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WEED MANAGEMENT IN TROPICAL TURFGRASS AREAS: A REVIEW

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Abstract - Cultural practices promoting vigorous, environmentally friendly dense turf are discussed. These are the most important and least recognized means of preventing weed establishment and encroachment which includes appropriate propagation material selection, sanitation and cultivation, adjustment of planting time, manual weed control (hand pulling, hoeing and rouging), turfgrass selection to better compete with weed populations, applying physiological stresses, fertilizer management, moisture management, mowing, and irrigation with salt water. Cultural management of weed is important because it reduces dependence on synthetic pesticides. A healthy turfgrass stand has been reported to be the best defense against weed colonization, and can be accomplished by proper mowing, watering, and fertilization. Mowing height is the clearest and best-documented cultural factor and a lower mowing height is always associated with more weeds in the turfgrass. Split application of fertilizer at intervals throughout the growing period is recommended for warm season turfgrasses. The application of fertilizer during dormant periods or periods of low growth may encourage weed growth. Hand pulling and hoeing effectively control annual and biennial seedling weeds for small areas. Irrigation by saltwater has been one method used recently to effectively control grassy broadleaved and sedge weeds in salt-tolerant turfgrass species. Cultural weed management practices in turf might provide a first defense: however, relying only on cultural control measures may not be a good idea. An integrated approach of combining cultural practices and chemicals can complement each other and give flexibility to decision making. Research is needed on optimizing the choices of herbicide and/or cultural practices as part of an integrated management system for turfgrass.

*Key words***:** Weed management, tropical turfgrass

INTRODUCTION

Chemical management of weeds in turfgrass includes the use of mowing, irrigation, sanitation, cultivation, planting materials, and turfgrass selection to better compete with weed populations. Cultural practices promoting vigorous, dense turf are the most important and least recognized means of preventing weed establishment and encroachment. Cultural management is important because it may reduce dependence on synthetic pesticides.

Cultural weed management in turfgrass originated in 1895 (Hansen, 1921), following the discovery of the selective toxicity of synthetic organic herbicides such as 2,4-D (2,4-dichlorophenoxyacetic acid; Marth and Mitchell, 1944). There has been considerable research into the chemical management of weeds in turfgrass, represented by more than 95 scientific papers published in referred journals by 2011. During the same period, only 55 scientific papers were published emphasizing the cultural management of weeds as they occur in turfgrass according to the objectives stated in the papers or their titles.

Integrated pest management (IPM) is the combined and attentive use of multiple approaches, such as chemicals and cultural practices for pest management. The lack of research on effective, low-cost IPM methods is an impediment to reducing chemical usage in lawn care and landscape management (Latimer et al., 1996). Extension recommendations often indicate that a dense, healthy turfgrass stand is the best defense against weed colonization, and can be accomplished by proper mowing, watering, and fertilization. While this seems reasonable, the methods are often stated in generalities, and are not based on published research. The objectives of the present review paper were to synthesize all the diverse and scattered scientific information on cultural management of weeds in turfgrass, and to describe opportunities for future research.

Propagation material selection, sanitation and cultivation

The need for establishing turf in a proper medium is paramount to weed management. Turfgrasses, often established from sods, are predisposed to adverse growing conditions, and they eventually result in turf that serves as a host for not only weeds but also pests. Topsoils used in new lawns, often 2-4 inches deep, have an inherent seed bank in them (Ashton and Monaco, 1991). Two ways to reduce the size of a seed bank are: 1) to obtain the topsoils from fields relatively free of perennial turf weeds, and 2) use a fumigant to kill the weed propagules present. Turf grown on amended sand had higher quality and tolerated drought better compared to unamended sand-grown turf, which had an indirect effect on weed pressure (Miller, 2000). When establishing a turf from seed, sanitary practices such as the use of pure seeds and clean equipment that has been used in other sites will help reduce future weed infestation. Hanson (1990) recommended mixing turf seed uniformly, especially if a blend is used, with straw mulch that enhances proper germination and establishment to reduce weed infestation. Soil amendments had significant effects on turfgrass establishment and quality, and decreased the competitive ability of weeds (Bigelow, 2001).

