Chapter 2

Effects of Exogenous Fructose and Adjuvant Applications on Leaf Injury of Supina Bluegrass under Reduced Light Conditions.

ABSTRACT

Turfgrass management in reduced light conditions (<30% full sunlight) is difficult because turf growth is affected by a lack of sufficient light energy. In turn, plant carbohydrates are reduced, due to insufficient light inhibiting photosynthesis. To combat this problem, a simple study was initiated to investigate the potentials for exogenous fructose applications to the leaves of turfgrass growing under reduced conditions. Thus, the objective of this study was to determine whether a physiological response occurs with exogenous fructose applications to turfgrass grown under reduced light conditions. Fructose applied to supina bluegrass under reduced light conditions five times per week for eight consecutive weeks causes too much leaf injury unless the application rate is 1.25% weight per volume fructose at the 815-L ha^{-1} rate with 0.1% weight per volume Break Thru® adjuvant. Weekly fructose applications (one time per week) yielded acceptable levels of leaf tissue injury for the 1,2,4,6, and 8 times application rates. The 1x rate provided the least amount of leaf tissue injury while demonstrating positive physiological responses compared to the control.

INTRODUCTION

Turfgrass is used for athletics, recreation, aesthetics, and utility. Each of these situations requires turf to perform a different role in a different setting. As a result of this dynamic utilization, turfgrass is often managed under sub-optimal growing conditions. One such condition is shade (reduced light conditions; RLC). Turfgrass located in RLC makes up about 20-25% of all managed turfgrass (Beard, 1973).

Turfgrass management in RLC (<30% full sunlight) is difficult because turf growth is affected by a lack of sufficient light energy (Stier and Rogers, 2001). Light intensity can be reduced by as much as 95% from surrounding plant material, clouds, or other shading structures (Beard, 1973). As a result, the light quality that reaches the turf surface is altered, creating an environment non-conducive to normal plant growth and development (Wilson, 1997).

Plants need light energy from the sun for photosynthesis to provide energy for growth, development, and reproduction (Taiz and Zeiger, 1991).

$$Energy_{light} + 24H_2O + 12CO_2 \longrightarrow 12O_2 + C_{12}H_{24}O_{12} + 12H_2O$$

Photosynthesis is driven by the visible portion of the light spectrum (400 to 700 nm), called photosynthetically active radiation (PAR; Lawlor, 1987), and comprises up to 50% of the earth's direct radiation (Salisbury and Ross, 1992). When plant carbohydrates are limiting, often due to insufficient light from inhibited photosynthesis, exogenous applications of sugars have shown potential to become a management technique for turf under RLC (unpublished data).

Early research has focused on the potential for exogenous sugar applications to be taken up by a myriad of plant species. Exogenous sucrose applications (10% in solution) were found to cause an increase in the dry weight of tomato plants (*Lycopersicum esculentum* Mill., Went, 1944; Went and Carter, 1948). In addition, Berrie (1960) determined a greater increase in tomato dry weight with exogenous sucrose applications (10% in solution) particularly in conditions where carbohydrate synthesis is limited, and especially when respiration is proceeding rapidly and photosynthesis slowly.

Other exogenous sugar absorption research has looked at plant uptake using leaf disks. Weatherley (1954) attempted to determine that sucrose absorption was an active transport when the water was absorbed through passive absorption using *Atropa belladonna* leaf disks. However, under aerobic and anaerobic conditions, evidence for the active uptake of sucrose is far from conclusive. Using carrot leaf disks, Grant and Beevers (1963) determined the optimal absorption times and conditions for several sugars. The greatest time for sugar absorption for carrot leaf disks was when the disks were respiring. Glucose uptake also increased ten fold when temperatures increased from 3 – 25 °C. Finally, withholding oxygen depressed the uptake of glucose, fructose, galactose and xylose (Grant and Beevers, 1963).

Mixed results have been found when exogenous applications of sucrose have been applied to plants as a spray mixed with urea (46-0-0). Eaton and Ergle (1952) found that spraying the upper leaf surface of cotton plants (*Gossypium hirsutum* var. Missdel x Acala) daily through the fruiting period with

20% sucrose, 1% nitrogen (urea) and the two in combination failed to improve plant growth and resulted in significant decreases in the number of bolls that were set. In a related study, Alvim (1960) determined that 10% sucrose and gibberellic acid were effective in protecting against injury by 2% urea spray on kidney bean plants (*Phaseolus vulgarus*). In addition, 10% sucrose sprays prevented a reduction in root dry weight as a result of gibberellic applications (Alvim, 1957).

