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Lawns and the Summer 2012 Drought/Heat Crisis: Now What?

PURDUE AGRONOMY

http://www.agry.purdue.edu/turf/

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The summer of 2012 has been one of the driest and hottest in decades. It has been characterized by a persistent drought, relentless heat and very high daily evaporation rates. As of 31 July almost 25% of Indiana was classified as experiencing "Exceptional" drought conditions (Figure 1). These conditions have put unprecedented stress on turf areas throughout the region and made this season one of the most challenging for growing turf (Figures 2 A-D). In addition, the summer stress of 2012 follows on the heels of two consecutive years of moderate autumn drought conditions. Drought injury is an additive problem. Many lawns had not fully recovered from prior injury/thinning entering this current period of severe drought/heat stress, and therefore were more prone to summer decline.

Most lawns in our region primarily contain cool-season grasses that grow best when the air temperatures are between ≈ 60 and 80 °F. Well cared for mature grasses can "tolerate" extended drought periods. When severe drought is coupled with temperatures above optimum, however, this imposes an

Figure 1. Drought severity in Indiana as of 31 July, 2012.

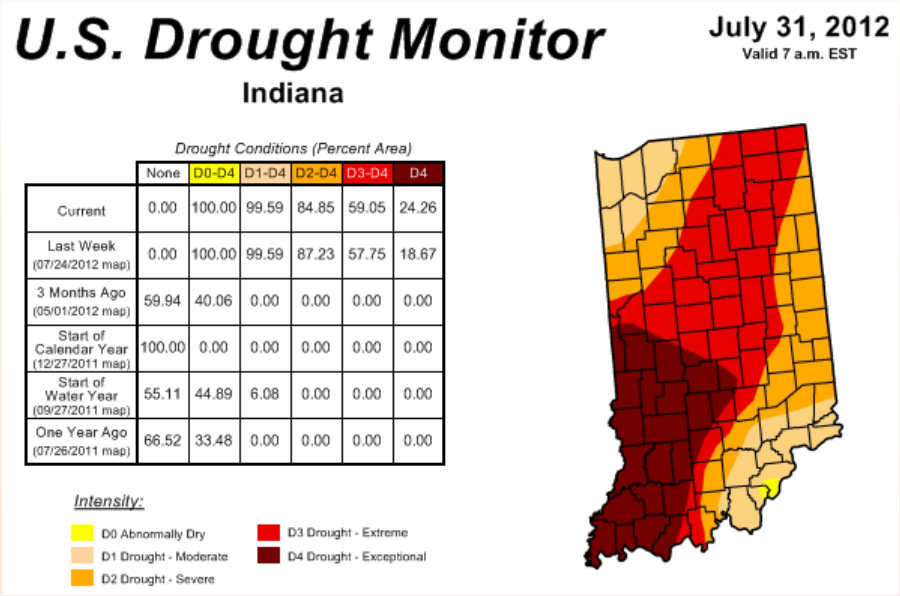

Figure 2 A. A newly planted home-lawn under drought stress with green patches of turf-type tall fescue.

Fig 2 B. A severely drought stressed lawn experiencing weed encroachment on a site that had prior stand density problems.

Figure 2C. A uniformly drought stressed lawn containing primarily bunch-type species like perennial ryegrass.

Figure 2 D. Lawn with thinning from summer stress and traffic damage from mowing when excessively dry.

additional physiological stress which can be lethal. In Southern Indiana some lawns contain warm-season grasses like zoysiagrass and bermudagrass which thrive with air temperatures > 80 °F and are more drought tolerant than cool-season grasses. This summer even these species have sustained injury.

One can only speculate why some lawns have fared better than others (e.g. superior genetics, higher mowing heights, proper seasonal fertilization, better soil conditions, etc.) but exact reasons remain unclear. One major factor affecting survival though has been supplemental irrigation or occasional rainfall. Water is required to make plant foods (carbohydrates) during photosynthesis, move nutrients and other metabolic compounds inside the plant and for evaporative cooling. Thus, properly managed (reasonable mowing heights, proper fertilization, etc.) lawns and those receiving "some" water prior to the onset of severe stress have survived better (Figure 3). This is most likely due to more reserve carbohydrates, deeper roots and the turf's ability to cool itself.