It is very important to prevent the introduction of weeds into lawn areas. If one can prevent weed establishment, there will be no need for control practices. Areas adjacent to fine turf, such as fencerows or ditch banks, are hard to mow and often serve as a source of weed seed that infests the nearby turf. These areas should receive weed management attention. Goosegrass is prevalent in compacted areas such as alongside cart paths (Busey, 1999). This may be because of stresses on the turfgrass, such as mechanical impediments to root growth, unfavorable conditions in the soil atmosphere, or reduced water and nutrient availability. Lawson (1993) observed progressively higher shoot density of annual bluegrass in green areas constructed of soil compared with sand and a USGA-specification construction. This may have been because of either the chemical or physical soil properties.

Adaptation to physiological stresses

Cold damage, which is worst on 'Floratam' St. Augustine grass when it is heavily fertilized, leads to weed infestation the following year (Laiche, 1979). Under reduced irrigation in California, perennial ryegrass *(Lolium perenne* L.) is more susceptible than other turfgrasses to colonization by spotted spurge (Gibeault et al., 1985). This is attributed to the poor performance of perennial ryegrass during the summer months.

After 3 years with no irrigation or fertilization, 'Bighorn' blue sheep fescue *Festuca ovina* L. subsp. *glauca* (Lam.) W.D.J. Koch (*F. ovina* var. *glauca* (Vill.) W.D.J. Koch) and 'Aurora' hard fescue *F. longifolia* auct. non Thuill. (*F. trachyphylla* (Hack.) Krajina) are more resistant to colonization by smooth crabgrass *Digitaria ischaemum* (Schreb. ex Schweigg. (Schreb. ex Muhl.)) and white clover *(Trifolium repens* L.) than either 'Silverado' or 'Rebel II' tall fescue *(F. arundinacea* Schreb.) (Dernocden et al., 1994). Despite providing very good quality during the first year after seeding, the poor performance of the tall fescue cultivars is explained by their defoliation caused by spring drought. Based on herbicide split-plot treatments, tall fescue cultivars could not be maintained under the low maintenance regime without the use of herbicides, but blue fescue and hard fescue had in-significant weed cover, regardless of herbicide treatment.

Fertilizer management

Fertilization influences the overall health of turfgrass areas, and can reduce in, or increase vulnerability to numerous stresses including weeds, insects, and disease. Split application of fertilizer throughout the growing period is recommended for warm season turfgrasses at monthly intervals. Applying a smaller amount of essential nutrients every one or two weeks during the growing period and adjusting the rates according to turfgrass response is the ideal practice (Turgeon, 1999). The application of fertilizer during dormant periods or periods of low growth may encourage weed growth. Application of fertilizer enhances the quick recovery of turfgrasses treated with herbicide for weed control (Johnson, 1984). Such a recovery can reduce competition from weeds that germinate and establish while the turf is under stress.

Moisture management

Maintaining proper soil moisture through irrigation and soil drainage encourages vigorous turf growth. Over-irrigation and poor surface and subsurface soil drainage results in low soil oxygen levels. Soil compaction also reduces oxygen diffusion and restricts rooting. Turf density decreases with compaction and weeds such as annual bluegrass, goosegrass, prostrate knotweed and various sedges often invade because they can tolerate these conditions

The weed in seashore paspalum can be controlled by irrigation practices. Due to the tolerance of seashore paspalum to periods of drought, irrigation is recommended on an as-needed basis. Signs of water deficit include rolling of the leaf blades, wilting, and foot imprints that remain on the lawn that has been walked on. At these signs of water deficit, application of 1/2 to 3/4 inch of irrigation to the entire lawn works better. To avoid over-watering when rainfall is adequate, frequency of irrigation should be reduced. Over watering lawn grasses not only wastes water, but also results in weakened root systems, nutrient leaching through the soil, and poor stress tolerance.