In his research on clover (*Trifolium repens* L.), Van Schreven (1959) found that concentrations of 0.5 and 1% glucose stimulated nodule formation, both in the absence and in the presence of additional light. The highest numbers of nodules were formed in the presence of 2% glucose. Van Schreven also found that in the absence of additional light, nodulation was stimulated by 0.5, 1, and 2% sucrose and in the presence of additional light, by 0.5 and 1% sucrose. In both cases, 0.5% sucrose effected the greatest stimulation.

Exogenous sugar applications for plants in light and dark conditions have also been studied using soybean (*Glycine max*) seedlings. In the light, translocation of sucrose-C^{14} or glucose-C^{14} out of the treated leaf was very slow. Only 1% of the C^{14} from sucrose was translocated after 14 hours. In the dark, 10% of the C^{14} from glucose was translocated to all parts of the seedling in 3 hours. The bulk of the translocated C^{14} accumulated in the stem between the treated leaf and the root (Nelson and Gorham, 1957). Although, this research was conducted on a legume, the findings between the effects of sugar applications in the light versus dark support reason for studying the effects of sugar applications to turfgrass under reduced light conditions.

While most of the exogenous sugar application research has focused on non-grass (*Poacea*) crops, some research has looked at the grass family. Exogenous applications to corn (*Zea maize*) roots concluded that entering glucose and fructose mixed readily with the endogenous pools (Grant and Beevers, 1963). Sucrose uptake also appears to depend on extracellular hydrolysis in young corn roots (Giaquinta, *et al.*, 1983; Lin, *et al.*, 1984; Singh and MacLachlan, 1986). Unfortunately, because turfgrass grows in a contiguous community, the practicality of the applied sugars reaching the roots before interception from shoots, thatch, soil, insects and microbes is not likely.

Compositions incorporating a postemergence herbicide and a sugar, particularly fructose, as a potentiator of the herbicide against weeds without decreasing the tolerance of a crop plant to the herbicide has become a new method for killing weeds. Fructose in solution can be used for plant uptake at a range of 1.25 – 11% weight per volume, but 1.25% is best (Penner and Roggenbuck, 1999). Although this research is focusing on the use of exogenous fructose applications to increase the efficacy of herbicides, subsequent findings have determined that the leaves of both broadleaf and grassy weeds readily take up exogenous fructose applications. However, in order for the fructose to be readily absorbed an organosilicone is necessary as an adjuvant (Penner and Roggenbuck, 1999).

Based on the aforementioned findings with exogenous sugar applications to plants, an investigation was warranted to determine if exogenous sugar applications can counter the effects of reduced light conditions (shade) for turfgrass situations. In this experiment our objective was to determine whether a physiological response occurs with exogenous fructose applications to turfgrass grown under reduced light conditions. Fructose application frequencies and rates were investigated to determine the positive and/or negative physiological responses when applied to turfgrass under reduced light conditions.

MATERIALS AND METHODS

On 20 September 1999 portable plots were filled with a sand root zone and sodded with one year old supina bluegrass sod (*Poa supina* Schrad.; Manderley Sod Inc., Napean, ON, Canada) using six 1.2 x 1.2 m high-density polyethylene ITM modules (GreenTech, Inc., Richmond, VA, USA) at the Hancock Turfgrass Research Center (HTRC) at Michigan State University, East Lansing, MI, USA. Beginning in May 2000 – January 2001, the plots were fertilized two times per month at 0.5-g N m^{-2} $application^{-1}$ using Lebanon Country Club 18-3-18 fertilizer (Lebanon Seaboard Corp., Lebanon, PA, USA).

On 15 September 2000 the established ITM modules were moved inside the indoor research facility at the HTRC. The indoor research facility is a 400 m^2 air-supported structure constructed of Ultralux® (Chemical Fabrics Corporation, Buffalo, NY, USA), a fiberglass fabric which transmits approximately 20% +/- 2% photosynthetically active radiation (Figure 5).

Two studies investigating the effects of exogenous fructose (ISOCLEAR 55, Cargill, Inc., Dayton, OH, USA) applications to supina bluegrass under reduced light conditions were conducted on 4 December 2000 through 26 January 2001 and 4 December 2000 through 12 January 2001 for studies one and two, respectively. The experimental design for these studies was a completely randomized block design with three replications. Statistical analysis was done using Agriculture Research Manager, version 6.18 (Gylling Data Management, Inc. Brookings, SD, USA).