At this point it does not matter why a turf may have declined, but most lawns are weak entering August to the extent they are more prone to both biological stresses (fungi, insects, etc.) and mechanical damage (traffic). In short, they are more vulnerable to everything and anything that can cause injury. The goal of this guide is to provide an overview of some best management practices to promote recovery. What follows are "common-sense" agronomic suggestions to promote a

Figure 3. A drought stressed non supplementally irrigated lawn (left) compared to a supplementally irrigated lawn (right).

Figure 4. Patches of turf-type tall fescue surviving in an otherwise severely drought stressed lawn turf.

Figure 5. Roughstalk bluegrass plants from a patch that appeard dormant/dead. Upon close inspection green leaf tissue still exists and this undesirable lawn species may fully recover.

vigorous, healthy turf, favor the desirable turfgrass species and build a store of carbohydrates that will prepare lawns for future uncertain environmental conditions.

Responses to Frequently Asked Questions

Is my lawn dead? Will it recover? Most unirrigated lawns have a tan/brown and "crunchy" appearance or in other words, they appear "dead". Look for signs of new growth near the soil surface (e.g. the crown or the location of most new turf growth). If the turf is not recovering even after recent rainfall or regular supplemental irrigation then there is a good chance large portions could be dead. This may be particularly true for stands consisting of weaker bunch-type grasses like perennial ryegrass or annual bluegrass. Kentucky bluegrass has underground stems called "rhizomes" which aid in drought survival. New growth will be slow from these structures but rhizome growth will allow it to spread into thinned areas. By contrast, areas containing fescues continue to be green and slowly growing (Figure 4). These areas will likely begin growth more quickly than bluegrass when favorable weather returns. Other areas containing large patches of undesirable grasses like roughstalk bluegrass may appear dead but will likely recover later this autumn (Figure 5). If an area has died, unfortunately we cannot say for certain "why" (e.g. extreme drought/heat, various pests, excess traffic, etc.) but the next important step is to develop a sensible recovery plan. This recovery process will require patience and persistence due to the extreme environmental stresses turfgrasses have endured.

What factors affect how long lawns can survive without water? It seems like a simple question, but it is not. There are many variables including turfgrass species, the specific cultivar/variety, rooting depth, soil-type/texture and turf age. Regardless of species, two major factors are soil conditions and rooting depth. For example, turf-type tall fescue or perennial ryegrass maintained at 3" will generally have a deeper root system and better stress tolerance than a thatchy Kentucky bluegrass. Lawns grown on extremely sandy sites, like those in Northeast Indiana, will be injured more severely than those on loamy or high clay content soils. This is due to differences in their soil water holding capacities or the

reservoir of available water. Seeded or sodded areas that are < 2 yrs old have immature root systems that do not withstand severe drought very well.

How do turfgrasses survive dormancy/extreme drought? Turfgrasses store carbohydrates from photosynthesis in various stems. These help the plant cope with weather extremes and aid in recovery. Lawn species like Kentucky bluegrass possess underground stems called "rhizomes" which enable it to survive drought for long periods (> 4-8 weeks). The primary survival mechanism for Kentucky bluegrass is for the plant to cease growth. When rainfall returns bluegrass will emerge from dormancy and resume growth. Tall fescue and perennial ryegrass respond differently by trying to maintain green growth to avoid dormancy. Tall fescue and ryegrass may also possess a deeper more extensive root system than Kentucky bluegrass and better initial stress tolerance. All of these mechanisms, dormancy, deep rooting, etc. provide the turf chances to best utilize soil moisture and prolong the need for irrigation or rainfall. Although desirable turfgrasses may "survive" extended droughts, the turf canopy will still lose density and less pleasing but more drought tolerant perennial grassy weeds like quackgrass, nimblewill, common bermudagrass or dallisgrass may expand (Figure 6). These grasses may eventually take over the lawn if management practices to promote the desirable grasses are not implemented.

