Controlling *Phalaris arundinacea* through the use of shade while promoting native species recruitment in a wet meadow

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Jonathan P. Kinney

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Jonathan Patrick Kinney

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Jonathan P. Kinney, Student Date

Approvals:

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Dr. Felicia P. Armstrong, Thesis Advisor Date

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Dr. Ian J. Renne, Committee Member Date

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Dr. Carl F. Chuey, Committee Member Date

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Mr. Harry C. Bircher, Committee Member Date

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Dr. Peter J. Kasvinsky, Dean of Graduate Studies Date

Abstract

Phalaris arundinacea (reed canarygrass) is a grass species native to Eurasia and the Pacific Northwest of the U.S. By nature it is an aggressive species and particularly invasive in areas with abundant light and nutrient resources. Repeated introduction of cultivars to the U.S. for purposes of feedstock and soil stabilization particularly around farmlands from the 1850s onward allowed cross-pollination with native cultivars to occur. This resulted in more aggressive phenotypes capable of forming monotypic stands. The susceptibility of wetland areas to invasion has become particularly problematic in the Pacific Northwest and the Midwest. One widely recognized method of control for reed canarygrass growth and establishment is the use of shade. This study proposed the use of artificial shade in combination with the planting of native grass species in an attempt to diversify a wet meadow dominated by reed canarygrass. Three-way ANOVAs were utilized to analyze shade, disturbance patch size, and mowing as treatment levels. Results showed reed canarygrass to be noticeably impacted by shading while one native grass species successfully established itself under the same conditions. Given a sufficient length of time, diversity of this area could potentially be increased both aboveground and in the seed bank.

Acknowledgements

The author would like to thank Dr. Felicia P. Armstrong, Dr. Ian J. Renne, Dr. Carl F. Chuey, and Mr. Harry C. Bircher for their assistance in design, execution, and advisement for this project. Special thanks to Jean S. Engle for the use of her property as a study site. Gratuitous thanks are extended to George A. Reedy and the many other graduate and undergraduate students who helped in the initial setup and the season-long study deserve gratuitous thanks as well. Finally, the statistical assistance provided by Erin K. Pfeil-McCullough and Dr. Thomas P. Diggins proved invaluable in compiling and assessing the data.

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CHAPTER 1: INTRODUCTION

Wetlands, as defined by the Clean Water Act, are lands that are either saturated with or covered by water for enough of a time period to allow for vegetation adapted to saturated soil conditions to persist (USEPA 1987). Hydrology plays the largest role in the types of soil that form as well as the species living in these areas. The two main inland wetland types are marshes, associated with a predominance of herbaceous plant species, and swamps which support mainly shrub and tree species. One common type of marsh in the U.S. Midwest is the wet meadow or wet prairie, which is associated with poorly-drained lowland areas. Wet meadows may resemble typical grassland areas; the major difference lies in the amount of saturation of the soil, particularly during periods of seasonal flooding. Otherwise, there is no standing water other than very short periods of time through the growing season (ILDNR 2009). Species commonly associated with wet meadows are hydrophytic grasses, sedges, rushes, and forbs (USEPA 2008).

Wetlands serve as natural filtration systems for nutrients, soil, and pollutants including pesticides and heavy metals. They efficiently prevent these materials from entering streams, rivers, lakes, and other bodies of water, where issues of eutrophication, surface water pollution, and excessive sedimentation may arise. However, wetland areas also are among the most susceptible to invasion from non-native plant species (most particularly grass species), especially in the presence of disturbance patterns (Lavergne and Molofsky 2006). The combination of disturbances from cultivation of nearby agricultural fields and the active promotion of the use of *Phalaris* arundinacea, or reed canarygrass (RCG), can allow homogenous stands of it to become established. This is particularly problematic in areas with abundant light and increased sedimentation rates, resulting in lower successful germination rates of native plant species (Perry and Galatowitsch 2006, Brooks et al. 2006). Once RCG invades wetland areas, species number and diversity decrease significantly. The resulting decrease leads to a breakdown in the functionality of wetlands. Over time the soil chemistry changes, bringing about a lessened ability of the wetland to filter nutrients and pollutants as well as prevent native species from re-establishing themselves (Kercher and Herr-Turoff 2007).

CHAPTER 2: LITERATURE REVIEW

One of the important functions of wetlands is the storage and release of excess surface and groundwater during storm and seasonal runoff events (USEPA 2008). Nutrients, soil, and pollutants including pesticides and heavy metals are commonly carried in these waters, and wetlands act as natural filtration devices for these dissolved materials (USEPA 2008). They efficiently prevent these materials from entering streams, rivers, lakes, and other bodies of water, where issues of eutrophication, surface water pollution, and excessive sedimentation may arise (Lavergne and Molofsky 2006). In addition, surface water runoff helps in the dispersal of seed propagules (Lavergne and Molofsky 2006). Propagule dispersion via water circulation allows for increases in species richness and number in surrounding areas (Lavergne and Molofsky 2006). This allows wetland areas to support a rich diversity of plant and animal species not found in other habitats (USEPA 2008).

It is estimated that of the 221 million acres of wetland existing in the lower 48 states before European colonization that more than half have been drained or filled in for agriculture. From the 1950s through the 1990s that number continued to increase, but increasing awareness of the importance of wetland function has begun to change that trend. In fact, there was a net increase in wetland acreage from 1998 to 2004 as many former agricultural lands were converted back to wetlands (Dahl 2006). However, reconstructed and newly created wetlands in most cases do not perform as well as their natural counterparts, so it is important to maintain the existing ones (Wilcox 2007).

Wetland areas also are among the most susceptible to invasion from non-native plant species (most particularly grass species), especially in the presence of disturbance patterns and particularly through anthropogenic activity (Lavergne and Molofsky 2004). Such disturbances lead to an excess of available nutrients in these areas. Because wet meadows are often found around farmland and other agricultural areas, they are particularly susceptible to both disturbance (many of these areas were historically drained and filled for agricultural use) and subsequent invasion (USEPA 2008, Lavergne and Molofsky 2006). When an imbalance occurs in the uptake of available nutrients, either through increased nutrient loads or decreased nutrient uptake capacity of the plant species community, there is an increased risk of invasion (Kercher and Zedler 2004). Of particular concern with wetland areas are the invasive tendencies of certain grass species, due to their ability to significantly alter the overall function and native plant diversity of the wetland (Lavergne and Molofsky 2006). With time these changes affect the hydrology of the area, altering the community structure, available wildlife habitat, and frequency of fires (Lavergne and Molofsky 2006). Given sufficient duration these changes can severely impact efforts at wetland restoration (Wilcox 2007).

The invasive species reed canarygrass:

Phalaris arundinacea L., or reed canarygrass, is one of a three species complex which includes *P.* rotgesii (Husn.) Baldini and *P. caesia* Nees (Barkworth et al. 2007). These species are very difficult to distinguish visually and often must rely on genetic information for successful identification. Of the three, the one of concern is the allotetraploid species *P. arundinacea* sensu stricto, since it has the most adaptable to changes in environmental conditions and across the largest scale of latitudes and altitudes and is the only one found in North America (Lavergne and Molofsky 2004). This species is native to temperate regions of Europe, Asia and possibly parts of the United States, although the pre-agricultural history of it is uncertain (Lavergne and Molofsky 2006, Kellogg and Bridgham 2004). Specimens collected in 1825 from the U.S. most closely resembled the diploid (*P. rotgesii*) and invasive genotypes found in North Carolina and Vermont seem to be tetraploid (Barkworth et al. 2007, Lavergne and Molofsky 2004). The allotetraploid form will be the one discussed since it is the type of most concern and will hereafter be referred to as RCG. RCG is a long-lived, perennial, cold season (C3) grass capable of reaching heights of between three and eight feet by June with dense crowns and rhizomatous mats (Lavergne and Molofsky 2006). Stems are typically hollow yet sturdy, hairless, and up to one-half inch in diameter (DOEWA 2011). Leaf blades are one to four feet in length, flat, hairless, tapering, and up to three-quarters of an inch wide. Ligules are long and transparent (CISEH 2010). Three to six inch panicles, or flower heads, appear from May to July and are brown, green, or purple in color (CISEH 2010; DOEWA 2011). Seeds are dropped within a week or so and may be either fertile or sterile (Foré 2002, Lavergne and Molofsky 2004). Because of this, individual plants may rely heavily on cross-pollination to reproduce, although each is capable of producing an abundance of seeds annually. These seeds are persistent in the seed bank and may lie dormant for several seasons before germinating. Germination occurs ideally under cool, well-lit, and high soil moisture conditions with best results under fully saturated soil conditions (USEPA 2008, Lavergne and Molofsky 2004). RCG is found primarily in marginal areas including wet meadows but is also quite drought tolerant (Kim et al. 2006, Lavergne and Molofsky 2004). Under drier conditions it has proven to have a competitive edge on other cool season grasses through relatively rapid adaptations to fluctuation in water availability (Lavergne and Molofsky 2004). Most RCG phenotypes typically have a high concentration of trytamine, carboline, gramine, and hordenine alkaloids, rendering them largely unpalatable and unsuitable as feedstock (Lavergne and Molofsky 2004, Kellogg and

Bridgham 2004). These particular alkaloids act as natural pesticides and toxins for RCG's self-defense against predation (CISEH 2011).

Non-native, low alkaloid (more palatable) phenotypes of RCG were repeatedly introduced to the U.S. since the 1850s in an attempt to provide feed for livestock as well as soil stabilization in disturbed farmland areas (Perry and Galatowitsch 2006, Lavergne and Molofsky 2006). It is currently an important component of hay feedstock utilized from Montana to Wisconsin (DOEWA 2011). More recent uses of RCG have included wastewater treatment and use as biofuel (Lavergne and Molofsky 2006, Conchou and Fustec 1988). It has also found uses in the paper and fiber industries (Lavergne and Molofsky 2004). Cultivars have also been developed for ornamental use and continue to be sold at present despite the extensive awareness of the aggressive tendencies of this species (Lavergne and Molofsky 2004, Lefor 1987). There have, however, been drawbacks to the repeated introduction of this species into the U.S. The act of hybridization of more vigorous cultivars for these various ends is believed to have contributed to RCG's spread in both the central and western portions of the U.S. (Lindig-Cisneros and Zedler 2001, CISEH 2011). RCG's ability to aggressively spread vegetatively, tolerate a wide range of hydrologic conditions including seasonal and anthropogenically-caused fluctuations, and demonstrate great phenotypic plasticity give it a competitive edge over other plant species in both its native and non-native regions (Wilcox 2007). The combination of disturbances from cultivation of nearby agricultural fields and the active promotion of the use of RCG can allow homogenous stands of it to become established (Wilcox 2007). RCG has thus successfully invaded surrounding wet meadows, stream banks, and flood plains of the U.S. and Canada (Wilcox 2007).

RCG invasiveness is particularly problematic in areas with abundant light and increased sedimentation rates, resulting in lower successful germination rates of native plant species (Perry and Galatowitsch 2006, Brooks et al. 2006). RCG uses this additional light to its advantage through rapid stem elongation, overshadowing its competitors, especially sedges often found in wet meadow communities (Lavergne and Molofsky 2006, Perry and Galatowitsch 2006). It is capable of rapid adaptation to changes in light and CO_2 levels, altering rates of photosynthesis and stomatal conductance (Broderson et al. 2008). Increased nitrogen-use efficiency and subsequent above-ground biomass by RCG lend a competitive advantage, particularly under conditions of excess nutrients either through the addition of organic matter or the removal of native vegetation in the area (Green and Galatowitsch 2002, Kellogg and Bridgham 2004). Nutrients normally taken up and stored by native vegetation are made available through these imbalances. RCG demonstrates an advantage over native forbs with its rapid early-season growth when most flowering species have yet to emerge vegetatively (Lavergne and Molofsky 2006). Specifically, it produces twice as much aboveground growth than belowground during its first two months of growth (Reinhardt and Galatowitsch 2005). RCG is capable of rapidly altering its shoot-to-total-biomass ratio by allocating energy into stem productivity, resulting in a larger canopy and shading its competitors (Miller and Zedler 2003). Once established, much of its biomass is invested in root production to take advantage of available soil nutrients (Reinhardt and Galatowitsch 2005). The presence of RCG has been shown to decrease the stem biomass of native species under a wide spectrum of nitrate levels, but the effect is more pronounced when higher levels are present (Green and Galatowitsch 2001). RCG seedling establishment is similarly enhanced under increased nutrient levels (Kercher and Zedler 2004).