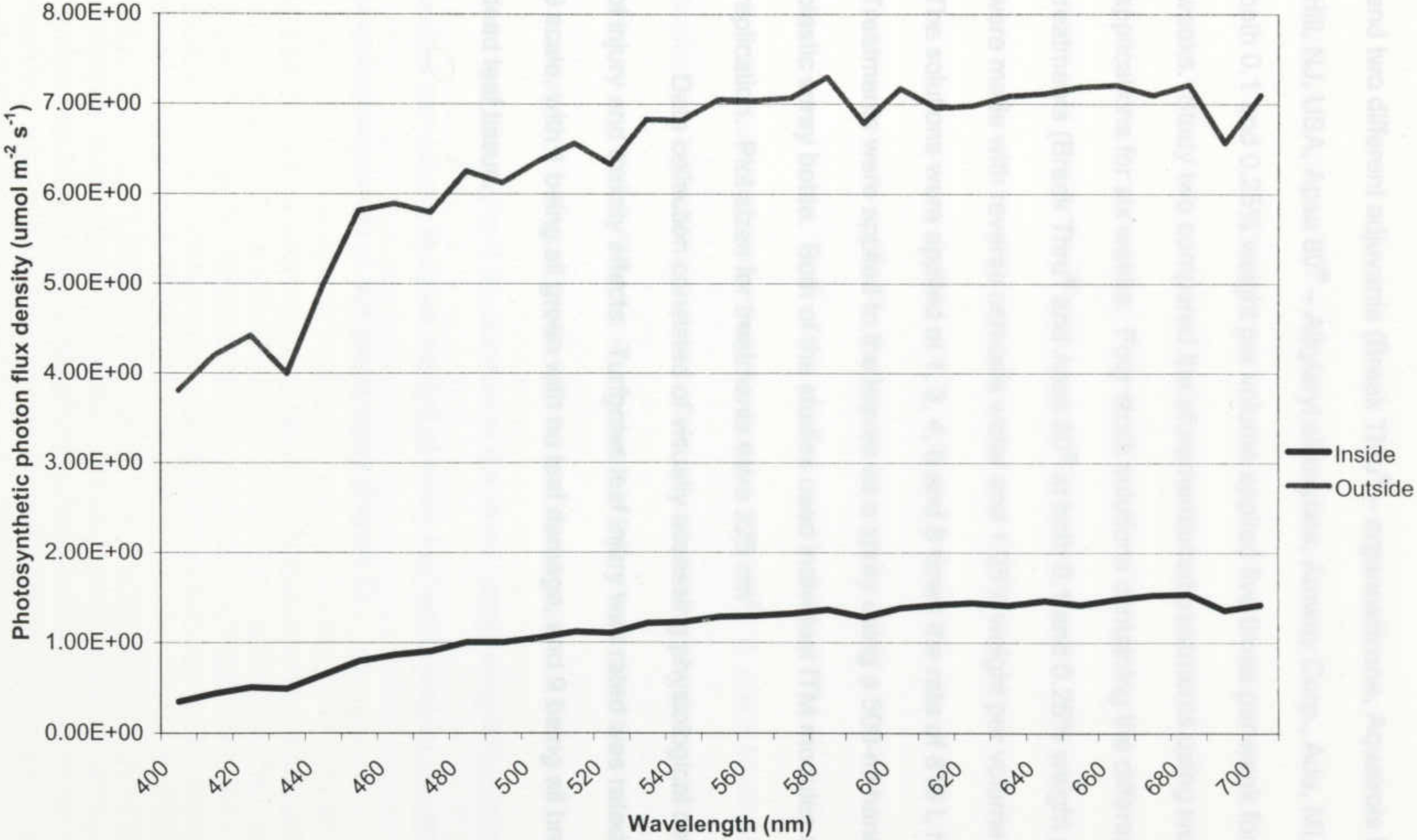

Figure 5. Photosynthetic photon flux density of sunlight and ambient light inside the indoor research facility, East Lansing, MI. 48824. 1430 h, 19 June 2000.

Study one investigated the effects of fructose at 1.25% weight per volume and two different adjuvants (Break Thru® – organosilicone, Aquatrols Inc. Cherry Hill, NJ, USA; Apsa 80® – Alkylaryl alkoxylate, Amway Corp., Ada, MI, USA) at both 0.1 and 0.25% weight per volume applied five times per week for eight weeks. Study two compared the aforementioned treatments using weekly applications for six weeks. Four stock solutions containing the different adjuvant treatments (Break Thru® and Apsa 80® at both 0.1 and 0.25% weight per volume) were made with reverse osmosis water and 1.25% weight per volume fructose. The solutions were applied at 1, 2, 4, 6 and 8 times the rate of 815 L ha^{-1}. Treatments were applied to the leaves as a spray using a 500-ml hand trigger plastic spray bottle. Both of the studies used individual ITM modules as a replication. Plot sizes for treatments were 225 cm^2.

Data collection consisted of visually assessing physiological comparisons of injury and toxicity effects. Turfgrass leaf injury was rated was rated using a 1-9 scale, with 1 being all green with no leaf damage, and 9 being all brown or dead leaf tissue.

