INTEGRATED WEED MANAGEMENT IN GOLF COURSES AND RECREATIONAL AREAS

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ABSTRACT
This paper provides an updated list of major weeds in some golf courses, recreation gardens, parks and football fields in Kuala Lumpur, Petaling Jaya, Shah Alam and Kampung Kuantan, Selangor from 1994 to 2004. Many broadleaf weeds, grasses and sedges are recorded, particularly in the roughs, collars and fairways of golf courses. In general, more weeds were observed on golf courses planted with Bermuda grass/Serangoon grass than carpet grass (*Axonopus compressus*).

In golf courses, some of the major weeds of fairways are *Borreria latifolia, Lindernia* spp., *Desmodium sp., Axonopus compressus* (a weed on fairways and aprons which have Serangoon grass or Bermuda grass), *Chrysopogon aciculatus, Digitaria fuscescens, Eleusine indica, Paspalum conjugatum, Paspalum vaginatum, Cyperus brevifolius, Cyperus rotundus* and *Fimbristylis miliacea.*

In recreation parks and football fields where carpet grass *(Axonopus compressus)* is the major turf species cultivated, the major weeds include *Asystasia gangetica, Borreria* spp., *Desmodium* sp., *Cleome spp., Euphorbia hirta, Mimosa pudica, Eleusine indica, Imperata cylindrica, Cyperus* spp., and *Fimbristylis miliacea.* In waterlogged areas, *Panicum repens, Cyperus aromaticus, Cyperus brevifolius and Fimbristylis miliacea tend to dominate.*

Integrated weed management (IWM) must start at the pre-planting stage and there should be a long-term action plan to manage the weeds in the turf itself and in its vicinity since weeds spread from their seeds, tubers, rhizomes and fragments. IWM includes preventive, cultural and mechanical approaches. Frequent mowing is the most popular method used in golf courses and sports fields, and it is in line with holistic management of turfgrasses today. Chemical control and biological approaches are also discussed. A list of 26 foreign weeds to watch is included as some of them may be capable of establishing a foothold in turfgrasses in Malaysia.

INTRODUCTION

Turf is defined as a covering of beneficial vegetation plus the matted upper stratum of earth filled with roots, rhizomes and stolons. Turfs are usually low growing perennial vegetation which are uniform in growth.

Turf grasses in Malaysia include Serangoon grass or Australian blue couch *(Digitaria didactyla),* Tifdwarf and Tifgreen (both hybrid Bermuda grass - *Cynodon dactylon x C. transvaalensis),* Creeping bent grass *(Agrotis stolonifera* sub sp. stolonifera) , carpet grass *(Axonopus compressus),* common carpet grass *(Axonopus affinis),* Manila grass *(Zoysia matrella),* Japanese lawn grass *(Zoysia japonica)* and Korean velvet grass *(Zoysia tenuifolia)* (Beard, 1973; Vengris and Torello, 1982; Lam, 1992). Bentgrass (*Agrostis tenuis, A. palustris and A.canina*) has also been used in golf courses.

A weed is defined as a plant growing where it is not desired. Unwanted plants in golf courses cover the turf species in the greens and fairways

and caused beneficial turf grasses to be suppressed during their establishment stage. Weeds are undesirable because they disrupt turf uniformity and compete with desirable grass species for moisture, light, and nutrients (Chee, 2000; Anon, 2004a).

The flight of the golf ball is deflected by the unwanted plants while placement of golf ball in the greens has to be repeated or re-localised when certain weeds are present in the locality. The roll of the golf ball is altered if the surface of a putting green is affected by disease, injury or weeds, and this influences the outcome of the match (Anon., 2004a).

Weeds or their stumps that remain after mowing affect the pathway of the golf ball as it rolls along the mid-section of the fairway. If the speed of the golf ball is reduced, there is greater deflection by the stumps of weeds like Love grass, Nutsedge grass and lalang.

The threshold level for golf putting greens is extremely low. The threshold levels for golf course fairways and roughs, however, are usually much higher than for greens since a smooth, blemish-free surface is not as important for play on these portions of the course (Anon., 2004a).