What Do I Do Now? How Can I Help My Lawn Recover?

Recovery from this severe summer will require patience and a coordinated effort in implementing the best cultural management practices.

Fertilization: Existing turf recovery and new seedlings will require a steady supply of available nutrients, supplied as fertilizer. It is extremely important that sufficient nutrients for growth are readily available to take advantage of upcoming cooler, more favorable growing conditions. *Do not wait to start the feeding process!* The clock is ticking and as day length begins to steadily decrease and temperatures cool, turf growth will slow. Recovery fertilization will likely focus on supplying nitrogen (N), which is the nutrient needed by the plant

Figure 6. A drought stressed lawn with minor traffic injury from mowing and an area of a thriving warm-season perennial grassy weed, dallisgrass (foreground).

in the greatest amount and often most limiting to growth and development. A proper strategy should promote controlled, steady growth and not force rapid flushes of lush, succulent tissue. A suggested total target N amount for a lawn which has suffered serious turf thinning is ≈ 3-4 # of actual N/1000 ft^2 this autumn or ≈ 1 # of actual N/1000 ft^2 per growing month. Depending upon application rate and frequency, controlled release fertilizers (e.g. coated products, etc.) are likely the best choice when individual N applications are > ½ # N 1000 ft^2 in August and early September. Although readily soluble N-sources like urea 46-0-0 may appear to make more economic sense, if this fertilizer is not immediately watered into the soil significant gaseous N losses may occur from volatilization and reduce N efficiency. *Remember*: apply no more than 1 pound of water soluble N/1000 ft^2 in any single application and if possible split 1.0 pound N applications into two ½ pound N/1000 ft^2 doses about 14-21 days apart. Continue this moderate (e.g. ½ pound N apps.) and steady feeding program through early November. More aggressive fertilization (> ½ pound N/1000 ft^2 for primarily water soluble based sources like urea) can resume when consistently cool autumn temperatures arrive (e.g. mid-Sept through mid-November). Fertilizer applied during this time will result in maximum carbohydrate production/storage and increased stand density.

Remember all fertilizers are not the same. If you have previously applied a primarily slow or controlled release fertilizer (e.g. coated fertilizers, methylene urea or

natural organics) earlier this summer and the site has not received rainfall nor supplemental irrigation, these nutrients are likely still in place and ready for plant use. By contrast, turf on irrigated sites have likely used these nutrients and a traditional fertilizer program can be followed. With the potential for additional hot and dry conditions, choose your fertilizer source carefully. High rates of predominately water soluble N-sources may result in leaf tip-burn.

Similar monthly fertilizer strategies can also be used for warm-season turfgrasses like zoysiagrass and bermudagrass. Once these grasses have been hydrated and active growth resumes, similar rates/N-sources can be used but fertilization should cease around the end of September prior to frost.

Maximizing fertilizer program effectiveness: If the soil has not been tested in the last 3 years, test it now. This will identify any potential nutrient deficiencies, which may limit recovery. A list of regional soil testing laboratories is provided at the end of this document. Only apply nutrients that are needed. If a soil test indicates no phosphorus is required, use zero phosphorus products (e.g. 29-0-10) and NEVER apply fertilizer to surface waters. "Starter" fertilizers (e.g. 24-24-4) containing phosphorus are still recommended for new seedings. If granular fertilizer prills are applied to hardscape (driveways, sidewalks, etc.) be sure these nutrients are returned to the turf. A broom or blower may be helpful. The Purdue fertilizer calculator link at the end of this document can help determine exact fertilizer needs based on the product's analysis. Additional suggestions: for small turf areas if a landowner wants to be part of the recovery process, a number of commercially available "hose-end" liquid feeding products may be helpful. These products deliver small amounts of nutrients and the ever-important water that will aid in recovery.