RCG shows a competitive advantage over other plant species under fluctuating hydrological conditions. It germinates successfully in all but the most flooded situations and grows either in clumps or mats given dry or flooded conditions, respectively (Kellogg et al. 2003, Lindig-Cisneros 2001). RCG's ability to form floating masses with adventitious roots allows it to grow over the top of other species. This can have profound effects on species diversity once water levels return to normal (Lefor 1987). RCG is capable of carbohydrate storage in its roots, which increases the species' productivity (Tamura and Moriyama 2001). Productivity extends into the fall, long after other species have begun to slow their growth rates, as well as allow overwintering of rhizomes and early tiller emergence in spring (Lavergne and Molofsky 2004). Additionally, it can adapt to drier soil conditions by allocating additional resources to root production, giving it a further adaptive advantage over most wetland species (Katterer and Andren 1999). Once RCG invades wetland areas, species number and diversity decrease significantly (Kercher and Herr-Turoff 2007). It is not unusual to see the formation of dense, highly-productive monocultures, and the resulting decrease in plant species diversity leads to a breakdown in the functionality of wetlands (DOEWA 2011, Kercher and Herr-Turoff 2007).

Although wetlands function to retain stormwater and sediment entering their systems, there is a limit to the amounts that can accumulate before breakdowns in function occur. In particular, anthropogenic activities can result in excessive sediment loads from stormwater events entering wet meadows. The organic soils found in healthy wetlands are capable of water retention due to their well-organized structure. Stormwater events carry sediment with a mineral structure and a lesser ability to retain water (Werner and Zedler 2002). RCG typically forms clumps in wet meadows, and due to its extensive root system, it is capable of retaining much of the sediment entering the system (USDA 2009). These mineral sediment deposits build up, burying other plant species and covering existing seed banks. Mineral sediments are low in organic matter content, less dense than wetland soils, and over time cause a change in soil chemistry; this brings about a lessened ability of the wetland to filter nutrients and pollutants as well as prevent native species from re-establishing themselves (Werner and Zedler 2002, Kercher and Herr-Turoff 2007). Soil heterogeneity is affected as decreases in organic matter and soil microsctructure occur (Lavergne and Molofsky 2004). Increased levels of phosphorus and toxins have been noted as sediments accumulate (Werner and Zedler 2002). Sensitive species found in wetland areas are particularly affected by changes in availability of oxygen, soil particle size, and burial (Werner and Zedler 2002). Species richness and diversity decline as the sediment accumulation rate increases (Werner and Zedler 2002). RCG negatively affects the rates of succession, in some cases irreversibly (Fierke and Kauffman 2006). Given sufficient time the seed banks of these areas become depleted of native species, making restoration efforts difficult to successfully achieve (DOEWA 2011). This effect can have a cascading effect on areas downstream or at lower elevations, increasing proportional RCG seed number in seed banks and germination rates (Wilcox 2007). The capacity of wet meadows to protect downstream waters is decreased as sediment loads accumulate as well (Werner and Zedler 2002). RCG negatively impacts stream flow and water circulation as sedimentation occurs. Formation of mats with adventitious roots by RCG can lead to complete cessation of water circulation in ponds and along shorelines (Lavergne and Molofsky 2004).

RCG is avoided by native herbivores in favor of more palatable grass species, and this adds to its competitive advantage (Foster and Wetzel 2005, DOEWA 2011). The growth habit of this species does not lend itself to providing habitat for native mammals and waterfowl as it forms clumps too dense for nesting (DOEWA 2011). Decreased insect populations in areas dominated by RCG have also been noted (USEPA 2008, Lavergne and Molofsky 2004). This can have pronounced effects on higher trophic levels in the community. Restoration efforts to improve the function of new or established wetland areas have been seriously hampered by the presence of RCG, and the multitude of ecological studies on its effects on native plant species diversity establishes that the drawbacks outweigh the advantages of utilizing this species outside its native region (Galatowitsch et al. 1999, Lavergne and Molofsky 2004). As of 2010 it has been listed as an invasive species in 21 states as well as the countries of Afghanistan, Hungary, Indonesia, Italy, Japan, Korea, Mauritius, New Zealand, Poland, and Portugal (CISEH 2011, Kim et al 2006).

Methods of control and restoration efforts:

Monocultures of RCG are resistant to eradication and require stringent, long-term methods of control to remove and prevent subsequent re-establishment (Annen 2008). RCG can be controlled through manipulation of various limiting factors, including light, soil nutrient, and water levels. Experimental management methods have included mowing, grazing, tillage, burning, herbicide application, mechanical barriers, cultivation, shading, and flooding (Kim et al. 2006). A study by Conchou and Fustec (1988) demonstrated increased vigor of RCG via excess nutrient uptake when plants were cut. Mechanical methods have proven insufficient on their own as an effective control method for RCG and require planting of native species as cover crops to prevent RCG re-emergence within a few seasons (Lavergne and Molofsky 2004). RCG seed germination can be significantly reduced by prolonged flooding (Lavergne and Molofsky 2006).

Most early studies examined limiting nutrient levels, and only recently has the potential for controlling growth through shade manipulation been tested. One such study proposed a model utilizing cover crops to control RCG (Perry and Galatowitsch 2006). Multiple-year treatments were deemed necessary for any long term RCG control. In one study a combination of tillage and herbicide application showed promising second-season results for RCG control (Annen 2008). Previous research efforts have shown that increasing the level of shade lowers the vigor of seedlings and established plants of RCG. Resulting RCG biomass was reduced up to 97%, particularly in the rhizomatous region. This experiment was conducted *ex situ*, sowing an assortment of native and non-native species, including RCG (Kim et al. 2006). Greenhouse experiments have shown reductions of 52% in partial shade and 99% in full shade (Perry and Galatowitsch 2003). Despite short-term success at controlling RCG growth, field studies have shown RCG to re-establish dominance within two years' time (Lavergne and Molofsky 2006). There is a limited amount of research available on native grass species and their ability to compete with RCG in field studies.

Restoration efforts have shown the necessity to plant native species in additions to attempts to remove invasive species (Reinhardt and Galatowitsch 2008). Because RCG is capable of inhibited plant growth and forming barriers to the native seed bank, it is necessary to implement sowing and planting regimens into any successful endeavor at native species recruitment. Propagule pressure has been identified as a key factor in determining not only the invasibility of an area, but also the long-term success of invaders in the community (Ervin 2006). In the case of restoration efforts, it is often necessary to simulate these invasions utilizing native species in place of non-natives. RCG is particularly problematic as complete removal of vegetation can still result in re-establishment within a few years by seedling formation without the presence of a canopy to effectively shade them (Perry and Galatowitsch 2008). Many of the wetlands undergoing restoration efforts are located in areas where RCG is prevalent, increasing the likelihood that reinvasion will occur due to increased propagule pressure (Reinhardt and Galatowitsch 2005). A study of 41 twelve-year-old restored wetlands in the northern U.S. found all of them invaded by RCG with coverage ranging from 75% to 100% (Reinhardt and Galatowitsch 2005).

Identification of native species that are able to compete with RCG is needed for restoration efforts. In addition methods used for controlling RCG have to allow the native species to out compete the RCG. This experiment was designed to use methods of RCG control with a minimization of disturbance while promoting the successful establishment of native wetland grass species. The objectives for this study included: (1) Determine the level of shade that promotes the highest control of RCG while allowing establishment of native plant species. (2) Ascertain the survival rate of seedling versus plant plug of introduced native plant species. (3) Evaluate the native introduced species that produces the best results under each shade level. (4) Evaluate the effect of disturbance patch size on successful establishment by native species plugs and seedlings. (5) Determine the success of mowing in controlling RCG growth rates and promoting native species success. It is hypothesized that *E. riparius* would successfully germinate and establish across all shade levels due to its tolerance of full sun to low-light conditions and high seedling vigor.

CHAPTER 3: MATERIALS AND METHODS

The site for this study is located in Greenville, PA (Mercer County) at N 41^{o} 24.391' latitude and W 80^{o} 16.740' longitude and is situated on 125 acres, which were formerly utilized for agriculture (Figure 3.1). This practice ceased in the mid to late 1970s and has since been allowed to naturalize. The site is a wet meadow dominated by reed canarygrass, effectively forming a monoculture. The study area measures 27.4 m x 8.8 m and is surrounded by *Cornus racemosa* Lam. (swamp dogwood) on three sides (Lamarck 1783). On its northern border is a second-growth forest. The study area was cut down in the fall of 2008 to facilitate plot placement, shade structure construction, and the plug/seed planting process the following season (Figures 3.2).

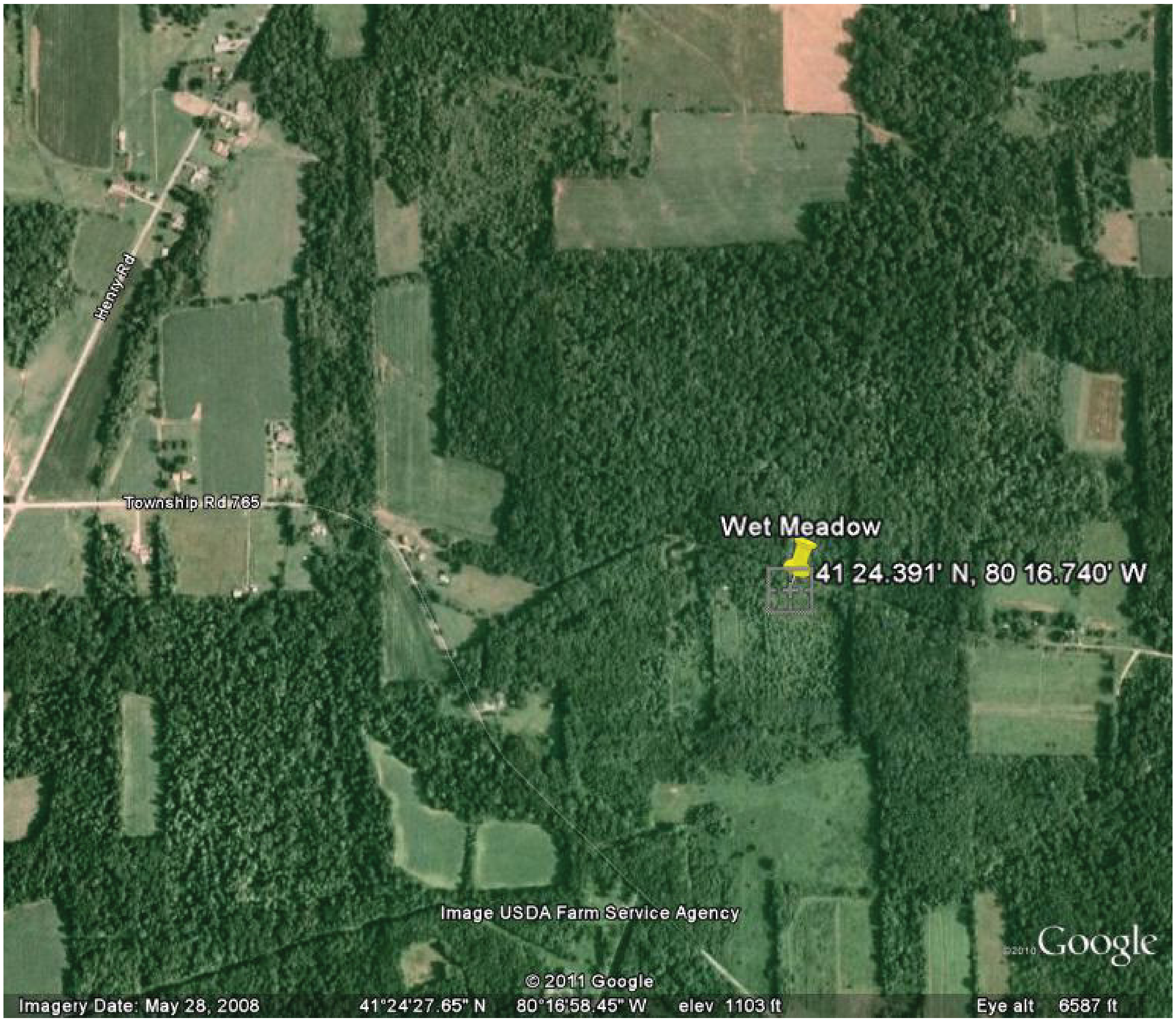

Figure 3.1 - Satellite image of field site location (Image: USDA Farm Service Agency Google ©2001).

