UBC Social Ecological Economic Development Studies (SEEDS) Student Report

The carbon sequestration potential of three common turfgrasses: *Lolium perenne; Fescue rubra; and Poa pratensis*

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BIOL 448 – DIRECTED STUDIES IN BIOLOGY

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Abstract

The objective of this study was to study the effect of trimming on different species of turfgrass and on their clippings as well as to find out which species has the greatest carbon sequestration ability. In the short term, clipping of the grasses results in an immediate decrease in net photosynthesis rate followed by an increase after 24 hours. Over the long term, uncut grasses decline in photosynthetic ability, most likely a result of physiological changes as grass blades age. Clippings from the grasses experienced an immediate decrease in photosynthesis followed by negative net photosynthesis at 4 hours before decreasing to approximately no net photosynthesis at the end of 24 hours. The carbon sequestration ability of these turfgrass species depends on their age and the time after mowing.

1.0 Introduction

Lawns and turfgrasses are a well-established feature of the urban landscape, originating in England and taking off in popularity in post-World War II America (Kolbert 2008). Turfgrass is estimated to make up 91% of all urban landscapes in North America (Zirkle et al. 2012). Urban turfgrasses also use 7.8 billion gallons of water daily in the US, which is 30% of all water consumption in the country (EPA 2008). Turfgrass appearance is also important in urban landscapes. In addition to watering, frequent cutting and fertilization is usually required for the stereotypical lawn that is evenly cut, uniformly green and free of weeds and other pests (Quigley 2000).

Urban and suburban expansion in North America usually brings with it a disproportionate increase in lawn coverage per lot even as lot sizes decreases (Robbins and Berkenholtz 2002). Developers plant quick-growing, though not always long-lasting, turfgrasses as a shortcut for new landscaping as they build new housing developments (Kolbert 2008). Turfgrass cover is estimated to increase by over 23% each year and surveys show no decrease in American public opinion on the necessity of the lawn as part of their property and life-style (Robbins and Berkenholtz 2002, Quigley 2000). Despite new developments to replace the traditional American lawn and an anti-lawn movement, the North American public have been hesitant to embrace alternatives to their greenery which helps fuel a 30 billion dollar industry (Pineo and Barton 2010).

Since turfgrass expansion is unlikely to stop soon, increasing the benefits and mitigating negative consequences of turfgrass expansion are very important. Turfgrass expansion is often done at the expense of losing valuable carbon sinks such as forests. Research on carbon sequestration, capture and storage of carbon dioxide, of turfgrasses is primarily done on the carbon sequestration ability of soil (Guertal 2012). Experiments are carried out not only on grasslands, but also in urban, agricultural and other different landscapes (Selhorst and Lal, 2012, Qian and Follet, 2012, Freibauer et al. 2004). Due to the different management practices that are used in each experiment, the variation in factors such as the height of the clippings, the fertilization rates and the amount of water received, each study is only applicable for certain sites. The carbon sequestration ability of some grasses, especially switchgrass, have been investigated for their use in producing biofuels. Switchgrass produces large amounts of biomass both aboveground and underground, which enhances the carbon sequestration ability of the soil (Boe and Beck 2008). Another factor is that great variability in the carbon sequestration ability of perennial ryegrass and assorted fescue species have been demonstrated through comparisons of root and aboveground biomass (Duller et al. 2012).

Locally, Vancouver has a wet temperate climate that supplies more water than what is needed in lawns for most of the year. At UBC, 53% of all soft landscape is turfgrass (UBC 2005). UBC turfgrass is a mix of *Poa pratensis* (Kentucky bluegrass), *Festuca rubra* (creeping red fescue) and *Lolium perenne* (perennial ryegrass) (Thrift 2013). The lawn endures heavy traffic from student and is maintained by UBC Plant Operations. This project will help inform and improve lawn-maintenance practices at UBC and help identify species with greater carbon sequestration potential. UBC may be able to decrease the amount of CO_2 produced from the lawns, helping UBC fulfill its greenhouse emission reduction goals.

The objectives of this study were (1) to study the effect of mowing on the photosynthesis rate of common turfgrasses, (2) to compare the carbon sequestration rate of three different species of turfgrasses and (3) to compare the overall carbon sequestration of turfgrass blends compared to the individual species.

