TWCA testing protocol:
Seed was obtained from the TWCA in mid-August and both the Plots at Prairie Turfgrass Research Centre (PTRC) and University of Guelph Kemptville (UGK) were established (Figure 1). The rain out shelter was erected at the UGK site in August due to some delays regarding building permits that were not fore seen as other TWCA cooperators did not run into this regulation (Figure 1).

In order to assure optimum trial conditions plots will be weeded and overseeded in the spring and to create a dense stand of each cultivar, and we anticipate the TWCA drought protocol to move forward as scheduled in the 2014 growing season. The drought study will begin in mid-June at UGK and in mid-July at PTRC.

Depth By Irrigation Trial for Establishment:

The delay in the rainout shelter necessarily delayed the establishment trials until 2014 as with the rainy weather in 2013 did not allow for a irrigation trial to be conducted without a rainout shelter. In addition the drought tolerant seed was not attained until August. The size of the shelter constructed at UGK is large enough to accommodate both the TWCA trial and multiple establishment trials in the coming growing season.

ET and Crop Coefficient Research:

This work is scheduled to take place over the winter of 2013-2014. The student in charge of the project, Nancy Xiao, has already conducted growth chamber and greenhouse trials on creeping bentgrass water to refine the protocols and create preliminary data for the Kentucky bluegrass trials to take place in the larger growth chambers this winter. Ms. Xiao is presenting data on the affect of phosphorus fertility on water use and drought tolerance of different species from golf course putting greens this week at the Crop Science Society of America annual scientific meeting (Figure 2). An additional study on the impact of nitrogen fertility rate on water use of creeping bentgrass under well watered versus deficit irrigation was performed. These studies were performed on golf green grasses due to their small stature allowing them to be performed in smaller growth chambers and with a canopy attachment for the equipment.

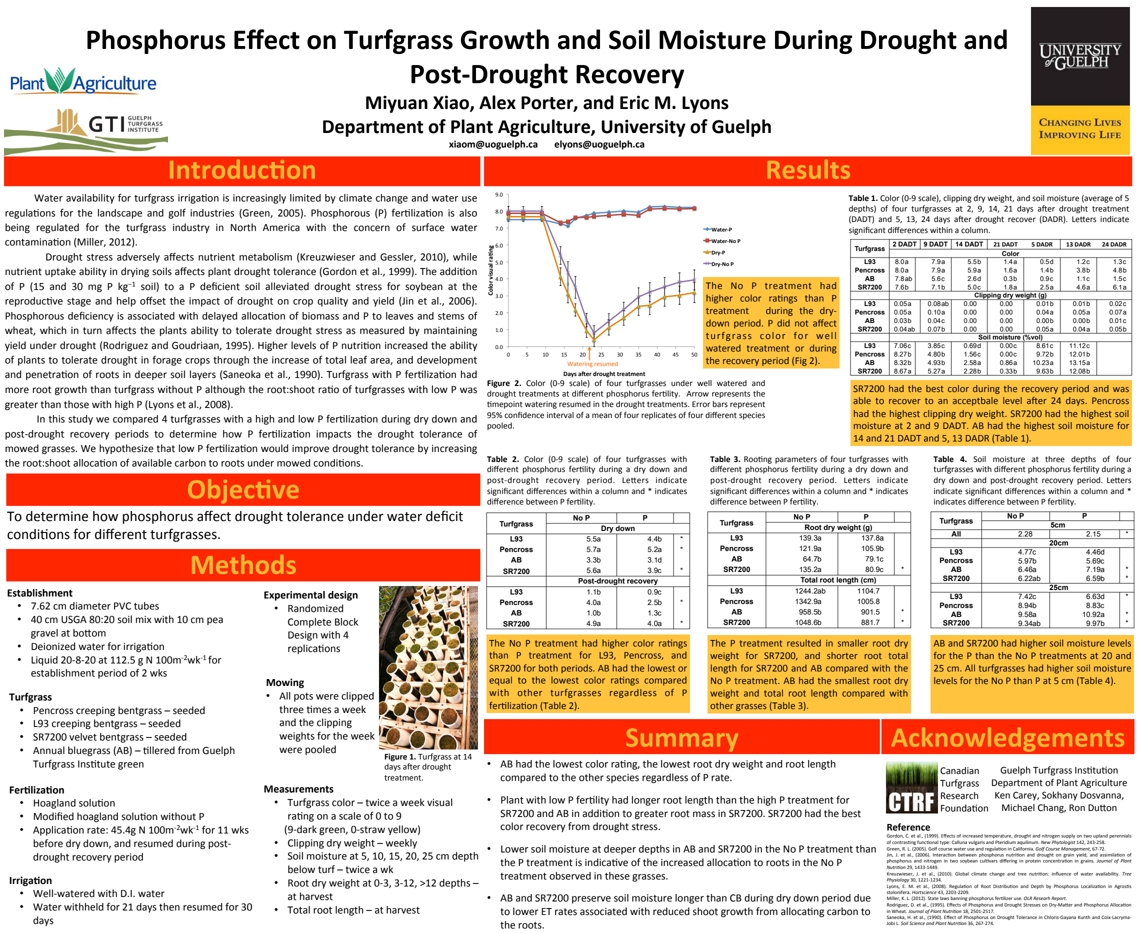
Evapotranspiration data at different vapor pressure deficits will be collected this winter in a series of greenhouse and growth chamber experiments and will be confirmed in the field comparing it to other species the following growing season.