Figure 3.2 – Mowed field site October 2008.

Two species of native plant species were utilized in this study: *Elymus riparius* Wiegand (Riverbank wild rye) (Soreng 2003) and *Panicum virgatum* (Switch grass) (Hitchcock 1951). *E. riparius* was chosen because it is a native C_3 facultative wetland grass species tolerant of a wide range of shade, pH, and soil texture and moisture levels, as well as being easy to grow from seed (USDA 2009). In addition, it reaches a mature height of 4.5 feet and grows equally well in sun or shade. *P. virgatum*, a native C_4 grass species reaching heights of 5 feet, is less shade tolerant and is both a facultative wetland species and an upland indicator. It was utilized as an alternate when a seeded forb species, *Rudbeckia laciniata* (cutleaf coneflower) (Linnaeus 1753), failed to germinate under greenhouse conditions prior to the commencement of the study. The importance of a wide range of light/shade tolerance in these species is important for this experiment but also later when the shade cloth is removed to allow for successful competition. Likewise, taller plant species were chosen to not only successfully compete with RCG but to ultimately continue the pattern of shading to prevent its re-establishment. No prior studies for *E. riparius* could be found, so it was of additional interest to ascertain the degree to which this species would germinate and establish itself under field conditions. Seeds for *E. riparius* and *P. virgatum* were purchased from Prairie Moon Nursery. *E. riparius* plugs were grown from seed and were 4 weeks old at the time of planting. Due to poor germination rates, *P. virgatum* plugs were purchased from Prairie Moon Nursery and were second year plants. The crowns of *P. virgatum* were split prior to planting to more closely resemble first season growth plugs.

A completely random split-plot design with disturbance patch size and shade level was utilized for the experiment. This consisted of 36 plots measuring 1 m x 0.5 m with a minimum of 0.5 m between each plot. Each treatment thus encompassed a 0.5m x 0.5m area and contained plugs and seeds for both *E. riparius* and *P. virgatum* (Figure 3.3). Light levels were altered over a gradient to determine an optimal condition for the control of reed canarygrass with the concurrent establishment of native plant species. Three shade levels were used: 0%, 40%, and 80%. A total of six areas of shade utilizing two of each of these shade levels were randomized along the length of the site. Within each shade area plots were again randomized by disturbance patch size: 8-inch diameter clearings (large disturbance), 4-inch diameter clearings (small disturbance), or uncleared areas (no disturbance). This was done to measure effects of distance to nearest neighbor to determine the role of competition in establishment. In each of the plots there were eight sub-plots, half of which were subjected to mowing. Half of the plots were devoted to Species A (*E. riparius*), and half were devoted to Species B (*P. virgatum*). Both species were planted as plug and seed forms (25 seeds/plot). This set-up allowed for all parameters to be established in triplicate. Finally, three control plots were randomly assigned for each shade level. These were not planted with plugs or seeds from either native species and were only split to measure mowed versus unmowed areas.

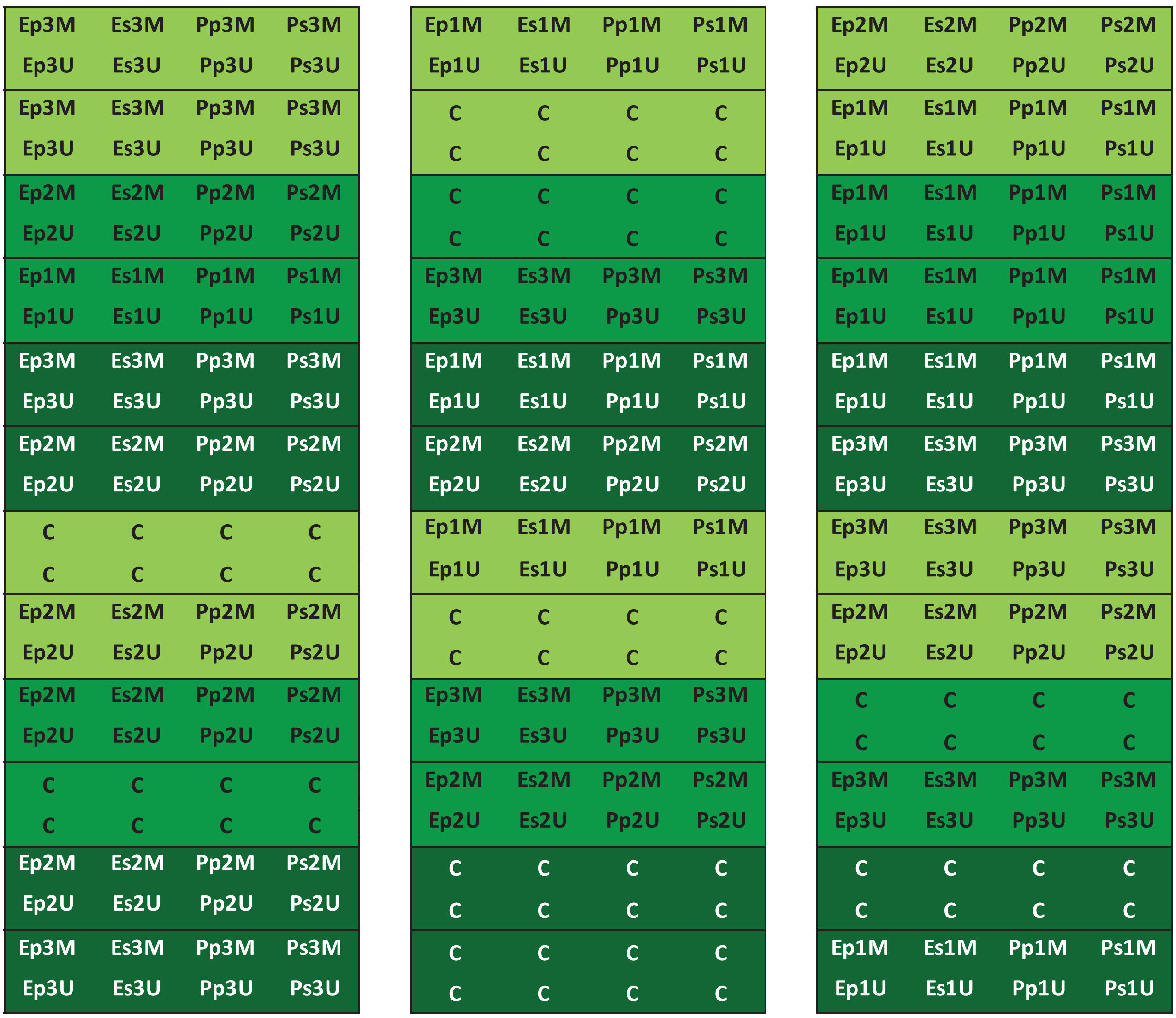

Figure 3.3 – Schematic of randomized split-plot design where Indicates 0% shade, indicates 40% shade, indicates 80% shade, E = *Elymus*, P = *Panicum*, C = Control (no plugs/seeds), p = plug, s = seeds, 1 = no disturbance, 2 = small disturbance, and 3 = large disturbance.

Figure 3.4 – Plot design demonstrating 8-inch disturbance patch size.

Shade was provided through the use of Green-Tek®, which is a black nylon mesh product manufactured by the International Greenhouse Company. Shade cloth was fastened to a structure at the perimeter of the site at a height of six to eight feet above the ground. Plastic zip ties were used to attach individual pieces of shade cloth to one another and to the structure itself. Tent pegs were in place and tied to the shade cloth to provide additional support. This method of construction allowed for consistent levels of shading, precipitation, and animal grazing throughout the season (Figure 3.4). Shade cloth was added the second week of June, much later than the original planned date of April.

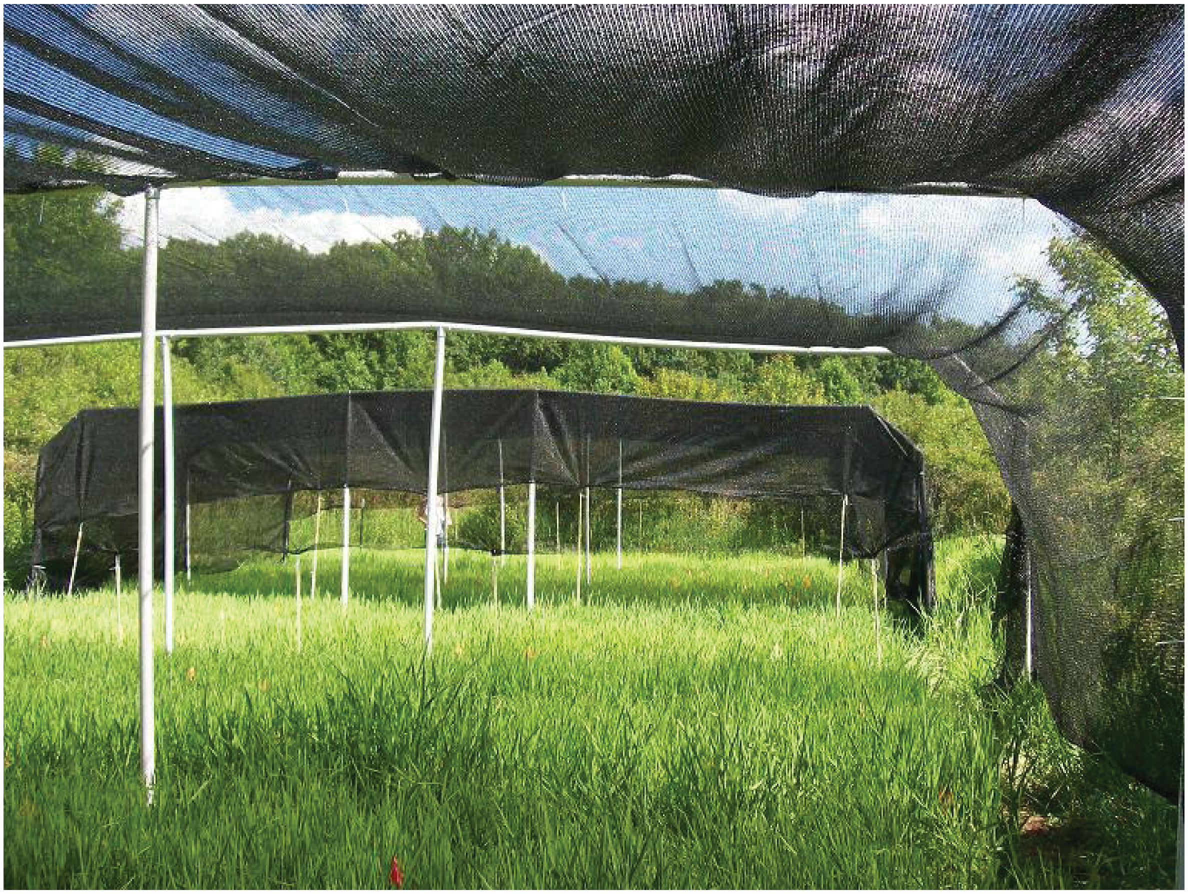

Figure 3.5 - Shade structure utilizing fence posts, PVC tubing, and nylon mesh shade cloth (June 2009).

Disturbance patches were placed in the center of the plots and made using soil corers of the appropriate dimension. This enabled the removal of RCG rhizomes to prevent initial RCG intrusion into the disturbance patches. *E.* riparius and *P.* virgatum plugs and seeds were planted June 15th, 2009 and situated in the center of the plots. Initial plant heights were taken. Dead or missing plugs were replaced two weeks after starting the experiment to ensure maximum plug survival at the onset. Plant heights for *E. riparius* and *P. virgatum* plugs as well as RCG plants were taken every two weeks. Seedling count and average height of these species were taken every two weeks as well. Plant height measurements were taken with a yardstick from base to tip of longest tiller. RCG tillers were selected randomly based upon visual average height estimations. Plant height was used for ease in measurement and because most plugs had single tillers. Percent coverage by RCG was visually estimated every two weeks as well. No effort was made to remove RCG rhizomes or other plant species from entering the plots throughout the season. Mowed areas were cut to 46cm (18 inches) every four weeks utilizing battery-powered trimmers. This was done after plug and seedling heights were measured for that date. Visual assessments of the sight were conducted, and any needed repair to the shade structure was made (i.e. loose tent pegs, etc.). Light level readings were taken using a Li-Cor LI-250A light meter throughout the season under full sun conditions. Readings were taken for each plot at the height of the mowed RCG. Dry weights of seedlings and plugs were taken at the end of the first season utilizing a Fisher Scientific accu-124 scale. Soil samples were also taken at this time to determine pH, nitrogen and phosphorus levels. The study was conducted for 20 weeks, beginning June 15th and ending October 21st, 2009.