Mowing

Mowing height is the clearest and most well documented cultural factor affecting weed populations in turfgrass. In cases where a significant effect has been detected, within the mowing heights studied, the lower mowing height is always associated with more weeds in the turfgrass. Studies of crabgrass infestation in cool-season turfgrasses have always shown that lower mowing height increases weed density in Chewing's fescue *Festuca rubra* var. *commutata* Gaudin (= *Festuca rubra* subsp. *fallax* (Thuill.) Nyman) (Jagschitz and Fbdon, 1985); Kentucky bluegrass (Niehaus, 1974; Dunn et al., 1981); tall fescue (Hall, 1980; Dernoeden et al., 1993; Voigt et al., 2001), and in a comparison of tall fescue and several fine fescue species (Dernoeden et al., 1998). In bermudagrass, mowing height effects were observed in both crabgrass and dandelion densities, but the effects were slight and inconsistent in direction (Callahan and Overtoil, 1978).

Differences in relative abundance values between sod farms and the other turfgrass areas evaluated may be due to mowing height. Athletic fields (20-30 mm) and golf course putting greens, are usually mowed at lower heights (3-6 mm) of cut than turfgrasses on residential lawns and sod farms (Emmons, 2008). Thus, the abundance of *C. aromaticus* and lack of *C. compressus* in these areas may be evidence of differences in mowing height tolerance between the two weed species. Lowe et al. (2000) reported 2-5-fold increases in abundance of *Kyllinga brevifolia* mowed at 2.5 cm compared to 5.0 cm. Other researchers have observed similar responses with *Cyperus rotundus*, *Cyperus esculentus* and *Kyllinga gracillima* (Summerlin et al., 2000). Busey (2003) also reported a reduction in *Digitaria ischaemum, Poa pratensis* L. and *Festuca arundinacea* mowed at 8.0 cm compared to 4.0 cm. Species of *Kyllinga*, a relatively low-growing spreading weed, are highly competitive with bermudagrass (Kawabata et al., 1994). Annual bluegrass has a higher cover at a 3.8 cm mowing height, 30.8%, compared with 8.6% at a 7.6 cm mowing height based on averages across N fertilization rates (Bush et al., 2000).

Mowing to prevent weed colonization

With their protected growing points, grasses survive and predominate in ecosystems with periodic defoliation by fire, grazing, or mowing. It is expected that mowing too high or too infrequently would increase weed colonization, just as mowing too low height encourages crabgrasses and other weeds, and an optimum intermediate mowing height and frequency would maintain a grass monoculture. Possible weed control benefits of mowing are that timely mowing that is low enough would cut seed heads and prevent weed seeds from maturing; also, most dicotyledonous plants are eventually killed by mowing. Close mowing reduces the aboveground dry weight and root dry weight of kikuyugrass, but is inadequate to control it (Wilen and Holt, 1996). The regrowth potential of broad-leaved dock *(Rumex obtusifolius* L.) is very high, and it is not controlled by variation in mowing frequency (Niggli et al., 1993). These examples represent highly persistent perennial weeds.

Hand pulling, hoeing, and rouging

Manual weed control often is performed by hand pulling, hoeing and rouging. Manual weed control is not widely practiced and is generally impractical on large sport turfgrass areas. However, because of herbicide-sensitive constraints on certain small turf and ornamental areas, manual weed control may be necessary.

Hand pulling and hoeing effectively controls annual and biennial seedling weeds. These practices are less effective on established perennial weeds, because underground reproductive parts are not eliminated by this method. If only a few weeds are present, it is easier and less time-consuming to physically remove the plant. If weeds are a major problem however, other alternatives should be considered.

The handling of clippings gives contradictory results depending on the situation. Return of clippings to creeping bentgrass increased annual bluegrass infestation by 12% more than plots in which clippings were removed, apparently because of addition of viable seeds (Gaussoin and Branham, 1989). Removing clippings reduced the number of viable seeds in the soil by 60%. In Texas, broadleaf weeds in St. Augustine grass and bermudagrass were most numerous when mown with a mulching mower, with clippings recycled during mowing, and were least numerous when clippings were removed (Colbaugh and Knoop, 1989), based on a short-term, 9- to 17-week study.

