Exchange of Science Between Turf & Field Crops: Commonalities Between Turf & Field Crops and Lessons

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Abstract

Concern for the environment and the global crisis on water is transforming the agricultural industry in the 21st century. Field crops have led the technology revolution and turfgrasses have benefited from this pioneering revolution. The primary difference between the field crop and turfgrass arenas has been in scale of production and focus. Field crops target consistent and reliable yield of usable products while turfgrass performance involves cosmetic performance, playability, and human-impact challenges. Abiotic and biotic stress challenges are similar genetically, but differ in scope for mechanisms of resistance between field and turf crops. Much of the pesticide and fertilizer use is interchangeable between the two cropping systems. Similar control strategies are involved, but sophistication in management is different. Turfgrasses require smaller equipment and are usually driven by height of cut. Field crops require larger equipment driven by large scale production and harvesting. The precision is similar but at different levels. The demands for recreational turf, green space, and land reclamation/stabilization will increase the use of grasses, and products to minimize the negative environmental impact will become more available. Interchangeable use of improving technology will continue for both field and turf crops, and contribute simultaneously to mankind and environmental sustainability.

Media summary

Environmental stewardship, water issues (availability of potable water for humans and use of alternative water for agriculture), and associated salinity challenges are changing the face of global agriculture.

Key Words

Abiotic stress, salinity, drought, shade, biotechnology

Introduction

Research on field crops has often preceded similar research on turfgrasses, and in many cases, turf science has pirated those results and re-adapted them to turf uses. Turfgrass science began a significant emergence into the scientific arena during the mid-1970s when J.B. Beard published his first major text on the subject (Beard 1976). Abiotic and biotic stress research has a long history with field crops and a shorter history with turfgrasses (Duncan and Carrow 1999, 2001). Biotechnology has a similar but more recent chronology and emergence between the two crops (Sticklen and Kenna 1998; Duncan 1997). Most of the marker technology developed with other grasses such as maize (*Zea* spp.), sorghum (*Sorghum* spp.), and sugarcane (*Saccharum* spp.) have been utilized in forages and turfgrasses (Duncan and Carrow 2001, Spangenberg 2001). Breeding and genetic texts have been dominated by field crops, including some forage grass species. Only recently has a similar text emerged that dealt solely with turfgrass biology, breeding, and genetics (Casler and Duncan 2003). The first text on turfgrass fertility has been recently published (Carrow, Waddington, Rieke 2001) after many years of transferring field crop technology into turf nutrient management protocols.

This scientific evolution between the two crops does not indicate that turfgrass research has been lacking during the last millennium. The demands for recreational turf and green space coupled with some additional funding earmarked for turfgrass research (U.S. Golf Association, Golf Course Superintendents Association of America, Turfgrass Producers International, state turf associations) has escalated publication of critical research results and has definitely brought increased awareness of parallel investigations between field and turf crops. The money expenditures have and will continue to favor the field crops because of food demands, but recreational and leisure time demands are enhancing the importance of turfgrass research for human needs and environmental sustainability. The global crisis involving water issues (quality, conservation) is changing the requirements for maintenance of turfgrasses.

Interplant Competition
The parallels between field crops and turfgrasses for interplant competition are similar. Both have utilized extensive research in eliminating, for the most part, competition from unwanted weedy species. Glyphosate and glufosinate are two chemicals that have been used extensively in both field crops and turfgrasses for weed control, mainly because of their broad spectrum of control and their short half life and minimal impact on the environment. Field crop use has mainly been in concert with gene manipulation of glyphosate and glufosinate (and similar herbicide chemistries) resistance and that biotechnology component is just now emerging in turfgrass programs involving creeping bentgrass (*Agrostis* spp.), fine fescues (*Festuca* spp.), and St. Augustinegrass (*Stenotaphrum* spp.). Glyphosate and glufosinate in turfgrass ecosystems have mainly been used for killing out old cultivars prior to renovation with new and improved cultivars as well as spot treatment of persistent weeds. The principle use of gene-manipulated glyphosate, glufosinate or similar chemistry resistance in turfgrasses is targeted to control invasions of Poa annua in greens and unwanted grassy species in other areas on golf courses. Many herbicides can be used interchangeably on grass crops in field crops and on turfgrasses, as long as labels allow such use. The major difference is herbicide quantity used, application rates, and its persistence on perennial-type turfgrasses versus 4-6 month field crops or perennial forage swards/fields. A major bio-engineering concern has been gene flow and intra-species cross-hybridization in turf seed production fields from transgenic creeping bentgrass (Wipff and Fricker 2001). Vegetatively propagated species have less outcrossing concern.