CHAPTER 4: RESULTS

Normal distributions for each parameter were determined utilizing the Statistical Package for the Social Sciences (SPSS version 17.0). If normal distribution was not obtained, no further analysis was done. Otherwise, a three-way ANOVA analysis was done with shade, disturbance patch size (DPS), and mowing as treatments to ascertain any significance in the data (Appendix). The dependent variable was height change in most cases, except for RCG percent coverage change in which percent coverage change was used instead. The significance of the results was based upon *p* values of 0.05 or less. The overall strength of any correlation was based upon the *F* value obtained.

Elymus **Growth and Survival**:

Throughout the study herbivory of *E. riparius* plugs was noted, particularly in plots with a larger disturbance patch size. In some cases the plug was entirely absent, but in others signs of herbivory would be in evidence. The remaining plugs appeared healthy with no apparent signs of stress or dieback. Herbivory appeared to play a heavier role early and late in the study (late spring and fall). Plugs surviving past week 6 (end of July) survived until week 14 (early October) with only one exception. No differences in growth habit or appearance were noted between treatments. Seedling success was mixed. Some plots had no seedlings germinate. However, when there was germination present seedlings quickly approximated the height and appearance of their corresponding plugs.

There was a normal distribution observed for *Elymus* plug data (Appendix), but the only significant interaction (p=0.035) observed was between combined shade level/ disturbance patch size and height change (Table 4.1). There was a significant decrease in height change in full sun and large DPS when compared with other full sun treatments or large DPS treatments under shade. There was an associated *F* statistic of 2.905 indicating a rather weak correlation.

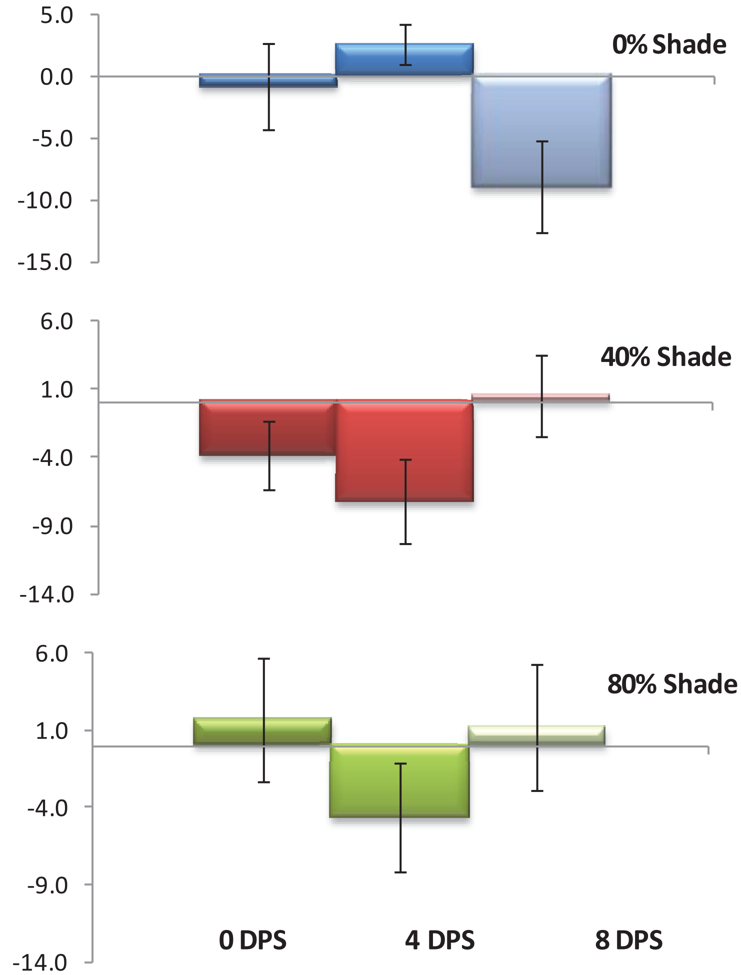

Figure 4.1 – *Elymus* plug data plotted as disturbance patch size (DPS) vs. height change (cm) over three shade treatments. Error bars are based upon standard error results for each treatment type. Significance ($p=0.035$) and overall strength ($F = 2.905$).

Under full sun conditions, large disturbance patch size treatments showed a 65.3% decrease in seasonal height versus 1.0% and 23% increases in no disturbance and small disturbance patch size treatments, respectively. Comparing large disturbance patch size treatments revealed increases of 22.3% and 25.5% for 40% shade and 80% shade, respectively versus this same 65.3% decrease for 0% shade.

There was no germination in 28 out of the 54 seeded plots of *Elymus*. However, this was not evidently in response to any particular treatment but rather a random occurrence in the data. Due to the large number of zeroes for this data, a skewed distribution curve occurred. Because the data was so heavily skewed, no further data analysis was done. For *Elymus* seedling height the data results were the same. No germination in over half of the plots led to many zeroes for height, so a normal distribution could not be obtained. Further analysis was not done.

***Panicum* Growth and Survival:**

The plugs of *P. virgatum* showed signs of stress from the onset of the study. Tiller tips began to turn brown, and this process continued throughout the season. Few new tillers were produced, and lengths of new tillers never approximated those originally present. No signs of herbivory were present throughout the course of the study. Seed success for this species was poor with very few plots showing germination. Those with germination typically had only a single seedling present.

The data for *Panicum* plugs showed normal distribution, and two significant results were observed. Shade level was determined to be significant with a p value of 0.000, and an F statistic of 10.960, demonstrating a very strong correlation (Figure 4.2). Under 80% shade there was a marked decrease in plug success compared to both 0% and 40% based upon height change. Height change decreased across all three shade levels, but it was only 14.2% under 0% shade and 12.6% under 40% shade. However, under 80% shade there was a 56.9%

decrease in seasonal height. These results support the data indicating intolerance of *P. virgatum* to shaded conditions (USDA 2009).

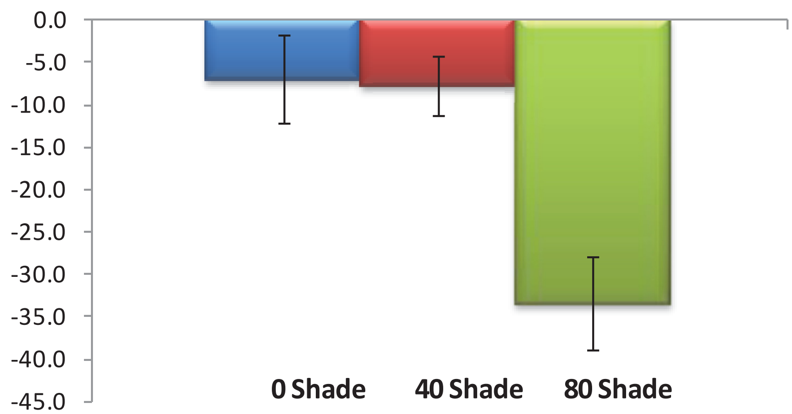

Figure 4.2 – *Panicum* plug data plotted as shade level vs. height change (cm). Error bars are based upon standard error results for each treatment type. Significance (p=0.000) and overall strength (10.960).

The second area of significance involved shade level and disturbance patch size (p = 0.038). The corresponding F statistic was 2.841, so the relationship was not as strong (Figure 4.3). In 80% shade there were decreases of 65.7% and 83.9% in seasonal height for *P. virgatum* under no disturbance and small disturbance patch size, respectively. Comparing to the values obtained for 0% and 40% shade showed a marked decrease in success for *P. virgatum*. There was an 18.8% increase in height with 0% shade/no disturbance treatments and an 18.0% decrease with 0% shade/small disturbance patch size. In 40% shade there were decreases of 10.0% and 23.2% for no disturbance and small disturbance patch size treatments, respectively. There was also significance when compared with combined 80% shade/large disturbance patch size, where the decrease was only 21.2%. This indicates that the poor performance of *P. virgatum* may be offset somewhat by RCG's lack of competitive advantage under heavily shaded conditions.

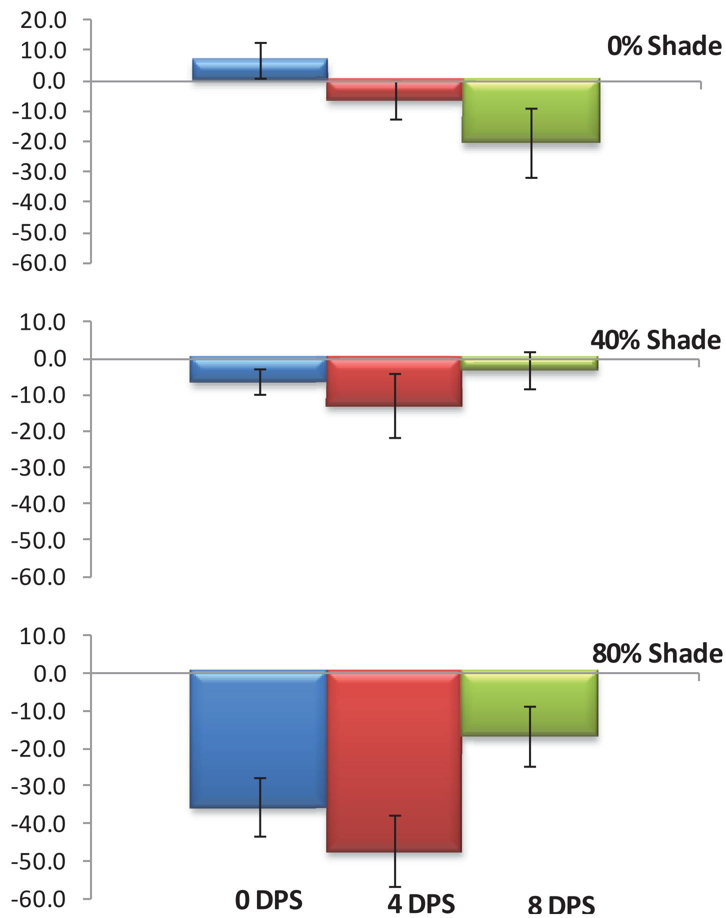

Figure 4.3 – *Panicum* plug data plotted as disturbance patch size (DPS) vs. height change (cm) across all three shade levels (0%, 40%, and 80%). Error bars are based upon standard error results for each treatment type. Significance ($p = 0.038$) and overall strength ($F = 2.841$).

There were no seedlings germinated in 47 out of 54 plots seeded with *P. virgatu,*. Due to this fact, the data for *P. virgatum* seedlings germinated and height did not show normal distribution patterns, and no further analysis was done.

RCG Growth and Survival:

There were apparent changes in RCG response to shade level treatments within four weeks of the onset of the study. A noticeable change in leaf blade color occurred under 40% and 80% change. Full sun RCG color was a pale green, whereas shaded RCG took on a more grey-green coloration. In addition, etiolation of the stems was in evidence in unmowed sections of 40% and 80% shade, showing a visible increase in height in these areas over their full sun counterparts. Within six weeks of the study RCG in 40% and 80% shade lost its rigid, upright form and instead formed heavy mats of foliage. No evidence of intrusion of RCG rhizomes into the disturbance patches occurred throughout the season, although RCG seedling recruitment into the plots began to occur around the tenth week (early September). Percent coverage change appeared to increase early in the study and then stabilize about halfway through the study, supporting data showing early season aboveground biomass increases followed by below-ground increases (Lavergne and Molofsky 2004). Very few seed heads were observed in any of the plots, including controls, which was unexpected especially under full sun conditions.