Weed management by salt water

General salt-tolerant turfgrass and their common weeds

The warm season grasses are represented by more genera than the cool season grasses but many of these generally have only one species that is suitable for use as a turfgrass. The salt-tolerant warm season grasses are given below (Table 1). Among the warm season turfgrasses, *Zoysia japonica, Zoysia matrella* and *Paspalum vaginatum* (seashore paspalum) are used in major turfgrass areas in Malaysia. The major weeds in turfgrass area are given in Table 2.

Irrigation by saltwater has been one method used to effectively control grassy broadleaved and sedge weeds in salt-tolerant turfgrass species. *Paspalum vaginatum* and *Zoysia japonica* are the most salt-tolerant turfgrasses where sea water or any type of reclaimed/recycled water can be used for irrigation (Carrow and Duncan, 1998; Duncan and Carrow, 2000; Dudeck and Peacock, 1985, Lee et al., 2004a, 2004b, Kamal Uddin et al., 2009, 2011). Salinity tolerance might allow for the application of sodium chloride to be used for post control of grassy weeds in seashore paspalum (Duncan and Carrow, 2000). Brosnan et al (2009b) suggested that sequential application of sodium chloride at 488 kg ha^{-1} is required for post control of grassy weeds. Brosnan et al (2009a) reported that sequential application of granular sodium chloride at 488 kg ha^{-1} provided more

Table 1. Scientific name, common name and subfamily of salt tolerant turfgrass species

Scientific name	*Common name*	*Subfamily*
Paspalum vaginatum Swartz	Seashore paspalum	Panicoideae
Zoysia japonica (L.)	Japanese lawn grass	Chloridoideae
Zoysia matrella (L.)	Manila grass	Chloridoideae

Source:Emmons, 2000.

Table 2: Some major common weeds in salt tolerant turf area.

Family	*Scientific name*	*Common name*	*Life cycle*
Grasses			
Poaceae	*Axonopus affinis* Chase	Narrow leaf carpet grass	P
	Bothriochloa intermedia (R.Br.)A. Camus	Sandhor	P
	Chrysopogon aciculatus (Retz.)Trin.	Love grass	P
	Cynodon dactylon (L.) Pers.	Bermudagrass	P
	Digitaria didactyla Willd.	Serangoon grass	P
	Digitaria fuscescens (J.Presl) Henr.	Yellow crabgrass	P
	Eleusine indica (L.) Gaertn	Goosegrass	A
	Eragrostis atrovirens (Desv.) Trin.	Wiry eragrostis	P
	Eragrostis malayana Stapf.	Doubtful grass	A
	Eragrostis viscosa (Retz.) Trin.	Sticky love grass	P
	Eragrostis tenella (L.) Beauv.	Feathery eragrostis	A
	Sacciolepis indica (L.) A. Chase	Short spiky Sacciolepis	A
	Sporobolus diander (Retz.) P.Beauv.	Lesser drop seed	P
Sedges			
Cyperaceae	*Fimbristylis dichotoma* (L.) Vahl	Two leaf fimbry	P
	Cyperus sphacelatus Rottb.	Roadside flat sedge	
	Cyperus compressus L.	Hedgehog cyperus	A
	Cyperus kyllingia Endl.	White kyllingia	P
	Cyperus aromaticus L	Greater kyllingia	P
	Fimbristylis pauciflora R.Br.	Flowered Fimbristylis	A
Broadleaf weed			
Asteraceae	*Aegaratum conyzoides* L.	Goat weed	A
	Emilia sonchifolia (L.) DC.	Purple sow thistle	A
	Tridax procumbens L.	Coat buttons	P
Commelinaceae	*Commelina nudiflora* L.	Day flower	A
Euphorbiaceae	*Euphorbia hirta* L.	Hairy spurge	A
	Phyllanthus niruri L.	Sleeping plant	A
	Phyllanthus urinaria L.	Chamber bitter	A
Fabaceae	*Desmodium triflorum* (L.) DC.	Three flower tick trefoil	P
Portulacaceae	*Portulaca oleracea* L.	Pig weed	A
Rubiaceae	*Borreria latifolia* Schum.	Broadleaf button weed	P
	Borreria repens DC.	False button weed	A
	Hedyotis corymbosa (L.) Lamk	Two-flowered oldenlandia	A
Scrophulariaceae	*Lindernia crustacea* (L.) F. Muell.	Malaysian false pimpernel	P

