Session 7B

Benefits and Implications of Pesticide Use on Amenity Grassland

Chairman	Dr R D Prew
Session Organiser	Dr B C Clifford
Papers	7B-1 to 7B-5

FUNGICIDE USAGE ON GOLF COURSE TURF: THE IMPLICATIONS IN A GROWING WORLD MARKET

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ABSTRACT

Turf diseases present a major management problem on golf courses worldwide and fungicides offer the only reliable, effective means of control at the present time. The likelihood for their replacement by cultural or biological control methods seems unlikely in the near future. Cultural practices that influence disease incidence and severity are well known to professional turf managers and are already integrated into their management programs. Biological agents for turf disease control await commercial exploitation. Increased world interest will result in many more golf courses and an increased overall demand for fungicides. Additional fungicides of new chemistry, environmentally friendly, and of low mammalian toxicity are needed to address current concerns and supplement our now dwindling arsenal.

TURFGRASSES AND THEIR USES

Grasses colonise a greater proportion of the earth's surface than any other plant species and comprise a major resource to human kind that ranges from the major food grains to the turf grasses. The greater leisure time available to more affluent societies and the consequent demand for recreational facilities, coupled with an awakening to the aesthetic value of good turf, has stimulated an increasing interest in maintaining turf of high quality. This is reflected in the growing number of turf research establishments world wide with personnel actively engaged in the study of all aspects of turf management. In the United States, turfgrass management as a discipline can be studied to the bachelors degree level and post-graduate courses on specialised aspects are offered at many universities. Job opportunities for graduates are good in a turfgrass industry that is estimated to spend in excess of 27 billion dollars annually on new establishment, replacement, renovation and routine maintenance of amenity turf.

GOLF IN THE UNITED STATES AND ELSEWHERE

Lawns occupy an estimated 10 - 12 million hectares in the United States with more than 56 million Americans participating in their own lawn care. A further substantial number enlist the services of lawn care companies, a business that burgeoned in the 1970 s and 1980 s but whose fortunes have declined of late. While lawn tending is a popular pursuit, one of the fastest growing recreational sports on turf is golf. Between 1985 - 1993 the number of golfers in the United States rose from 17 million to 28 million and their estimated annual expenditure in equipment and fees translates into an economic impact in excess of 54 billion dollars. The number of golf courses now surpasses 15,000 involving something in the region of 800,000 hectares. The economic impact of maintaining these courses is estimated as 6.2 billion dollars. New courses are being built at the rate of about 300 each year as the number of golfers continues to climb to a projected 40 million by the turn of the century.

Other parts of the developed world are seeing a similar avid demand for golf. The United Kingdom now has over 3,000 courses. Numerous golf facilities have been and are being built throughout Europe, Africa, Australasia, South and Central America, Canada, the Caribbean, and Asia. Japan, in particular, has a thriving golf industry that includes over 2,000 courses and countless driving ranges. Lawns and turf areas for other sports contribute to a greater or lesser extent in the organised scenery of many of these locations but it is commonly the highly visible golf courses with their substantial space needs and their intensive management requirements of water, nutrients, and pest and disease control that generate some public concerns regarding land use and potential environmental effects.

TURFGRASS DISEASES: AN HISTORICAL PERSPECTIVE

Though various agents can incite disease in grasses, by far the most common and damaging pathogens on cultivated turf are the fungi. A turfgrass sward supports a multitude of fungal species most confining their activity to plant residues as saprobes and contributing to the very necessary process of decay. However, there still remains an impressive number that are potential pathogens and these include species from all the major taxonomic groups in the fungal kingdom.

References to lawns and sports turf in the Old World reach back into early history but any documentation regarding turf diseases is of fairly recent occurrence. Descriptions of early turfgrass swards indicate they were of diverse botanical composition and their quality left a lot to be desired by our present day standards. Nonetheless, the common cool season turfgrass species probably were well represented together with a wide range of fungal pathogens. As settlers ventured to the New World, inadvertently or otherwise they transported plant materials including the common turfgrass species together with their associated microorganisms. The fungal pathogens accordingly colonised the new environments along with the grass hosts. In the reverse direction, New World pathogens were similarly dispersed as trading between the continents developed. Turfgrasses indigenous to Europe introduced into New Zealand and into North America formed the basis for a turf seed production industry that now supplies seed worldwide. Thus, wherever turfgrasses are grown the common turf pathogens are likely to occur and the association is presumed to be, in most instances, of long standing occurrence.

In the wild or on turf of low quality, depredation from disease is of little consequence as the symptoms pass unnoticed. As first the art and then the science of turf management developed, there was a gradual upgrading in turf quality and turf diseases assumed increasing importance. Activities of the various pathogens intensified, damage became more evident, turf disease diagnosis improved and the early decades of the century saw the recording of these events. The first turf disease, brown patch (*Rhizoctonia solani*), was recorded in 1913 but by the early-1930's, a bulletin listing many more of the common fungal diseases of turfgrasses was available (Monteith & Dahl, 1932). Since World War II, the introduction and widespread use of new cultivars, improved equipment, efficient irrigation systems, better fertilizers and, particularly, selective herbicides gave another major boost to turf quality and laid the foundation for the impeccable putting surfaces that all golfers demand today.

The intensive management practices (close and frequent mowing, ample nutrients and water) that are imposed in a monoculture situation (swards of single grass species or clones of narrow genetic base) provide the means to improved turf quality but, in turn, they offer an environment more conducive to fungus-incited disease. In essence, turf pathogens are presented with a constantly wounded host that has limited photosynthetic area, and restricted root development. The ability of such plants to resist infection, or if infected, to replace or repair damaged tissues is limited severely. Additional stresses (inclement weather, high parasitic nematode populations, heavy play) may tip an already delicate balance further in favor of the pathogen. Highly visible symptoms soon develop that spread rapidly and, unless the problem is addressed immediately, a superintendent's job is in jeopardy!

TURFGRASS DISEASES: AN EVOLVING SITUATION

From time to time, new diseases have been added to the list prompting the query as to how and why they arise. In these days of rapid and extensive world travel, the introduction of a pathogen into a new location is always a possibility. Spores or other inoculum in plant debris and soil may traverse a continent or an ocean in a few hours, borne unwittingly for example on the shoes of itinerant golfers. As already described, it seems likely, that the various turf pathogens already are widely distributed. Given conditions that are less than ideal for their disease expression, indigenous or long established turf pathogens may be the cause of chronic diseases which are overlooked or misdiagnosed. 'New' diseases may therefore only be a product of keener observation and better diagnostic technique. Yellow tuft (*Sclerophthora macrospora*) is an example of a turf disease misdiagnosed for over fifty years. Other new diseases have arisen following a reappraisal of existing ones that were in fact disease complexes. In these situations identical symptoms are caused by different fungi. Thus, brown patch symptoms may be generated by any of three *Rhizoctonia* species. Red thread (*Laetisaria fuciformis*) and pink patch (*Limonomyces roseipellis*), once thought the same, are caused by two distinct fungal species. The Fusarium blight syndrome is now known to embrace several fungi and has spun off the new diseases necrotic ringspot (*Leptosphaeria korrae*) and summer patch (*Magnaporthe poae*). The management of these diseases has improved appreciably with their better elucidation. More appropriate control strategies can now be adopted and some long standing controversies have been resolved.

The sudden appearance of a severe outbreak of a new disease results most probably from changes taking place in the local fungal populations. A genetic shift to a more virulent biotype may cause a disease flare up. For example, dollar spot (*Sclerotinia homoeocarpa*) and red thread, thought of as low fertility diseases, now seem able to invade vigorously growing turfs. Another explanation is a change in the naturally occurring checks and balances that previously restrained a potential pathogen but were altered or diminished by the use of a different root zone mix or the introduction of certain pesticides. Pythium root rots and root dysfunction (*Pythium* spp.) have become an increasing problem with the move towards greens of high sand content. The increased incidence and severity worldwide of take-all patch (*Gaeumannomyces graminis* var. *avenae*) and other similar patch diseases caused by ectotrophic root-infecting fungi may fit this scenario. Soils are known to acquire suppressive properties to the causal agent of take-all. It may be that this suppressive mechanism has been compromised, allowing the severe outbreaks to occur. What triggered the change is not clear but the effect of some pesticides (especially fungicides and herbicides) to increase the incidence of particular turf diseases is well established.

THE NEED FOR DIAGNOSIS

Accurate diagnosis of diseases by identification of the pathogen and a thorough understanding of the etiology of a particular disease have been and will continue to be the major requisites in determining any control program. Early turf managers realized that manipulation of cultural practices could influence disease incidence and severity. Essentially they were early practitioners of integrated pest management. They strove to provide the best cultural milieu for grass growth by adjusting the soil pH and soil fertility levels, optimising soil water and air content (through efficient drainage and aeration procedures), utilising timely and judicious irrigation, varying the mowing height, removing clippings, dispersing dew, reducing thatch, and topdressing with composts. Maybe the composts used then provided some measure of pathogen suppressive activity (a "modern" biological control strategy), but they were also looking towards fungicides as a vital auxiliary to their efforts. In hindsight, they seem to have managed fairly well with the few chemicals available to them -- hydrated lime, iron sulfate, copper sulfate, mercury chlorides. Evidently, green speed was not a major quality criterion and acceptable standards perhaps were somewhat lower. During the 62 years since 1932, the list of turf diseases has expanded considerably and turf research endeavours over that period have confirmed the limited value of cultural control methods alone where quality expectations and disease pressures are high. The integrated management strategies are being rediscovered, but reliance on fungicides has increased tremendously wherever golf is played.