The data for RCG height change showed a normal distribution and three significant correlations. The strongest of the three was the obvious relationship between grazing level and height change (F = 176.873, p = 0.000), with height decreases under mowed conditions (Figure 4.6). Under mowed conditions there was a 196.8% increase in height over the course of the study, whereas there was a 305.6% increase in height in umowed treatments. The other expected trend was a strong relationship between shade levels and height change, with significance under 80% shade levels (F = 10.297, p = 0.000), suggesting 80% shade the threshold at which RCG began adaptation mechanisms (Figure 4.4). Height level change increases were 65.8%, 66.0%, and 73.3% for 0% shade, 40% shade, and 80% shade, respectively. This trend was observed visually throughout the season and might have been more pronounced had full season data been obtained. The third observed correlation involved that of disturbance patch size and change in height (see Figure 4.5). Although shown to be statistically significant (p = 0.017) and a relatively strong correlation (F = 4.256), the error involved did not distinguish one treatment from another. Changes in height were increases of 253.7%, 237.8%, and 260.9% for no disturbance, small disturbance, and large disturbance, respectively. The slight decrease in height under small disturbance also did not follow logical explanation.

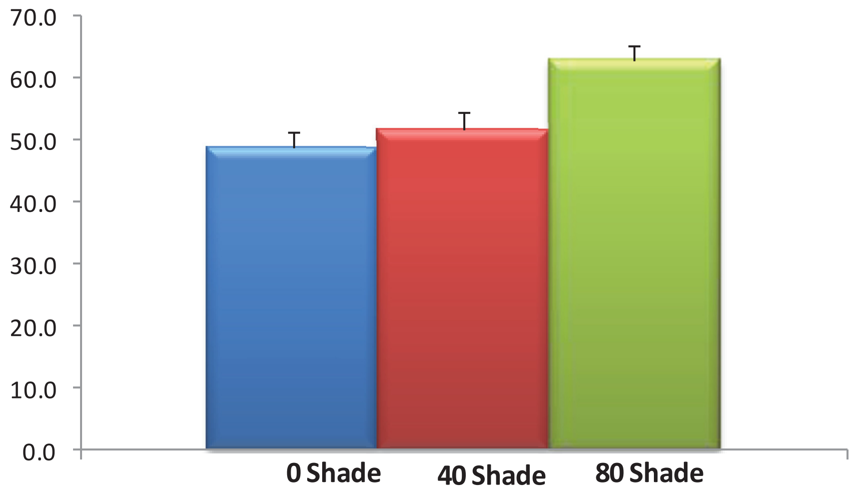

Figure 4.4 – *Phalaris* data plotted as shade level vs. height change (cm). Error bars are based upon standard error results for each treatment type. Significance (p = 0.000) and overall strength (F = 10.297).

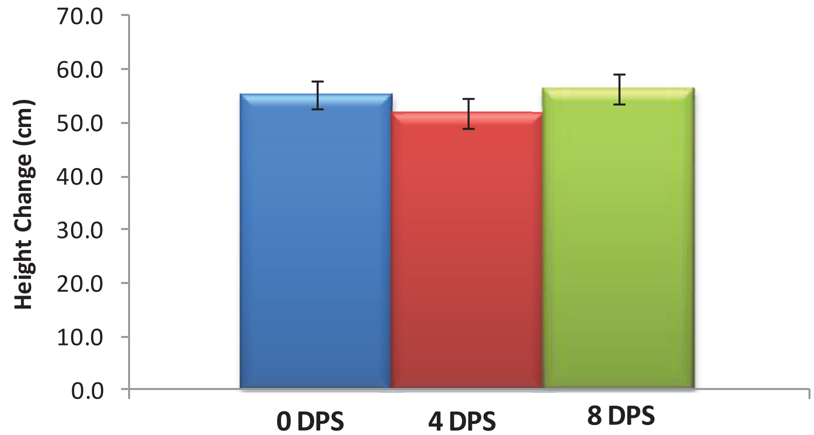

Figure 4.5 – *Phalaris* data plotted as disturbance patch size (DPS) vs. height change (cm). Error bars are based upon standard error results for each treatment type. Significance (p = 0.017) and overall strength (F = 4.256).

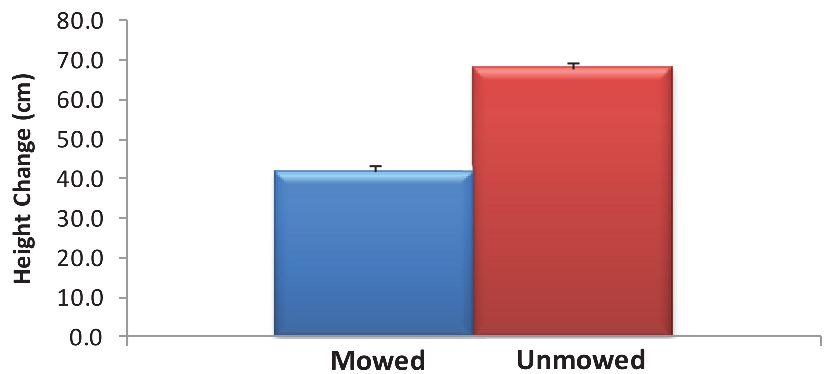

Figure 4.6 – *Phalaris* data plotted as mowing Level vs. height change (cm). Error bars are based upon standard error results for each treatment type. Significance (p = 0.000) and overall strength (F = 176.873).

Percent coverage of RCG showed normal distribution and a significant, but relatively weak, correlation was shown between disturbance patch size and change in percent coverage (F = 3.101, p = 0.050). Figure 4.7 demonstrates that RCG showed a significantly larger change in percent coverage with the large disturbance patch size (18.1%) than with either no disturbance (11.5%) or small disturbance patch size (9.4%).

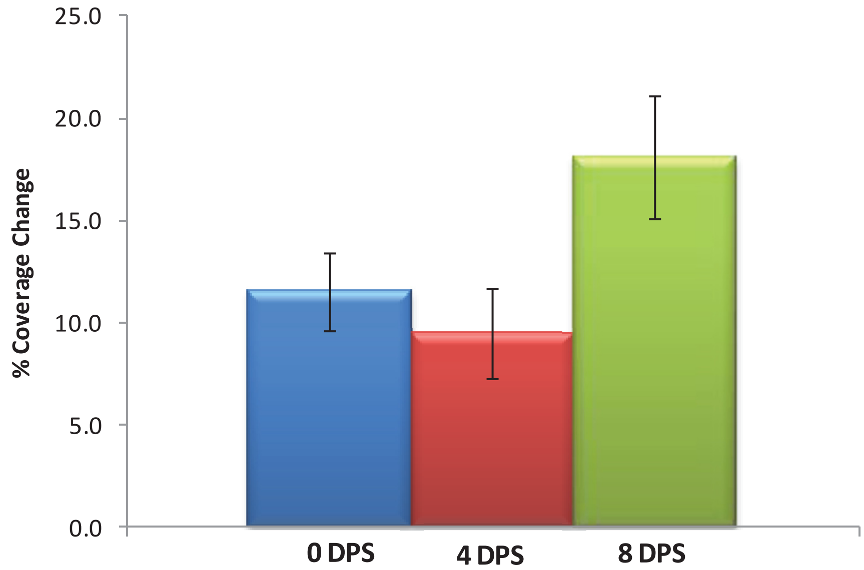

Figure 4.7 – *Phalaris* data plotted as Disturbance Patch Size (DPS) vs. Percent Coverage Change. Error bars are based upon standard error results for each treatment type. Significance ($p = 0.050$) and overall strength ($F = 3.101$).

CHAPTER 5: DISCUSSION

The first objective of this study was to determine the level of shade that promotes the highest control of RCG while allowing establishment of native plant species. The nylon mesh shade cloths were 40% shade and 80% shade according to the manufacturer. The measured light readings taken from the site under these shade cloths were 51.8% (+/- 15.7) shade and 73.2% (+/- 12.1) shade, respectively (Figure 5.1). Given the margin of error in the samples, these values support the shade factor levels provided by the manufacturer.

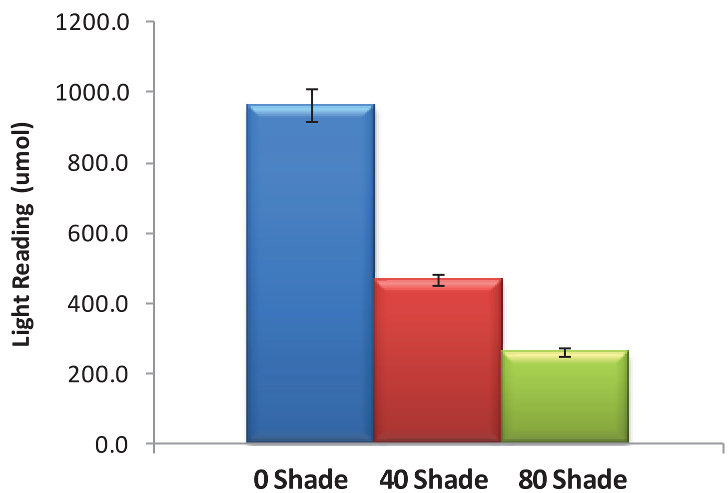

Figure 5.1 – Light reading data plotted as shade level vs. seasonal average light reading (umol). Error bars are based upon standard error results for each shade level.

The 80% shade level was effective in significantly altering the height of RCG and *P. virgatum* plugs. Etiolation in stems of RCG caused an increase in height, whereas *P. virgatum* height was lowered due to its intolerance to shade. *E. riparius* plugs displayed no significant change in height among shade levels with the exception of combined 0% shade/8 inch DPS. This treatment resulted in reduced *E.* riparius plug height, which has been attributed to RCG's competitive advantage under full sun disturbance patterns. In addition, this level of shade brought about visible changes in RCG, notably lighter leaf blade color and less rigid stem structure through stem flop. Leaf blade color change and stem flop took place under 40% shade as well, but it is possible to conclude that 80% shade was the threshold at which RCG would devote greater energy towards aboveground biomass since there was the additional factor of stem elongation involved. Because RCG has been documented as devoting its early season growth to aboveground biomass and late season growth to below-ground biomass, extending this study for several seasons might show a weakening of its root and energy storage systems if etiolation continued into the latter part of the season (Lavergne and Molofsky 2004). Potentially heavy shading could lead to changes in percent coverage and overall RCG strength which might allow native species an opportunity to establish themselves. Based upon the study results, 80% shade is the recommended level of shade for future studies in control of RCG, as it demonstrated adverse effects on RCG without significantly altering the capacity for native, shade-tolerant species recruitment.

The second objective of this study was to ascertain the survival rate of seedling versus plug of introduced native plant species. Unfortunately, the results for seed germination and establishment were inconclusive for this experiment. *E. riparius* showed better germination success (26 out of 54 plots) than *P. virgatum* (7 out of 54 plots), but due to the large number of plot in which no germination occurred no further information is available. There are several potential explanations for the low germination rate observed. The first, and most important, has to do with insufficient levels of mowing. Given more stringent mowing levels (6 inches rather than 18 inches), there is the potential for greater establishment success as available light at ground level increases (Perry and Galatowitsch 2006). When RCG biomass is reduced through mowing, its competitive advantage is decreased by weakening plants' overall vigor (Lavergne and Molofsky 2006). This can also lead to reduced RCG seed production, thereby increasing seed bank diversity (Perry and Galatowitsch 2006, Lavergne and Molofsky 2006). Increased light levels would bolster germination rates as they are critical factors in seedling establishment (Lindig and Zedler 2001). Second, the timing of sowing is important in germination success. The study was begun the third week of June, and grass cultivar seeds germinate either in late spring or early fall (Prairie Moon Nursery 2011). The timing of sowing in this study gave seeds a narrow window of time to germinate and could have affected the results. Third, the potential exists that seeds could have washed out of their individual plots. Shortly after seed placement water levels increased, which could have affected seed germination results. Placing barriers around these plots could have helped prevent this from occurring. Furthermore, the seed count for each plot could have been increased from 25 to 50 to help ensure some seedling germination in more plots. Finally, lower rates of *P. virgatum* germination reflect species intolerance for shade, so other native species should be investigated.

The third objective of the study was to evaluate the native species which produces the best results under each shade level. Overall, *E. riparius* plugs showed success in establishment over all three shade levels. Because there was no significance in height change over shade treatments, this species is recommended for experiments involving shade. The fact that *E. riparius* showed no significant decrease in performance under shaded conditions could allow it to successfully compete with RCG due to the latter's inability to demonstrate competitive advantage under these conditions. As expected, *P. virgatum* plugs performed significantly worse under heavily shaded (80%) conditions than in full sun or 40% shade.