Some weeds have purple leaves or red-brown stems, and such colours do not blend with the green background of Bermuda grass/Serangoon grass/Zoysia grass. There are weeds which are light yellow in colour and they show up as patches against the green colour of the golf grass or turf. A uniform green colour for turf is expected by the majority of golfers.

The seeds of Love grass adhere to the long pants of golfers and are a nuisance as the golfers have to remove each spiky seed by hand. Some weeds are harmful to people because they attract bees, cause skin irritation, or cause poisoning if ingested (Anon., 2004a). Thorny weeds like the sensitive plant (*Mimosa pudica)* have sharp spikes that hurt the bare hands of human weeders.

TYPES OF WEEDS

Broadleaves, grasses and sedges are the main types of weeds found in golf courses and recreational areas.

Broadleaf weeds can produce a fibrous root system or a root system dominated by a large, fleshy taproot. Broadleaf weeds often bear colourful flowers of different sizes and shapes. They may have noded stems like *Asystasia,* or several trailing stems like *Mimosa,* and bunchy bases as seen in *Elephantopus.*

Grass weeds can be bunch-type (e.g. Goosegrass), rhizomatous (e.g. lalang) or stoloniferous (e.g. *Paspalum*). Bunch-typed grasses produce tillers, which are stems that arise from buds in the crown bud region (Anon., 2004a). Some spread by means of creeping above-ground stems called stolons. Stolons are horizontal creeping above-ground stems, and they originate from buds in the crown that break through the outer leaf sheath. Stolons produce nodes that can give rise to new tillers. Stolons are usually green or yellowish-green, whereas rhizomes are usually white or pale yellow.

Rhizomatous grasses can spread by their seeds or by underground stems that have nodes. Most nodes have buds that can give rise to new shoots. Fragments of rhizomes from weeds like lalang can regenerate new plants (Lee, 2003).

Sedges have stems that are triangular in cross-section; their narrow leaves have pointed ends, and they reproduce by seeds, underground tubers and rhizomes. They generally prefer moist and waterlogged habitats. Examples of sedges are *Cyperus* spp. and *Fimbristylis* spp.

Life cycles of weeds

Turfgrass weeds can be grouped into one of three life cycles: annual, biennial, or perennial. Annuals are plants that complete their life cycle in one growing season. Examples include *Hedyotis spp.* and *Ageratum conyzoides.* Biennials require two growing seasons to complete their life cycles. They usually produce

vegetative growth the first year, then flower and set seed during the second year.

Perennial weeds live for three or more years (although leaves and above-ground stems often die back at the end of the growing season). Perennials produce new vegetative growth from growing points at or below the soil surface. Perennials also produce new plants from seeds. An example is lalang (*Imperata cylindrica).*

WEEDS IN GOLF COURSES

Weed specimens were collected mainly from fairways but a few specimens were from greens, apron and roughs. They were identified by referring to books by Henderson (1959) and Barnes and Luz (1990). Frequent mowing has resulted in dwarfing of some weeds. When the flowers or fruiting bodies were absent it was difficult to identify the species.

In general more weeds were observed on golf courses planted with Bermuda grass/Serangoon grass than carpet grass (*Axonopus compressus).* Some of the major weeds of fairways include *Borreria latifolia, Lindernia* spp., *Desmodium sp., Axonopus compressus, Chrysopogon aciculatus, Digitaria fuscescens, Eleusine indica, Paspalum conjugatum, Paspalum vaginatum, Cyperus brevifolius, C. rotundus* and *F. miliacea* (Table 1).

Asystasia gangetica is one of the fastest spreading weeds in Malaysia over the last two decades. From Johore it has spread during the early 1980s northwards to Malacca, Negri Sembilan, Selangor and other states. Today it is found amongst ornamental plants that are planted within 20 metres from the collars of golf courses.