Source: Kamal Uddin et al., 2009; 2010
P= Perennial, A= Annual

than 90% control of sour grass in seashore paspalum turf. Pool et al (2005) reported that applications of 54 dSm^{-1} saline water provided more than 70% control of goosegrass in seashore paspalum. Most of the weed species (grass, sedge and broadleaf) were very susceptible and found to be effectively controlled (100%) at salinities of 48 and 72 dS m^{-1} salinity treatment (Kamal Uddin et al., 2010).

The high level of salt tolerance may allow the use of salt water for weed control in place of injurious post-emergence herbicides (Wiecko, 2003). Couillard and Wiecko (1998) evaluated injury from saltwater on large crabgrass (*Digitaria sanguinalis* (L.) Scop.) and mimosa-vine (*Mimosa pudica* Torr.). Mimosa only recovered from the 1/3 seawater treatment subjected to 3 d salt-stress. Complete crabgrass control was only achieved with pure seawater under 6 d salt-stress. Other studies were conducted by Wiecko (2003) with the addition of goosegrass, Alyce clover (*Alysicarpus vaginalis* (L.) DC.), and yellow nutsedge (*Cyperus esculentus* L.) to the species previously evaluated. Mimosa-vine showed complete necrosis at 54 dSm^{-1} and 37 dSm^{-1} under both salt stress durations, respectively. Alyce clover showed >90% injury at 34,500 ppm under both salt stress durations, and >70% at 37 dSm^{-1}. Large crabgrass and goosegrass showed >90% injury at 54 dSm^{-1}. Yellow nutsedge had the greatest salt tolerance among the weeds with injury <40% at all salt concentrations (Wiecko, 2003). Ocean water can be used as an alternative to herbicides to control weeds in certain turfgrasses (Couillard and Wiecko, 1998). Most annual grass and broadleaf weed species cannot tolerate continuous irrigation with saltwater or saltwater blends (wastewater) (Duncan and Carrow, 2000). At 13 dSm^{-1}, goosegrass and southern crabgrass control was 39 and 25%, respectively, increasing to 53 and 51% at 27 dSm^{-1}, respectively, and to 74 and 81%, respectively, at 41 dSm^{-1} (Pool et al., 2005).

Wiecko (2003) exposed goosegrass and crabgrass to saltwater twice daily for 3 and 6 days and observed similar results. Both weed species were controlled > 90% with a saltwater concentration of 55 dSm^{-1}, while 18 dSm^{-1}saltwater concentrations provided little control.

Tropical signalgrass control with saltwater was similar to that observed with goosegrass and southern crabgrass. Control at 13 $dSm^{-1}$was 33%, increased to 73% at 41 $dSm^{-1}$and 100% control at 55 dSm^{-1}. Purple nutsedge control increased to 41% and 81% control at 55 dSm^{-1} (Pool et al., 2005).

CONCLUSION

Cultural management of weeds in tropical turfgrass is reportedly a gradual process, with reduction in weed populations, sometimes taking a number of years. Herbicides cannot be relied on exclusively to manage weeds because there are cases where there is no known selective herbicide for suppressing or killing a particular weed. In this situation, an integrated approach is the most likely solution to manage weeds effectively in turfgrass. Cultural practices and chemicals can complement each other and give flexibility to decision making. To predict the long-term benefits of cultural vs. chemical management of weeds and their integration requires knowing both the persistence of consecutive annual herbicide applications to the same ground, as well as the weed seed bank in soil, resulting from both chemical and cultural methods.

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