RESULTS AND DISCUSSION

Study one – *Five times per week applications*

Significant differences occurred throughout the eight weeks of data collection for both treatments (adjuvants and fructose rate; Table 2). The effects of the two adjuvants (Apsa 80® and Break Thru®) at application rates of 0.1 and 0.25% weight per volume showed significant differences for injury on turfgrass leaf tissue when applied five times per week for eight weeks regardless of the rate of fructose applied (Figure 6). All treatments yielded unacceptable turfgrass leaf tissue quality with the exception of the 0.1% weight per volume rate using the adjuvant Break Thru®.

In addition, different application rates (1, 2, 4, 6, and 8 times 815-L ha^{-1}) of fructose at 1.25% weight per volume, regardless of the adjuvant treatment, showed significant differences for injury to turfgrass leaf tissue when applied five times per week (Figure 7). Only the 1x rate of fructose (815-L ha^{-1}) showed very little injury throughout the duration of the study, suggesting that a rate of 1.25% weight per volume fructose applied at 815-L ha^{-1} is the limit for preventing unacceptable levels of leaf tissue injury (Figure 7).

Table 2. Study one - analysis of variance for leaf tissue injury from exogenous fructose† applications with an adjuvant‡ applied five times per week on supina bluegrass under reduced light conditions. E. Lansing, MI. 48826. 8 December 2000 – 28 January 2001.

		Mean Square Error					
SOURCE	DF	8 Dec.	15 Dec.	30 Dec.	7 Jan.	12 Jan.	28 Jan.
Total	59						
R	2	2.22	0.60	0.02	3.47	3.22	0.00
Adjuvant (A)	3	9.00*	7.26*	6.95*	21.29*	29.71*	71.48*
Fructose rate (B)	4	21.9*	13.61*	9.98*	17.10*	20.11*	35.68*
AB	12	0.82	0.55	0.84	0.49	0.59	2.65*
ERROR	38	0.66	0.86	1.40	0.36	0.71	0.12

† The two adjuvants tested were Break Thru® – organosilicone, Aquatrols Inc. Cherry Hill, NJ, USA; Apsa 80® – Alkylaryl alkoxylate, Amway Corp., Ada, MI, USA) at both 0.1 and 0.25% weight per volume

‡ Fructose application rates were 1, 2, 4, 6, and 8 times 815 L ha^{-1} using 1.25% weight per volume fructose - ISOCLEAR 55, Cargill, Inc., Dayton, OH, USA.

