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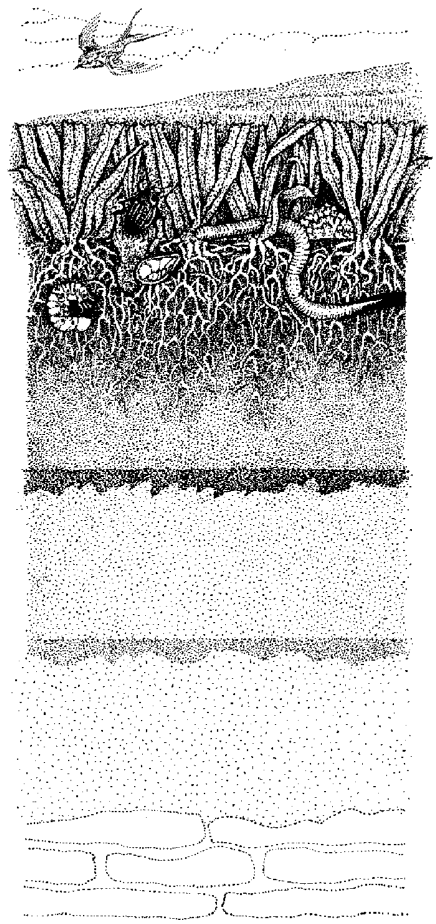

Everything You Ever Wanted to Know About Crabgrass...

but didn't know who to ask!

A well maintained turfgrass area provides many aesthetic and functional benefits. Decades of scientific research has been conducted to help managers maximize plant health and minimize environmental impact. Still, significant concern for environmental quality and human health has raised public awareness and led to increased scrutiny of management practices, especially pest management.

For many years, the turfgrass industry has been implementing a broad-based decision-making management system, known as Integrated Pest Management (IPM). IPM has evolved, since its inception, to more completely embrace the importance of turf culture that maximizes plant health. Still, misconceptions persist regarding the more traditional aspects of IPM such as "using only biological control" and "no use of pesticides." ■

The misconceptions of IPM pose a unique challenge from a weed management perspective, where visual thresholds are subjective (some like the look of weeds, some don't), functional thresholds are exceptionally low or not known (how many weeds can an athletic field have before the game is disrupted) and lack of effective biological controls once the weed is established. Therefore, the most effective IPM program for weed management is prevention by maintaining a dense turf.

The role of turfgrass density is critical for IPM, as well as for maximizing the environmental benefits of turf. For example, studies from the University of Wisconsin have indicated that a thin, unfertilized turf resulted in greater nutrient runoff that could contaminate surface water bodies. Subsequently, as weeds invade a thin turf, while initial density of weeds and turf is adequate to cover the soil, annual weeds, such as crabgrass, die off in the fall and leave bare soil exposed to the spring rains. It is these scenarios where weed control can be justified to preserve surface water quality.