Asystasia has noded stems which regenerate easily after slashing or mowing. It had a seed germination rate of 82%, and the nodded cuttings had a sprouting rate of 27 per cent after 4 weeks; it produced an average of 58 pods per plant (Sahid *et al.*, 1990). They also found that the seedlings could survive under moisture stress. Lee (1984) studied the morphology and reproductive capacity of the same weed and found that seeds could be ejected from the parent plant to some 7 metres away.

The other rapid colonizer is Mission grass (*Pennisetum polystachion),* with its familiar yellow inflorescences, and rapid regrowth from stem cuttings. Today it is also found in the vicinity of golf courses.

Murdannia has tough stems while *Portulaca* has fleshy stems which regenerate after fragmentation. *Eleusine indica* is the most difficult weed to handpull because its roots are deeply entrenched in the soil. *Cyperus brevifolius* has a series of connected stolons that are difficult to dislodge completely from the soil.

The ascent of *Paspalum vaginatum* is also of concern; in the mid-1990s, this weed was problematic, and its stoloniferous fragments were also spread by the rotavator blades and the soils adhering to the shoes of workers. After the heavy rains in October till December, sedges spread quickly, forming thickets or dense clumps in the low-lying regions or in areas which are not well-drained. Nutsedge *(Cyperus rotundus)* has tubers (containing buds) and scaly rhizomes. Isolated tubers can sprout to produce new shoots. Some of its dormant buds in the tubers resist the action of herbicides.

Yellow nutsedge (*Cyperus esculentus*) plants have green leaves, and its stems are yellow-green and shiny. In the United States, new growth occurs in spring and summer from vigorous, scaly rhizomes and nutlets that grow underground. Chestnut-brown seedheads may be present on plants that are not mowed (Anon., 2004 a; 2004b).

Some golf courses and recreational areas are on peat and sandy soils. On peat, there is an abundance of *Cyperus* spp., *Scleria* spp., *Fimbristylis* spp. and ferns. Nevertheless many common weeds found in the inland sedimentary soils are also found on peat. On sandy soils, *Eleusine indica* can dominate in highly fertilized areas and in situations after repeat use of

Table 1. A preliminary list of some major weeds of greens, apron, fairways and roughs on golf courses in Selangor

	Botanical name	Common name
I.	BROADLEAF WEEDS	
	Asystasia gangetica	Common Asystasia
	Borreria latifolia	Button weed
	Desmodium sp.	
	Elephantopus scaber	Elephant's foot
	Euphorbia hirta	Milky spurge
	Emilia sonchifolia	Purple sowthistle
	Hedyotis corymbosa	Two-flowered Oldenlandia
	Hedyotis pinifolia	
	Lindernia crustacean	
	Lindernia pedunculata	
	Murdannia nudiflora	Common Spiderwort
	Phyllanthus nirur	Pick-a-back; lagoon spurge
	Phyllantus urinaria	-
	Portulaca oleracea	Purslane Hair
II.	GRASSES	
	Axonopus compressus	Carpet grass
	Chrysopogon aciculatus	Love grass
	Digitaria ciliaris	Common crab grass
	Digitaria fuscescens	Lesser crab grass
	Eleusine indica	Goose grass, Crowsfoot grass
	Eragrostis tenella	Feathery Eragrsostis; Bug's egg grass
	Paspalum conjugatum	Buffalo grass
	Paspalum scrobiculatum	Bull Paspalum
	Paspalum vaginatum	Couchgrass
	Pennisetum polystachion	Cat's tail grass
III.	SEDGES	
	Bulbostylis sp.-	
	Cyperus aromaticus	Greater Kyllingia
	Cyperus brevifolius	Short Kyllingia
	Cyperus compressus	Hedgehog Cyperus
	Cyperus distans	Slender Cyperus
	Cyperus iria	Grasshopper's Cyperus
	Cyperus rotundus	Purple nutsedge
	Cyperus zollingeri	-
	Fimbristylis miliacea	Lesser Fimbristylis

herbicides where other annual soft weeds have been eliminated.