CURRENT PESTICIDE USE

According to a recent United States Environmental Protection Agency report, "Pesticide Industry Sales and Usage", world use of conventional pesticides in 1993 was 2 billion kilograms active ingredient. This represents a user expenditure of about 25.3 billion dollars. Herbicides comprise 47% (46%), insecticides 36% (31%), and fungicides 12% (16%), respectively in the two categories. Conventional pesticide use in the United States was approximately 500 million kilograms active ingredient (one quarter of the world's market) which at 8.5 billion dollars approximates one third of the world market user expenditure. Herbicides comprised 57% (56%), insecticides 23% (30%), and fungicides 12% (7%) in volume of active ingredient and user expenditure, respectively.

Agricultural and home and garden fungicides comprised 43 million kilograms active ingredient at a user expenditure of 477 million dollars. The turf and ornamentals industries user spending amounted to 120 million dollars. Twenty million dollars of this total was allocated to nursery and ornamentals, 15 million dollars to miscellaneous (sod growers, lawn care) and 85 million dollars to golf courses. Estimates supplied by industry sources in 1986 and 1987 (Ciba-Geigy, Mobay, personal communications) show fungicide sales to golf courses of 41 million dollars and 42 million dollars, respectively, indicating that expenditure on fungicides has doubled over the past seven years. Of particular interest, the 1986 / 1987 figures showed that, even then, fungicide spending for golf courses outstripped spending for all other agricultural commodity groups by a substantial margin. Current comparative figures are not available but there is every reason to believe that the margins have widened even further since overall expenditure in the agriculture / home and garden fungicide category increased from 450 million dollars in 1985 and 1986 to 477 million dollars in 1993.

In 1985, Mobay developed a list of fungicides used on golf courses in the United States by product sales. The leader was chlorothalonil (15.2% of the market), followed by iprodione (14.7%), triadimefon (11%), benomyl (9%), cycloheximide (7.2%), propamocarb (6.7%), metalaxyl (4.8%), and fenarimol (4%). A similar list for 1993 again shows chlorothalonil (17% of the market) in the lead, followed by iprodione (16%), triadimefon (12%), propiconazole (9%), and metalaxyl (8%) (Mobay, personal communication).

For 1993, estimates relating the percentage of total fungicide use for particular turf disease were provided by Miles (formerly Mobay). Treatment for dollar spot absorbed 37%, brown patch (30%), leaf spot (*Bipolaris* spp. and *Drechslera* spp.) (9%), Pythium diseases (8%), summer patch (3%), snow molds (*Microdochium nivale* and *Typhula* spp.) (2%), Fusarium diseases (1%), and others (9%) (Miles, personal communication).

Estimates of golf course fungicide use outside the United States are not available for comparison, but one thing is certain, golf is a truly international game with international star players. High standards are demanded wherever competitive golf is played. Utilisation of the same few cool season or warm season turf species and cultivars occurs worldwide, and the same intensive management practices are employed. The turf diseases are truly international too. They occur, with varying incidence and severity, throughout the world and require fungicides for their control. The fungicides used may vary from country to country, depending on availability or regulatory constraints, but the number of effective materials is not large, so everybody draws from the common pool to solve their problems. In the absence of any imminent major breakthrough by plant breeders to produce cultivars of turfgrasses with multiple disease resistance, and the slow commercial development of biological control agents, fungicides will continue as the prime means of disease control in any high quality turf. Given the strong potential for growth of the golf industry worldwide, the market for fungicides can be expected to increase appreciably.

PESTICIDES AND HEALTH

Chemical inputs, including pesticides, are an integral part of turf management practice but the fate of these chemicals and their overall impact in the environment have prompted public concern. Efforts to evaluate the risks are the subject of extensive, painstaking and costly scientific research by the chemical industry, universities, and government agencies. Issues of primary concern include exposure of human and non-target organisms to foliar residues, runoff into surface water and the potential for contamination of ground water.

Stringent regulations that address these pesticide safety issues control the registration and release of new chemicals onto the market. Pesticides not previously subject to this rigorous development program now face required reregistration. Where the market share for a particular product is small, cost of reregistration may far exceed the predicted economic return so the product is discontinued. Anilazine, a valued turf fungicide for many years is a recent case. Other old established fungicides like mercury and cadmium compounds, cycloheximide and benomyl have been withdrawn because of possible human health problems. As far as the author is aware, no fatalities among golfers and superintendents attributable to turf fungicides have been confirmed. However, because of the notion of zero risk, all it takes is a comment by the media sensationalizing some incident and a surge of chemophobia in the general public is the result. An unfortunate and tragic death on an American golf course that implicated chlorothalonil as the cause received widespread attention and this incident is still used repeatedly in documentaries and reports critical of golf course pesticide use. That this chemical, currently the most widely used turf fungicide, was exonerated completely seems immaterial.

A recent study funded by the Golf Course Superintendents Association of America (Kross *et al.*, 1994) noted a high rate of cancer deaths among its members. This report was seized upon immediately as evidence of a direct relationship between turf pesticides and the several forms of cancer documented, even though the authors, a team from the University of Iowa medical school, had stressed that no causal link had been established and there was no danger to golfers. The high incidence of lung cancer they considered most likely related to heavy smoking by superintendents. The report did indicate, however, that since other cancers may be linked to pesticides it would be prudent for superintendents to minimize their exposure to the chemicals.

Most golf course managers apply pesticides as sprays since dry formulations generally are less efficient. The major risk, either through skin contact or inhalation, occurs when handling or preparing the concentrate for spraying. Sprayer operatives in the United States have to undergo training and be licensed applicators. Protective clothes are required practice but the United States Golf Course Association recently funded a major new study to optimise applicator protection. Industry is also doing its part. Improvements by equipment manufacturers in the design of spraying machinery have greatly reduced drift, accidental spills and operator contamination. Developments in formulation technology that over the years led to great improvements in product sprayability and uniformity of dispersal, now look to facilitating tank mixing of fungicides or their joint application with other pesticides, both to lessen operator exposure time and reduce labor costs. Dusty powders are still on the market but dust-free dispersible-wettable-granules, flowables, and liquids are in the majority, many now offered in novel packaging -- preweighed soluble bags, metered, automatic containers, bulk returnable containers with metered dispensers, etc. A major effort is being made by all concerned to make pesticide application an effective and safe operation.

PESTICIDES IN THE ENVIRONMENT

The question now arises as to what happens to the chemicals applied to turf. A wide ranging research endeavour is a directed towards finding the answers but the program is still in its infancy. Early work has concentrated on fertilisers (especially nitrogen), some herbicides and insecticides, and a few fungicides.

A dense turfgrass sward presents a large leaf surface area for interception of a pesticide but the process has not been intensively investigated. Many variables influence the process but, suffice to say, in dense mature turf most pesticide remains in the leaf canopy and the thatch layer. Granular formulations will act differently than liquids but, regardless of formulation, some of the active ingredient may be absorbed into leaf tissues, volatilized into the atmosphere, degraded chemically, photochemically or by microorganisms, removed in clippings and leached by water. Opportunity for leaching or surface movement of pesticides is greatest in thin or immature swards but, in well maintained mature turf, the high shoot density, the thatch layer and an extensive fibrous root system all contribute to restricting pesticide movement. The high organic matter content in thatch is highly adsorptive to most pesticides, sometimes to the detriment of their efficacy. However, by hindering pesticide movement, populations of microorganisms in the thatch and the root zone have increased opportunity to degrade pesticides.

Chemicals vary widely in physical properties that determine their movement in soils. In general, pesticides that are water insoluble or hydrophobic tend to be readily adsorbed by organic matter while those that are highly water soluble or hydrophilic do not. Parameters are now established for all pesticides that allow ranking of their likelihood to leach, volatilize or degrade under comparable soil conditions. Corroborative field data for most turf fungicides is still lacking but the predictive information does point to where prudent choice and application practice should be adopted. Those pesticides that are persistent, mobile, and nonvolatile have the highest chance of contaminating ground water.

While fungicides are an essential tool in managing top quality turf, their indiscriminate or excessive use is to be avoided. Nontargeted microorganisms may be affected adversely and the delicate balance between pathogenic fungi and their antagonists may be altered in favor of the former. This phenomenon, where enhanced recovery and early return of a particular disease occurs in previously treated turf is termed disease resurgence and has been observed commonly with dollar spot and brown patch diseases.

In addition to some herbicides and growth retardants, the author has observed that some fungicides may actually encourage turf disease. Effective against one disease, they may promote another. Benomyl can enhance red thread, leaf spot (*Drechslera poae*) and Pythium diseases. Iprodione can increase the incidence and severity of yellow tuft. Maneb, mancozeb and flutolanil exacerbate dollar spot symptoms and chlorothalonil may promote summer patch. In each case, it is likely that specific antagonists to the pathogens are compromised.