Attached is a table of Milestones from the grant proposal. In addition the poster being presented at the CSSA meetings is also being attached as its content in pertinent to the grant.

The attached table has been colour coded with the activities of the grant to date.
Completed
Delayed
On Schedule For the Year
Added

PROJECT MILESTONES SUMMARY (list in point form)	
Year 1 – expected completion date: March 2014	
Objectives: Begin TWCA protocol testing following establishment of grasses Begin water needs during establishment testing at the GTI Determine ET crop coefficients and water use efficiency of Kentucky bluegrass cultivars	Estimated success measured by: Building of the rainout shelter Establishment of cultivar trial First frequency by depth irrigation trial for establishment completed Well watered and deficit irrigation water use efficiencies for Kentucky bluegrass calculated Nutrient effects on drought and water use in golf green species trials compeleted
Year 2 – expected completion date: March 2015	
Objectives: Continue TWCA protocols Traffic testing of cross section of cultivars under rainout shelter Complete water needs during establishment test Determine ET crop coefficients and water use efficiency of Tall Fescue and bentgrass cultivars Measure landscape functioning	Estimated success measured by: Inclusion of Canadian data in the TWCA reports Presentation of water needs testing at both industry and scientific conferences. Publication of crop coefficients for KBG, tall fescue and bentgrasses at different mowing heights Presentation of landscape data at landscape industry shows
Year 3 – expected completion date: March 2016	
Objectives: Continue TWCA Protocols Complete traffic resistance during deficit irrigation of cross section of cultivars from TWCA trials Publication of results Complete water use efficiency testing	Estimated success measured by: Joint publication of TWCA results with all regional testing sites Publication in both trade and scientific journals of water use efficiency and crop coefficients for turfgrasses

Figure 1. Seeding at the Prairie Turfgrass Research Centre in mid-August (Left). Plots (Univesity of Guelph) under the rainout shelter without canopy attached for the winter in Mid-October (Right).



Phosphorus Effect on Turfgrass Growth and Soil Moisture During Drought and Post-Drought Recovery

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Introduction

Water availability for turfgrass irrigation is increasingly limited by climate change and water use regulations for the landscape and golf industries (Green, 2005). Phosphorous (P) fertilization is also being regulated for the turfgrass industry in North America with the concern of surface water contamination (Miller, 2012).