WEEDS IN RECREATION PARKS AND SOCCER FIELDS

The usual turf species in above areas is carpet grass *(Axonopus compresses)*. Table 2 gives a preliminary list of some major weeds in such areas. Many weeds not listed in Table 2 can also occur in turf grasses of agricultural parks.

In recreation parks, football fields and highways where carpet grass *(Axonopus compressus)* is the major turf species cultivated, the major weeds include *Asystasia gangetica, Borreria* spp., *Cleome spp., Euphorbia hirta, Mimosa pudica, Eleusine indica, Imperata cylindrica, Cyperus* spp., and *Fimbristylis miliacea.* In waterlogged areas, *Panicum repens, Cyperus aromaticus, Cyperus brevifolius and Fimbistylis miliacea* tend to dominate.

During the last decade, *Asystasia gangetica and Pennisetum polystachion* have spread rapidly into the turf areas in housing zones. In wet and waterlogged areas, the ascent of *Cyperus* spp. and *Fimbristylis spp.* is noted with concern.

INTEGRATED WEED MANAGEMENT

With the current trend on holistic turfgrass management, Integrated Weed Management (IWM) is a pest management system that is gaining popularity and acceptance in the turfgrass industry. IWM involves the formulation of strategies which provide maximum downsizing of the weed population with minimal effects on the agro-eco-system (Lee, 1996).

IWM should result in a reduction in pesticide use (Lee and Teoh, 1995). For IWM to be successful, the managers and supervisors must be able to identify weeds and understand their life cycles.They must also understand the environmental conditions that favour their spread, and the selection of combination of methods.

IWM includes preventive, cultural, mechanical and biological approaches. The denser the cover of the turf, be it Bermuda grass or Carpet grass, the more effective the prevention of weed infestation (Anon., 1985). However, it is not always possible to prevent weeds from establishing a foothold in turf or golf courses. Weed seeds are dispersed by wind, water, wheels and rotor blades of mowing machines, hoes, weeding implements, footwear and golfers. Weed problems often magnify when control is delayed.

1. Preventive measures

Weed management must start at the pre-planting stage and there should be a long-term action plan to manage the weeds in the turf itself and in its vicinity since weeds encroach into the turf areas and spread their wind-borne or soil-borne seeds. Proper seedbed preparation is needed to ensure that the tubers, stolons and rhizomes of weeds are removed before seeding the turfgrass. When a specified golf grass species is imported, the batch of planting materials may contain the seeds or vegetative materials of another golf grass.

Inspect the areas near the "buggy" tracks where excessive trampling occurs, resulting in soil compaction. The turf species will "dieback", leaving some sporadic patches of turfgrass. Tough weeds like Goose grass, Nutgrass and *Asystasia* can colonise these border areas. This situation applies to golf course areas where there is heavy human traffic or poor drainage. To overcome this situation, close the heavily-trampled areas and perform renovation work; remove the weeds and replant with the turf species.

Frequent surveys of the greens, fairways, aprons and surrounding areas are done to record the weed species and their spread. The golf course supervisor should be able to identify the weeds, classify them into noxious and non-noxious categories, note their level of infestation, and choose the appropriate method(s) of control. Good record keeping for each golf area is vital for long term weed control and for environmental auditing.

Table 2. A preliminary list of some major weeds of recreation parks, football fields and highways

	Botanical name	Common name
I.	BROADLEAF WEEDS	
	Asystasia gangetica	White flowered weed
	Borreria setidens	-
	Borreria latifolia	Button weed
	Cleome rutidosperma	Cat's whiskers
	Desmodium sp.	-
	Eclipta alba	
	Euphorbia hirta	Hairy Spurge
	Hedyotis corymbosa	Two-flowered Oldenlandia
	Mikania micrantha	Mile-a-minute
	Mimosa pudica	Sensitive plant
	Phyllanthus niruri	Pick-a-back; lagoon spurge
	Phyllanthus urinaria	
	Tridex procumbens	Coat buttons
II.	GRASSES	
	Choris barbata	Plush grass
	Digitaria ciliaris	Crab grass
	Eleusine indica	Goose grass
	Eragrostis tenella	Feathery Eragrostis, Bug's egg grass
	Imperata cylindrica	Lalang, blady grass
	Ischaemum muticum	Centipede grass
	Ottochloa nodosa	Slender panic grass
	Panicum repens	Creeping panic grass, Torpedo grass
	Paspalum conjugatum	Buffalo grass
	Paspalum scrobiculatum	Bull Paspalum
	Pennisetum polystachion	Cat's tail
III.	SEDGES	
	Cyperus brevifolius	Short Kyllingia
	Cyperus iria	Slender cyperus
	Cyperus polystachyos	-
	Cyperus zollingeri	-
	Fimbristylis miliacea	Lesser Fimbristylis