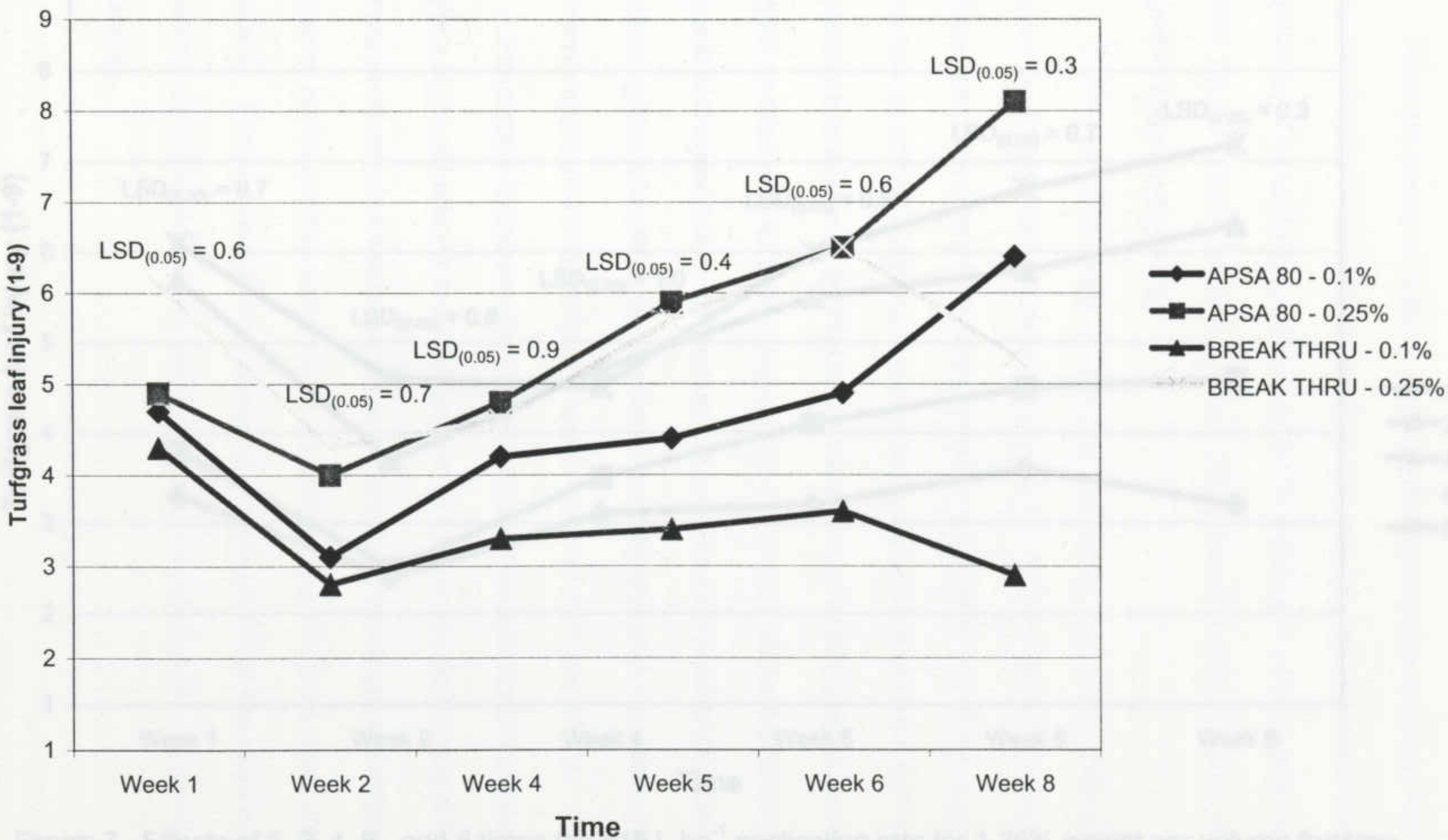

Figure 6. Effects of different adjuvant concentrations for two adjuvants (Apsa 80 - alkylaryl alkoxylate and Break Thru - organosilicone) when applied five times per week with 1.25% weight per volume fructose to supina bluegrass under reduced light conditions. East Lansing, MI. 48824. 8 December 2000 - 27 January 2001.