2.0 Materials and Methods

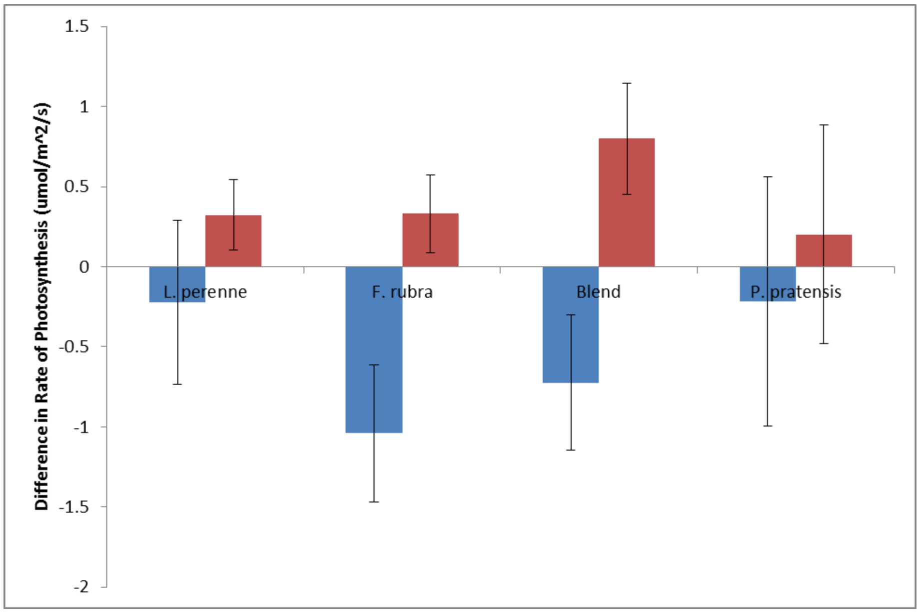
Photosynthesis rates were measured using the CI-340 Handheld Photosynthesis System from CID Biosciences Inc and followed directions outlined in the Ci-340 Handheld Photosynthesis System Instruction Manual. The leaf chamber used was the wide rectangular with a window size of 55x20mm and a window area of 11cm^2. All readings performed were done within a range of PAR 140-150 to simulate direct sunlight in a lab environment and a time interval of 20 seconds.
Three grass species, *Poa pratensis, Lolium perenne* and *Festuca rubra* were used. A seed blend was also made, consisting 40% each of *P. pratensis* and *L. perenne* and 20% *F. rubra* by volume. Six pots of grass were planted for each grass species and the blend for a total of 24 pots. Three pots were used as the controls and not trimmed while the other three pots were trimmed weekly. Dilute 20-20-20 fertilizer from Plant-Prod was added in the 10th, 11th, and 13th weeks after seeding.
P. pratensis was infected with both fungus and mildew for the first 2 and a half months after germination. A solution of Organique Neem oil and sodium bicarbonate was used to control the mildew and rust.

To measure the effect of cutting on the grasses, one reading was taken of a sample of rooted grass before the grass was trimmed and another reading taken directly after. Masking tape was used to indicate where the sample of grass was and this was kept in place until a reading was taken 24 hours after the initial trimming.

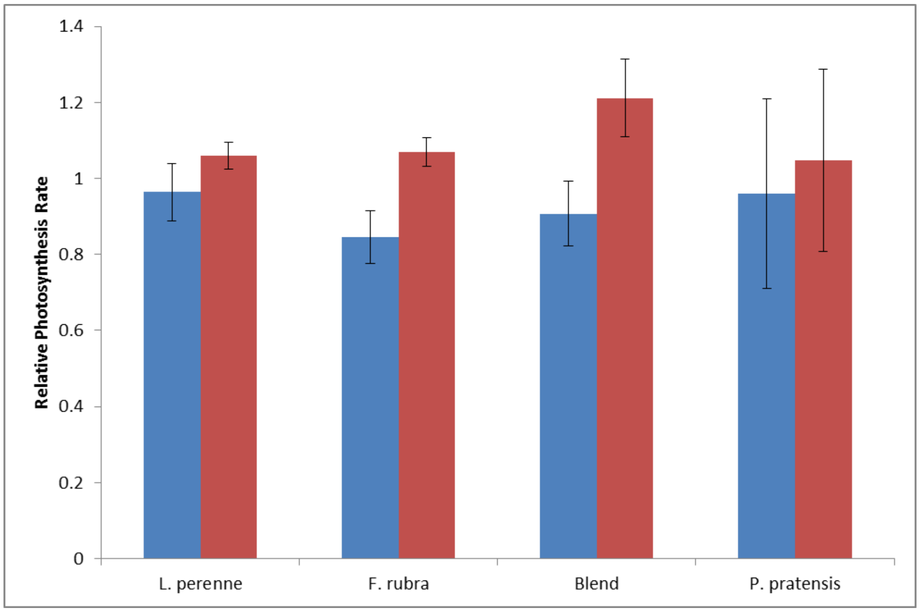
The trimming treatment was repeated on the *L. perenne*, *F. rubra* and the blend but there was insufficient length in the *P. pratensis* pots to do the treatment in time with the other plants. Photosynthesis rates in clippings were also measured right after cutting, 4 hours after cutting and 24 hours after cutting. The clippings were wrapped in masking tape at the top and bottom to keep them in the same position for taking readings.