The frequency of control is important, as we need to control the weeds before they flower and set seed. The common types of weed seeds in Malaysia have a germination rate of between zero to 85 per cent under alternating temperatures of 15 and 35 degrees Celsius within 2 weeks (Lee, 1977). Rapid germination applies to a figure of more than 65 per cent attained within 6 weeks; weeds in this category are *Hedyotis corymbosa, Ageratum conyzoides, Amaranthus blitum, Mikania micrantha, and Cyperus zollingeri.*

Weeds in the intermediate category have a germination of 15 to 65 per cent within 6 weeks; these are *Axonopus compressus, Eleusine indica, Borreria latifolia, Echinochloa colonum, Mimosa pudica, Euphorbia hirta, Fimbristylis pauciflora, Paspalum conjugatum, Digitaria longflora, and Chromolaena odorata.* Some weeds flower and set seed within 45 days. Weeds like Love grass regrow very fast after mowing. Lalang seeds had a germination of 80 per cent within two weeks (Lee, 1977). The lalang shoots start to flower within one month after slashing, mowing or accidental burning.

Noded stems of some broadleaf weeds can regenerate easily, sprouting new shoots which can flower even earlier. Frequent light watering also encourages germination and development of weeds at the expense of turfgrasses (Anon., 2004b).

2. Cultural control

It is very vital to handweed the unwanted plants that start to encroach into the greens from the aprons. Spot handweeding is done to reduce the sporadic patches of weeds that have started to establish themselves. If the weeds have stolons, removal of the stem fragments is done. Underground tubers of nutgrass or the rhizomes of lalang are removed by digging into the soil.

Early surveillance followed by handweeding is absolutely essential before the problem becomes so acute that replanting of the turfgrass is needed. Handweeding also includes removal of stumps of the weeds that often escape the mower's rotor blades. Small patches of nutgrass, Goosegrass, *Paspalum* and *Digitaria* are easy to eradicate by cutting below their crowns or by manual removal of the tubers, stolons and crown buds, followed by reseeding the turf on the bare patches.

In waterlogged or low-lying areas, manual removal of nutgrass present a formidable task; the areas are so densely infested with rhizomatous, stoloniferous and tuberous weeds that it is not uncommon for replanting of the whole stretch of golf course to be done. This is preferred to repeat handweeding.

For cultural control to be enhanced, it should consider factors like fertilizer application, irrigation and drainage, thatch management, aeration and mowing practices. For instance, by constructing an underground drainage network, the turfgrass area is not waterlogged. Thus weeds like Nutsedge, *Cyperus* spp., *Fimbristylis* and *Panicum repens* do not become prevalent after they have been handweeded or mowed.

3. Mechanical control

Good mowing practices are perhaps the most important single factor contributing to the appearance, attractiveness and longevity of any turfgrass area (Vengris and Torello, 1982; Anon., 2004c). Mechanical control is effective and is supplemented by manual weeding. Currently all golf courses use a broad range of hand-held mowers, reel-, thread- and rotary-mowers to trim the golf grasses and to manage the unwanted plants. Rotary mowers have been used on love grass.