Field crops have used legumes and grasses together in conservation tillage or rotational programs to reduce soil erosion as well as supply nitrogen to grass crops. Legumes and grasses are often planted in rotation to break disease and insect cycles as an integrated pest management strategy. Turfgrasses utilize overseeding and interseeding between warm and cool season grasses to maintain a green playing surface during winter dormancy periods for the warm season species (Volterrani et al 2001). A prime example is hybrid bermudagrasses overseeded with *Poa trivalis* or perennial ryegrass (*Lolium* spp.). Intensive warm season grass management is required for transitioning into and out of the cool season grass overseed or interseed.

Dwarfness
Field crops and turfgrasses have a similar history on utilizing dwarfing genes, but differ in scale of plant effective dwarfness. Field crop dwarfing has been focused on height reductions to facilitate efficient and effective harvesting of end products and to avoid lodging and associated yield losses. Traditional breeding techniques such as intra- and inter-specific hybridization plus mutation breeding, and more recently molecular genetic manipulation, have been utilized to develop more dwarf-type plants. The concern with this breeding endeavor in field crops is to not sacrifice yield production significantly. Turfgrasses have utilized dwarfing characteristics for reduction in grass heights, especially on putting greens where speed of ball roll, trueness of ball roll, and mowing height ranges of 2-3 mm are required. Cool season grasses have been bred for finer leaf textures and shorter heights for enhancement of seed harvest/reduced lodging. Breeding programs with warm season grasses such as bermudagrasses (*Cynodon* spp.) have reduced internode length and leaf length/width beginning with the common bermudagrasses and genetically manipulating through intraspecific hybridization to achieve a finer leaf-textured (triploid hybrid) bermudagrass. Additional selection and reselection has lead to the recent evolution of the 'super-dwarf' class of hybrid bermudagrass cultivars such as 'Tifeagle', 'Champion', 'Miniverde', 'MS Supreme' and 'Floradwarf'. With the manmade evolution of these more dwarf ecotypes, turfgrass management programs have undergone major changes also, especially concerning equipment precision, fertility, irrigation scheduling, thatch control, topdressing, cultivation, and use of plant growth regulators. These management programs have shifted from the macro-management regimen of field crops to micro-management strategies for turfgrasses.

Changes in Grass Systems
Precision agriculture in grass management has taken a major step forward as turfgrasses have become increasingly important. Equipment in both field crops and turfgrasses has utilized computers more effectively, but micromanagement of turf ecosystems has emerged as both essential and critical for long term turfgrass performance. The large scale, bulky equipment of field crops has been supplanted by highly technical, smaller versions to manage 24-50 hectares of a highly dense grass surface compared to