3.0 Results

Readings of the photosynthesis rate for the different grass were taken over a period of 12 weeks starting at 4 weeks after seeding and germination. Due to fungus and mildew, the readings for Kentucky bluegrass could only be started 8 weeks after germination.

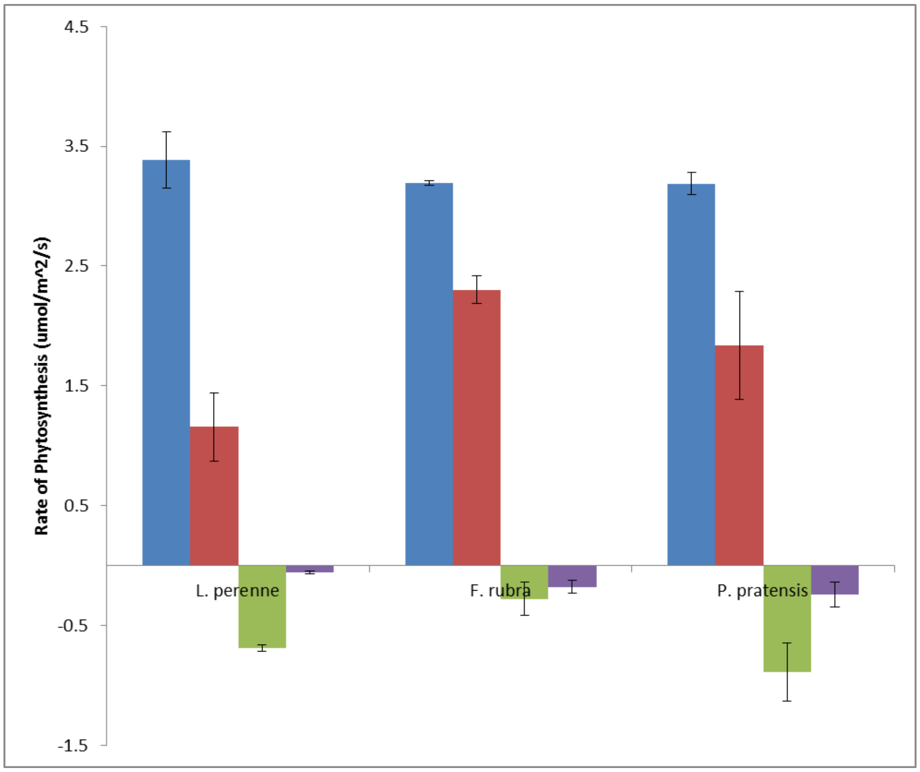


Graph 1. The average difference (±SE) between the initial photosynthesis rate and the rate measured immediately afterward trimming (in blue) and between the initial rate and the rate after 24 hours rate (in red) for each species and the blend.



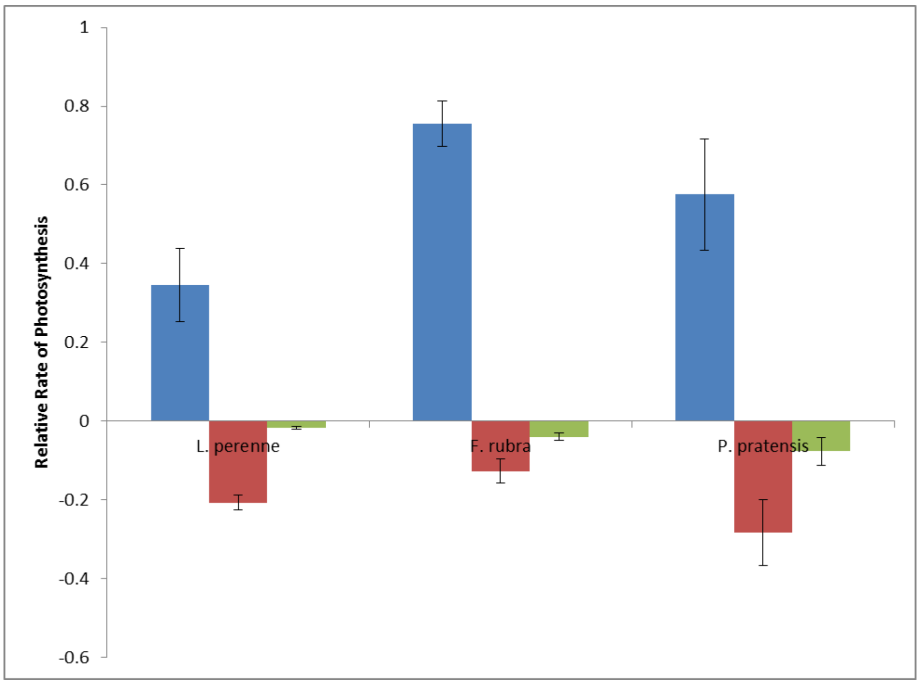
Graph 2. The average photosynthesis rate (±SE) immediately after trimming (in blue) and at 24 hours after trimming (in red) expressed as a proportion of the original photosynthesis rate for each species and the blend.