The microorganisms involved in the processes of decay may also be affected adversely. Repeated use of certain fungicides has been observed by the author to increase thatch build up. Benzimidazole fungicides, mancozeb, maneb, and thiram, have all been implicated. The reduced capacity of the microorganisms to degrade thatch is attributed largely to an indirect effect of these sulfur containing chemicals in lowering pH to levels below the optimum for thatch degradation. These fungicides may also promote thatch because of their toxicity to earthworms. The latter bring soil into the thatch layer to aid in the organic matter decomposition. In greens turf, their surface casting is a nuisance so fungicide suppression of earthworms is an acceptable benefit.

A major problem with the excessive use of fungicides and especially where the choice of material is limited, is the development of fungicide tolerance. A few instances of seed-borne fungi with tolerance to mercury based seed dressings were known previously but in the mid-1960's widespread occurrence of dollar spot disease, highly tolerant to cadmium fungicides (and also mercury compounds) was documented in the United States. Cadmium fungicides were routinely recommended at that time for dollar spot control and presumably, under repeated use of cadmium, a selection pressure and an accumulation of tolerant biotypes occurred in the population. Replacement of cadmium with the then newly developed benomyl resulted (within two years) in benomyl tolerant biotypes. Related benzimidazole fungicides were equally ineffective. Additional biotypes of the dollar spot fungus, tolerant to anilazine, the dicarboximides, and most recently the sterol-inhibiting fungicides have been reported. It is interesting to note that chlorothalonil, in widespread use over this period as a dollar spot fungicide, is still effective. Some small reduction in the optimum spray interval may have occurred over the years but biotypes highly tolerant to chlorothalonil have not been seen under field conditions. Fungicide tolerance is no longer limited to dollar spot disease. Instances of tolerance to dicarboximides (pink snow mold (*Microdochium nivale*)), benzimidazoles (powdery mildew (*Erysiphe graminis*) and Fusarium blight), and metalaxyl (Pythium blight) have been observed.

While the dollar spot fungus seems particularly resourceful, able to develop tolerance to both protectant (contact) and penetrant (systemic) fungicides, it is generally accepted that protectants with their multisite mode of action in the fungal cell are much more stable in the field. In marked contrast, some penetrant fungicides have lost effectiveness shortly after their commercial release. Target fungi developed tolerance to the fungicide in question (and often to related compounds) because the mode of action involves highly sophisticated, but limited, single site activity that a fungus can evade or circumvent.

CONCLUSIONS

The development of tolerance in turf fungi appears to be worldwide in occurrence. Golf superintendents are aware of the problem and are adjusting their disease management programs to try and eliminate the selection pressure on the fungal pathogens arising from the use of one or two fungicides. Tank mixing or alternate sprays with as wide a range of appropriate materials as possible is becoming standard practice. Industry must also be aware of the problem and continue to develop new turfgrass fungicides. One does wonder, however, how many more sterol inhibitors we need? Some new fungicide categories (with zero risk!) would be welcome to swell the now oft times threatened and dwindling arsenal.

REFERENCES

Kross, B.C.; Burmeister, L.F.; Ogilvie, L.K. (1994) Mortality study among golf course superintendents, *Golf Course Management*, **56**, 49-56.

Monteith, J. Jr.; Dahl, A.S. (1932) Turf diseases and their control. *Bull. US Golf Assoc. Green Sect.*, **12**, 85-187.

DISEASE PROBLEMS OF AMENITY GRASS IN FRANCE AND SOUTHERN EUROPE

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ABSTRACT

The French and southern European turfgrass market can be classified into three main segments: ornamental, service and sports. Each area has specific disease and pest problems and these are influenced by climate, local conditions and turfgrass species used for particular purposes. The effects of these factors on the major diseases and pests and their management are discussed.

INTRODUCTION

The southern European turfgrass market can be divided into three main segments for convenience, although there is clearly overlap between them.

Ornamental turf

This may be defined as amenity grass that is moderately to intensively managed in terms of cutting, fertilising and disease and pest control. It includes public or municipal parks and gardens, urban streets, roundabouts, cemeteries etc., as well as domestic lawns. Quality, as measured by appearance, colour and texture, is of prime importance and so disease and pest control is a major consideration.

Service turf

These are more extensive, lower maintenance areas of grass and include roadside verges, airports, industrial parks etc., where the main requirements are for good coverage, slow growth and low maintenance in terms of cutting, nutrient and water requirements.

Sports turf

This is largely restricted in France and southern Europe to soccer and rugby pitches, horse race tracks and golf courses. For the actual playing areas, the most important requirements are wear tolerance and recovery after use but appearance, which can be seriously affected by pests and diseases, is also important.

PEST AND DISEASE MANAGEMENT

The development of a particular disease or pest is a function of interactions between the host species, the pathogen and the environment. Each of these can be manipulated by the amenity grass manager with the objective of reducing the disease or pest problem to where it is not of economic or cosmetic importance. Each of these components will be considered separately and then discussed in terms of integrated pest management.

Turfgrass species and cultivars

Annual seed sales for France are some 15,000 t, for Italy 7,000 t and Spain 4,000 t with the bulk of seed being imported. The principal species are listed in Table 1 in order of their importance.

TABLE 1. Turfgrass species used in southern Europe.

Perennial ryegrass	*Lolium perenne*
Smooth-stalked meadowgrass	*Poa pratensis*
Slender creeping red fescue	*Festuca rubra litoralis*
Strong creeping red fescue	*Festuca rubra rubra*
Chewings fescue	*Festuca rubra commutata*
Browntop bentgrass	*Agrostis tenuis*
Creeping bentgrass	*Agrostis stolonifera*
Velvet bentgrass	*Agrostis canina*
Tall fescue	*Festuca arundinacea* (x)
Bermuda grass	*Cynodon dactylon* (o)
Annual meadow grass	*Poa annua* (+)

(x) Mostly in the south
(o) South of France, Spain, Italy
(+) More considered as a weed.

Within each species, cultivars are available that differ in specific characteristics including disease and pest resistance. Commonly, turfgrass seed is sold as mixtures of different species and cultivars for specific purposes and their choice can influence the inherent susceptibility of the sward and the subsequent management required in terms of environmental manipulation, fertiliser and pesticide applications required to control pests and diseases.

Following choice of species and cultivar, it is important to buy seed of high quality. High germination, right timing for sowing and good soil preparation ensure good and rapid establishment. This can reduce diseases such as damping-off caused by *Fusarium* spp and *Pythium* spp. The use of chemical-treated seed with fungicides and insecticides helps the young plant to pass the dangerous period of germination and first growth. This application method has also a very favourable impact on the environment because the quantity of applied product is only a very small fraction of a normal full soil surface treatment.

Another way of establishing a sward is to use turf rolls, but it is important to buy quality-guaranteed turf that is of known species composition and is weed-free. The soil mixture should also be compatible with the soil on which the turf is to be laid especially with regard to pH. The author has observed complete destruction of laid turf by *Pythium* which could be attributed to wide pH differences. Careful consideration also has to be given to conditions of temperature, soil moisture etc. to ensure quick establishment and growth of the turf, thus reducing disease and pest attack on weak, poorly growing plants.

Major diseases and pests of turfgrasses

TABLE 2. Frequently-occurring turfgrass diseases in France and southern Europe.

Disease	Pathogen	Season (a)	Turf (b)
Major			
Snow mould	*Microdochium nivale*	10-4	Pa/A
Red thread/pink patch	*Laetisaria fusiformis*/ (*Limonomyces roseipellis*)	4-6/8-10	RG/F
Brown patch	*Rhizoctonia solani*, *R. zeae*	5-10	Pp/A
Leaf spots	*Drechslera* spp., *Bipolaris* spp.	2-6/8-10	all
Summer *Fusarium*	*Fusarium roseum*/*culmorum*, *F. tricinctum*/*poae*	6-9	A/F/Pp
Dollar spot	*Lanzia* spp., *Moellerodiscus* spp.	4-10	A/F
Take-all	*Gaeumannomyces graminis*	6-9	A
Anthracnose	*Colletotrichum graminicola*	5-9	Pa
Pythium rot/blight	*Pythium* spp.	(2-11)/6-9	A/C
Minor			
Rusts	*Puccinia* spp., *Uromyces* spp.	6-10	all
Powdery mildew	*Erysiphe graminis*	2-4/9-11	Pp
Typhula blight	*Typhula incarnata*, *T. ishikariernis*	1-3	A/RG
Stripe smut	*Ustilago striiformis*	6-9	Pp
Fairy rings	*Marasmium* spp., *Agaricus* spp.	1-12	all
Slime moulds	*Mucilago* spp., *Physarium* spp.	6-9	all

(a) most damaging periods (months)
(b) most susceptible species

A: *Agrostis*; C: *Cynodon*; F: Fescue; Pa: *Poa annua*; Ph: *Poa pratensis*; RG: Ryegrass

The most important diseases are caused by a wide range of fungi and these are listed in Table 2.

Surveys conducted in France and Spain over the last 10 years indicate that the red thread/pink patch complex is the most frequent disease on soccer fields, with snow mould, dollar spot, summer *Fusarium* and brown patch prevalent on golf courses, followed by rusts and leaf spots on ornamental turf.

In addition, take-all (*Gaeumannomyces graminis*) together with *Pythium* spp. are particularly damaging to *Agrostis* in golf greens built on pure sand.