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This Times

Crabgrass

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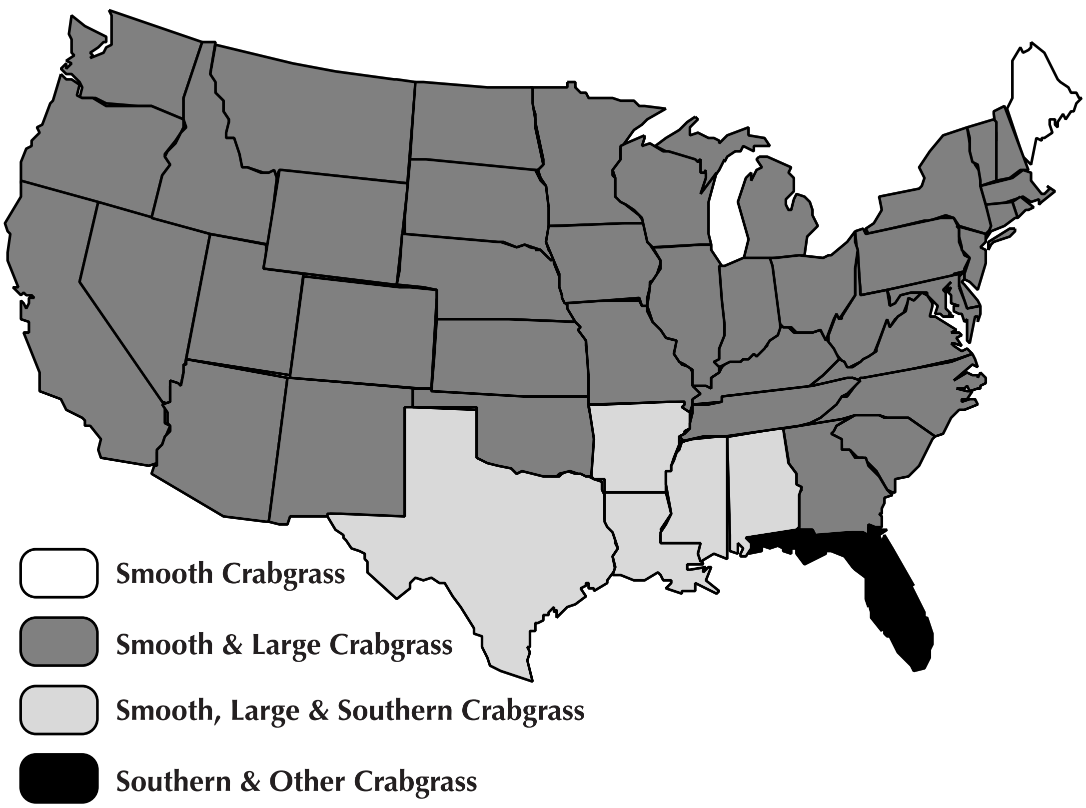
Reductions in turf density that result from insect and disease damage, excessive traffic, poor drainage, etc.. are likely to fill with weeds that arise from the soil seedbank (weed seeds stored in the soil). A primary weed arising from seed in turf stands is the annual grass weed species, crabgrass (*Digitaria* spp.). There are three major crabgrass species distributed in the United States; large, smooth and southern. Smooth crabgrass is prominent in the northern climates, especially the north eastern US, large crabgrass is found throughout the US, and southern crabgrass, primarily found in Florida and mid-southern states. (Figure 1).

Figure 1

Distribution of Major Crabgrass Species



Crabgrass management has evolved over the last 60 to 70 years with the introduction of selective herbicides. Years ago, the preferred management method was to alter the growing environment to limit crabgrass. Typically, this was achieved by drastically lowering the soil pH, unfortunately, the turf usually suffered as well.

The principle that a pH manipulation strategy employed was the concept of ecology. Ecology is the study of the relationship between an organism and its environment. Reducing the pH altered the environment so that the organism (crabgrass) could not be successful. Today, we rely on selective herbicides applied prior to crabgrass germination (preemergence) or postemergence herbicides applied when crabgrass has emerged. Again, concern over pesticide use has increased the need for understanding turfgrass and crabgrass ecology as well as the development of innovative herbicide application programs that minimize exposure and use of fertilizers and organic-based approaches.

Ecology

In spite of the available technology for managing crabgrass, it remains one of the most troublesome weeds in the US. Fidanza and Dernoeden (1996) have provided some useful information regarding crabgrass emergence patterns as influenced by growing degree days. In addition, studies from the 1950's and 1970's suggest that crabgrass could have up to a four month period where seeds could continually emerge from the top 2" of soil. Of course, most managers are familiar with the phenological indicators such as Forsythia and Lilac flowering as tools to predict timing of emergence. Still, many ecological questions remain unanswered.

Among the 60 species in the genus *Digitaria*, thirteen weedy species infest crops in the US. To more thoroughly understand the distribution and adaptation of crabgrass to regions and cropping systems, a survey was sent to weed science specialists in the US. Of the 117 survey forms that were sent, 62% were returned.

Approximately 90% of the respondents indicated that the three major species (smooth, large, southern), are regional problems. Large crabgrass was the most prominent species in all cropping systems from orchards to forage crops to golf and other turf areas, yet, smooth crabgrass was a more significant problem in turf than the other systems. When asked what factors limit distribution and adaptation, the respondents believed that temperature, light and seedbank were the most important, with moisture, cultivation, and soil pH to be of less importance.