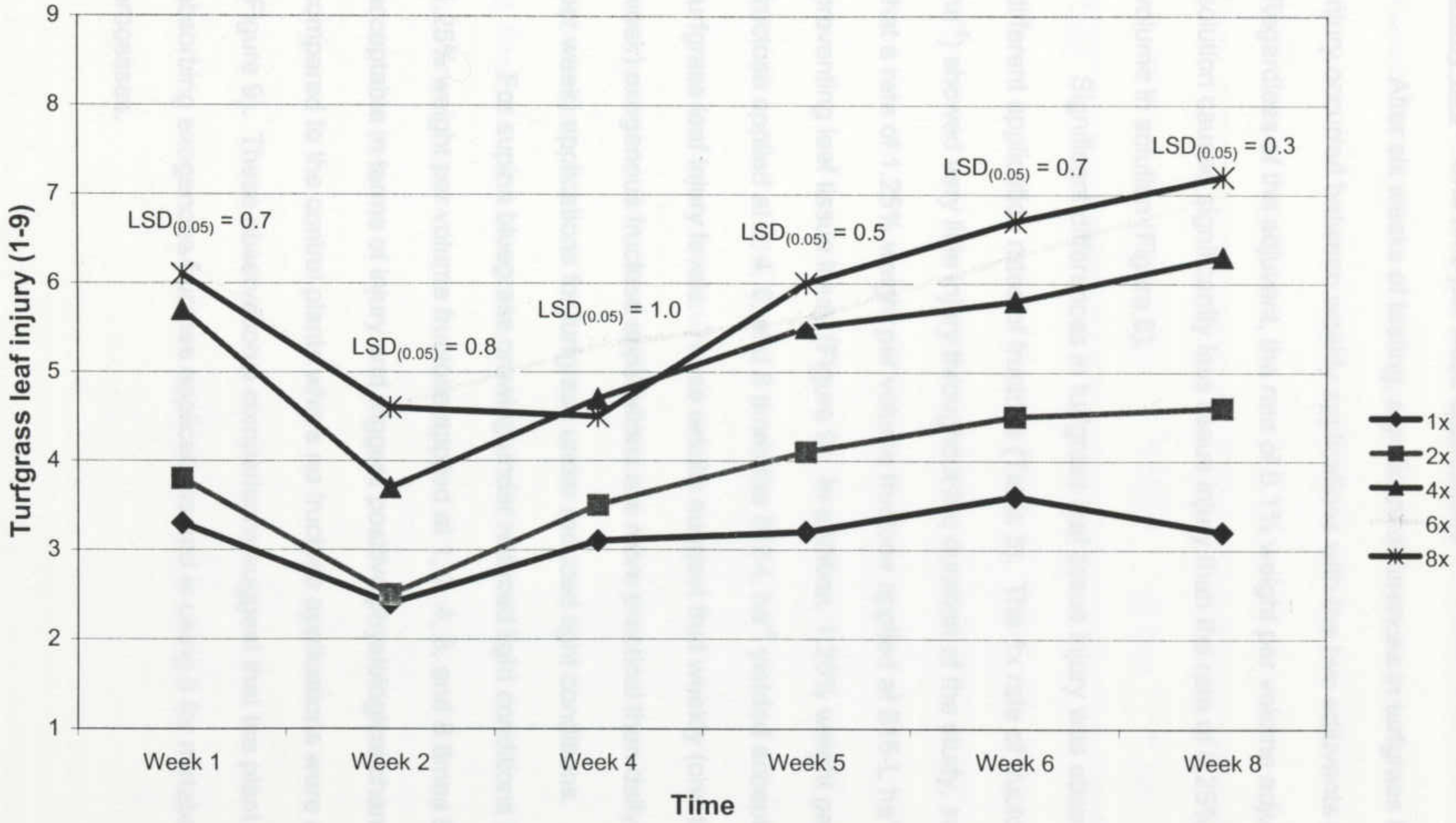

Figure 7. Effects of 1, 2, 4, 6, and 8 times the 815 L ha^{-1} application rate for 1.25% weight per volume fructose applied to supina bluegrass under reduced light conditions five times per week. East Lansing, MI. 48824. 8 December 2000 - 27 January 2001.

Study two *– One time per week applications*

After six weeks of testing, significant differences in turfgrass leaf tissue injury occurred between weekly applications with the two adjuvants (Table 3). Regardless of the adjuvant, the rate of 0.1% weight per volume adjuvant in solution caused significantly less tissue injury than the rate of 0.25% weight per volume in solution (Figure 8).

Significant differences in turfgrass leaf tissue injury was observed with different application rates of fructose (Table 3). The 1x rate of fructose (815-L ha^{-1}) showed very little injury throughout the duration of the study, suggesting that a rate of 1.25% weight per volume fructose applied at 815-L ha^{-1} is ideal for preventing leaf tissue injury (Figure 9). In addition, 1.25% weight per volume fructose applied at 2, 4, 6, and 8 times the 815-L ha^{-1} yielded acceptable turfgrass leaf injury levels. These results suggest that weekly (one time per week) exogenous fructose applications are more practical than daily (five times per week) applications for turfgrass under reduced light conditions.

For supina bluegrass growing under reduced light conditions the rate of 1.25% weight per volume fructose applied at 1, 2, 4, 6, and 8 times 815-L ha^{-1} is acceptable in terms of injury and triggers positive physiological changes to occur compared to the control plants where no fructose applications were applied (Figure 9). These observational comparisons suggest that the plant is readily absorbing exogenous fructose applications and is using it for metabolic processes.

Table 3. Study two - analysis of variance for leaf tissue injury from exogenous fructose† applications with an adjuvant‡ applied one time per week on supina bluegrass under reduced light conditions. E. Lansing, MI. 48826. 8 December 2000 – 12 January 2001.

		Mean Square Error				
SOURCE	DF	8 Dec.	15 Dec.	30 Dec.	7 Jan.	12 Jan.
Total	59					
R	2	6.47	0.17	0.47	0.35	0.72
Adjuvant (A)	3	3.78*	1.31	1.00	1.35*	2.55*
Fructose rate (B)	4	10.54*	1.56	1.81*	1.43*	2.60*
AB	12	0.88	1.05	0.43	0.27	0.30
ERROR	38	1.06	0.68	0.38	0.32	0.42

† The two adjuvants tested were Break Thru® – organosilicone, Aquatrols Inc. Cherry Hill, NJ, USA; Apsa 80® – Alkylaryl alkoxylate, Amway Corp., Ada, MI, USA) at both 0.1 and 0.25% weight per volume

‡ Fructose application rates were 1, 2, 4, 6, and 8 times 815 L ha^{-1} using 1.25% weight per volume fructose - ISOCLEAR 55, Cargill, Inc., Dayton, OH, USA.