Invertebrate pest problems (Table 3) are of secondary importance in southern Europe. The most important pest appears to be larvae of the European crane fly (*Tipula* spp.) which are active in the soil for about 5 months, feeding on the turf roots. In addition, leaf sucking insects such as aphids and leafhoppers may cause direct damage or may transmit virus diseases. In the southern part of France, Spain and Italy ants can cause an indirect problem by removing freshly sown seed to their nests.

TABLE 3. Turf insect pests in southern Europe.

Common name	Causal organism
Leatherjackets	larvae of *Tipula* spp.: daddy long legs; European crane fly
Wireworms	larvae of *Elateridae* spp.: click beetle
White grubs	larvae of *Scarabaeidae* spp: May beetle
Cut worms	larvae of *Noctuidae* spp.: night butterflies
Mole crickets	adult of *Gryllotalpa gryllotalpa*

Damage to turf can also be caused by people, dogs, rabbits, rodents and birds as well as by machinery, by oil and petrol spillages etc.

<u>Climatic and environmental conditions</u>

The climate across France, Spain and Italy is quite diverse. In the north of France the climate is cool and wet, similar to the U.K., Holland and Belgium. In S.W. France and western Spain, there is a moderating effect of the sea giving warm and humid conditions. The south of France, eastern Spain and Italy have a Mediterranean climate of mild winters and hot summers. Within this region, the mountains of the Alps and Pyrenees have long, cold winters and short, warm summers. Finally, a continental climate of cold winters and hot summers is found in central Spain and eastern France. These diverse climatic conditions determine the use of different turfgrass species such as tall fescue (*Festuca arundinacea*) and Bermuda grass (*Cynodon dactylon*) in the south and also dictate cultivation and management practices.

Within these regions, local conditions will greatly influence disease and pest epidemiology in particular amenity grass situations of parks, gardens, golf courses etc. Factors such as soil type and drainage, shading from trees, houses etc., prevailing wind and aspect of the sward will all greatly influence development of pests and diseases.

CONTROL

Cultural control

The two most critical climate factors for the growth and development of fungal pathogens are temperature and water. Although temperature cannot be controlled, attention can be paid to carrying out some management practices when conditions are optimum. For example, sowing in cold, wet soil can result in slow growth and susceptibility to damping-off fungi such as *Pythium* spp. Under warm, dry conditions, *Fusarium* may be more of a problem. High humidity and soil moisture are conducive to the development of the majority of foliar and root pathogens and this can be controlled by the turfgrass manager to a certain extent. Attention to soil drainage, timing and level of water application and removal of surface water and dew can all significantly reduce disease.

Thatch build-up is also an important factor as a number of diseases are caused by facultative parasites that survive and may increase in this organic layer.

Soil fertility is important by having a direct effect on plant health and vigour. Nitrogen level has a direct effect on speed of growth and thickness of cell walls. Potassium is implicated in resistance to drought and cold and root growth is affected by phosphorus. Other major elements are magnesium, sulphur and calcium and there are also trace element requirements, some of which, such as boron and silicon, are directly implicated in disease resistance.

It is not only the absolute level of a nutrient that is important but the balance between them and the rates at which they become available to the plant. Slow release fertilisers such as urea-formaldehyde can give a more measured release of nitrogen allowing a regulated growth of the sward.

On golf courses the area at greatest disease risk is the green constructed of pure *Agrostis* on sand. This is a highly artificial situation where there is little or no retention of water or absorption of nutrients, large temperature changes and a mono-culture of one variety of a particular host plant species. In this situation control of diseases by cultural methods is at its most difficult and least effective.

Chemical control

As in other European countries, the use of pesticides on turf in France, Spain and Italy is linked to an official registration scheme. In France, five fungicidal formulations are registered for use on turf. These are:

Rovral WP	(Iprodione WP)
Rovral Green	(Iprodione SC)
Fusatox Royal	(Amilazine + Chlorothalonil + Benomyl)
Eagle	(Cyproconazole + Chlorothalonil)
Cabestan SP	(Propiconazole + Carbendazim + Chlorothalonil)

In Italy only Tilt (propiconazole) is approved but Rovral is on its way as is Rovral Green in Portugal. In Spain, only Rovral WP is registered.

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ICIA5504: A NOVEL, BROAD-SPECTRUM, SYSTEMIC TURFGRASS FUNGICIDE

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ABSTRACT

ICIA5504, a β-methoxyacrylate fungicide, has been evaluated over the past 3 years on turfgrass diseases in the eastern USA. Efficacy data is presented on the following diseases: brown patch (*Rhizoctonia solani*), Pythium blight (*Pythium aphanidermatum*), Fusarium patch (*Microdochium nivale*), melting-out (*Drechslera poae*), grey snow mold (*Typhula incarnata*), red thread (*Laetisaria fuciformis*), necrotic ring spot (*Leptosphaeria korrae*), and anthracnose (*Colletotrichum graminicola*).

ICIA5504 provided good to excellent control for all of these diseases, in many cases outperforming the current standards. ICIA5504 is the first turf fungicide to control both Pythium blight and brown patch, two diseases which often occur simultaneously. Laboratory studies supported field results and also confirmed the systemic movement of ICIA5504 in turfgrass.

INTRODUCTION

ICIA5504 was first reported in 1992 (Godwin *et al., 1992)* as a broad-spectrum, systemic fungicide with a spectrum of activity initially tested on agricultural crops. In 1991, this fungicide was first evaluated on turf in the USA. These initial trials were conducted at The Pennsylvania State University on creeping bentgrass (*Agrostis palustris*) and tall fescue (*Festuca arudinacea*). The number of trials and locations was increased in 1992 and 1993. ICIA5504 also was evaluated extensively in growth chamber studies at the Western Research Center of Zeneca Ag Products. This paper summarizes the data from those field and laboratory studies.

MATERIALS AND METHODS

Field trials

All of the field trials were conducted in 1991-1993 by University scientists. These trials were located in Pennsylvania, New Jersey, Maryland, Georgia, Michigan, Minnesota, North Carolina, South Carolina, Indiana, and Illinois. The grass species in these trials were creeping bentgrass, Kentucky bluegrass (*Poa pratensis*), tall fescue, or perennial ryegrass (*Lolium perenne*), depending on the disease to be evaluated. All trials were conducted on small plots, ranging in size from 1-4 m^2 depending on cooperator preference. In some locations, test chemicals were applied and plots were artificially inoculated 24 h after application, whereas other locations had reliable annual epidemics and the treatments were applied at the onset of disease. Application equipment generally included backpack or other small-plot sprayers. Application volumes were 800 or 1200 l/ha.

Application schedules were varied by disease and location. Pink snow mold (*Microdochium nivale*) and grey snow mold (*Typhula incarnata*) trials received a single application in early November prior to snow cover. Fusarium patch is the disease caused by the pink snow mold pathogen (*M. nivale*) in the southeastern US during the winter months and received one or two fungicide applications, depending on the severity of the epidemic. Necrotic ring spot (*Leptosphaeria korrae*) and anthracnose (*Colletotrichum graminicola*) required 1-3 applications on a 28-day schedule, while melting-out (*Drechslera poae*) and red thread (*Laetisaria fuciformis*) trials had 1-3 applications on a 14-21 day schedule. Dollar spot (*Sclerotinia homoeocarpa*), brown patch (*Rhizoctonia solani*) and Pythium blight (*Pythium aphanidermatum*) trials received multiple applications on a 14-, 21-, or 28-day schedule, depending on the standard fungicide used for comparisons. In this paper, data from the 14-day schedules are used for comparisons of these latter three diseases. Disease assessments are reported as % disease severity. With multiple application trials, the assessments following the final fungicide application are reported. Tables generally include the average severity values for each treatment across all trials conducted over the 3-year period (1991-1993).

Growth chamber studies

For brown patch tests, perennial ryegrass was grown for 12-14 days in the glasshouse in 10.2 cm pots filled with coarse sand. The grass was trimmed 8 and 11 days after planting. After the 12-14 day growth period, fungicide applications were made with a track sprayer in a water volume of 1200 l/ha. The pots were then placed in a growth chamber (28°C). After 24 h, each pot was inoculated by placing 4 rye berries, infested with *R. solani*, in the center of each pot on the sand surface. The pots were transferred to a dew chamber at 28°C and 80% relative humidity. The pots were returned to the growth chamber 24 h before each of two assessments. The disease evaluation was recorded as the % disease severity. There were five replicate pots per treatment per trial.

A study to investigate the distribution of ICIA5504 in turf grass utilized perennial ryegrass in sand pots as described above. An application of 1 kg ai/ha was applied to a series of pots and at 2 h after treatment, 5 pots were destructively sampled and separated into grass cuttings, roots and sand. This procedure was repeated at 3, 7, 10, 14, 17, and 21 days after treatment. ICIA5504 was extracted from the samples into acetone either by desorption or by maceration with liquid nitrogen and analyzed by HPLC. Results presented are the means of the 5 replicate pots.

RESULTS

Brown patch

In growth chamber studies, ICIA5504 provided excellent brown patch control at extremely low rates in contrast to the standards (Table 1). If the study was continued for more than 8 days after treatment, all commercial standards reached 100% severity. In contrast, ICIA5504 rarely exceeded 30% severity after 14 days.

Table 1. Comparison of ICIA5504 and four standards at low rates for efficacy against brown patch in a growth chamber study, 1993.