Because this species is known to not perform well under shade conditions and is an upland indicator, it did not lend itself well to study conditions. A forb species, such as *Rudbeckia laciniata* (cutleaf coneflower), which is a native facultative wetland forb capable of rapid growth, reaching heights of 8 feet, and tolerant of a wide range of shade and soil texture conditions, would be a better choice for future studies (USDA 2009).

The fourth objective of this study was to evaluate the effect of disturbance patch size on successful establishment by native species plugs and seedlings. Due to insufficient seed germination by either *E. riparius* or *P. virgatum*, no determination could be made for recommended disturbance patch size. In terms of *E. riparius* plugs, disturbance patch size played a role only at the large (8-inch DPS) level, where it caused a stimulation of growth in RCG under full sun conditions. This corresponded to a significant negative impact on plant height of *E. riparius* plugs when compared with no disturbance or small disturbance. This pattern was not repeated under shaded conditions, possibly reflecting a decreased competitive advantage by RCG at these levels. *P. virgatum* plugs showed a significant increase in height under 80% shade and large disturbance patch size when compared with no disturbance or small disturbance. The pattern was not observed under full sun or 40% shade levels. Therefore, it is recommended that the larger disturbance patch size be utilized as well as an 18-inch (full plot) disturbance size in future studies to further determine RCG's role in competitive suppression when presented with excess nutrient levels and light.

The final objective of the study was to determine the success of mowing in controlling RCG growth rates and promoting native species success. Mowing did not play a significant role as administered in this study except in relation to decreased seasonal RCG height. Due to the frequency of mowing (bi-monthly), this result is of little consequence. A more stringent regime of mowing (6 inches rather than 18 inches) would allow greater ground light levels for seedling germination and plug/seedling establishment by native species. It would also increase rates of RCG suppression by causing increased energy to be spent on stem/leaf growth rather than on late season root/rhizome growth. An alternate method of plug/seedling measurement is recommended as well. Tiller count would be utilized instead, as it would be a more accurate measure of aboveground biomass and overall plant vigor.

A second season of study was planned to study second-year growth of plugs and seedlings, and this would have allowed the implementation of improvements to the study. However, none of the plants from the previous season successfully overwintered, owing largely to their small size and the capacity of RCG to establish itself early in the season and utilize available resources. No attempt was made at repeating the experiment for a second season. Increased light availability through more stringent mowing techniques (6” height) in combination with the implementation of a second species tolerant to a wider array of shade and hydrology regimes were two of the proposed changes to be implemented. In addition, the replacement of the smaller disturbance patch size with a larger disturbance patch size of 18” is recommended for future studies.

CHAPTER 6: CONCLUSIONS

Promising first season plug growth and seedling germination of the native facultative wetland grass species *Elymus riparius*, which had limited experimental data prior to this study, demonstrates the potential for this species to be included in future restoration efforts. Other native wetland species should be investigated, including forbs as well as grasses. Previous studies utilizing shade cloth as a means of controlling RCG growth have been limited and were mainly done under greenhouse conditions, so the successful implementation of artificial shade under field conditions was of considerable importance. Adverse effects on RCG were demonstrated in this study, including loss of green color, etiolation and reduced invasion after disturbance, with the most significant changes occurring at 80% shade. Therefore, use of a shade cloth structure is an effective means to help in the control of RCG growth and one which can be later removed with minimal site disturbance to return the site to previous light conditions. Altering disturbance patch sizes to include a small (8-inch) disturbance and large (18-inch) disturbance in future studies is recommended, due to lack of results from this study's small (4-inch) disturbance patch size. Mowing to a height of 6 inches instead of 18 inches as applied in this study would allow increased seed germination as well as increased rates of seedling and plug establishment due to increased light levels at ground level. In addition, the potential for overwintering and second-year study of native species would be improved by these changes in mowing practices. Finally, tiller count is recommended rather than plant height as a measure of aboveground biomass and plant establishment, as a great deal of early growth is devoted to tiller establishment as well as overall height.

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APPENDIX A – Distribution Curves and ANOVA Tables

Elymus Plugs

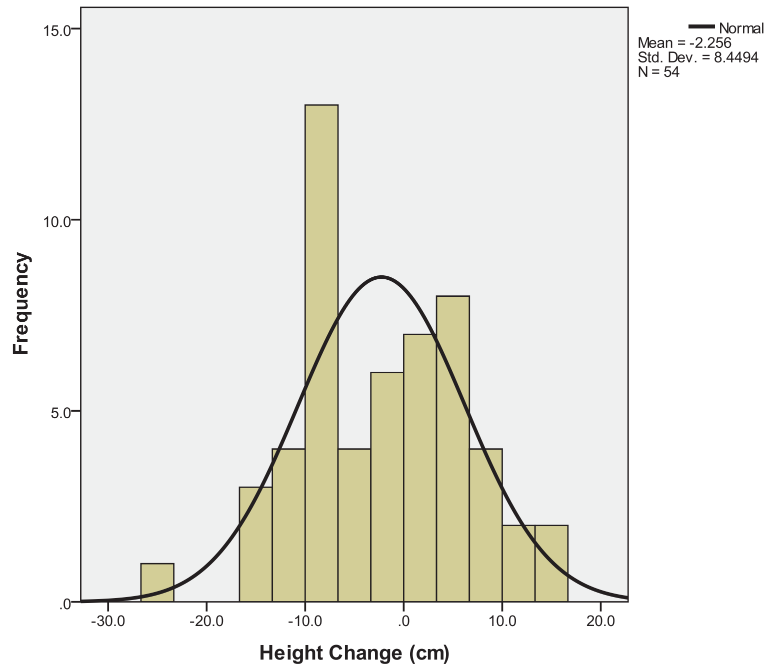

Figure 8.2 – Distribution curve for *Elymus* plug data.

Table 8.1 – Between-Subjects Factors for *Elymus* plug data, where SHD = shade percentage, DPS = disturbance patch size, and GRZ = grazing level (0 = unmowed, 1 = mowed).

Between-Subjects Factors

		N
SHD	0	18
	40	18
	80	18
DPS	0	18
	4	18
	8	18
GRZ	0	27
	1	27

Table 8.2 – One-way ANOVA results for *Elymus* plug data. Significant results have been highlighted.

Tests of Between-Subjects Effects

Dependent Variable:HTCHG16

Source	Type III SS	df	Mean Sq.	F	Sig.
Corrected Model	1587.193[a]	17	93.364	1.530	0.139
Intercept	274.727	1	274.727	4.503	0.041
SHD	78.643	2	39.322	0.644	0.531
DPS	40.884	2	20.442	0.335	0.718
GRZ	82.140	1	82.140	1.346	0.254
SHD * DPS	708.996	4	177.249	2.905	0.035
SHD * GRZ	323.588	2	161.794	2.652	0.084
DPS * GRZ	35.040	2	17.520	0.287	0.752
SHD * DPS * GRZ	317.902	4	79.476	1.303	0.288
Error	2196.580	36	61.016		
Total	4058.500	54			
Corrected Total	3783.773	53			

a. R Squared = .419 (Adjusted R Squared = .145)

***Elymus* Seedling Count**

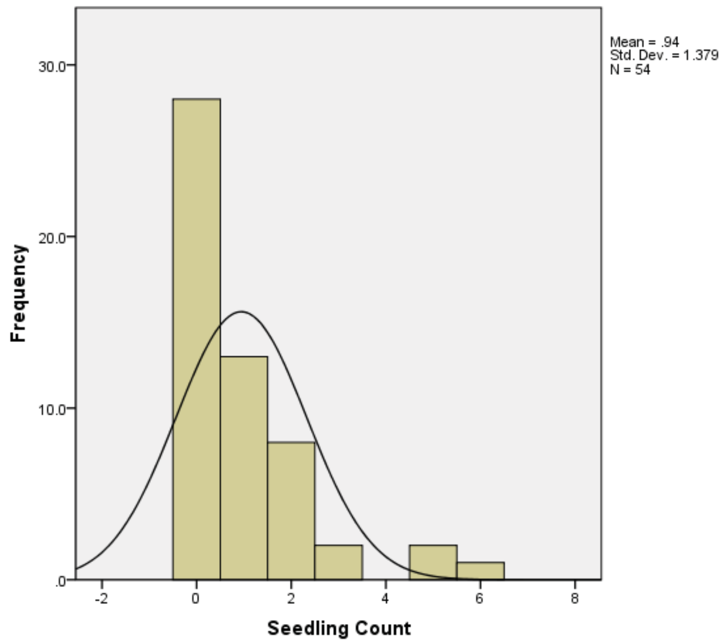

Figure 8.3 – Distribution curve for *Elymus* seedling count data.

***Elymus* Seeds**

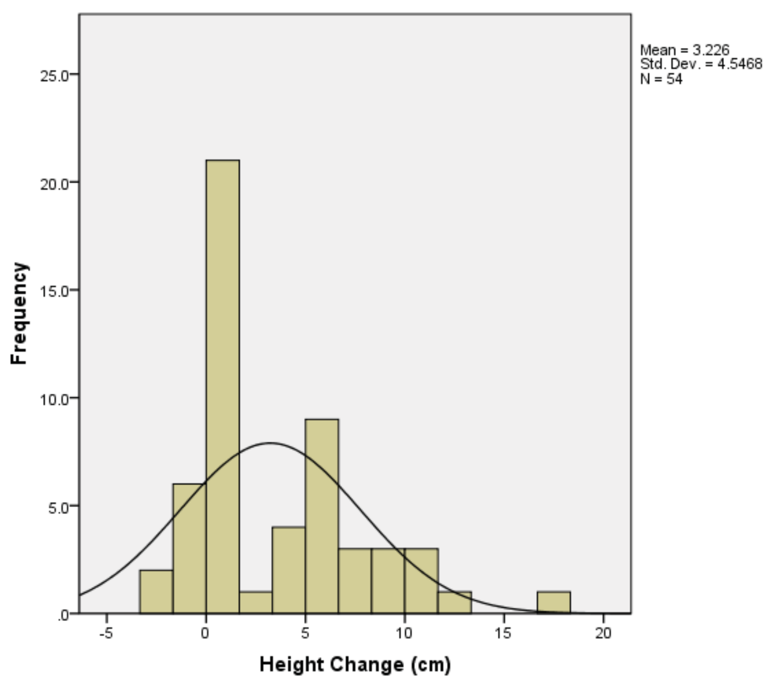

Figure 8.4 – Distribution curve for *Elymus* seedling height data.

***Panicum* Plugs**

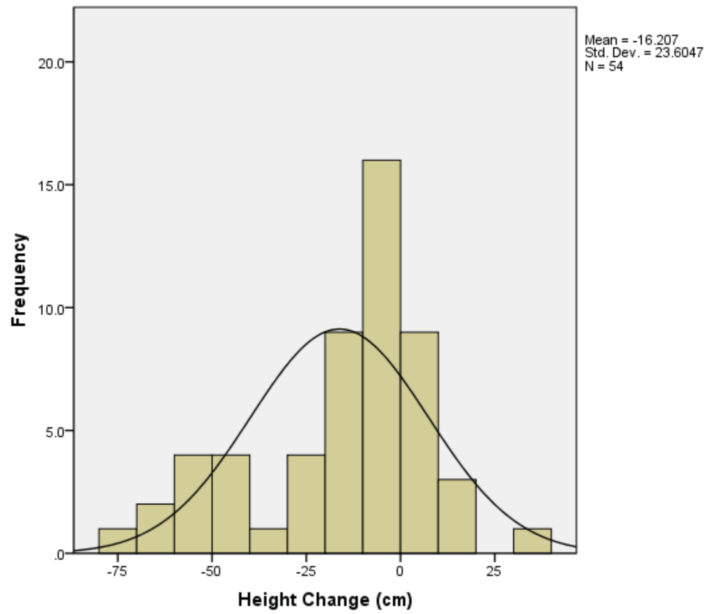

Figure 8.5 – Distribution curve for *Panicum* plug data.

Table 8.3 - Between-Subjects Factors for *Panicum* plug data, where SHD = shade percentage, DPS = disturbance patch size, and GRZ = grazing level (0 = unmowed, 1 = mowed).