The frequency of mowing ranges from daily mowing to once every few days depending on the rate of regrowth of the turf, weather, and standards set by golf tournaments, turf areas, level of weed infestation and so forth. In general when a grass is about 1.25 cm to 2.4 cm above standard height in a lawn, it should be mown (Vengris and Torello, 1982); mowing heights are

0.6–1.3 cm for bent grass, 1.2–2.5 cm for Bermuda grass and Zoysia grass, and 2.5–5 cm for carpet grass.

A properly planned mowing programme will enhance the appearance of the turf. Turfgrasses need to build up its carbohydrate reserve to sprout new buds and shoots; thus over-mowing may shock the turf, resulting in reserves being burned up, and leaving little for future regrowth. To prevent excessively fast build-up of thatch it is recommended that the clippings from normal frequency mowing be removed at least 50 per cent of the time (Anon., 2004c).

The mechanical mowers cut off many broadleaf weeds. To prevent the weed seeds from accumulating in the soils, the mowing should be done before they set seeds. This is important in the vicinity of golf courses where many weeds are flowering and seeding profusely if they are not controlled. The weeds in the outskirts are a source of infestation.

Golf courses are infested with more weeds if mowing is not done properly. If the mowing heights are too short, the turfgrasses are weakened, and weeds may spread rapidly. Mechanical tools for mowing must be kept sharp and in good operating condition. If the mechanical tools are not properly adjusted, there will be discoloration and damage to the leaves of turf grasses; pathogenic bacteria and fungi invade the damaged leaf tips easily.

It is important to choose the appropriate mowing equipment for Bermuda grass, Zoysia or Serangoon grass, taking into account the weeds (e.g. Love grass or Nutgrass or Goosegrass) present. Sharp, properly adjusted reel type mowers are recommended for cutting quality turfgrass areas because they provide a clean even cut and leave the lawn with a well groomed appearance.

Several units of reel mowers are to be used for fast and efficient control. They are best for fine turf areas and require less power than rotary ones. For tall weeds and tough grasses, it is advisable to use rotary mowers for a better cut. Rotary mowers should be used where grass control rather than appearance is the predominant consideration. They are more versatile, easy to adjust to 5–7 cm mowing height and they do not jam on small twigs and chops (Anon., 2004c).

In IWM, safety should be considered always. Reel mowers are generally considered safer than rotary mowers (Anon., 2004c). Always check the reel blade to bedknife adjustment. Rotary mowers should be well shielded, and have the grass discharge port at the side or front - never at the back of the mower. Always keep all blade bolts tight and use a blade that is properly balanced.

Alternate directions of mowing will partially control runners of creeping grass and aid in the prevention of grain and thatch (Anon., 2004c). In West Malaysia, the main rainy season is usually from October till December, and it takes more efforts to mow on wet grounds.

4. Biological control

Biocontrol has generated a lot of interest, and many cases of successful control of weeds by insects have been reported (Ibrahim *et al.*, 1995; Lee and Teoh, 1995). An exciting new approach is to harness plant pathogens to destroy noxious weeds. These natural pathogens are known as bioherbicides. Collego (*Collectotrichum gloeosporioides* f.sp. aeschynomene) is a commercial bioherbicide that is used to control Northern Joint Vetch in soybean and rice in the United States.

There is potential to use endemic native pathogens as biocontrol agents of weeds in golf courses. The development starts with field surveys of pathogenic fungi on selected troublesome weeds like Nutgrass, Goosegrass and *Asystasia*. This is followed by isolation, identification and host-specificity tests. The fungus chosen must be safe to the turfgrasses, able to produce abundant spores and adaptable

to a wide range of environmental conditions.

In Malaysia, preliminary research was done by scientists from the University of Science Malaysia and the Malaysian Agricultural Research and Development Institute (Lee and Lee, 1995). Caunter (1995) isolated five pathogenic fungi from lalang in his experiments in USM.

Research on the use of *Dactylaria higginsii*, a bioherbicide,to control *Cyperus rotundus,* was reported by Kadir and Charudattan (2000). To control water hyacinth, Adam *et al.* (2004) reported a formulation of *Myrothecium roridum* for improving mycoherbicide as a biocontrol agent. Fungal pathogens associated with barnyard grass seeds were reported by Sajili and Kadir (2003). Kadir and Ng (2004) reported the effect of oil emulsions on the control efficacy of *Exserohilum longirostatum* on Barnyard grass.