L. perenne and *P. pratensis* showed no significant changes in the photosynthesis rate after the grass was trimmed. *F. rubra* had a significant reduction in its photosynthesis rate after trimming, with an average of 1.04 umol/m^2/s, a decrease of 15% from the initial rate. However, the photosynthesis rate returned to the initial levels after 24 hours as shown in Graphs 1 and 2. The blend did not show any significant changes in the photosynthesis rate measured immediately after trimming but the photosynthesis rate after 24 hours had a significant increase of 0.33 umol/m^2/s when compared to the initial rate measured. The trend as shown in Graph 2 is a reduction in the photosynthesis rate immediately after trimming but an increase back to the initial rate or even higher after 24 hours.

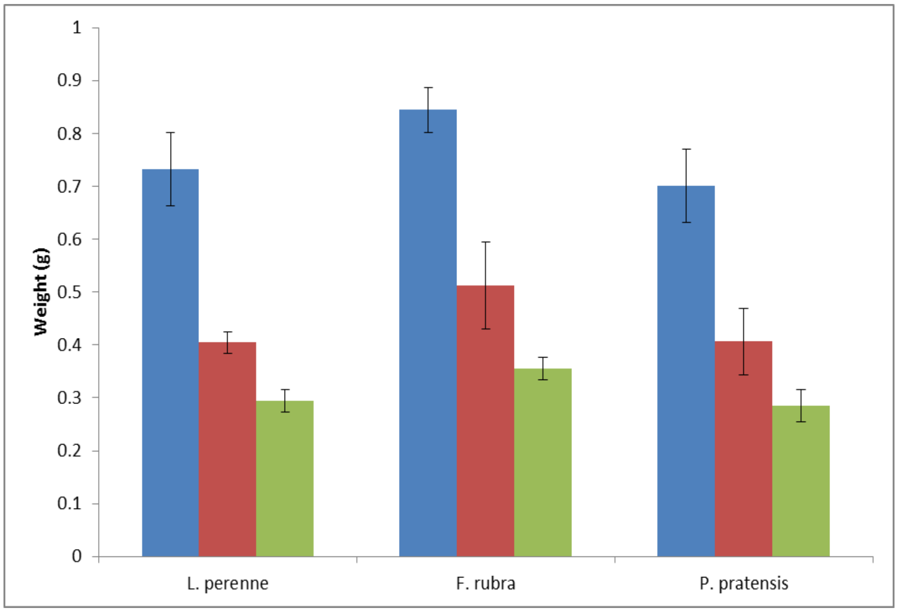


Graph 3. The average photosynthesis rate (±SE) of clippings of each species before trimming(in blue), immediately after trimming(in red), at 4 hours after trimming(in green) and after 24 hours after trimming(in purple).