Between-Subjects Factors

		N
SHD	0	18
	40	18
	80	18
GRZ	0	27
	1	27
DPS	0	18
	4	18
	8	18

Table 8.4 - One-way ANOVA results for *Panicum* plug data. Significant results have been highlighted.

Tests of Between-Subjects Effects

Dependent Variable:HTCHG16

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	16124.424[a]	17	948.496	2.547	0.009
Intercept	14184.723	1	14184.723	38.090	0.000
SHD	8162.889	2	4081.445	10.960	0.000
GRZ	392.581	1	392.581	1.054	0.311
DPS	1126.917	2	563.459	1.513	0.234
SHD * GRZ	1232.896	2	616.448	1.655	0.205
SHD * DPS	4231.927	4	1057.982	2.841	0.038
GRZ * DPS	40.117	2	20.059	0.054	0.948
SHD * GRZ * DPS	937.096	4	234.274	0.629	0.645
Error	13406.233	36	372.395		
Total	43715.380	54			
Corrected Total	29530.657	53			

a. R Squared = .546 (Adjusted R Squared = .332)

***Panicum* Seedling Count**

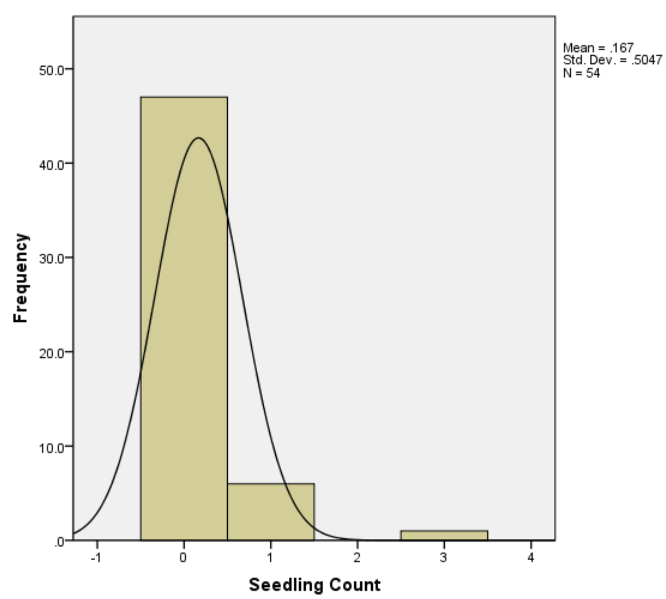

Figure 8.6 – Distribution curve for *Panicum* seedling count data.

***Panicum* Seeds**

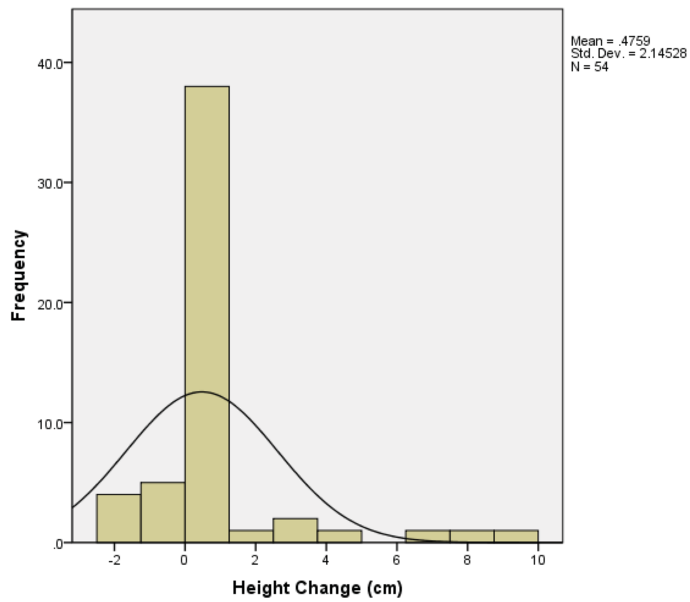

Figure 8.7 – Distribution curve for *Panicum* seedling height data.

***Phalaris* Height**

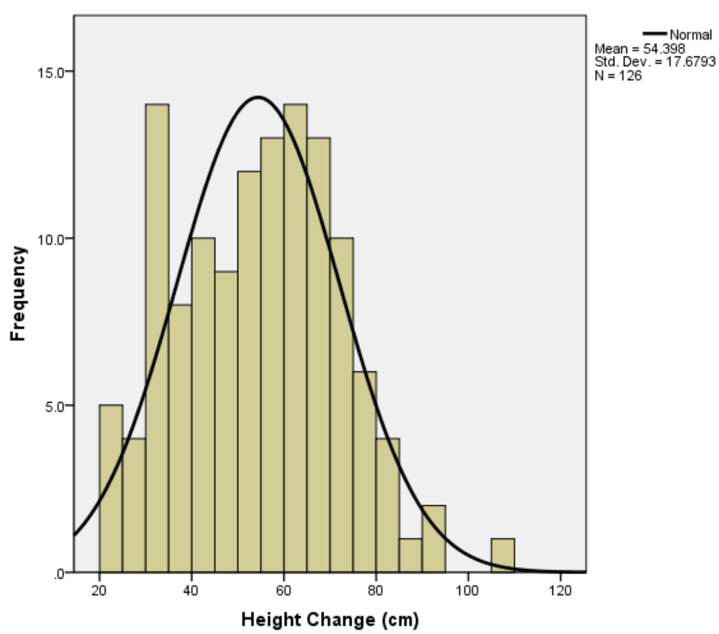

Figure 8.8 – Distribution curve for *Phalaris* height change data.

Table 8.5 – Between-Subjects Factors for *Phalaris* height change data, where SHD = shade percentage, DPS = disturbance patch size, and GRZ = grazing level (0 = unmowed, 1 = mowed).

Between-Subjects Factors

		N
SHD	0	42
	40	42
	80	42
DPS	0	54
	4	36
	8	36
GRZ	0	63
	1	63

Table 8.6 - One-way ANOVA results for *Phalaris* height change data. Significant results have been highlighted.

Tests of Between-Subjects Effects

Dependent Variable:HTCHG14

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	26175.274[a]	17	1539.722	13.037	0.000
Intercept	168918.667	1	168918.667	1430.215	0.000
SHD	2432.282	2	1216.141	10.297	0.000
DPS	1005.294	2	502.647	4.256	0.017
GRZ	20889.934	1	20889.934	176.873	0.000
SHD * DPS	251.611	4	62.903	0.533	0.712
SHD * GRZ	183.464	2	91.732	0.777	0.462
DPS * GRZ	130.269	2	65.134	0.551	0.578
SHD * DPS * GRZ	606.335	4	151.584	1.283	0.281
Error	12755.580	108	118.107		
Total	215406.570	126			
Corrected Total	38930.854	125			

a. R Squared = .672 (Adjusted R Squared = .621)

***Phalaris* % Coverage Change**

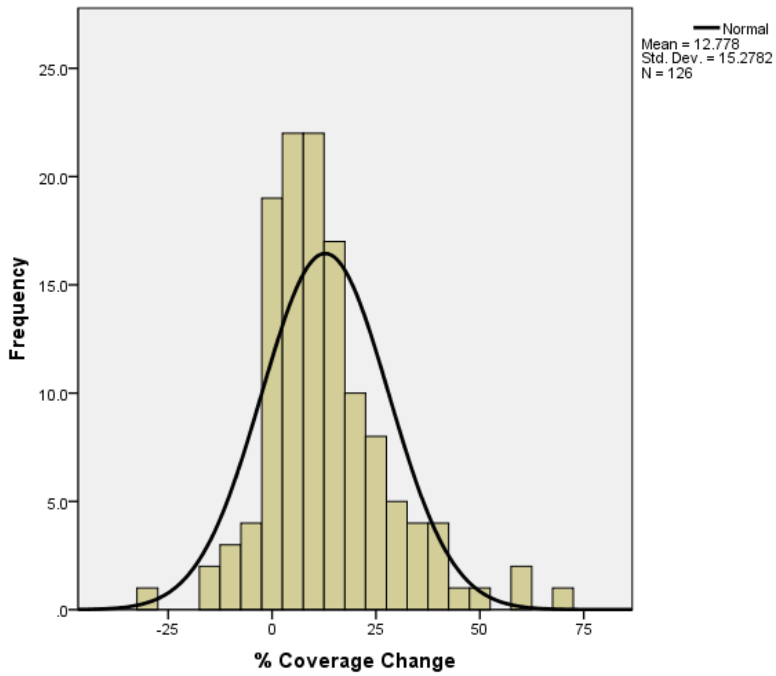

Figure 8.9 – Distribution curve for *Phalaris* percent coverage change.

Table 8.7 - Between-Subjects Factors for *Phalaris* percent coverage change data, where SHD = shade percentage, DPS = disturbance patch size, and GRZ = grazing level (0 = unmowed, 1 = mowed).

Between-Subjects Factors

		N
SHD	0	36
	40	36
	80	36
GRZ	0	54
	1	54
DPS	0	36
	4	36
	8	36

Table 8.8 - One-way ANOVA results for *Phalaris* percent coverage change data. Significant results have been highlighted.

Tests of Between-Subjects Effects

Dependent Variable:PCTCHG14

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5808.333[a]	17	341.667	1.472	0.123
Intercept	18408.333	1	18408.333	79.334	0.000
SHD	529.167	2	264.583	1.140	0.324
GRZ	92.593	1	92.593	0.399	0.529
DPS	1438.889	2	719.444	3.101	0.050
SHD * GRZ	131.019	2	65.509	0.282	0.755
SHD * DPS	394.444	4	98.611	0.425	0.790
GRZ * DPS	1118.519	2	559.259	2.410	0.096
SHD * GRZ * DPS	2103.704	4	525.926	2.267	0.068
Error	20883.333	90	232.037		
Total	45100.000	108			
Corrected Total	26691.667	107			

a. R Squared = .218 (Adjusted R Squared = .070)

APPENDIX B – Field Data

Table 8.9 – Dry weight data for *Elymus* and *Panicum* where SPC = species, PS = plug/seed, SHD = shade level, DPS = disturbance patch size, GRZ = grazing (0 = unmowed, 1 = mowed).

ID	SPC	PS	SHD	DPS	GRZ	Wt.(g)
1	Elymus	P	0	0	1	0.0015
2	Elymus	P	0	0	1	0.0166
3	Elymus	P	0	0	1	0.0388
4	Elymus	P	0	0	0	0.0000
5	Elymus	P	0	0	0	0.0000
6	Elymus	P	0	0	0	0.0104
7	Elymus	P	0	4	1	0.0000
8	Elymus	P	0	4	1	0.0155
9	Elymus	P	0	4	1	0.0317
10	Elymus	P	0	4	0	0.0025
11	Elymus	P	0	4	0	0.0129
12	Elymus	P	0	4	0	0.0328
13	Elymus	P	0	8	1	0.0000
14	Elymus	P	0	8	1	0.0032
15	Elymus	P	0	8	1	0.0183
16	Elymus	P	0	8	0	0.0000
17	Elymus	P	0	8	0	0.0000
18	Elymus	P	0	8	0	0.0000
19	Elymus	P	40	0	1	0.0000
20	Elymus	P	40	0	1	0.0000
21	Elymus	P	40	0	1	0.0035
22	Elymus	P	40	0	0	0.0000
23	Elymus	P	40	0	0	0.0042
24	Elymus	P	40	0	0	0.0105
25	Elymus	P	40	4	1	0.0000
26	Elymus	P	40	4	1	0.0000
27	Elymus	P	40	4	1	0.0112
28	Elymus	P	40	4	0	0.0000
29	Elymus	P	40	4	0	0.0000
30	Elymus	P	40	4	0	0.0000
31	Elymus	P	40	8	1	0.0000
32	Elymus	P	40	8	1	0.0029
33	Elymus	P	40	8	1	0.0193
34	Elymus	P	40	8	0	0.0000
35	Elymus	P	40	8	0	0.0026