The R & D work involving a number of steps is labourious and often uneventful. These involve surveys of pathogenic fungi on selected noxious weeds in the field, idenfication and multiplication of the parent weed (to find out if they are capable of causing re-infection). If the results are positive, and rate and severity of infection high, the pathogens have to be tested on at least 35 economic crops to ensure that these economic crops are not affected. In Malaysia, for example, the economic crops would include rubber, oil palm, cocoa, rice, coconut, durian, pineapple and vegetable crops.

The next step involves production of fungi for more small scale tests in the field and if successful commercialization involves production by liquid fermentation in bioreactors. The greatest problem is contamination, and therefore, the need to maintain sterile or pure cultures is non-negotiable. All these development entail the need for funds.

Biopesticides are inherently less toxic than conventional chemicals; they are relatively specific and are effective in small quantities; they also decompose quickly, thus reducing or avoiding pollution (Bateman, 2004). Different strains may be mixed to give a broader spectrum of control (Oudejans, 1994); it may take 4 to 5 weeks for the bioherbicide to kill the weeds, and its activity is improved by warm, humid conditions. Note that bioherbicides are usually destroyed when mixed with herbicides or certain liquid fertilizers.

Successes with bioherbicidal approach are few due to natural and artificial constraints to their introduction and success. The pathogenic fungi often require favourable environmental conditions for their establishment and multiplication. The lack of inoculum at the critical time is a natural constraint. There is a need to develop bioherbicides which are stable and are able to multiply and germinate spores without the need of dew or irrigation (Lee, 1996).

Nevertheless, the challenge of bioherbicides research is great, and any nation which invests in human resources and finance to fund such work and reap economic benefits. For example, the introduction of the rust fungi (*Puccinia chondrillinae)* into Australia in the early 1970s to control skeleton weed resulted in an estimated annual savings of 16 million Australian dollars in 1986. The actual research project involved a low budget of 500,000 Australian dollars.

5. Chemical control

It is vital to ensure that the herbicide to be used is approved by the Malaysian Pesticide Board. While many hold the view that herbicides can do a quick job of knocking off the weeds, the introduction of a chemical programme would require application machines, maintenance of such machines, training of spray operators and calibration of the tractor-driven boom sprayers.

Environmental management is part and parcel of IWM and both are implemented on a daily basis. Research has shown that supervisors have to deal with chemical burns on beneficial turfgrasses that result from over-dosage, incorrect calibration of application equipment, wrong selection of chemicals, or use of

non-selective chemicals. General reports are available from various books and publications (for example, Beard, 1973; Vengris and Torello, 1982; Anon., 1985; Anon., 1992; Barnes and Chan, 1990; Lam, 1992; Anon., 2004a; 2004b; 2004c).

Supervisors and employees should be provided with critical information relating to the judicious handling of chemicals, spray drift and chemical contamination management procedures. Emergency showers are installed so that spray workers can decontaminate themselves if there is excessive exposure or spillage of concentrates on their spray suits or body regions. Some golf courses are equipped with concrete slabs protected by bunding; chemicals are mixed in the concrete zone.

WEEDS TO WATCH

Prevention of foreign weeds from entering Malaysia is part and parcel of an effective IWM programme. Table 3 shows some weeds of golf courses in the United States, and we need to watch them as they can enter Malaysia via planting materials, soils and other means. Quarantine measures and detailed inspection of imported turfgrass materials are very important measures to be implemented constantly.

Early detection is most important and it is vital to contact the Department of Agriculture and authorities should you find some "foreign" noxious weeds in the nursery or lawn. The ascent of a number of foreign weeds has shown that they can migrate quickly in all directions.