A few respondents (4%) indicated that within a species, such as smooth crabgrass, the plants

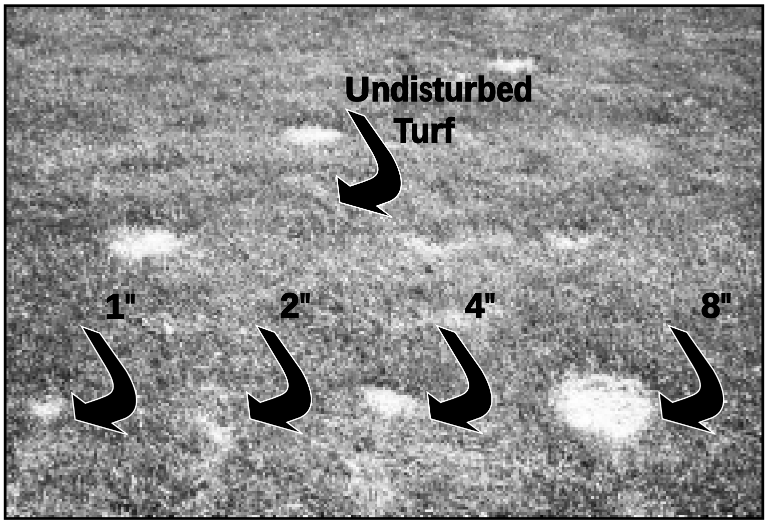


Figure 2
Crabgrass test plot showing the 4 different sized openings.

looked very different, and some suspected responded different to environmental factors. For example, is smooth crabgrass from Rhode Island different than smooth crabgrass from Long Island, NY and from smooth crabgrass from State College, PA?

The results from several field and growth chamber experiments conducted here at Cornell University, indicated that in fact, plants of the same species from different areas in the same region, look different. Of course, this is also common with another "weed" species known as annual bluegrass. However, when evaluating characters important for control programs, such as emergence date, growth rate, and flower initiation, there were no significant differences *between* smooth and large crabgrass and *within* each species. Simply, while species and plant may look different, in general they respond similarly.

A difference between the species worth noting was observed with flowering (seed production). The study found that smooth crabgrass plants that germinated after mid-July did not produce seed. These late germinating plants serve only to deplete the seed bank, in that the plants contribute less to the seedbank than they withdraw, an observation noted in other field studies.

Physical Disturbance and Crabgrass Invasion

To more thoroughly understand the influence of soil temperature and seedbank factors, a comprehensive field study was initiated to investigate various types of physical disturbance on crabgrass emergence, development and seed production.

Two study sites were established on mature stands of tall fescue and Kentucky bluegrass with different histories of crabgrass infestation. In both sites, 4 openings were created, 1", 2", 4" and 8" as well as an undisturbed area. (Figure 2). Each opening was maintained throughout the season by weekly clipping the encroaching leaf blades. The study area was maintained at 2.5" clipping height with no supplemental fertilization. One site had the thatch layer removed on half the plots to investigate the influence on crabgrass invasion; thatch layer was measured to be 0.5" thick. Soil temperatures were monitored in each opening and in the undisturbed turf at 1" and 2".

Crabgrass Emergence

As expected, undisturbed turf had significantly less crabgrass plants than any of the openings, but was not able to completely exclude the crabgrass seedlings. The thatch layer reduced the crabgrass emergence in the disturbed plots, but not in the undisturbed plots. In general, the undisturbed turf had 10 to 25% the amount of seedlings as the disturbed turf. In fact, crabgrass emergence varied little among the openings greater than 2", suggesting that any disturbance will result in crabgrass infestation if a seedbank is available.

Timing of emergence (seedlings emergence date) was not different relative to the of the amount of disturbance, however smooth crabgrass germinated 1 week earlier than large in disturbed versus undisturbed turf. In fact, initial crabgrass emergence began when soil temperatures in the undisturbed turf were between 54° and 58° F for 3 consecutive days at the 1 inch depth. This is within the range of temperatures reported by Fidanza and Dernoden. Interestingly, the length of emergence (number of weeks that new seedlings emerged) was greater in undisturbed turf than in disturbed turf. This was possibly related to soil temperature which was significantly moderated by turf cover.