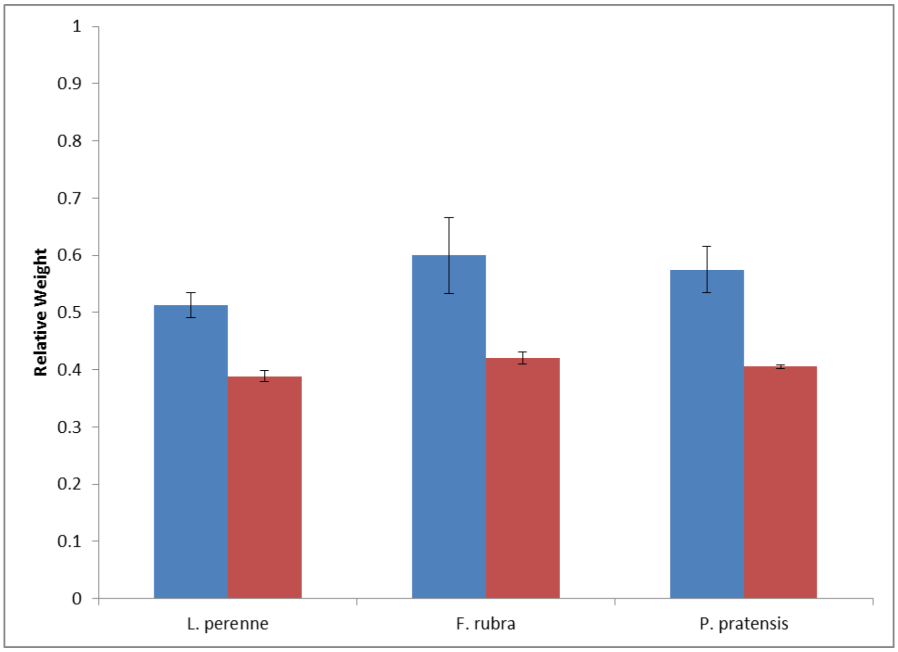
Both *L. perenne* and *P. pratensis* showed significant changes in the photosynthesis rate and the weight of the clippings over 24 hours. *F. rubra* clippings did not have a significant reduction in photosynthesis rate immediately after trimming. The photosynthesis rate of all three grass species decreased as the length of time after trimming increased. For *L. perenne,* the average reduction in the photosynthesis rate immediately after trimming was 2.23 umol/m^2/s or a decrease of 65% compared to the initial rate which was the greatest immediate decrease in photosynthesis over all three species. The photosynthesis rate declined to an average of -0.69 umol/m^2/s after 4 hours but increased back to an average of -0.056 umol/m^2/s. The trend was repeated in both *F. rubra* and *P. pratensis* as shown in Graph 3. The photosynthesis rate of *P. pratensis* decreased an average of 42% after trimming and reached a maximum of -0.89 umol/m^2/s, a relative decrease of 128%, before increasing back to -0.24 umol/m^2/s at 24 hours mark. The photosynthesis rate of *F. rubra* decreased only 24% immediately after trimming, to an average of 2.39umol/m^2/s which can be seen in Graph 4. This was the smallest reduction in photosynthesis out of the three species. *F. rubra* also had the smallest negative photosynthetic rate of -0.28umol/m^2/s after 4 hours before increasing back to an average of -0.178 umol/m^2/s.



Graph 4. The average photosynthesis rate (±SE) of the clippings of each species expressed as a proportion of the original photosynthesis rate immediately after the cut (in blue), 4 hours after the cut (in red) and 24 hours after the cut (in green)