Many are tough weeds, prolific seeders and fairly resistant to some herbicides. Watch out for foreign grasses also as they would be difficult to eradicate in turf areas planted with grass species. However, many foreign weeds may not survive in the lowlands where temperatures are between 23 and 35 degrees C, but some may be able to survive in Cameron Highlands, Genting Highlands and Fraser's Hill.

SUGGESTIONS FOR FURTHER RESEARCH

Research on IWM in Malaysia is at its infant stage; most of the work on herbicides was conducted on plantation and cash crops. As mowing is the major approach used in golf courses, more research is needed on the height of mowing to control the various types of weeds. There is an urgent need to develop IWM so that the current weeds like *Desmodium*, Goosegrass, *Paspalum vaginatum*, Nutsedge and *Asystasia* are better controlled by non-chemical methods.

There is also a need to conduct research on a combination of drainage and IWM to control weeds like nutsedge and *Fimbristylis miliacea* in waterlogged areas of the golf courses. The search continues for selective chemicals to control noxious grasses in the golf courses and recreational areas continues with the view of using them judiciously, without affecting the turf species.

Finally, cost-effectiveness is certainly an important consideration. Various IWM approaches need to be appraised for their cost-effectiveness. More research is also needed on safer ways of handling chemicals and environmental auditing.

CONCLUDING REMARKS

Holistic management of turfgrasses involves the use of several methods of weed management with emphasis on efficient and effective control of unwanted plants with minimal side-effects on the environment. Adults and children visit golf courses and recreational parks. There is growing interest in maintaining the golf courses and green parks as beautiful zones where flora and fauna can co-exist in harmony.

It is a vital that Golf course supervisors and Turf managers adopt an eco-friendly approach in weed management so that these areas bring forth new life, with fishes in the ponds, clear water in the lakes, healthy earthworm activity in the soils and green fields.

Table 3. Weeds to watch (After Vengris and Torello, 1982; Anon., 2004 a).

	Common name *(Botanical name)*	Undesirable characteristics
I.	BROADLEAF WEEDS	
	Black medic *(Medicago lupulina)*	Perennial; spread by stems
	Broadleaf plantain *(Plantago major)*	Deep tap roots; seedheads
	Buckhorn plantain *(Plantago lanceolata)*	Compact seedheads
	Common chickweed *(Stellaria media)*	Creeping stems
	Corn speedwell *(Veronica arvensis)*	Creeping stems
	Cinquefoil *(Potentilla spp.)*	Spread by stolons
	Creeping buttercup *(Ranunculus repens)*	Extensive stolons and seeds in capsules
	Dandelion *(Taraxacum officinale)*	Long tap roots, rosette of flower heads
	Dog fennel *(Anthemis cotula)*	Ability to escape damage by lawn mowers. Grows till 15 cm tall.
	Ground ivy *(Glecoma hederacea)*	Low-growing perennial, stolons with roots at nodes; survives in shade and sunny area
	Heal-all *(Prunella vulgaris)*	Spread through stems and seeds
	Henbit *(Lamium amplexicaule)*	Many seeds
	Mallow *(Malva rotundifolia)*	Sprawling branches
	Prostrate knotweed *(Polygonum aviculare)*	Adapted to trampled areas
	Prostrate spurge *(Euphorbia supine)*	Spreads over other low-lying turf grasses
	Purslane *(Portulaca oleracea)*	Seeds can stay dormant in the soils for long periods
	White clover *(Trifolium repens)*	Creeping above-ground stems with rooted nodes
	Wild violet *(Viola papilionacea)*	Thick underground stems
	Yellow and orange hawkweed *(Hieracium spp.)*	Perennial
	Yellow rocket *(Barbara vulgaris)*	Perennial with seeds
	Yellow woodsorrel *(Oxalis stricta)*	Seed pods
II.	GRASSES	
	Summer grass *(Digitaria sanguinalis)*	Prolific seeder
	Paspalum grass *(Paspalum dilatatum)*	Seeds and stems
	Water couch *(Paspalum paspaloides)*	Stolons
	Winter grass *(Poa annua)*	Tough weed
	Paramatta grass *(Sporobolus africanus)*	Prolific seeder

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