thousands of hectares for field crops with less dense grass surfaces (the exception being forage grass swards/fields).. Turfgrasses utilize topdressers, core/tine aerators, hydrojects, greens mowers, fairway mowers, rough mowers, verticutters, groomers, brushes, and bunker rakes to manage areas as small as 3 m^2, and often not much larger - 3000 m^2. The focus is not on yield production, but on cosmetic appearance and grass surface performance. Irrigation equipment precision is critical on both crops, but field crops often require center pivot large scale systems while turfgrass systems require ground installed sprinkler systems. Computerization is driving the irrigation systems for both field crops and turfgrasses. Both field and turfgrass crops are challenged by effectiveness of the irrigation system and in water distribution efficiency. Field crop irrigation has progressed from sprinklers mounted high on the center pivot or lateral systems to one of drop nozzles located low in the canopy to decrease wind effects and maximize water applied per surface area. Turfgrass systems have decreased distance between sprinklers, have moved from 360 degree circular sprinklers common in field crops to 180 degree or less coverage, and increased the number of partial distribution sprinklers to promote water conservation and improve distribution efficiency. Turfgrass irrigation systems also utilize low-flow sprinklers to minimize wet areas and maximize water delivery to moisture challenged microenvironments on fairways, berms, surrounds, and mounds where moisture flux and evapotranspiration are normally high. Both field crop and turfgrass irrigation systems utilize chemigation or delivery of various chemicals, including fertilizers, growth regulators (PGRs), and other amendments such as hydrated lime or gypsum through the irrigation system. As water quality decreases, proper irrigation management becomes even more critical. Use of water treatment equipment such as acid injectors, sulfur dioxide generators, gypsum or lime injectors, and in extreme cases—reverse osmosis (RO) is being integrated into systems to ameliorate poor quality water before pumping onto both field crop and turfgrass systems. Turfgrass systems will become a primary utilizer of such equipment in the future as more alternative water resources, including effluent, are used as sole-source irrigation. Long term management of salts will be a critical concern (Carrow and Duncan 1998). In the case of RO, proper disposal of the discharge (concentrate) will be an environmental challenge.

Plant Growth Regulator use

Research into plant growth regulators has involved both field crops and turfgrasses. Again the focus in field crops for PGR use is tied to quality of product harvested and timing of harvest. In turfgrasses, the focus has been in reducing the mowing frequency of the grass, in reducing the clipping yield especially on greens (secondarily to minimize thatch buildup), in improving cosmetic appearance ie. seed head unattractiveness and suppression, and in regulating seed production in fields, particularly for indeterminate species. Rates, timing, and equipment precision are critical on both crops, but especially on turfgrasses when mowing heights are often less than 25 mm (Ferrell, Murphy and Duncan 2003). Typical PGRs and some of their trade names used in the turfgrass industry include trinexapac-ethyl (Primo), flurprimidol (Cutless), paclobutrazol (Trimmit), maleic hydrazide (Retard), and mefluidide (Embark).

Abiotic Stresses

A significant amount of research has been devoted to both field crops and turfgrasses concerning drought (Carrow 1996; Huang and Fu 2001; Nguyen et al 1997), while salinity research has been conducted more on field crops. Leaders in this latter area of research has been the National Salinity Lab at Riverside, CA, researchers in Israel and other middle East countries, and in other arid environments such as Australia (Katerji et al. 2000; Maas and Hoffman 1977). Only recently have turfgrass researchers devoted some research on salinity tolerance in turfgrasses (Carrow and Duncan 1998), with seashore paspalum emerging into the market place with a level of salinity resistance to withstand variable salt loads in soil and water, but encompassing turf quality attributes that make it competitive with other warm season grasses (Duncan and Carrow 2000, 2001). Private companies (Rose-Fricker and Wipff 2001) are shifting a portion of their turfgrass breeding programs to improving inherent salinity tolerance in cool season species because of an emerging global problem with water quality and availability. The one deficiency involving screening and evaluation of salinity responses in both field and turfgrass crops has been a standardized screening protocol across plant species (Isla et al. 1998: Lee 2000).