Irrigation: Active growth and photosynthesis requires the availability of water. The traditional recommendation for supplemental lawn irrigation is to apply water "deeply and infrequently". Another way to interpret this is to water to the depth of the root system, which varies seasonally. Where lawns can be watered, keep the surface of the soil moist but not wet! Allow for periodic drying between irrigation events. For mature turfgrass areas, ideally apply irrigation during the early morning hours (e.g. 4-8 am) to maximize application uniformity and minimize evaporation.

The potential for further extended summer drought/heat stress will likely continue through early September. Many lawns have not been supplementally irrigated all summer and remain dormant. A dormancy watering strategy is good if you do not plan to regularly supplement rainfall. The dormancy watering strategy should involve only watering enough to keep some moisture in the growing points, like the crown. Research in dormancy watering practices is unfortunately limited but there is some evidence that ¼ to ½ inch every 14 days is sufficient to keep Kentucky bluegrass growing points hydrated. As sufficient rain has returned to the region many lawns have returned to their "green and growing" conditions. Supplemental irrigation is advisable during short dry periods to maintain active growth and promote recovery. Realize the process of going into and emerging from dormancy is physiologically stressful. Each time the turf emerges from dormancy it uses stored energy reserves. Carbohydrates are replenished during photosynthesis and if the plant goes dormant prior to making enough carbohydrates it may be further weakened and recovery is lessened.

Shortly after the Labor Day holiday or about the time when more consistently cooler and ideal weather for

Figure 7. Where an automatic in-ground irrigation systems is not available areas may need to be prioritized (e.g. highly visible front lawns) focusing supplemental watering efforts on recovery.

cool-season grass growth occurs, it is very important to keep the soil hydrated so that recovering turfgrasses can take full advantage of the optimum growing conditions and maximize carbohydrate production and storage. If sufficient rainfall has not returned and a comprehensive "in-ground" sprinkler system does not exist, it may be necessary to prioritize lawn areas and focus water resources on highly visible (e.g. front lawns) or the most damaged areas (Figure 7).

Mowing: A suggested all purpose mowing height for cool-season lawns is about 3". This height provides plenty of leaf tissue for photosynthesis, promotes a deep root system and allows for less frequent mowing. Caution should be used when mowing severely drought stressed sites because heavy equipment may damage unhydrated leaf tissues. To minimize traffic injury, reduce mowing frequency and use care when turning machinery on drought stressed turf. Although the lawn canopy may be thin and it might be difficult to see where you have mown, DO NOT significantly lower mowing heights or scalp the turf < 2" as this removes potential leaf tissue vital to photosynthesis and may negatively affect future rooting.

The soil environment: Turfgrasses with a deep, extensive root system are less stress prone and more likely to survive drought. Optimum rooting occurs in soils that possess an even balance of aeration/drainage and moisture holding pore space. Many urban soils are often severely compacted and/or sealed at the surface making them less able to absorb water/rainfall and also preventing oxygen from entering. Furthermore, many urban soils are shallow and contain substantial quantities of construction debris, stones and gravel. These conditions and objects will impair optimum root development and affect drought tolerance. Using core aeration equipment to relieve compaction and reduce thatch can help but this practice is difficult in hard, dry soil. Soil coring will be more successful in moist, not WET, soil. For poorly structured soils a regular program combining core aeration with organic matter (e.g. compost, etc.) additions may improve the soil physical properties and hence rooting. Note: irrigation practices (e.g. overwatering) or conditions that result in saturated soils (e.g. poor internal drainage) will be detrimental to rooting. Properly timed seasonal fertilization will also promote root growth and development.

Traffic management: Excessive traffic from machinery or foot traffic causes compaction and results in mechanical abrasion which may injure or kill turf. Minimize traffic on highly stressed turf and any new seedings. Fewer mowing events and directional signage/ barriers for traffic patterns may help spread wear.

Seeding to Promote Recovery?

Overseed or renovate? Where cool-season lawns are cultivated in Southern States, autumn overseeding is a routine maintenance practice to maintain stand density following summer stress. For lawns in our region that have thinned in 2012, overseeding to increase density should strongly be considered. Additionally, if you have experienced persistent problems with the existing turf during the last several severe summers it may be time to consider switching species or planting more stress tolerant varieties for your location, intended use and management inputs. A turf species selector link for the state of Indiana is located at the end of this document.