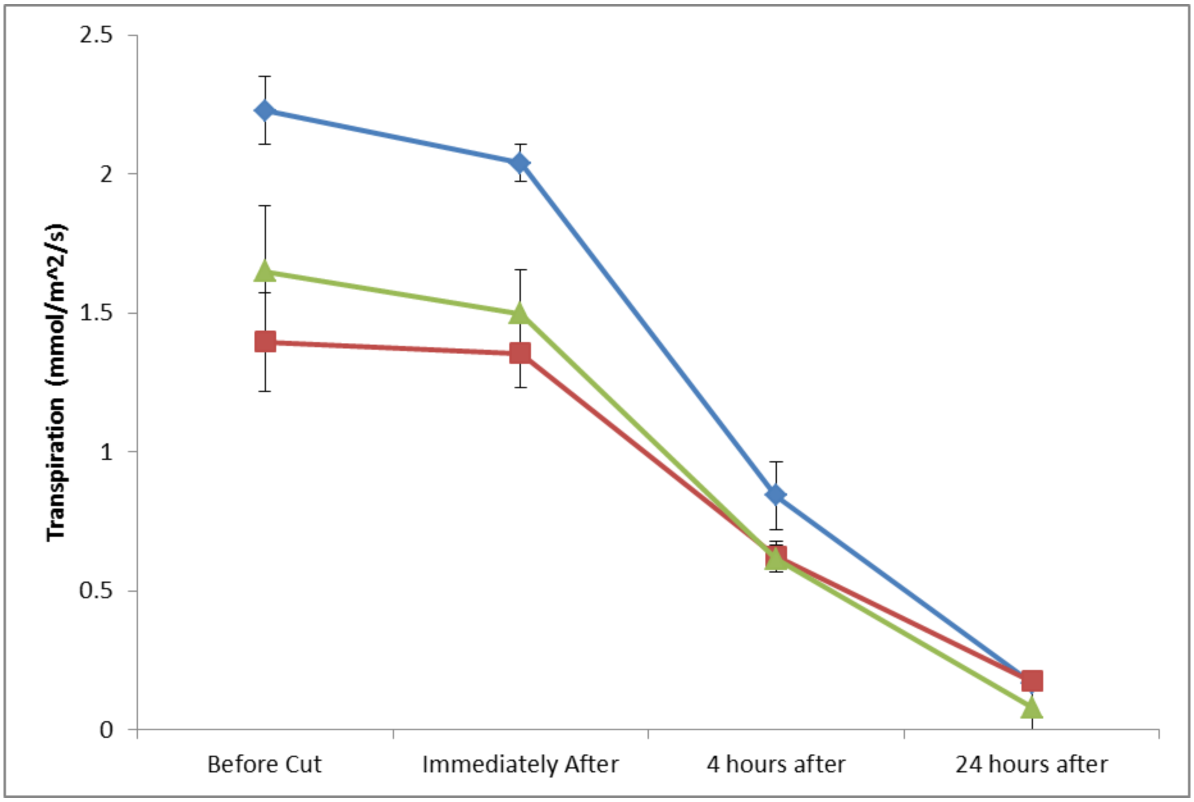


Graph 5. Average weight (±SE) of the clippings of each species immediately after the cut (in blue), after 4 hours (in red), and after 24 hours (in green)



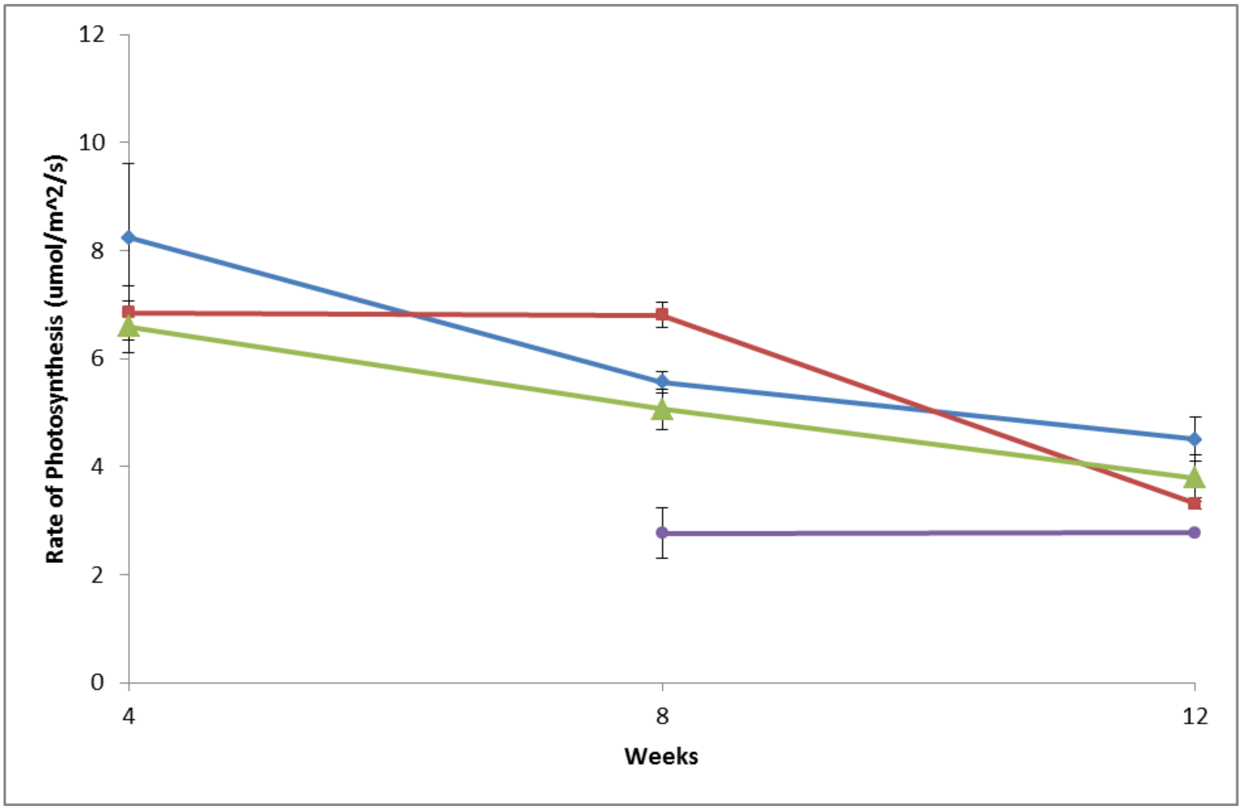
Graph 6. The average weight (±SE) of the clippings of each species after 4 hours (in blue) and after 24 hours (in red) expressed as a proportion of the original weight.