Treatment	Rate (kg ai/ha)	% Disease severity	
		5 DAT[1]	8 DAT
ICIA5504	0.10	5	11
ICIA5504	0.05	7	11
ICIA5504	0.01	8	20
Propiconazole	0.10	5	95
Triadimefon	0.10	44	100
Iprodione	0.10	58	100
Chlorothalonil	0.10	92	100

[1]DAT = Days after fungicide treatment

ICIA5504 provided superior brown patch control compared to the standards in all field trials over the three year period (Table 2). Control persisted for a minimum of four weeks at the 0.50 kg ai/ha rate. *Pythium* blight developed in one of the trials in 1993 and ICIA5504 was the only test compound to provide control of both *Pythium* blight and brown patch.

Table 2. Mean efficacy for ICIA5504 on turfgrass diseases *Pythium* blight and brown patch, 1991-1993.

Treatment	Rate (kg ai/ha)	% Disease severity	
		Pythium blight	Brown patch
Untreated		44.3	30.8
ICIA5504	0.25	4.8	3.7
ICIA5504	0.50	2.3	1.7
ICIA5504	0.75	3.6	1.2
ICIA5504	1.00		1.3
Chlorothalonil	10.00		13.5
Iprodione	3.00		10.9
Propiconazole	0.80		18.3
Fosetyl-Al	9.00	9.5	
Metalaxyl	1.50	8.6	

Results reported from applications made on a 14-day schedule

Pythium blight

ICIA5504 provided consistent control of *Pythium* blight over the three years of trials. The mean disease severity in the ICIA5504 treated plots was lower than in plots treated with either metalaxyl or fosetyl-Al (Table 2). As an overall observation, under natural disease pressure, ICIA5504 was comparable to these two standards, but under heavy disease pressure or in inoculated trials, ICIA5504 provided superior disease control.

Melting-out

In all three years of trials, ICIA5504 provided excellent control of melting-out on Kentucky bluegrass. The mean disease severity was comparable to that for iprodione, the best standard for this disease (Table 3).

Red thread

None of the standards evaluated provided complete control of red thread during 1991-1993. Iprodione was consistently the best standard in these trials and ICIA5504 provided comparable control , regardless of application rate (Table 3).

Table 3. Mean efficacy for ICIA5504 on turfgrass diseases melting-out and red thread, 1991-1993.

		% Disease severity	
Treatment	Rate (kg ai/ha)	Melting-out	Red thread
Untreated		49.1	40.4
ICIA5504	0.25	7.5	15.4
ICIA5504	0.50	2.8	12.8
ICIA5504	0.75		13.7
ICIA5504	1.00	1.6	
Chlorothalonil	10.00	10.1	22.8
Iprodione	3.00	1.0	16.2
Propiconazole	0.80	31.7	29.6

Results reported from applications made on a 21-day schedule

Anthracnose

These data were generated from a single trial in 1993. From this preliminary investigation ICIA5504 appears to have activity comparable to iprodione against anthracnose and greater activity than the other two standards (Table 4).

Snow molds

A mixture of pink and grey snow mold generally was present in the trials and evaluators estimated the ratio between the two pathogens based on visual symptoms. Because a compilation of all snow mold data would be difficult with mixed pathogen populations and individual trial data would have to be reported, an overall summary follows. Under low disease pressure (untreated 15-40% disease severity), ICIA5504 at rates of 0.5 kg ai/ha or 1.0 kg ai/ha provided significant control of both pink and grey snow mold comparable to any of the standards evaluated except the products containing mercury. Under heavy disease pressure (untreated > 60% infected), all non-mercury fungicides provided sub-optimal disease control. However, ICIA5504 provided good disease control when tank-mixed with chlorothalonil or iprodione. Many of the non-mercury standards are 2-and 3-fungicide mixtures.

Fusarium patch

ICIA5504 provided excellent control of *Fusarium* patch (Table 4). Although disease pressure was low in both 1992 and 1993, the efficacy of ICIA5504 was superior to iprodione, the standard in these trials, even at the 0.25kg ai/ha rate.

Necrotic ring spot

The weather in 1992 and 1993 contributed to lower than average disease severity in this non-inoculated trial site and to significant variability. However, ICIA5504 treated plots had lower disease severities than either of the two standards (Table 4).

Table 4. Mean efficacy for ICIA5504 on turfgrass diseases *Fusarium* patch, necrotic ring spot and anthracnose, 1991-1993.

		% Disease severity		
Treatment	Rate (kg ai/ha)	*Fusarium* patch	Necrotic ring spot	Anthracnose
Untreated		10.1	36.5	42
ICIA5504	0.25	2.7		15
ICIA5504	0.50	1.8	11.0	11
ICIA5504	0.75	0.4	14.0	22
ICIA5504	1.00	0.0	8.0	
Chlorothalonil	10.00			39
Iprodione	6.00	4.4		14
Propiconazole	0.80			41
Triadimefon	1.40		29.5	

Results reported from applications made on a 28-day schedule

Dollar spot

Under average to severe disease pressure, ICIA5504 did not provide acceptable control of dollar spot. In all three years the standards provided excellent control of this disease. However, in two 1993 trials, brown patch developed in the same plots being evaluated for dollar spot and ICIA5504 provided complete control of the brown patch.

ICIA5504 uptake and distribution

At 3 days after fungicide treatment there were 226 μg of ICIA5504 in the leaf blades. The amount of ICIA5504 dropped to 25 μg after 7 days and to a low of 4 μg after 14 days. However, at 17 days the concentration was 11 μg and at 21 days it was 16μg. These numbers demonstrate a rapid initial decrease followed by a stabilization, indicating that ICIA5504 is either being absorbed from the sand or translocated into the leaves from the roots. At 21 days the concentrations of ICIA5504 in the roots and sand were 160 and 106 μg, respectively.

CONCLUSIONS

The term broad-spectrum systemic fungicide is a fitting description for the activity of ICIA5504 on turfgrass diseases. Applied against a wide range of important turf diseases, it has demonstrated levels of control equivalent to or greater than current commercial standards. Most importantly, ICIA5504 is unique in providing excellent control of both brown patch and *Pythium* blight. These diseases often occur simultaneously in southern USA and require mixtures of different products to achieve acceptable control.

ICIA5504 can be applied at spray intervals consistent with its properties of systemic and residual activity. ICIA5504 also represents an important new area of fungicide chemistry, providing the turfgrass manager with a chemical with a novel and highly effective mode of action for use in fungicide resistance management strategies.

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REFERENCES

Godwin, J. R.; Anthony, V. M.; Clough, J. M.; Godfrey, C. R. (1992) ICIA5504: A novel, broad-spectrum, systemic β-methoxyacrylate fungicide. *Proceedings 1992 Brighton Crop Protection Conference - Pests and Diseases*, 1, 435-442.

REDUCED-RATE, THREE-COMPONENT FUNGICIDE MIXTURES FOR CONTROL OF *SCLEROTINIA* DOLLAR SPOT ON *AGROSTIS PALUSTRIS* TURF

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ABSTRACT

The objectives of a four-year field study have been the identification and testing of balanced, reduced-rate, three-component fungicide mixtures to provide acceptable suppression of dollar spot (*Sclerotinia homoeocarpa*) on *Agrostis palustris* turf and to reduce fungicide resistance risk in populations of the pathogen. During the 1991 growing season, individual mixture partners were tested alone at various reduced rates to select rates that would be likely to provide balanced dollar spot suppression in three-component mixtures. Reduced-rate mixtures and individual components were tested over the ensuing three growing seasons for balance of components and efficacy of dollar spot control. A reduced-rate benzimidazole-dicarboximide-chlorothalonil mixture has been found to be as effective as standard single fungicides in dollar spot suppression. Three-component mixtures incorporating DMI fungicides with benzimidazoles, dicarboximides, or chlorothalonil have been equally efficacious.

INTRODUCTION

Dollar spot (*Sclerotinia homoeocarpa*) may be found throughout the United States, except in the arid regions of the West. The pathogen attacks most turfgrass species and is active at temperatures of 15-32 C. The disease is most damaging, however, on closely-mown *Agrostis palustris* golf greens, where it produces killed, sunken areas that average 2-4 cm in diameter, destroying the putting quality of greens surfaces (Vargas, 1994).

Disease management on turfgrasses represents the largest single-crop market for fungicides in the USA, and golf greens are the areas of most intense fungicide application in US agriculture. The control of *Sclerotinia* dollar spot accounts for a major portion of the fungicide applied to *Agrostis palustris* greens turf in the USA (Vargas, 1994). The high fungicide input to these areas has been related to early development of field resistance to the benzimidazoles (Detweiller, *et al*., 1983; Warren, *et al*., 1974), the dicarboximides (Detweiler & Vargas, 1982; Detweiler, *et al*., 1983), and, more recently, the DMI fungicides (Vargas, *et al*., 1992).

Reduced-rate, three-component fungicide mixtures have been found to be effective for control of *Pythium* blight (*Pythium aphanidermatum*) on turfgrasses and for stabilization of resistance levels in populations of the pathogen (Sanders, *et al.*, 1985). The objectives of the present four-year field study have been the identification and testing of balanced, reduced-rate, three-component fungicide mixtures to provide acceptable suppression of *Sclerotinia* dollar spot and to reduce the risk of fungicide resistance in *S. homoeocarpa* populations.