Should I plant now? The optimum window for planting cool-season grasses in this region begins around 15 August. Regardless of whether you can supply irrigation or not, it is advisable to begin overseeding immediately. Even if the turf is dry, the seed will filter down into the canopy and remain in place within the existing stubble and be ready to germinate and emerge once moisture is available.

Besides water, the most important factor affecting seedling establishment success is seed-to-soil contact. In many cases soil cultivation (core aeration or vertical mowing/power-raking) may not be feasible prior to seeding due to the dry, hard ground. Ideally cultivation should occur prior to seeding but you can still seed now and cultivate in a few weeks if the seed has not emerged. Be aware that some spotty seedling emergence will likely occur. These areas can be quickly documented and additional small quantities of seed can be worked into those areas throughout the recovery process. Realize that periodic seeding for thin areas will be an ongoing process this autumn.

What species/cultivars and how much should I plant? One major advantage to overseeding is that newer grasses and cultivars can be introduced. These grasses have been developed to be more tolerant of environmental and pest stresses. Species like the fescues (tall and fineleaf) and perennial ryegrasses (annual ryegrass is NOT recommended) will emerge more quickly than Kentucky bluegrass. For most lawns, forage-type tall fescues like Kentucky-31 are NOT recommended. If Kentucky bluegrass is the preferred species, then it is even more important to begin the seeding process immediately. Be cautious with seeding rates, excess seed may result in rapid initial cover. Long term; however, seedlings may remain immature, mortality may be high, and a deep root system may not develop very quickly. Suggested seeding rates range from 1-2, 6-10 and 5-7 lbs/1000 ft^2, for Kentucky bluegrass, tall fescue and perennial ryegrass. A link to calculate your seed needs and costs is available at the end of this document.

Note: If you are reseeding immediately then you should expect some competition from weeds like crabgrass. Do not apply pre-emergence herbicides during this period. A post emergence herbicide like quinclorac or mesotrione can suppress crabgrass and aid in seedling establishment but for lawns with dense weeds and sparse turf you may need to consider a complete renovation. If you plan to completely renovate/"start over" and will be using a non-selective herbicide like glyphosate to eradicate all existing vegetation the area must be hydrated and actively growing prior to herbicide application to improve herbicide effectiveness. Failure to do so may result in the survival of undesirable plants (e.g. forage-type tall fescue, quackgrass, etc.). At least two glyphosate applications about 3-4 weeks apart are suggested for complete control of undesirable vegetation. Areas can be reseeded any time after the final glyphosate application. For more information on lawn renovation, see the link to "Lawn Improvement Programs" publication at the end of this document.

Post seeding care? Like the mature turf recovery process, practices that promote slow, steady growth are recommended. These include: keeping the soil surface moist but NOT WET, avoiding excess N which may result in increased disease, sensible fertilization, ≈ ½ # N every 2-3 weeks following emergence, and mowing the turf as tall as possible. The heat associated with late summer seeding often results in disease concerns, some seed is sold with a fungicide coating which can minimize seedling disease problems and improve establishment success.

What About Lawn Pests?

Weeds: Non-desirable plants will compete with lawn grasses for all resources (light, water, nutrients and space) critical to maximizing the recovery process. (Figures 8 - 9) During this late-summer period many of the actively growing weeds present, like crabgrass, are warm-season plants. During hot and dry conditions these plants are physiologically more competitive than cool-season lawn grasses. Furthermore, many of our traditional herbicides

Figure 8. Broadleaf and grassy weeds encroaching into a severely thinned lawn. These should be controlled to allow desirable turfgrasses a maximum competitive advantage.

Figure 9. Areas containing large weeds like broadleaf plantain should be sprayed to remove this weed to ensure fertilizer and water resourses are utilized by the desirable turfgrasses.

Figure 10. Sedges, annual grasses and viney broadleaf weeds should be controlled because they will limit recovery and seedling establishment.

