been inoculated with the MSU1 isolate, using the tiller-puncture technique. To date, no variety has remained free of infection. It is hoped that this technique will at some time aid in detecting a source of germ plasm that has a high degree of physiological resistance to *Fusarium* blight.

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Products

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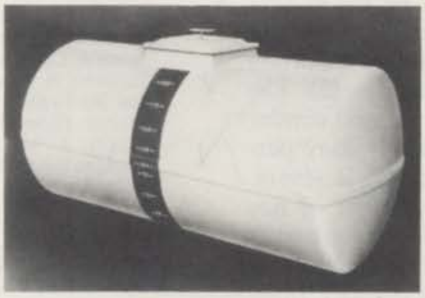

company to build the bottom half heavier where the tank is subject to most stress from saddle mounting, etc.

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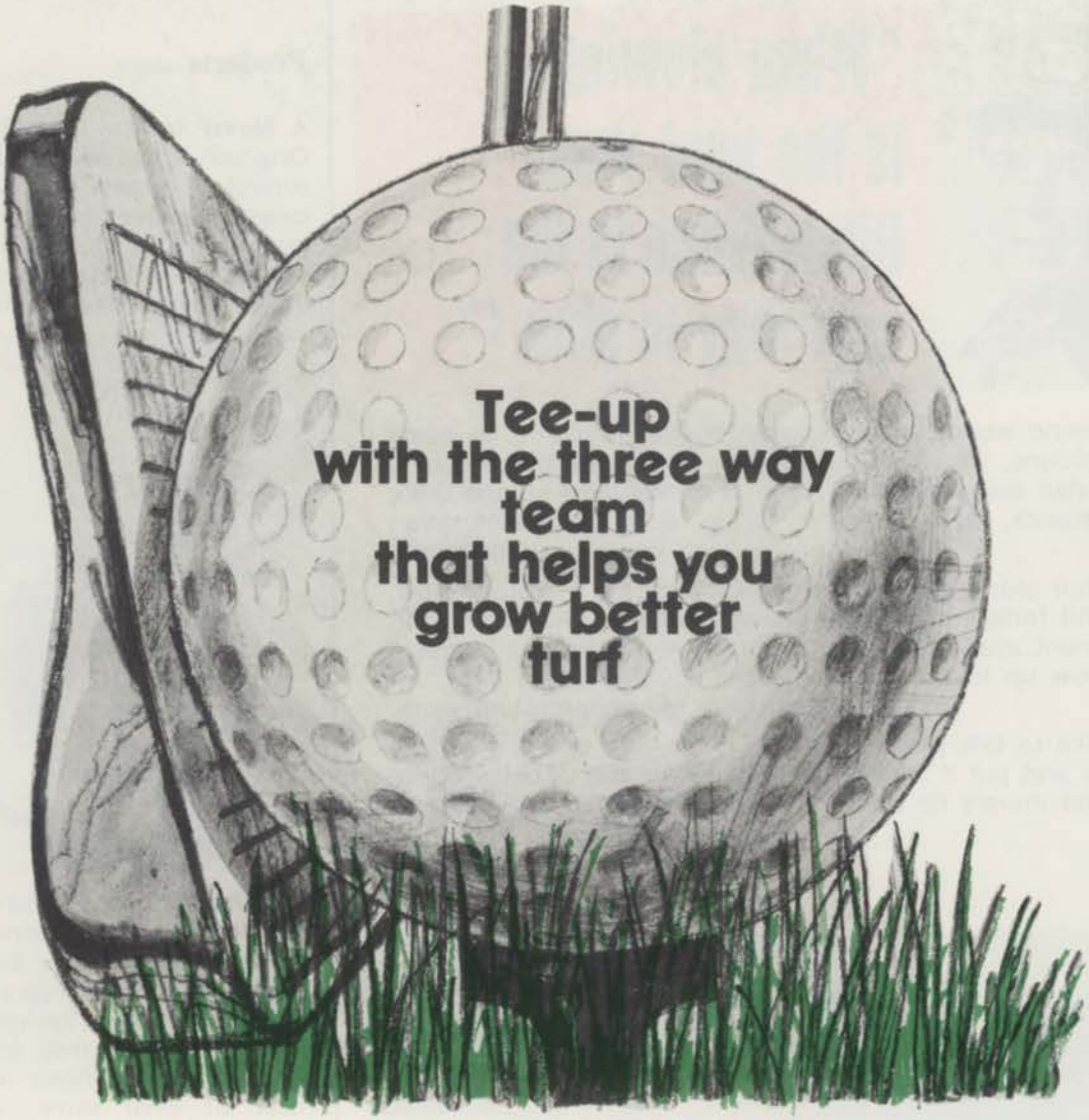

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its nozzle, and people have found new uses for it, the company said. Its engine permits the dusting or spraying of trees as high as 35 feet and its compact backpack-type design makes it handy for use in cleaning sport stadiums of debris, litter or even snow. Another application is whitewashing.

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Industrial Lawn Vac from PeCo, Inc. has been designed specially for the John Deere 400 tractor to pick up and mulch leaves, grass clippings and other lawn debris. Used in large lawn maintenance programs, the unit can be operated without the driver leaving his seat.

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The Woodsman, a rugged machine that clears land by cutting a five-foot-wide swath through dense brush and trees, is described in a bulletin recently published by Royer Foundry & Machine Co. According to the bulletin, the unit can clear up to three acres of land in a day and easily handle six-inch-diameter trees.

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