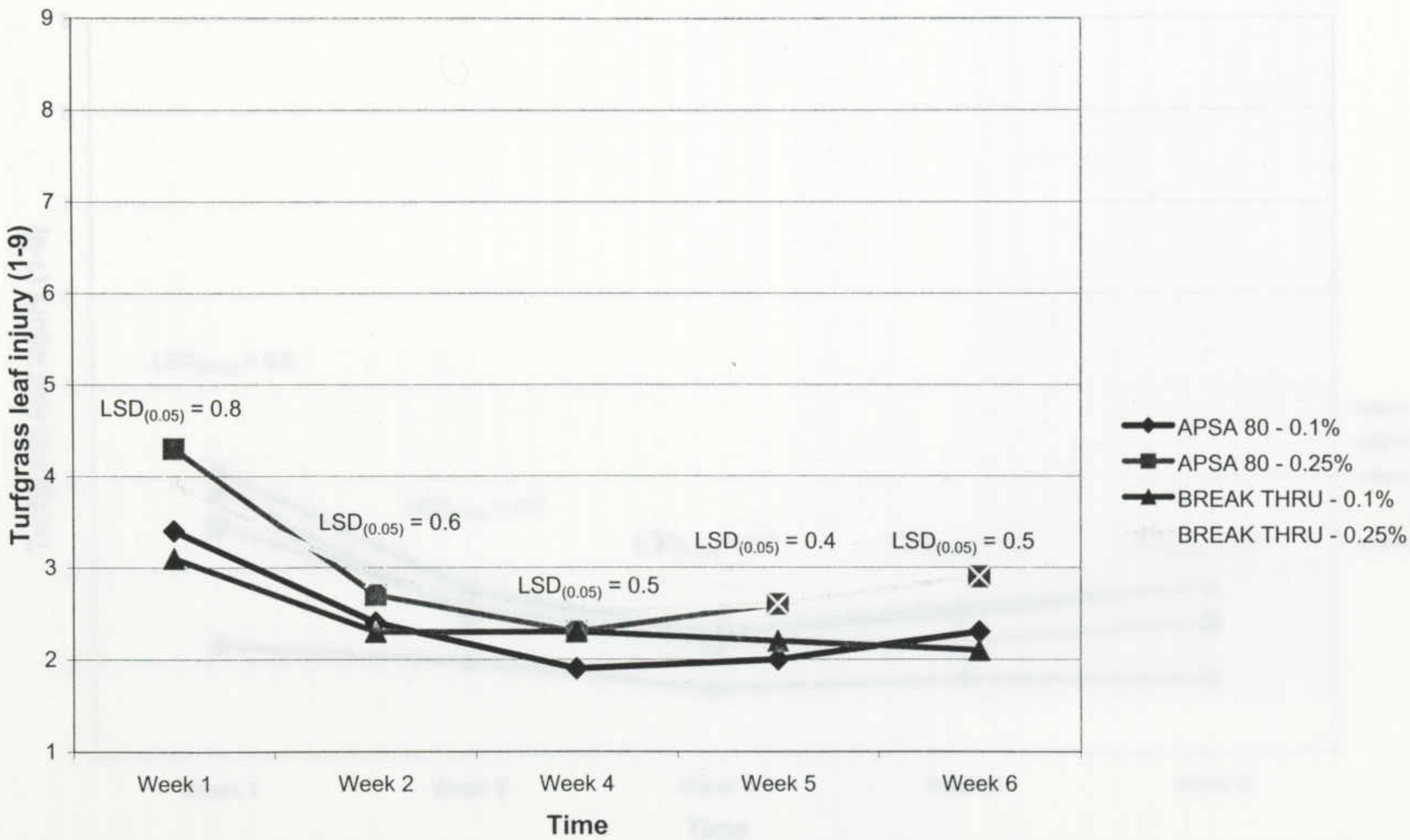

Figure 8. Effects of different adjuvant concentrations for two adjuvants (Apsa 80 - alkylaryl alkoxylate and Break Thru - organosilicone) when applied once per week with 1.25% weight per volume fructose to supina bluegrass under reduced light conditions. East Lansing, MI. 48824. 8 December 2000 - 27 January 2001.