It is clear from Graph 5 that the overall weight of the clippings decreased as time after trimming increased. Similar to the photosynthesis rate, the weight of *F. rubra* clippings decreased the least to 60% of its initial weight after 4 hours. The weight of *L. perenne* and *P. pratensis* clippings decreased to 56% and 58% of their initial weight respectively. The weight of *F. rubra* decreased the most in the interval between the last two reading, dropping to 42% while *L. perenne* and *P. pratensis* decreased to 40% and 41% of their initial weight.



Graph 7. The average transpiration rate (±SE) of *L. perenne* (blue), *F. rubra* (red), *and Poa pratensis* (green) in the clippings before the cut, immediately after, at 4 hours and 24 hours later.

The rates of transpiration of the clippings were also measured for each time interval. *L. perenne* experienced significant decreases in the transpiration rate at each interval from the original control rate. *F. rubra* and *P. pratensis* did not have significant decreases in the transpiration rate immediately after the grass was cut but the differences became significant after 4 and 24 hours. *P. pratensis* had the greatest initial reduction in transpiration, declining to 91.39% of the original rate. *L. perenne* and *F. rubra* respectively declined to 91.76% and 98.35%,. *F. rubra* had the least overall reduction in transpiration at 15% of the original transpiration rate. *P. pratensis* declined to 5.08% of the original rate, giving it the greatest reduction while *L. perenne* was intermediate at 7.6%.



Graph 8. Average photosynthesis (±SE) measured after 4, 8 and 12 weeks for *L. perenne* (blue), *F. rubra* (red), and the blend (green) as well as measurements for *P. pratensis* (purple) at 8 and 12 weeks.

Readings of the control pots for each species and the blends were taken at 4 weeks, 8 weeks and 12 weeks after germination. Due to the fungal infection, no readings could be taken for *P. pratensis* at 4 weeks. *L. perenne, F. rubra* and the blend control pots did not have significantly different rates of photosynthesis from 4 to 8 weeks. All three showed significant differences when the readings after 8 weeks were compared to the readings after 12 weeks and when readings after 4 weeks were compared to the readings after 12 weeks. The general trend for *L. perenne*, *F. rubra* and the blend control pots was a general decrease in the rate of photosynthesis over time as shown in Graph 8.

In the trial pots, the blend followed the same general trend as the control pots. However, *F. rubra* displayed no significant differences in photosynthesis rate between any of the readings while the blend displayed a significant decrease between weeks 4 and 12 but not weeks 8 and 12. *L. perenne* displayed a significant decrease from weeks 4 to 12 but not at 8 weeks.

There was no significant difference in net photosynthesis rates between *L. perenne, F. rubra* and the blend at 4 weeks and at 12 weeks for the control pots. *P. pratensis* has a significantly reduced photosynthesis rate compared to *L. perenne* at both 8 and 12 weeks. At 8 weeks, there was a significant difference between *F. rubra* and all of *L. perenne, P. pratensis* and the blend. However, this difference disappeared by the 12th week.

4.0 Discussion

The trend seen in figure 2 of an immediate decrease in photosynthesis rate following trimming and an increase in the day after is consistent with data from Detling et al (1979). Their experiment was performed using *Bouteloua gracilis*, a perennial grass used for grazing and erosion control (Detling et al. 1979, USDA NRCS 2002). Trimming of *Bouteloua gracilis* produced an immediate 60% decrease in the net photosynthesis rate. The net photosynthetic rate increased by 21% by the end of three days after the trimming. While the average reduction and increase in net photosynthesis rate in this experiment for each species and the blend was not as great as the Detling experiment, the general trend is the same.

Over the 10 days, Detling et al. found that while above-ground leaf biomass increased, root mass decreased. These results are consistent with a study by Kuzyakov et al. in 2002 which traced the allocation of carbon in *L. perenne* after cutting. The study showed that most of the newly fixed carbon is allocated into shoots and not root biomass. This holds great implications for the carbon sequestration abilities of turfgrass. If newly fixed carbon does not move into the roots where it can be stored, a second trimming of the turfgrass will remove nearly all of the new shoots and destroy any positive impact of the increased carbon fixation rate.

The delayed increase in photosynthesis after trimming in grass has been attributed to several factors. First, the removal of larger and older leaves exposes newer and smaller leaves to the light which increase the photosynthesis rate (Belsky 1986). Secondly, Detling et al. discovered that photosynthate was reallocated from the roots to the new shoots, causing the reduction in root biomass. A reduction in root biomass may defeat the objective of planting turfgrasses, such as Kentucky bluegrass, for their erosion control abilities (Bush 2002).