MATERIALS AND METHODS

Tests of individual mixture partners

During the summer of 1991, individual mixture partners were tested alone at various rates to select those rates that would be likely to provide balanced dollar spot suppression in three-component mixtures. Benomyl, chlorothalonil, fenarimol, iprodione, propiconazole, and triadimefon were applied to mature, field-grown *Agrostis palustris* turf at a range of rates (0.11, 0.22, 0.33, and 0.50 of label rate). Individual treatment plots, 0.9 x 4.6 m, were arranged in a randomized block design with three replications. Fungicides were applied at 28-day intervals with a CO_2-powered boom sprayer, using 8004 nozzles, at a spray pressure of 241318 pascals, in water equivalent to 8 l per 93 m^2. Two days after the first fungicide application, the experimental site was inoculated by hand-scattering *S. homoeocarpa*-infested rye grain over the entire test area at a density of 20-30 grains per 0.093 m^2. Dollar spot was evaluated visually 28 days after each fungicide application by determining the number of infection centers per 0.093 m^2 of individual plot area. Data obtained were subjected to analysis of variance and Duncan's Multiple Range test. Rates that provided approximately equal suppression of dollar spot were selected for inclusion in reduced-rate, three-component mixtures to be evaluated during the 1992 growing season.

Tests of reduced-rate, three-component mixtures

During the summer of 1992, evaluations of individual mixture components and three-component mixtures were conducted using the previously-described methodology. Based on interpretation of 1991 test data, the following individual component rates were chosen for evaluation alone and in three-component mixtures in the 1992 test:

chlorothalonil @ 0.33 label rate
benomyl @ 0.33 label rate
iprodione @ 0.33 label rate
fenarimol @ 0.33 label rate
propiconazole @ 0.11 label rate
triadimefon @ 0.11 label rate

Mixture rates of some of the individual components were adjusted slightly in succeeding seasons in an attempt to improve the balance of the test mixtures. In the 1993 test, and based on 1992 results (Figure 1), the mixture rate of chlorothalonil was increased from 0.33 to 0.4 of label, and the mixture rate of iprodione was increased from 0.33 to 0.5 of label. Additionally, in the 1993 test, commercial thiophanate formulations from two different manufacturers were tested as potential substitutes for benomyl in the test mixtures, because of the decreasing availability of benomyl in the US turf market. The two thiophanate formulations were tested in 1993 at 0.5 of label rates, and the mixture rate of benomyl was reduced from 0.33 to 0.25 of label.

In the 1994 test, and based on results from previous seasons, the following individual rates were evaluated alone and in three-component mixtures:

chlorothalonil @ 0.5 label rate
iprodione @ 0.5 label rate
fenarimol @ 0.33 label rate
thiophanate @ 0.25 label rate
propiconazole @ 0.11 label rate
triadimefon @ 0.11 label rate

RESULTS

Tests of individual mixture partners

Results of the 1991 test of individual mixture partners indicated that benomyl, chlorothalonil, fenarimol, and iprodione at 0.33 of label rates, and propiconazole and triadimefon at 0.11 of label rates provided approximately 33% suppression of dollar spot at 28 days after fungicide treatment.

Tests of reduced-rate, three-component mixtures

The results of the 1992 test of individual mixture components and nine reduced-rate, three-component mixtures are presented in Figure 1. Presented data represent means of statistically analyzed data from three disease ratings (LSD = 6.3, 2.7, 5.3) taken during the 1992 season at 28 days after successive fungicide applications. Eight of nine of the test mixtures provided season-long dollar spot control that was not statistically different from standard single fungicides. The chlorothalonil+iprodione+fenarimol mixture was statistically less efficacious than the other test mixtures, indicating that the mixture rates of some of the components of this mixture should be increased.

Dollar spot suppression values for individual mixture components in 1992 revealed that the mixture rates of chlorothalonil and iprodione should be increased for 1993 testing, and the mixture rate of benomyl should be decreased.

Figure 1. 1992 - Suppression of dollar spot by reduced-rate three-component fungicide mixtures

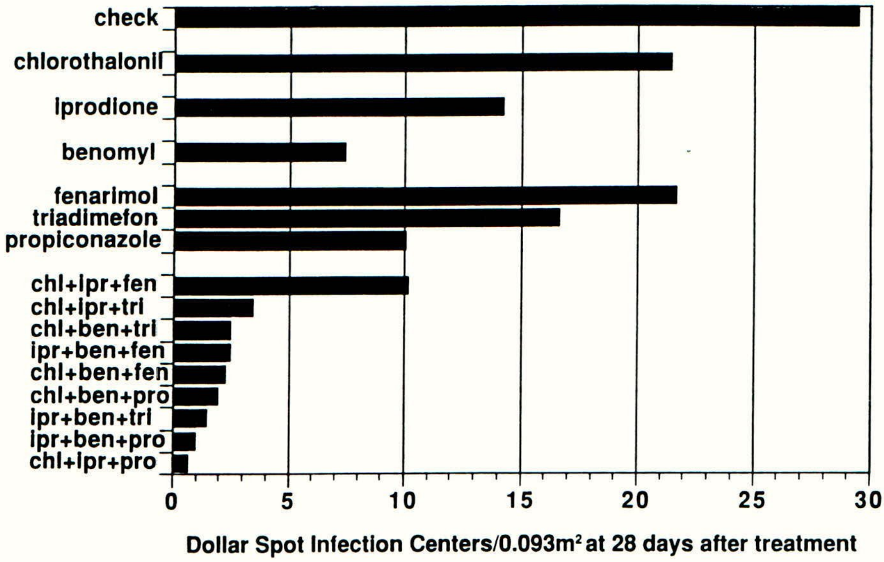
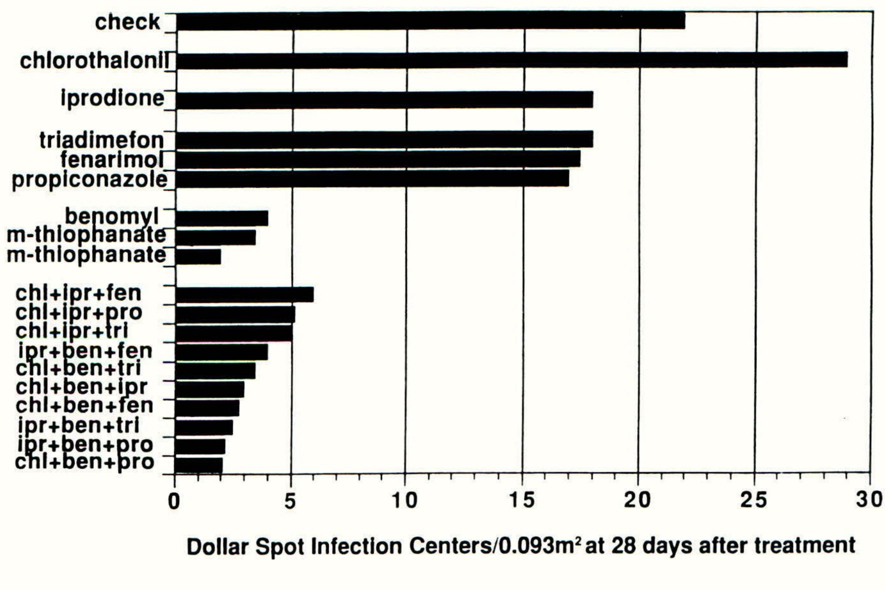


Figure 2. 1993 - Suppression of dollar spot by reduced-rate, three-component fungicide mixtures



The results indicated that the mixture rates of fenarimol also should be increased, however, this change was not made. Because of the large inputs of DMI fungicides commonly used for control of other diseases on greens turf, it was considered undesirable to increase the DMI component in the test mixtures.

Results of the 1993 test of individual mixture components and ten reduced-rate, three-component mixtures are presented in Figure 2. As previously described, the presented data represent means of statistically analyzed data from three successive disease ratings (LSD = 5.9, 4.3, 5.2) taken at 28-day intervals in 1993. All ten of the test mixtures provided season-long dollar spot suppression that was not statistically different from standard single fungicides. Based on interpretation of 1993 test results, the individual mixture rate of chlorothalonil was increased to 0.5 of label rate for 1994 testing. Mixture rate of the individual thiophanate component was decreased to 0.25 of label rate.