From a weed management perspective, based on these studies the window for successful preemergence control of smooth crabgrass in a disturbed turf is earlier and more narrow as compared to undisturbed turf. However, an un-

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Crabgrass

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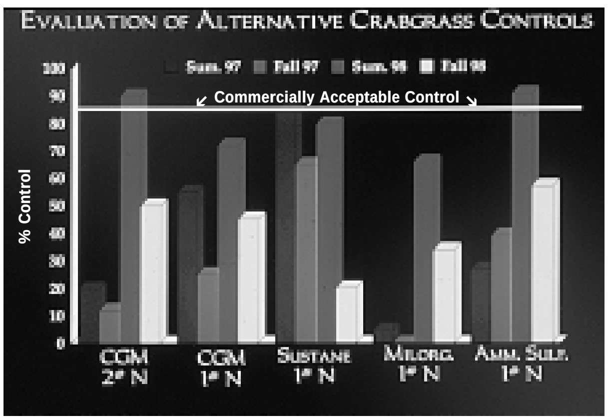
Preemergence herbicides can pose a risk for surface runoff; most of the active ingredients have a medium to large potential for surface runoff as rated by the Soil Conservation Service.

disturbed turf that may become disturbed will need sustained protection from infestations. Yet, as previously observed, late germinating smooth crabgrass plants will not produce seed and while short term visual quality is reduced, long term seedbank management is enhanced.

Do Fertilizer or Organic-based Approaches Work?

The growth curve of a cool-season grass is marked by two significant periods of top growth. These are periods when temperatures are cool and daylength is long. In fact, research has shown that cool season turfgrasses produce about 60% of the entire shoot growth for the season in the first 6 weeks in the spring (roughly about 25% of the growing season). This marked increase in turf density at the time of crabgrass emergence might have some ability to reduce crabgrass infestations.



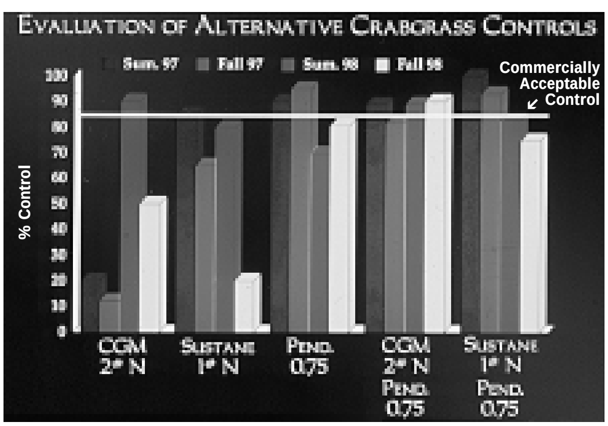


Figure 3

Evaluation of corn gluten meal, natural organic and synthetic fertilizer and low-rate herbicide applications for crabgrass control.

Former Cornell Team Members Hummel and Neal conducted a demonstration in seven locations throughout NY State comparing fertilizing to not fertilizing, with or without preemergence herbicides. The results indicated that when turf quality was acceptable prior to treatments, the fertilized plots reduced crabgrass populations by an average of 84% over the unfertilized plots. However, where turf quality began poor, fertility alone provided only 31% control as compared to unfertilized plots.

Recently, the natural organic product, corn gluten meal (CGM) has demonstrated herbicidal activity. Moreover, the specific chemical responsible for the activity has been isolated and characterized. Still, CGM is 10% nitrogen and when applied according to label directions supplies 2 lb. of actual N per 1000 square feet. Nitrogen applications that are part of the CGM, are not consistent with recommendations when a fall-based fertility program is followed. The nitrogen applied at this time extends top growth at the expense of root growth. However, when the turf is thin, the spring nitrogen will increase density that might provide some weed control.

Several studies have concluded that CGM was able to provide about 30 to 60% crabgrass control in the first year, with greater than 80% control reported in subsequent years. To overcome this reduced control in the first year, several researchers have suggested applying a preemergence herbicide at the half rate in conjunction with the CGM.

Recently, Cornell Turf Team Members Andy Senesac, Ph.D. (Suffolk County Extension Weed Scientist) and myself began an experiment comparing the use of corn gluten meal (Weed-Z-Stop, With Out Weeds, Safe and Simple) at two rates with and without herbicide application, to organic fertilizer and synthetic fertilizer applications. The study, initiated in 1997, is being conducted in Ithaca and in Riverhead, NY on thin turf stands with history of crabgrass invasion.

Results from the studies have been consistent with regard to the level of crabgrass control achieved with the CGM. After two years of applications of the different formulations, season-long control with CGM does not exceed 60% (Figure 3). In addition, control from the CGM is not significantly different from the synthetic fertilizer applications, or in some cases from the other natural organics. Both sites have demonstrated a substantial increase in turfgrass density in response to the nitrogen from the various sources. Interestingly, the CGM plus herbicide treatment has maintained above 90% control, suggesting that the transitional program might be effective. The experiment will be continued in 1999.