The decrease in the photosynthesis rate of the clippings, as shown in Graph 3, correlates to a reduction in transpiration rate as shown in Graph 7. The stomata would have closed in response to water loss as the clippings had no roots to bring up replacement water (Kimball 2011). The weight loss in the clippings over time, which can be seen in Graph 5, is most likely caused by water loss in the clippings. Negative net photosynthesis readings at 4 hours and 24 hours would have been caused by increased respiration in the grasses coupled with decreased carbon fixation due to decreased transpiration. A sugar beet and potato study done by Lafta and Fugate (2011) monitored the respiration of potatoes and sugarbeets after wounding. The situation is similar to this experiment where the clippings are isolated and have no other source of water and nutrients. Wounded sugarbeets had higher respiration rates than the controls while concentrations of stored plant compounds such as fructose decreased (Lafta and Fugate 2011).

On average, the negative net photosynthesis rate at 24 hours for the clippings was lower than the negative net photosynthesis at 4 hours. One possible explanation for this is with the decrease in carbon fixation and increased respiration, nearly all of the stored compounds are consumed within a day and so the clippings would not be photosynthesizing or respiring at the end of 24 hours. The release of CO_2 by the clippings if they are left on the lawn would not be a major factor in decreasing overall carbon sequestration as the addition of nitrogen provided by the clippings enhances the overall growth rate of the plant while decreasing the amount of fertilizer needed (Kopp and Guillard 2002).

The overall decline in the photosynthetic rate found in the control pots is consistent with experiments done by Jewiss and Woledge as well as Treharne and Eagles with *L. perenne* (Robson et al. 1988). The decline can be explained by two changes. First, there is a fall in stomatal conductance as each leaf ages. This means that stomates, microscopic pores on the surface of the plant that control gas exchange, are decreasing the rate of exchange of carbon dioxide into the plantand water vapour out of the plant (Roberts 1990). Secondly, ribulose biphosphate carboxylase/oxygenase (Rubisco), the enzyme which is responsible for most of the carbon fixation on Earth, slows down its activity (Plants in Action 2009). Photosynthesis in the older leaves is therefore constrained by these two changes which decrease the amount of CO_2 available for fixation and slows down the rate of carbon fixation. The significance of this decrease in photosynthetic ability in older leaves is that while it looks as though each blade has an increased area for photosynthetic activity, the reality is that older grass blades do not have as high a net photosynthetic rate as younger blades. Frequent trimming of lawns would in fact remove older blades and allow for greater photosynthesis overall. Constant cutting of the grass keeps the plants locked in a vegetative growth phase as reproductive structures would be removed before they can mature. From Graph 8, it can be seen that the changes in net photosynthesis over time differ from species to species. It is difficult to say which species has the greatest carbon sequestration ability overall. Even though *P. pratensis* had a significantly lower photosynthesis rate than with *L. perenne*, it was infected by fungus and mildew, and the lower photosynthesis rate measured may have been a result of that.

One limitation in this experiment was that it was impossible to measure root respiration and biomass in the trial and control pots. That data would have given a greater overall picture of how trimming grass impacts the overall plant. Additionally, the sod in the pots was newly established and the blades would have been approximately the same age. Changes in the net photosynthesis rate would occur if the plant was actively reproducing and forming seeds. Reekie and Bazzaz concluded that reproductive structures in plants are capable of very significant photosynthesis (1987). A study by Jackson and Dewald on *Tripsacum dactyloides*, a perennial grass, showed that reproductive structures during initial growth is heterotrophic and consumes stored compounds (1994). It may be likely that allowing grasses to reproduce by flowering would reduce overall carbon sequestration even if the reproductive structures can photosynthesize.

The photosynthesis rate of the blend may not be representative of the real photosynthesis rate of UBC lawns for several reasons. As mentioned above, the age of the grass is significant as the grasses used in the experiment were significantly younger than a normal lawn. Additionally, overseeding every year means the grass would be a mixture of different ages. Depending on the grass used for overseeding, which is creeping red fescue at UBC, the overall ratio of the blend would change depending on the lawn (Thrift 2013).

Overall, cutting the leaves of grass impacts their carbon sequestration ability. The photosynthetic rate of constantly cut grass remains higher than uncut grass in the long term. Trimming grass may bring an increase in overall biomass in the short term but the new biomass would be removed during the following trimming. Clippings are capable of positive photosynthetic ability but lose that ability after 4 hours and have nearly no photosynthetic ability at all after 24 hours. Overall, the carbon sequestration ability of these tuftgrass species appears to depend on various factors, such as the age of the plant, the stage of plant development, the time after trimming, disease, nutrition and abiotic stresses.

5.0 Acknowledgments

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