Figure 11. White grubs can consume turfgrass roots, cause drought symptoms and slow recovery efforts. These insects should be controlled in late-summer.

can cause temporary injury when applied during extremely hot weather or to seedlings.

Weeds should be controlled as much as possible to allow the desirable grasses a maximum competitive advantage. For seedling weed control, consider the following options which are generally safer than traditional herbicides: quinclorac (Drive, Eject, QuinPro and others), carfentrazone (Quicksilver), quinclorac + carfentrazone (SquareOne), and mesotrione (Tenacity). Notes on when they can be used before seeding or after seedling emergence can be found on the herbicide label and summarized in Table 1. Drive and Tenacity will suppress mature crabgrass and some broadleaf weeds, while Quicksilver and SquareOne quickly suppresses many broadleaf weeds. Where sedges are present products containing halosulfuron can be used (Figure 10). It is not recommended for application to seedlings but small areas containing sedges could be spot treated. If large areas of perennial grasses like quackgrass, roughstalk bluegrass, and others are present these areas may require complete renovation. Links to the publications regarding perennial grassy weed control and information regarding weed control for professionals are listed at the end of this document.

Insects: Anticipate insect feeding and damage to be more problematic on weakened turf and be prepared to address white grubs, caterpillar insects like fall armyworms, black cutworms or sod webworms and potentially billbugs. Be on the look-out for bird feeding activity and be prepared to respond. White grub activity will be more concentrated in lush, green turf that had received supplemental irrigation. White grub identification and suppression information can be found in the publication listed at the end of this document. (Figure 11) If the soil is extremely dry delay insecticide applications as it is likely the insects are deep in the soil profile and the product will be less effective at this time.

Green turf "islands" in an otherwise drought stressed landscape may also attract caterpillars since they provide much needed green plants for feeding. Damage from caterpillars such as black cutworm, fall armyworm and sod webworms can be difficult to diagnose in drought stricken turf even though the overall impact of their feeding may be elevated by these stressful conditions. Application of surface insecticides to control caterpillars should therefore be limited to areas where there is clear evidence of feeding activity. Caterpillar damage to seedling turf is not likely since these insects rarely lay eggs in immature turf. Billbugs can actually thrive under dry conditions making damage difficult to notice until turf recovery begins. For billbugs, insecticide applications at this time of year will unfortunately have a minimal impact. Keep records of damaged areas and plan to treat these areas next spring.

Table 1. Label statements on the use of herbicides for weed control in areas to be renovated with cool-season turf or applied to cool-season turf seedlings. See label for full instructions.

Trade Name (product/A)	Common Name (lbs ai/A)	Label statements about applications before seeding	**Label statements for use over newly seeded turf**
Drive XLR8 (0.7 to 2 qts) Drive 75DF (0.33 to 1.0 oz) Quinclorac 75DF (0.33 to 1.0 oz) others	quinclorac (0.25 to 0.75)	Drive can be applied 7 days or greater prior to seeding cool-season turf or at seeding for tall fescue or Kentucky bluegrass. The use if Drive XLR8 before or after seeding or overseeding a turf area will not significantly interfere with turf seed germination and growth.	No adjuvant or additive should be used when Drive herbicide applications are made on newly emerged turf seedling until 28 days after emergence . See Table in label which includes notes on when to apply after emergence. This varies from species to species.
Quicksilver T&O (1.0 to 6.7 floz) Quicksilver (see label)	carfentrazone (see label)	Turf can be seeded or overseed one day following Quicksilver application.	Quicksilver T&Q can be applied to the following species of turfgrass at 7 days or more after emergence of seedling: creeping bentgrass, tall fescue, perennial ryegrass and Kentucky bluegrass.
SquareOne (8 to 18 oz)	carfentrazone + quinclorac (see label)	Areas treated with SquareOne Herbicide may be seeded or overseeded one day following application.	SquareOne can be applied to the following species of turfgrass at 7 days or more after emergence of seedling: creeping bentgrass, tall fescue, perennial ryegrass and Kentucky bluegrass.
Tenacity (4 to 8 floz)	mesotrione (0.125 to 0.25)	Can safely apply prior to seeding.	Wait until the newly germinated turfgrass has been mowed two times or four weeks after emergence (whichever is longer) before making a postemergence application. Tenacity may reduce the density of fine fescue seedings.