Preemergence Herbicides

IPM and Water Quality Perspective. The indiscriminate use of preemergence herbicides runs counter to a well implemented IPM program. Clearly, by inhibiting the successful emergence of crabgrass plants, there is little information available on the population that might develop. As a result, there is limited ability to develop historical records which lead to reasonable aesthetic and functional thresholds, the cornerstone of an IPM program. Still, preemergence herbicides are widely used.

Most preemergence herbicides have a great attraction for soil particles (adsorption coefficient; Koc). In addition, the herbicides tend to be largely insoluble. Therefore, it is rare (only on extremely sandy soils) when preemergence herbicides used for turf in the north are found in the groundwater. However, they can pose a risk for surface runoff with most of the active ingredients having a medium to large potential for

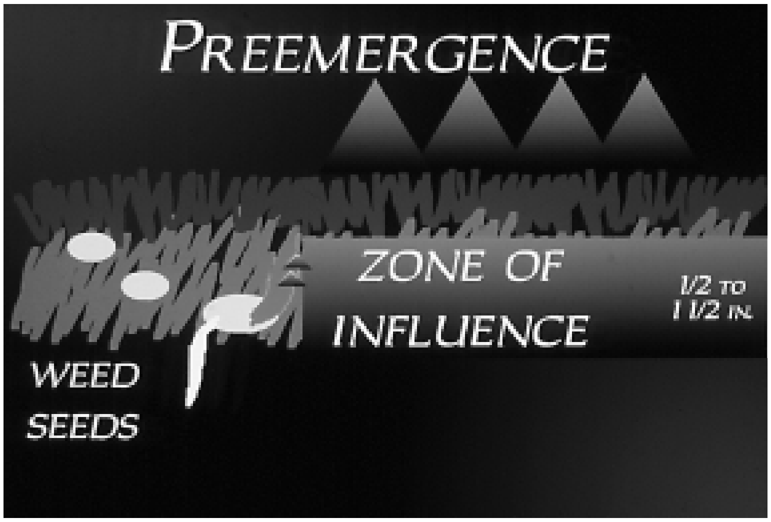


Figure 4

A visual representation of the soil-thatch interface where crabgrass seeds encounter preemergence herbicides.

surface runoff as rated by the Soil Conservation Service. Still, environmental fate studies conducted by turfgrass researchers in the last decade have concluded that a dense turf will significantly reduce runoff loss to surface water. Why then, if the turf is dense, do we need to apply preemergence each year, even if there is little risk to water quality?

How do they work? Preemergence herbicides that reduce the emergence of weed seedlings primarily act by inhibiting cell division. Cell division is one of the first steps in plant growth, as one cell divides into two cells, and then both cells elongate. Following the application of a preemergence herbicide, the chemical must be activated by moisture in the soil. It then becomes resident at the soil-thatch interface where many weed seeds are present (Figure 4). As weed seeds germinate under optimal environmental conditions, a small seedling protrudes from the seed and begins to grow towards the soil surface. The seedling has enough energy stored in the seed to reach the surface, at which time it is then able to begin using light energy in a process we call photosynthesis. It is important to note that preemergence herbicides do not affect ungerminated (dormant) seeds. The seed must germinate to encounter the herbicide that is resident at the soil-thatch interface.

Once the seedling encounters the herbicide, cells in the seedling continue to expand, but not divide. This expansion (not growth) depletes the energy stored in the seed before the seedling can emerge and become "self-sufficient". The result is that the plant does not survive. Over time, there are questions as to how many years of preemergence herbicide applications are needed to reduce the crabgrass seedbank below the threshold level. Are preemergence herbicide applications needed every year to every area of turf, or just on areas where the turf is always thin (along paved surfaces)?

How long do they work? The duration of herbicide activity (residual) is dependent on environmental conditions such as moisture, temperature, light and amount of organic matter in the soil. Once applied and activated, the herbicide remains at a critical concentration at the soil-thatch interface for periods ranging from 6 to 16 weeks depending on the product (Table 1). Preemergence herbicides degrade through chemical or microbial processes in the soil until the concentration falls below the critical level where activity is reduced. This can be accelerated when the soil remains warm for extended periods of time. Warm, moist soils encourage microbial degradation of the herbicide's carbon structure, using it as a food source. This is why in years of early and extended soil warming, preemergence herbicides fail to provide season-long control. Simply, the crabgrass germination period exceeds the residual activity of the herbicide.