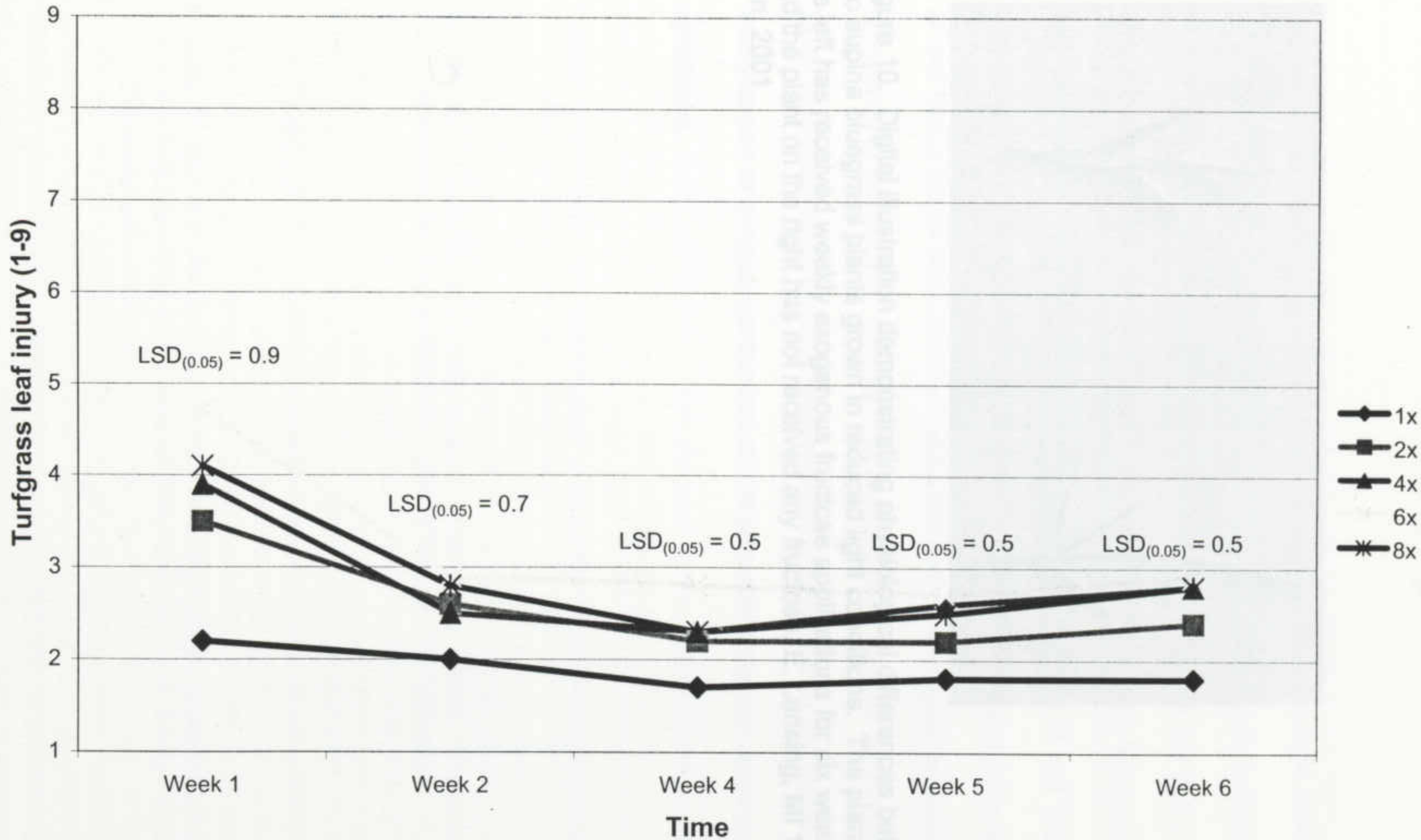

Figure 9. Effects of 1, 2, 4, 6, and 8 times the 815 L ha^{-1} application rate for 1.25% weight per volume fructose applied to supina bluegrass under reduced light conditions once per week. East Lansing, MI. 48824. 8 December 2000 - 27 January 2001.

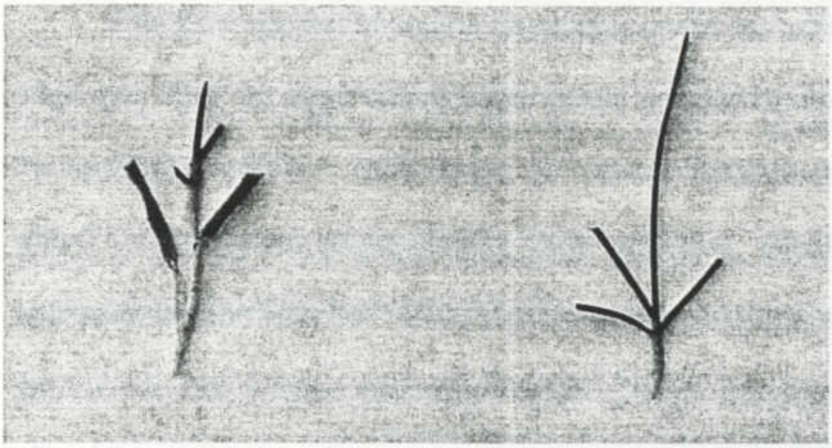

Figure 10. Digital illustration demonstrating physiological differences between two supina bluegrass plants grown in reduced light conditions. The plant on the left has received weekly exogenous fructose applications for six weeks and the plant on the right has not received any fructose, E. Lansing, MI 12 Jan. 2001

CONCLUSIONS

Fructose applied to supina bluegrass under reduced light conditions five times per week for eight consecutive weeks causes too much leaf injury unless the application rate is 1.25% weight per volume fructose at the 815-L ha^{-1} rate with 0.1% weight per volume Break Thru® adjuvant. Weekly fructose applications (one time per week) yielded acceptable levels of leaf tissue injury for the 1,2,4,6, and 8 times application rates. The 1x rate provided the least amount of leaf tissue injury while demonstrating positive physiological responses compared to the control. Overall, this study was successful as a preliminary study to warrant more in-depth research for understanding the uptake and translocation of exogenous fructose applications to turfgrass under reduced light conditions.

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