Drought stress adversely affects nutrient metabolism (Kreuzwieser and Gessler, 2010), while nutrient uptake ability in drying soils affects plant drought tolerance (Gordon et al., 1999). The addition of P (15 and 30 mg P kg^{-1} soil) to a P deficient soil alleviated drought stress for soybean at the reproductive stage and help offset the impact of drought on crop quality and yield (Jin et al., 2006). Phosphorous deficiency is associated with delayed allocation of biomass and P to leaves and stems of wheat, which in turn affects the plants ability to tolerate drought stress as measured by maintaining yield under drought (Rodriguez and Goudriaan, 1995). Higher levels of P nutrition increased the ability of plants to tolerate drought in forage crops through the increase of total leaf area, and development and penetration of roots in deeper soil layers (Saneoka et al., 1990). Turfgrass with P fertilization had more root growth than turfgrass without P although the root:shoot ratio of turfgrasses with low P was greater than those with high P (Lyons et al., 2008).

In this study we compared 4 turfgrasses with a high and low P fertilization during dry down and post-drought recovery periods to determine how P fertilization impacts the drought tolerance of mowed grasses. We hypothesize that low P fertilization would improve drought tolerance by increasing the root:shoot allocation of available carbon to roots under mowed conditions.

Objective

To determine how phosphorus affect drought tolerance under water deficit conditions for different turfgrasses.

Methods

Establishment
- 7.62 cm diameter PVC tubes
- 40 cm USGA 80:20 soil mix with 10 cm pea gravel at bottom
- Deionized water for irrigation
- Liquid 20-8-20 at 112.5 g N $100m^{-2}wk^{-1}$ for establishment period of 2 wks

Turfgrass
- Pencross creeping bentgrass – seeded
- L93 creeping bentgrass – seeded
- SR7200 velvet bentgrass – seeded
- Annual bluegrass (AB) – tillered from Guelph Turfgrass Institute green

Fertilization
- Hoagland solution
- Modified hoagland solution without P
- Application rate: 45.4g N $100m^{-2}wk^{-1}$ for 11 wks before dry down, and resumed during post-drought recovery period

Irrigation
- Well-watered with D.I. water
- Water withheld for 21 days then resumed for 30 days

Experimental design
- Randomized Complete Block Design with 4 replications

Mowing
- All pots were clipped three times a week and the clipping weights for the week were pooled

Figure 1. Turfgrass at 14 days after drought treatment.

Measurements
- Turfgrass color – twice a week visual rating on a scale of 0 to 9 (9-dark green, 0-straw yellow)
- Clipping dry weight – weekly
- Soil moisture at 5, 10, 15, 20, 25 cm depth below turf – twice a wk
- Root dry weight at 0-3, 3-12, >12 depths – at harvest
- Total root length – at harvest

Results

Figure 2. Color (0-9 scale) of four turfgrasses under well watered and drought treatments at different phosphorus fertility. Arrow represents the timepoint watering resumed in the drought treatments. Error bars represent 95% confidence interval of a mean of four replicates of four different species pooled.

The No P treatment had higher color ratings than P treatment during the dry-down period. P did not affect turfgrass color for well watered treatment or during the recovery period (Fig 2).

Table 1. Color (0-9 scale), clipping dry weight, and soil moisture (average of 5 depths) of four turfgrasses at 2, 9, 14, 21 days after drought treatment (DADT) and 5, 13, 24 days after drought recover (DADR). Letters indicate significant differences within a column.

Turfgrass	2 DADT	9 DADT	14 DADT	21 DADT	5 DADR	13 DADR	24 DADR
	Color						
L93	8.0a	7.9a	5.5b	1.4a	0.5d	1.2c	1.3c
Pencross	8.0a	7.9a	5.9a	1.6a	1.4b	3.8b	4.8b
AB	7.8ab	5.6c	2.6d	0.3b	0.9c	1.1c	1.5c
SR7200	7.6b	7.1b	5.0c	1.8a	2.5a	4.6a	6.1a
	Clipping dry weight (g)						
L93	0.05a	0.08ab	0.00	0.00	0.01b	0.01b	0.02c
Pencross	0.05a	0.10a	0.00	0.00	0.04a	0.05a	0.07a
AB	0.03b	0.04c	0.00	0.00	0.00b	0.00b	0.01c
SR7200	0.04ab	0.07b	0.00	0.00	0.05a	0.04a	0.05b
	Soil moisture (%vol)						
L93	7.06c	3.85c	0.69d	0.00c	8.61c	11.12c	
Pencross	8.27b	4.80b	1.56c	0.00c	9.72b	12.01b	
AB	8.32b	4.93b	2.58a	0.86a	10.23a	13.15a	
SR7200	8.67a	5.27a	2.28b	0.33b	9.63b	12.08b	