Do Preemergence Herbicides Effect Turf Growth? The effect of preemergence herbicides on rooting has been investigated during sod establishment, where new roots must penetrate the preemergence herbicide barrier. Hummel found that annual applications of prodiamine applied at 2 lb. ai/A (4 times the high use rate) did reduce rooting of established Kentucky bluegrass by about 8%. However, in general, preemergence herbicides are thought to be less injurious to root development in established turf.

Turfgrass ecology and physiology could explain this further. Grass root tips are regions of active cell division (meristems). The root mer-

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Over time, there are questions as to how many years of preemergence herbicide applications are needed to reduce the crabgrass seedbank below the threshold level.

Crabgrass

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istems could be affected if it contacts a preemergence herbicide which inhibit cell division. As mentioned previously, turfgrass rooting is most active in the early spring when the soil is cool and top growth is yet to be initiated. It follows then, that a preemergence herbicide which inhibits cell-division could affect root production during a critical development stage. Accordingly, delaying preemergence application until soil temperatures warm, so that roots are through their active stage would avoid injuring the new roots. Yet, if crabgrass has already emerged most preemergence products will not provide postemergence control, hence, proper timing remains critical.

For many years, turfgrass pathologists have speculated that the use or preemergence herbicides can contribute to reduced disease tolerance. There are several anecdotal reports of increased bluegrass susceptibility to leafspot, but few documented studies. Researchers at Clemson University identified several preemergence herbicides that can increase the incidence of brown patch on tall fescue, however, the class of herbicides investigated are not widely used on cool-season turf. In addition, Hummel found an increase in severity of Necrotic ringspot with prodiamin applied above the labeled rates. Still, the preemergence herbicide influence on cell division, may have physiological side effects that are not well understood.

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Core Cultivation and Preemergence Herbicide Activity. The role of physical disturbance on crabgrass emergence and development has been discussed. However, many questions have been asked regarding the influence of core cultivation on preemergence herbicide performance. One might think that by disrupting the herbicide barrier crabgrass control would be reduced. However, in two separate studies where preemergence herbicides were applied and then the area core cultivated, no reduction in crabgrass control was observed. This was true even regardless if the cores were processed or removed.

Preemergence Herbicides Applied in the Fall. In an effort to reduce the amount of activity required on a turf stand in the spring, many managers have experimented with preemergence application in the fall, or late season. Researchers over the years have concluded that the effectiveness of this practice is highly product, rate and environmental related. Bhowmik at the University of Massachusetts found that prodiamine (Barricade) applied at 0.5 lb. ai/A in October 1997 provided 65% control when rated in August 1998. In fact, this was not significantly different from the April 1998 application of prodiamine at 0.65 lb. ai/A. The best prodiamine program (92% control) was 0.65 lb applied in October, followed by 0.38 lb. applied in April. Comparatively, dithiopyr (Dimension) applied at rates of 0.25 to 0.38 lb. ai/A did not provide even 80% control regardless of application strategy in 1998. These results confirm previous reports that the dinitroaniline family (pendimethalin, prodiamine, trifluralin+benefin) of herbicides can provide season long control when applied in the previous fall, while materials such as bensulide (Betasan), dithiopyr, oxadiazon (Ronstar) and siduron (Tupersan) are not as effective.

A significant limitation to the use of preemergence herbicides in the fall, is the potential to restrict overseeding or other turf establishment procedures the following spring. As discussed earlier, the effect of the herbicides on cell division is rarely selective, in that all germinating grass seeds can be inhibited (except in the case of siduron which is selective for warm season grass seed and can be used at the time of turf establishment). Consequently, if there is turf loss over the winter, the ability to recover the area from seed might be affected.

Researchers at Penn State University applied several preemergence herbicides in October and then overseeded the areas with creeping bentgrass (CB), Kentucky bluegrass (KBG) or perennial ryegrass (PR) in the spring. The plots were rated for density in June. All preemergence herbicides delayed seed germination and seedling development of all species. Overall, PR seedings were the most successful in establishing on oxadiazon and dithiopyr treated plots. Of the three species tested, bentgrass was the most sensitive to herbicide residual with no plot reaching 50% density by June.