In 1993, an outbreak of Rhizoctonia brown patch (*Rhizoctonia solani*) on the experimental area allowed the evaluation of the test mixtures for suppression of this disease. The following reduced-rate mixtures provided good suppression of brown patch:

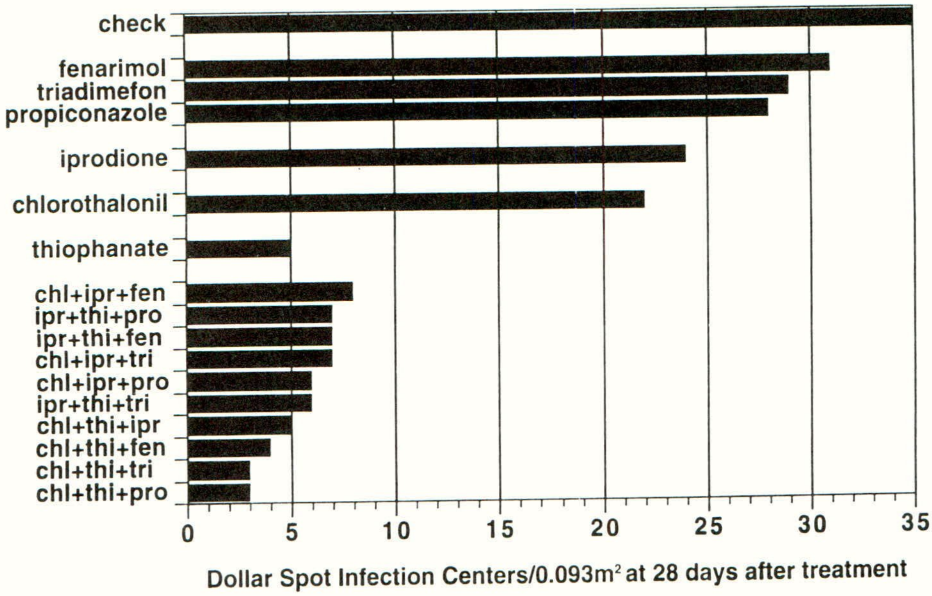
chlorothalonil+iprodione+fenarimol
chlorothalonil+iprodione+propiconazole
chlorothalonil+benomyl+fenarimol
chlorothalonil+benomyl+propiconazol

Results of the 1994 test are presented in Figure 3, and are, as previously indicated, means of three successive disease ratings (LSD = 3.4, 3.4, 6.5) taken at 28-day intervals throughout the growing season. All ten test mixtures again provided season-long efficacy equal to that of standard single fungicides.

The findings of the present study establish that reduced-rate, three-component fungicide mixtures are as effective as standard single fungicides in suppression of *Sclerotinia* dollar spot on *Agrostis palustris* turf. These balanced, multi-component mixtures should be useful in reducing fungicide selection pressure on *S. homoeocarpa* populations, and should, thereby, effectively reduce the risk of fungicide resistance in field populations of this pathogen.

Houston B. Couch, turfgrass pathologist at Virginia Polytechnical Institute and State University (Blacksburg, VA), has reported synergistic interactions between propiconazole and several other fungicides (Anonymous, 1992). At no time during this study was synergism noted among any of the fungicides in the mixtures under test.

Figure 3. 1994 - Suppression of dollar spot by reduced-rate, three-component fungicide mixtures



REFERENCES

Anonymous. (1992) DMI fungicides: the discussion continues. *Golf Course Management* **60** (7), 100-104.

Detweiler, A. R.; and Vargas, J. M., Jr. (1982) Resistance of *Sclerotinia homoeocarpa* to iprodione. *Phytopathology* **72**, 976.

Detweiler, A. R.; Vargas, J. M., Jr.; and Danneberger, T. K. (1983) Resistance of *Sclerotinia homoeocarpa* to iprodione and benomyl. *Plant Disease* **67**, 627-630.

Sanders, P. L.; Houser, W. J.; Parish, P. J.; and Cole, H. (1985) Reduced-rate fungicide mixtures to delay fungicide resistance and to control selected turfgrass diseases. *Plant Disease* **69**, 939-943.

Vargas, J. M. (1994) Management of Turfgrass Diseases, 2nd Edition, Lewis Publishers, Ann Arbor, MI, USA, 23-27.

Vargas, J. M., Jr; Golembiewski, R.; and Detweiler, A. R. (1992) Dollar spot resistance to the DMI fungicides. *Golf Course Management*, **60** (3), 56-60.

Warren, C. G.; Sanders, P. L.; and Cole, H. (1974) *Sclerotinia homoeocarpa* tolerance to benzimidazole-configuration fungicides. *Phytopathology* **64**, 1139-1142.

example, compaction and poor drainage, leading to an increased risk of disease incidence and severity. The presence of annual meadow-grass *(Poa annua)* in fine turf swards may also lead to an increase risk of damage from disease. This colonising grass species is highly susceptible to *Microdochium nivale* the causal fungus of fusarium patch disease, which is the most damaging and disfiguring disease of fine turf during the winter months in most Western European countries (Baldwin, 1990).

The common practices in intensively managed amenity turfgrass areas adopted to enhance both visual and playing qualities of the sward are not always in harmony with effective pest and disease control. Although integrated programmes using complementary cultural, chemical and biological methods are used in agricultural production (Parry, 1990), little is known about their potential use in the establishment and maintenance of turfgrass in the UK. This paper briefly describes the principle pests and diseases of intensively managed turfgrass, together with current practices for their control. It outlines potential future trends and opportunities to enhance effectiveness of pest and disease management, whilst minimising risks to turfgrass management personnel, the public and the environment.

USES, AREAS AND GRASS SPECIES OF INTENSIVELY MANAGED TURFGRASS

The total area of intensively managed sports turf in the UK has been estimated at *c.* 185,500 ha. Of this total, urban parks, school playing fields and golf fairways represent the largest areas of 62,564, 45,500 and 32,602 ha respectively (Symes, 1987) (Table 1).

TABLE 1. Type, number and area of intensively managed amenity turfgrass in UK

Type	Number	Hectares
Bowling greens	9,650	1,423
Cricket	12,300 (pitches)	686 (squares)
Soccer pitches	35,000	15,050
Golf	3,212 (courses[1])	1,561 (greens)
		838 (tees)
		32,602 (fairways)
Hockey pitches	7,220	2,108
Horse race tracks	60	486
Putting greens[2]	1,321	321
Rugby pitches	5,316	3,579
Tennis courts	10,156	218
School playing fields	26,000	45,500
Other pitches or tracks	4,500	5,900
Urban parks - Royal	9	1,500
- Other	9,830	62,564
Armed service grounds and ornamental lawns	N/A[3]	7,000
Turf farms	N/A	3,344

[1]Equivalent 9-hole units. [2]Municipal greens. [3]Not available. Source: Symes (1987).

This data, however, can be misleading as the intensity of management, and the level of inputs will be significantly greater for areas such as golf and bowling greens, which represent much smaller areas. In Great Britain, Symes also estimated the number of domestic lawns as 15.2 million, representing an area of 152,639 ha. However, the area of intensively managed high quality ornamental lawns is much lower and has been given as 6000 ha (Shildrick, 1990).

Uniformity of the grass sward is important for sports turf and ornamental lawns. This is needed to ensure that the required appearance and consistency of the sward is achieved (Shildrick, 1990). Ideally, to achieve the desired uniformity, the sward should consist of one or two grass species. The principle UK turfgrass species are listed in Table 2.

TABLE 2. Principle UK turfgrass species

Common Name	Scientific Name
Perennial ryegrass	*Lolium perenne*
Slender creeping red fescue	*Festuca rubra ssp. litoralis*
Strong creeping red fescue	*Festuca rubra ssp. rubra*
Chewings fescue	*Festuca rubra ssp. commutata*
Smooth-stalked meadow-grass	*Poa pratensis*
Rough-stalked meadow-grass	*Poa trivialis*
[1]Annual meadow grass	*Poa annua*
Browntop bent	*Agrostis tenuis*
Creeping bent	*Agrostis stolonifera*
Velvet bent	*Agrostis canina*

[1]Widely distributed invasive species, often regarded as a weed grass.

UK PESTS AND DISEASES

Pests

A diversity of fauna may cause occasional damage to turf, however, damage is most often caused by the activity of insects. It is the larvae feeding below the soil surface, severing grass roots and stem bases with their biting mouthparts that can cause the most serious damage. The activity of birds feeding on larvae may also cause secondary damage. Leatherjackets *(Tipula paludosa)* larvae are found throughout the UK and represent the most serious pest of turfgrass. In severe attacks over 1,000 larvae per m^2 may be found. The feeding activity leads to areas of turf discolouration and bare patches which are subsequently invaded by weed species.

The feverfly *(Dilophus febritis)* and St. Marks fly *(Bibio marci)* larvae, although less common than *T. paludosa*, also may damage turf. Frit fly *(Oscinella frit)* larvae may damage newly sown areas. There are five species of chafer beetles that damage turfgrass. These are the May bug *(Melolontha melolontha)*, garden chafer *(Phyllopertha horticola)*, summer chafer *(Amphimallon solstitialis)*, Welsh chafer *(Hoplia philanthus)*, and the brown chafer *(Serica* *brunnea)*. Occasionally, damage may be so severe from the activity of these pests, the turf may be rolled up like a carpet.

Casting earthworms *(Lumbricus terrestris, Allotobophora longa, A. nocturna)* can cause a problem, not from direct damage, but through leaving casts on the turfgrass surface. These may be smeared, creating an uneven surface, especially on golf greens. The casting may also adversely affect surface drainage and provide a seedbed for weeds. Detailed information on turfgrass pests is given by Shurtleff *et al* (1987).

Diseases

In the UK seedling, young and established turf may be attacked by fungal pathogens. Bacteria and viruses have not yet been recognised as being significant pathogenic organisms of turfgrass. A number of diseases and their causal agents have been recognised (Table 3) and of these, fusarium patch caused by *M. nivale* is probably the most damaging.