SR7200 had the best color during the recovery period and was able to recover to an acceptbale level after 24 days. Pencross had the highest clipping dry weight. SR7200 had the highest soil moisture at 2 and 9 DADT. AB had the highest soil moisture for 14 and 21 DADT and 5, 13 DADR (Table 1).

Table 2. Color (0-9 scale) of four turfgrasses with different phosphorus fertility during a dry down and post-drought recovery period. Letters indicate significant differences within a column and * indicates difference between P fertility.

Turfgrass	No P	P	
	Dry down		
L93	5.5a	4.4b	*
Pencross	5.7a	5.2a	*
AB	3.3b	3.1d	
SR7200	5.6a	3.9c	*
	Post-drought recovery		
L93	1.1b	0.9c	
Pencross	4.0a	2.5b	*
AB	1.0b	1.3c	
SR7200	4.9a	4.0a	*

The No P treatment had higher color ratings than P treatment for L93, Pencross, and SR7200 for both periods. AB had the lowest or equal to the lowest color ratings compared with other turfgrasses regardless of P fertilization (Table 2).

Table 3. Rooting parameters of four turfgrasses with different phosphorus fertility during a dry down and post-drought recovery period. Letters indicate significant differences within a column and * indicates difference between P fertility.

Turfgrass	No P	P	
	Root dry weight (g)		
L93	139.3a	137.8a	
Pencross	121.9a	105.9b	
AB	64.7b	79.1c	
SR7200	135.2a	80.9c	*
	Total root length (cm)		
L93	1244.2ab	1104.7	
Pencross	1342.9a	1005.8	
AB	958.5b	901.5	*
SR7200	1048.6b	881.7	*

The P treatment resulted in smaller root dry weight for SR7200, and shorter root total length for SR7200 and AB compared with the No P treatment. AB had the smallest root dry weight and total root length compared with other grasses (Table 3).

Table 4. Soil moisture at three depths of four turfgrasses with different phosphorus fertility during a dry down and post-drought recovery period. Letters indicate significant differences within a column and * indicates difference between P fertility.

Turfgrass	No P	P	
	5cm		
All	2.28	2.15	*
	20cm		
L93	4.77c	4.46d	
Pencross	5.97b	5.69c	
AB	6.46a	7.19a	*
SR7200	6.22ab	6.59b	*
	25cm		
L93	7.42c	6.63d	*
Pencross	8.94b	8.83c	
AB	9.58a	10.92a	*
SR7200	9.34ab	9.97b	*

AB and SR7200 had higher soil moisture levels for the P than the No P treatments at 20 and 25 cm. All turfgrasses had higher soil moisture levels for the No P than P at 5 cm (Table 4).

Summary

- AB had the lowest color rating, the lowest root dry weight and root length compared to the other species regardless of P rate.
- Plant with low P fertility had longer root length than the high P treatment for SR7200 and AB in addition to greater root mass in SR7200. SR7200 had the best color recovery from drought stress.
- Lower soil moisture at deeper depths in AB and SR7200 in the No P treatment than the P treatment is indicative of the increased allocation to roots in the No P treatment observed in these grasses.
- AB and SR7200 preserve soil moisture longer than CB during dry down period due to lower ET rates associated with reduced shoot growth from allocating carbon to the roots.

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Figure 2. A scaled down version of the poster being presented at the CSSA meeting this fall. Ful sized version of the poster is attached.