Clearly, the fall strategy has a trade-off, in that dithiopyr and oxadiazon will allow turf establishment in the spring following preemergence application in the fall but do not provide acceptable season-long crabgrass control. In contrast, the dinitroaniline materials provide acceptable season-long control, but severely limit the success of spring seedings.

Postemergence Crabgrass Control

Crabgrass Growth and Development. Studies have indicated that crabgrass plants in more highly disturbed turf with low density, reach a size more difficult to manage (greater than two tillers) more rapidly. In contrast, the plants that emerge in undisturbed turf need almost 7 weeks to reach the two tiller size. This would permit the turf manager to observe crab-

Table 1. Preemergence Herbicide Effectiveness				
Herbicide	**Crabgrass Control** 4-6 weeks	**Crabgrass Control** 12-15 weeks	**Dicot Control**	**Injury/Safety**
Bensulide (Betasan)	E	G	F	Safe on *Poa annua*
Oxadiazon (Ronstar)	E	E	E	Injures annual bluegrass, bentgrass, red fescue
Siduron (Tupersan)	F	P	F	Safe at seeding
Bensulide & Oxadiazon (Scott's)	E	E	E	Safe on benrgrass fairways
Dithiopyr (Dimension)	E	E	G	Safe on bentgrass; pre/EPO activity. Not on LI
Pendimethalin (Halts)	E	E	E	Injures close mown bentgrass & *Poa annua*
Benefin (Balan)	E	F	P	Injures close mown bentgrass & *Poa annua*
Trifluralin (Treflan)	E	F	P	Injures close mown bentgrass & *Poa annua*
Benefin & Trifluralin (Team)	E	VG	P	Injures close mown bentgrass & *Poa annua*
Prodiamine (Barricade)	E	E	E	Injures close mown bentgrass & *Poa annua*
DCPA (Dacthal)	E	P	F	Injures annual bluegrass, bentgrass, red fescue
Isoxaben (Gallery)	G	G	EE	Not in NY

grass pressure following germination then determine the appropriate postemergence strategy over a longer period.

When reviewing the ecological aspects of infestations of summer annual weeds that invade exclusively from seed, an annual measure of contributions to the seedbank is vital. Undisturbed turf reduced crabgrass seed production in the plants that survived as compared to disturbed plots. For example, the slightly disturbed turf produced 5 times the amount of seed as the undisturbed plots. This is a significant long term management strategy. If crabgrass thresholds could be increased as part of an IPM program, there would be a net depletion of the seedbank in dense turf stands.

IPM Approach. Monitoring weed populations is not widely practiced in the turfgrass industry, mostly because adequate turfgrass density restricts weed invasion, but also as a result of the widespread use of preemergence herbicides. In addition, aesthetic thresholds on high value turf areas and functional thresholds on golf putting greens and sports fields are essentially zero. By the time crabgrass is visible it has exceeded threshold levels or it might be too large a plant to effectively control. Therefore, historical information from the previous fall, using crabgrass skeletons will provide insight into where infestations might occur, or as mentioned previously, areas where turf is consistently thin could be more closely monitored.

Certainly, the time required for the level of monitoring for a successful reduction in pesticide use maybe prohibitive to traditional lawn care companies that visit the site 4 to 5 times per year. However, golf superintendents, sports field and grounds managers at the site each day, could implement a population based approach by monitoring at appropriate times.

Postemergence Herbicides. Effective control of emerged crabgrass plants is highly dependent on growth stage and environmental conditions, independent of the herbicide. MSMA, is a contact-action herbicide, in that it is absorbed, but not transported throughout the plants vascular system, the vegetation is contacted but not killed. As a result, several applications are required for plants greater than 1 tiller.

Fenoxaprop (Acclaim or Acclaim Extra) is effective on crabgrass plants from emergence to the 3 tiller stage. Larger plants may need several applications and the crabgrass may take 14 to 21 days before elimination. Additionally, the effectiveness of fenoxaprop is reduced when plants are not actively growing in response to drought stress. Research has indicated that moisture stress must be alleviated within 48 hours of fenoxaprop application for effective control.