Figure 12. Lawns thinned by drought and heat stress will recover more slowly when they are competing with weeds and diseases that may be present.

Figure 13. Diseases like leaf rusts of slow growing turf may slow turf vigor and recovery efforts.

Diseases: Several diseases are more severe in slow-growing, drought/heat-stressed turf (e.g. leaf spots, dollar spot, rust, etc.) and if active will slow recovery efforts (Figures 12-13). Diseases are difficult to diagnose. Descriptions of symptoms and conditions that promote disease are available in the on-line series of Turfgrass Disease Profiles listed at the end of this document. Before taking any remedial action regarding a suspected disease, be sure to obtain an accurate diagnosis. Note: where ryegrass seed is used overseed thin turf areas, be on the look-out for gray leaf spot which can severely damage ryegrass seedlings at this time of year. In a few cases, fungicides can slow disease development and help accelerate turf recovery. Like most other pesticides, they are best applied by licensed professionals.

The best strategy to minimize disease incidence is promoting steady growth. Careful water management is a cornerstone practice and the soil should be kept moist but NOT WET. Allow the soil to dry between irrigation events and early morning (4-8 am) watering is recommended. Additionally, nitrogen fertilizer applications should not be so excessive that they promote lush, succulent growth. See the fertilization section for additional information.

Final Thoughts and What to Potentially Expect for the Next 9-12 Months

First, be realistic! Some areas have sustained serious losses in stand density and it is important to realize that there is no simple switch or magic potion that will instantly result in full turf recovery. Summer decline is a complex problem brought on by the combination of drought stress, extreme heat, various pests, mechanical injury, and other factors. It can be frustrating how quickly decline occurs and how slowly some areas recover, if at all!!!, even with the best cultural efforts. The recovery process will take time, patience and employing a "common sense" fundamental agronomic program (keeping the turf hydrated, sensible feeding and mowing practices). In addition, weed suppression, scouting for potential insects and diseases combined with overseeding and perhaps soil cultivation will all aid recovery and future turf survival. Remember, whatever cultural program you employ it should be flexible enough to adapt to the uncertainty of weather patterns in our region.

On a positive note, in just a few weeks we will be entering a period that cool-season turfgrasses grow best. Make sure to take full advantage of the weather during the entire months of September and October. Waiting to start the recovery process until late September when turfgrasses grow more slowly or worse next spring would

be a grave mistake. It makes sense for those that truly care about their lawns and landscapes to consider hiring professionals to aid in the recovery process. Professionals can keep up with correct application schedules, select appropriate fertilizers/seed, scout for pests and know how to best prepare your turf for future stresses.

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Helpful Web-link Resources:

Lawn Species Selector: http://www.agry.purdue.edu/turf/turfgrassSelectionTool/index.html

Fertilizer Needs Calculator: http://www.agry.purdue.edu/turf/fertilizerCalculator/index.html

Certified Soil Testing Laboratories: http://www3.ag.purdue.edu/agry/extension/Pages/soil-testing-labs.aspx

Seed Needs Calculator: http://www.agry.purdue.edu/turf/seedCalculator/index.html

Turf: Dead or Alive?: http://purdueturftips.blogspot.com/2011/08/turf-dead-or-alive.html

Lawn Improvement Programs: http://www.agry.purdue.edu/turf/pubs/ay-13.pdf

Turfgrass Weed Control for Professionals (AY-336): www.the-education-store.com

Identification and Control of Perennial Grassy Weeds: http://www.agry.purdue.edu/turf/pubs/AY-11.pdf

White Grub Pests of Indiana: http://extension.entm.purdue.edu/publications/E-259.pdf

Turfgrass Disease Profiles: http://www.agry.purdue.edu/turf/professional.html