TABLE 3. Diseases of turfgrass found in the UK

Common Name	Causal Organism(s)	
Seedling diseases		
Seed rot	Caused by number of fungi including *Microdochium nivale, Fusarium culmorum, Phythium spp., Rhizoctonia spp., Cladochytrium spp., Drechslera spp.*	
Pre-emergence damping off		
Post-emergence damping off		
Young and established turf		
Anthracnose (basal rot)	*Colletotrichum graminicola*	
Fusarium Patch (pink snow mould)	*Micodochium nivale*	
Grey snow mould	*Typhula incarnata*	
Red Thread (corticium disease)	*Laetisaria fuciformis*	
Take-All Patch (Ophibolus patch)	*Gaeumannomyces graminis*	
Dollar Spot	*Sclerotinia homoeocarpa*	
Leafspot (melting out)	*Drechslera spp., Cladosporium spp.*	
Powdery mildew	*Erysiphe graminis*	
Fairy rings	Type 1	*Marasmius oreades*
	Type 2	*Agaricus campestris*
	Type 3	*Hygrophorus spp.*
Superficial fairy rings (thatch fungi)	*Trechispora alnicola, Coprinus spp.*	

Fusarium patch can be particularly severe on golf and bowling greens and ornamental lawns. Disease development is encouraged by moist turf surface, excessive nitrogen and alkaline conditions. The ubiquitous *P. annua* is very susceptible to attack. Baldwin (1990) described the first symptoms of the disease as the appearance of small (up to 50 mm diameter) orange/brown circular spots. Under favourable conditions these areas develop and coalesce into large, irregular scars which are subsequently invaded by weeds and moss.

Take-all patch or Ophiololus patch (causal agent: *Gaeumannomyces graminis*) may also cause severe damage on sand-constructed golf greens supporting a monoculture of bentgrass, which is particularly prone to attack. Early symptoms of this damaging and disfiguring disease are small patches, often of dying bentgrass which rapidly develop and coalesce to form large patches. A full account or turfgrass diseases are given by Smiley (1983) and Smith *et al* (1989).

PEST AND DISEASE MANAGEMENT

Cultural operations which promote vigour and create a healthy competitive plant increase the tolerance of the turfgrass to pest and disease attack. However, many current practices undertaken to establish and maintain high quality turf, e.g. close mowing, heavy fertilisation and intensive irrigation, weaken the turf and create conditions that favour invasion by pathogenic fungi. The use of disease resistant grass species and cultivars can be highly effective in managing the incidence and severity of turf grass diseases. However, often grass species highly susceptible to damaging diseases predominate in the sward, either by design, e.g. bentgrass golf green (highly susceptible to *G. graminis)* or as a result of the colonisation of *P. annua* (highly susceptible to *M. nivale)*. There is a range of pesticides approved for use on amenity turfgrasses to control pests and fungal pathogens (Table 4) which have a significant role in pest and disease management practices

TABLE 4. Approved* UK turfgrass pesticides

Active Ingredient	Pest/Disease										
	1	2	3	4	5	6	7	8	9	10	11
carbaryl						*					
carbendazim						*	*	*	*		
chlorothalonil							*	*	*		
chlorpyrifos	*	*									
fenarimol							*	*	*		
gamma HCH	*	*	*	*	*						
iprodione							*	*	*		*
oxycarboxin										*	
quintozene							*	*	*		
thiabendazole							*	*	*		
thiophanate-methyl							*	*	*		
triforine										*	
vinclozolin							*	*	*		*

*Ivens (1994)

Key
1. Leatherjackets
2. Frit Fly
3. Millipedes
4. Wireworms
5. Chafers
6. Casting Earthworms
7. Fusarium Patch
8. Red Thread
9. Dollar Spot
10. Fairy Rings
11. Leaf Spot

It is considered that pesticides need to be used together with cultural and biological methods, although this approach is not widely practised in the UK. From a series of interviews with Local Authorities, information on the cost and benefit of using pesticides was audited by the Institute of Public Finance (Anonymous, 1994). This showed that the average cost of maintaining a golf green was £25. The cost of returfing a green, which may become necessary as a result of a severe attack by pests of diseases, was given as £7,000 - £8,000. If closure of the course is needed to repair damage caused by insect and disease, the lost revenue from green fees could be between £4,000 - £10,500 per week.

FUTURE TRENDS

Pesticide Development

Operator and Public Safety

Recent legislation requires a pesticide safety evaluation for operators, bystanders and the environment through a series of EC directives. Operator exposure has been significantly reduced by improvements in formulation technology, container design and methods of application, and this is expected to continue in addition to active ingredients and analogues being selected at the predevelopment stage for improved safety characteristics. This increased safety for the operator is reflected in increased safety for the bystander. If exposed, the bystander would come into contact with diluted spray, which in turn can be assessed and monitored using the same procedures for operators, combined with models for spray drift and exposure to dislodgeable residues from plant surfaces.

Environmental Safety

Environmental safety in terms of protecting non-target fauna and flora, is determined by toxicity/exposure ratios (TERs) which are generated from the experimentally derived values for non-target organisms and the predicted environmental concentrations (PECs) of the compound in relevant compartments of the ecosphere. The use of models for the transport of compounds between various compartments is gaining in importance, in particular, models dealing with the aqueous environment have been subjected to extensive study. A range of models is available covering leaching to ground water and transfer by run-off to surface waters.

Any undesirable effect of established compounds can be addressed with varying degrees of success by formulation changes. However, in the selection of new candidate compounds for turfgrass opportunities exist to design compounds that have good environmental safety profiles. In order to achieve this aim, it is essential to understand the factors that control the environmental fate of these compounds in the turfgrass context when the use pattern differs from conventional agricultural practice. For example, in turfgrass, the amount of thatch above the rooting media is important in the retention and degradation of most pesticides (Smith and Tillotson, 1992).

Efficacy

Together with advances in operator, public and environmental safety, with the introduction of new active ingredients for use on turfgrass, significant improvements in efficacy would be expected. For example, the introduction in 1993 of fenarimol to control turf diseases in the UK gave a compound that was more effective at lower dose rates, than with existing products. Good selectivity is also particularly important on desirable turfgrass species to avoid any adverse effects on the visual appearance of the sward.

Pesticide Usage

Advances in operator training in the use of pesticides have been made and a specific code of practice has been published for amenity and industrial areas (Anonymous, 1991). Maintaining and improving standards is, however, a continuous process. Turf managers need to ensure that the disease or pest problem is identified early and accurately and if a pesticide is selected for use, it is applied accurately at the optimum time. Although no resistance to a turfgrass pesticide has been reported to date in the UK, it would appear prudent to avoid intensive and extensive use to delay or prevent its occurrence.

Integrated Pest and Disease Management

Pesticides have an important role to play in the effective management of turfgrass pests and diseases, together with cultural practices and biological methods. The use of integrated systems needs to be more widely adopted in the UK. Organisations such as the Sports Turf Research Institute and the British and International Golf Greenkeepers Association, together with education establishments and industry can do much to promote the concept and practical adoption of the approach. The type of programme adopted may differ according to the situation and knowledge of the biology and ecology of the pest and disease causing organism needs to be fully understood before implementation.

Desirable grass species need to be encouraged to promote strong, healthy, competitive swards. Adopting management practices that do not favour the pest or disease causing agents, or a highly susceptible host, can do much to prevent the incidence and severity of the pest or disease. Continual improvements in pesticide technology and the introduction of new resistant turfgrass cultivars could also form an important part of future integrated systems.

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REFERENCES

Anonymous (1977) Amenity grasslands - the needs for research. *Natural Environment Research Council Publication Series* C, No. 19.

Anonymous (1991) *Code of Practice for the Use of Approved Pesticides in Amenity and Industrial Areas.* National Association of Agricultural Contractors and National Turfgrass Council, 72 pp.

Anonymous (1994) *The Cost Benefits of Pesticide Use in the Community.* British Agrochemicals Association, 12 pp.

Baldwin, N.A. (1990) *Turfgrass Pests and Diseases.* Sports Turf Research Institute, Bingley, P.17.

Baldwin, N.A. and Drinkall, M.J. (1992) Integrated pest and disease management for amenity turfgrass. *Aspects of Applied Biology*, **29,** Vegetation management in forestry, amenity and conservation areas, p265 - 272.

Parry, D (1990) *Plant Pathology in Agriculture.* Cambridge University Press, Cambridge, 385 pp.

Shildrick, J.P. (1990) Weed control in sports turf and intensively managed amenity grassland. *In: Weed Control Handbook: Principles* p. 407 - 430 Eds. R.J. Hance and K. Holley, Blackwell Scientific Publications, Oxford.

Shurtleff, M.C., Fermanian, T.W. and Randell R. (1987) *Controlling Turfgrass Pests*, Prentice-Hall Inc., Englewood Cliff, 449 pp.

Smiley, R.W. (1983) *Compendium of Turfgrass Diseases.* American Phytopathological Society, St. Paul, 102 pp.

Smith, J.D., Jackson, N. and Woolhouse, A.R. (1989) *Fungal Diseases of Amenity Turfgrasses.* E. and F.N. Spon, London. 401 pp.

Smith, A.E. and Tillotson, W.R. (1992). Potential leaching of herbicides applied to golf greens. *In: Pesticides in Urban Environments*, K.D. Racke and A.R. Leslie (Eds), Washington, D.C., p.168 - 181.

Symes, B. (1987) *A Research Study and Review of Intensively Managed Amenity Turfgrass in the U.K.* National Turfgrass Council, Bingley, 40 pp.

The UK Pesticide Guide. 1994 Ed. G.W. Ivens, C.A.B. International and British Crop Protection Council, 561 pp.