Turfgrass programs have devoted extensive research into low light intensity (reduced light quality from smog, fog, persistently cloudy conditions) (Jiang, Carrow and Duncan 2003; Jiang, Duncan and Carrow 2004) and tree shade (Van Huylenbroeck and Van Bockstaele 2001), while that objective is generally not a priority on field crops with 3-6 month growing seasons or in forage pasture/sward situations. Indirect and direct high temperature (Downs et al 1998; Heckathorn et al 1998) (for cool season grasses) and low temperature (for warm season grasses) (Anderson, Taliaferro and Martin 1993; Cardona, Duncan and Lindstrom 1997; Cyril et al 2002; Palta and Simon 1993) responses in perennial turfgrasses with variable mowing heights are a priority, while in field crops, it depends on the crop (Levitt 1980). Tolerance to the acid soil complex has received extensive research in field crops and less in turfgrasses (Duncan 2000; Foy 1988; Liu 2001). Acid sulfate problems have received major attention in Australia and other isolated areas of the world. Alkalinity problems have persisted normally in arid or semi-arid regions and iron deficiency stress has been a detriment primarily to field crops and secondarily to turfgrasses, with a significant difference in response to iron efficiency among C3 and C4 plants. (Duncan 1994, Clark and Goss 1986; Romheld 1991). Low oxygen or waterlogging (hypoxia) tolerance has received more consideration in field crops, especially the cereal grains (Huang and Johnson 1995; Huang et al 1994; Justin and Armstrong 1987), than in turfgrasses (Li et al 2001). Nutrient deficiencies and toxicity research has been devoted primarily to field crops and only minimally on turfgrasses (Baligar and Duncan 1990; Clark and Duncan 1991; Carrow, Waddington and Rieke 2001; Duncan and Carrow 1999). More research on high soil strength/traffic/compaction has been done on turfgrasses (Carrow et al 2001; Shearman et al 2001; Trenholm, Duncan and Carrow 1999; Trenholm, Carrow and Duncan 2000; Wiecko, Carrow and Karnok 1993) than on field crops due to extensive and frequent end-use under perennial turf conditions. Equipment to handle these cultivation events on turfgrasses include aerators, vertidrains, verticutters, hydrojects—all of which are smaller in scale than comparable field crop units.

The grass-fungus symbiotic association can enhance abiotic stress tolerance in cool-season grasses (Bacon 1993; Bacon et al 1997; Schardl and Phillips 1997). Endophyte-infected grasses acclimate to extreme environmental stresses quickly, recover from stress conditions rapidly, and are more aggressive, and thus resist biotic challenges better than noninfected grasses (Richardson et al. 1998). Similar parallels have been found in perennial forage grass swards.

Summarizing abiotic stress comparisons on field crops and turf systems as areas of concern, the perception might exist that turfgrasses can be subjected to greater degrees of drought and salinity than field crops before a measurable effect is visible on the turf and that these levels would reduce crop yields to zero. The two systems cannot sensibly be compared, since the priorities are different (overall yield versus playability/cosmetic appearance/traffic or number of rounds of golf/sports games over time) and other than forage crops, the turf systems are perennial in nature and because of the level of intensive management required to meet the expectations, prolonged or even short duration drought and salinity stresses can significantly impact overall performance. Neither system can sustain productivity when the stresses overwhelm them.

Biotic stresses

Insecticides and fungicides were initially developed for field crop use. Companies expanded the labels to facilitate use on turfgrasses. In recent years, more specialized chemistry has been developed for turfgrasses and field crops that promotes integrated pest management strategies by incorporating systemic modes of action with specific insect or pathogen targets and moves somewhat away from the contact, broad spectrum pesticides. Examples include imidacloprid and halofenozide (insecticides) and azoxystrobin, trifloxystrobin, pyraclostrobin (fungicides) that either target feeding insects and not beneficial predators (Braman et al. 2003; Cockfield and Potter 1983; Naranjo and Stimac 1985; Terry, Potter and Spicer 1993) or foster control systemically of similar acting fungi in turfgrass ecosystems by using low rates and a preventative cultural/chemical strategy for managing pathogen buildup. Contact pesticides are still utilized in both field and turf crops periodically to suppress rapidly increasing insect populations when needed and some natural pyrethroids are carefully being used for this strategy as opposed to the older organophosphate insecticides. The problem facing much of the industry is the phasing out of older pesticides because of their perceived negative impact on environmental stewardship. Examples include DDT, diazinon, dursban, nemacur, methyl bromide and other broad-spectrum chemicals.

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