A herbicide that has been investigated for many years, but only recently labeled in many parts of the country (not labeled for use in NY), quinchlorac (Drive) is effective on large crabgrass plants (greater than 3 tillers). In fact, the use of quinchlorac in an IPM approach could be an integral part to reducing or eliminating the use of preemergence herbicides. Specifically, crabgrass populations could be monitored and treated

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Crabgrass

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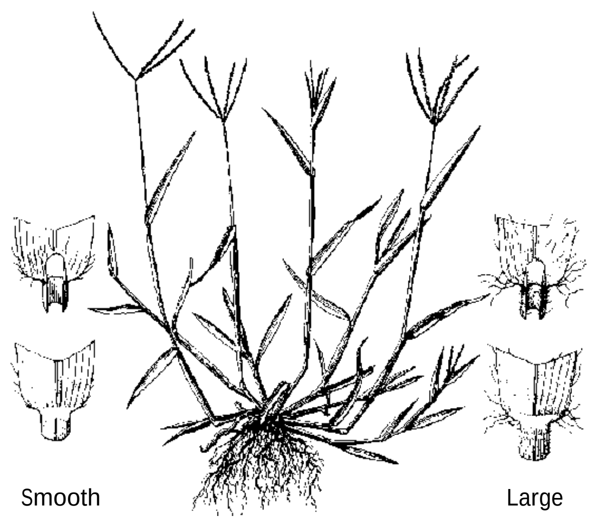
The use of quinchlorac (not in NY) in an IPM approach could be an integral part to reducing or eliminating the use of preemergence herbicides. Specifically, crabgrass populations could be monitored and treated postemergence regardless of growth stage.

postemergence regardless of growth stage. If this is performed before seedhead formation, the result will be a net depletion of the seedbank. Interestingly, quinchlorac is also very effective on white clover and *Veronica filiformis*.

An Integrated Approach to Crabgrass Control.

Crabgrass invasion reduces the visual and functional quality of a turf. In fact, crabgrass infested areas that leave bare soil exposed to spring rains may actually compromise water quality where there is significant amounts of paved surfaces. The successful implementation of IPM programs based on reasonable thresholds poses a unique challenge for managers, lawn care providers and do-it-yourselfers. The widespread use of preemergence herbicides in most instances insures a weed-free turf, regardless of whether or not it is needed to provide that weed-free turf.

Still, while an additional load on the environment, research indicates that when used properly, the application of these materials do not pose water quality concerns and have low environmental toxicity. However, a more integrated approach that sets reasonable thresholds, utilizes ecological information as the basis for management, monitors populations and implements effective control strategies is likely to reduce pesticide use.



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First and foremost maintain turfgrass density. If the turf is thin implement a spring based fertilizer program or begin applying CGM. Additionally, introduce rapidly germinating turfgrass species such as ryegrass to compete with crabgrass seedlings for resources. This improved density alone in the first year can provide 30 to 80% control, depending on how thin the turf was to start.

In areas where crabgrass infestation is likely, along paved surfaces, a preemergence strategy might be warranted where competition from turf might be reduced. However, one could argue that crabgrass and other annual weeds invade these areas and stabilize the soil; a key aspect of urban water quality. Nevertheless, the visual quality expectations of most turf areas will not allow this level of infestation.

An integrated approach would be to observe the emergent population, then utilize a timely postemergence herbicide to control existing plants in combination with a preemergence herbicide to prevent further infestation. This strategy will reduce the influence of preemergence herbicides on turfgrass rooting which will have slowed in response to environmental conditions and reduce the amount of preemergence herbicide applied, by targeting areas known to be infested. However, if fall seeding is planned consider using a preemergence herbicide with a shorter residual to reduce the influence on turf seedling development.

Finally, managing annual weeds, such as crabgrass, that infest exclusively from the seedbank can be challenging on highly disturbed turf areas. However, annual weeds do provide an opportunity to utilize ecological information to the advantage of the turf. Turf density does reduce crabgrass infestations, however, not always below threshold levels. If density can be maintained until emerged seedlings are not able to produce viable seed, the seedbank will be depleted. This will require adjustments in threshold levels. Furthermore, the impact of the annual use of preemergence herbicides on the crabgrass seedbank must be better understood to justify the continuance of this indiscriminate practice. A crabgrass management program must be viewed in the larger context of environmental quality and realistic expectations of turfgrass quality. As such, society will more completely grow to understand the role of a well-maintained turf in an urban environment and demand a more integrated approach.

Frank S. Rossi
Cornell University Turfgrass Team