36	Elymus	P	40	8	0	0.0156
37	Elymus	P	80	0	1	0.0000
38	Elymus	P	80	0	1	0.0000
39	Elymus	P	80	0	1	0.0279
40	Elymus	P	80	0	0	0.0043
41	Elymus	P	80	0	0	0.0053
42	Elymus	P	80	0	0	0.0221
43	Elymus	P	80	4	1	0.0000
44	Elymus	P	80	4	1	0.0000
45	Elymus	P	80	4	1	0.0230
46	Elymus	P	80	4	0	0.0000
47	Elymus	P	80	4	0	0.0000
48	Elymus	P	80	4	0	0.0067
49	Elymus	P	80	8	1	0.0000
50	Elymus	P	80	8	1	0.0000
51	Elymus	P	80	8	1	0.0486
52	Elymus	P	80	8	0	0.0044
53	Elymus	P	80	8	0	0.0079
54	Elymus	P	80	8	0	0.0311
55	Elymus	S	0	0	1	0.0090
56	Elymus	S	0	0	1	0.0179
57	Elymus	S	0	0	1	0.0453
58	Elymus	S	0	0	0	0.0000
59	Elymus	S	0	0	0	0.0000
60	Elymus	S	0	0	0	0.0054
61	Elymus	S	0	4	1	0.0000
62	Elymus	S	0	4	1	0.0039
63	Elymus	S	0	4	1	0.0188
64	Elymus	S	0	4	0	0.0000
65	Elymus	S	0	4	0	0.0000
66	Elymus	S	0	4	0	0.0073
67	Elymus	S	0	8	1	0.0000
68	Elymus	S	0	8	1	0.0000
69	Elymus	S	0	8	1	0.0170
70	Elymus	S	0	8	0	0.0042
71	Elymus	S	0	8	0	0.0055
72	Elymus	S	0	8	0	0.0132
73	Elymus	S	40	0	1	0.0000
74	Elymus	S	40	0	1	0.0000
75	Elymus	S	40	0	1	0.0344

76	Elymus	S	40	0	0	0.0000
77	Elymus	S	40	0	0	0.0011
78	Elymus	S	40	0	0	0.0108
79	Elymus	S	40	4	1	0.0000
80	Elymus	S	40	4	1	0.0000
81	Elymus	S	40	4	1	0.0000
82	Elymus	S	40	4	0	0.0000
83	Elymus	S	40	4	0	0.0036
84	Elymus	S	40	4	0	0.0049
85	Elymus	S	40	8	1	0.0000
86	Elymus	S	40	8	1	0.0033
87	Elymus	S	40	8	1	0.0039
88	Elymus	S	40	8	0	0.0000
89	Elymus	S	40	8	0	0.0070
90	Elymus	S	40	8	0	0.0106
91	Elymus	S	80	0	1	0.0000
92	Elymus	S	80	0	1	0.0000
93	Elymus	S	80	0	1	0.0055
94	Elymus	S	80	0	0	0.0000
95	Elymus	S	80	0	0	0.0000
96	Elymus	S	80	0	0	0.0024
97	Elymus	S	80	4	1	0.0000
98	Elymus	S	80	4	1	0.0000
99	Elymus	S	80	4	1	0.0000
100	Elymus	S	80	4	0	0.0000
101	Elymus	S	80	4	0	0.0000
102	Elymus	S	80	4	0	0.0045
103	Elymus	S	80	8	1	0.0000
104	Elymus	S	80	8	1	0.0000
105	Elymus	S	80	8	1	0.0000
106	Elymus	S	80	8	0	0.0000
107	Elymus	S	80	8	0	0.0076
108	Elymus	S	80	8	0	0.0083
109	Panicum	P	0	0	1	0.6603
110	Panicum	P	0	0	1	0.7984
111	Panicum	P	0	0	1	0.8305
112	Panicum	P	0	0	0	0.5260
113	Panicum	P	0	0	0	0.7291
114	Panicum	P	0	0	0	1.1172
115	Panicum	P	0	4	1	0.0000

116	Panicum	P	0	4	1	0.7381
117	Panicum	P	0	4	1	1.2233
118	Panicum	P	0	4	0	0.4340
119	Panicum	P	0	4	0	1.1907
120	Panicum	P	0	4	0	1.7294
121	Panicum	P	0	8	1	0.0000
122	Panicum	P	0	8	1	1.5248
123	Panicum	P	0	8	1	1.8575
124	Panicum	P	0	8	0	0.0000
125	Panicum	P	0	8	0	0.8295
126	Panicum	P	0	8	0	0.8988
127	Panicum	P	40	0	1	0.4501
128	Panicum	P	40	0	1	0.4715
129	Panicum	P	40	0	1	1.1875
130	Panicum	P	40	0	0	0.4199
131	Panicum	P	40	0	0	0.6903
132	Panicum	P	40	0	0	0.7555
133	Panicum	P	40	4	1	0.2584
134	Panicum	P	40	4	1	0.4985
135	Panicum	P	40	4	1	0.8623
136	Panicum	P	40	4	0	0.0000
137	Panicum	P	40	4	0	0.7225
138	Panicum	P	40	4	0	1.0521
139	Panicum	P	40	8	1	0.7615
140	Panicum	P	40	8	1	1.0633
141	Panicum	P	40	8	1	2.5807
142	Panicum	P	40	8	0	0.3363
143	Panicum	P	40	8	0	1.0603
144	Panicum	P	40	8	0	1.0899
145	Panicum	P	80	0	1	0.0000
146	Panicum	P	80	0	1	0.5543
147	Panicum	P	80	0	1	0.8859
148	Panicum	P	80	0	0	0.0000
149	Panicum	P	80	0	0	0.0000
150	Panicum	P	80	0	0	0.3072
151	Panicum	P	80	4	1	0.0000
152	Panicum	P	80	4	1	0.0000
153	Panicum	P	80	4	1	0.0000
154	Panicum	P	80	4	0	0.0000
155	Panicum	P	80	4	0	0.0000

156	Panicum	P	80	4	0	0.7514
157	Panicum	P	80	8	1	0.9188
158	Panicum	P	80	8	1	1.3069
159	Panicum	P	80	8	1	1.3217
160	Panicum	P	80	8	0	0.1262
161	Panicum	P	80	8	0	0.5271
162	Panicum	P	80	8	0	1.3070
163	Panicum	S	0	0	1	0.0000
164	Panicum	S	0	0	1	0.0000
165	Panicum	S	0	0	1	0.0000
166	Panicum	S	0	0	0	0.0000
167	Panicum	S	0	0	0	0.0000
168	Panicum	S	0	0	0	0.0000
169	Panicum	S	0	4	1	0.0000
170	Panicum	S	0	4	1	0.0000
171	Panicum	S	0	4	1	0.0025
172	Panicum	S	0	4	0	0.0000
173	Panicum	S	0	4	0	0.0000
174	Panicum	S	0	4	0	0.0000
175	Panicum	S	0	8	1	0.0000
176	Panicum	S	0	8	1	0.0000
177	Panicum	S	0	8	1	0.0000
178	Panicum	S	0	8	0	0.0000
179	Panicum	S	0	8	0	0.0000
180	Panicum	S	0	8	0	0.0018
181	Panicum	S	40	0	1	0.0000
182	Panicum	S	40	0	1	0.0000
183	Panicum	S	40	0	1	0.0000
184	Panicum	S	40	0	0	0.0000
185	Panicum	S	40	0	0	0.0000
186	Panicum	S	40	0	0	0.0000
187	Panicum	S	40	4	1	0.0000
188	Panicum	S	40	4	1	0.0000
189	Panicum	S	40	4	1	0.0010
190	Panicum	S	40	4	0	0.0000
191	Panicum	S	40	4	0	0.0000
192	Panicum	S	40	4	0	0.0000
193	Panicum	S	40	8	1	0.0000
194	Panicum	S	40	8	1	0.0000
195	Panicum	S	40	8	1	0.0027

196	Panicum	S	40	8	0	0.0000
197	Panicum	S	40	8	0	0.0000
198	Panicum	S	40	8	0	0.0000
199	Panicum	S	80	0	1	0.0000
200	Panicum	S	80	0	1	0.0000
201	Panicum	S	80	0	1	0.0000
202	Panicum	S	80	0	0	0.0000
203	Panicum	S	80	0	0	0.0000
204	Panicum	S	80	0	0	0.0000
205	Panicum	S	80	4	1	0.0000
206	Panicum	S	80	4	1	0.0000
207	Panicum	S	80	4	1	0.0000
208	Panicum	S	80	4	0	0.0000
209	Panicum	S	80	4	0	0.0000
210	Panicum	S	80	4	0	0.0000
211	Panicum	S	80	8	1	0.0000
212	Panicum	S	80	8	1	0.0010
213	Panicum	S	80	8	1	0.0157
214	Panicum	S	80	8	0	0.0000
215	Panicum	S	80	8	0	0.0000
216	Panicum	S	80	8	0	0.0087

Table 8.10 – *Elymus* plug data where SHD = shade level, DPS = disturbance patch size, GRZ = grazing (0 = unmowed, 1 = mowed).

ID	SHD	DPS	GRZ	T0	W2	W4	W6	W8	W 10	W 12	W 14	W 16	HT CHG 16
1	0	0	1	15.4	7.3	7.3	8.9	10.0	10.0	10.5	10.1	13.9	6.6
2	0	0	1	11.5	6.0	3.8	2.2	4.1	5.3	5.3	5.5	5.5	-0.5
3	0	0	1	16.9	9.3	9.8	9.8	11.1	14.0	14.5	17.1	17.1	7.8
4	0	0	0	19.1	12.9	3.5	0.0	0.0	0.0	0.0	0.0	0.0	-12.9
5	0	0	0	18.4	7.7	8.5	10.8	10.9	11.0	10.8	10.7	10.8	3.1
6	0	0	0	15.9	9.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-9.5
7	0	4	1	8.5	7.0	8.0	6.5	6.9	10.7	13.4	12.9	11.4	4.4
8	0	4	1	15.6	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.0
9	0	4	1	15.6	10.5	10.1	13.1	12.9	12.4	18.3	18.6	18.5	8.0
10	0	4	0	5.4	3.7	4.5	1.2	0.0	7.3	7.5	7.2	5.9	2.2
11	0	4	0	14.0	9.5	11.1	14.0	13.7	13.5	14.2	14.2	13.9	4.4
12	0	4	0	12.6	12.9	11.2	11.8	10.8	9.7	12.7	12.3	12.0	-0.9
13	0	8	1	11.8	9.0	12.8	0.0	0.0	0.0	0.0	0.0	0.0	-9.0
14	0	8	1	11.5	8.4	10.5	6.3	9.2	11.8	12.1	10.0	7.5	-0.9
15	0	8	1	18.9	11.1	3.0	8.5	8.3	8.1	12.4	10.8	13.2	2.1
16	0	8	0	12.3	10.0	10.0	2.3	2.9	5.0	5.2	1.5	0.0	-10.0
17	0	8	0	13.6	23.5	6.0	9.5	6.5	4.0	7.1	2.9	0.0	-23.5
18	0	8	0	17.2	12.8	0.8	4.0	3.8	5.0	0.0	0.0	0.0	-12.8
19	40	0	1	7.5	5.8	6.2	6.0	5.5	7.5	7.6	8.2	8.3	2.5
20	40	0	1	18.0	9.9	9.5	11.5	0.0	0.0	0.0	0.0	0.0	-9.9
21	40	0	1	11.4	9.2	7.7	9.2	8.5	9.4	0.0	0.0	0.0	-9.2
22	40	0	0	NA	11.0	7.2	11.0	10.9	14.3	15.5	14.1	12.8	1.8
23	40	0	0	19.2	9.5	5.5	0.0	0.0	0.0	0.0	0.0	0.0	-9.5
24	40	0	0	9.7	4.4	7.2	8.4	10.0	10.1	10.0	10.3	5.0	0.6
25	40	4	1	10.4	5.5	7.2	8.3	8.2	10.5	10.6	11.9	1.1	-4.4
26	40	4	1	11.2	4.0	5.3	4.4	6.5	6.7	6.5	7.5	0.0	-4.0
27	40	4	1	9.0	9.2	12.2	12.5	15.7	15.5	15.9	13.7	13.8	4.6
28	40	4	0	9.0	14.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-14.8
29	40	4	0	18.4	10.2	9.0	0.0	0.0	0.0	0.0	0.0	0.0	-10.2
30	40	4	0	14.1	15.1	5.5	0.0	0.0	0.0	0.0	0.0	0.0	-15.1

31	40	8	1	13.4	6.0	13.2	4.3	13.5	6.5	12.7	14.4	14.5	8.5
32	40	8	1	13.2	10.0	16.6	0.0	0.0	0.0	0.0	0.0	0.0	-10.0
33	40	8	1	15.8	10.3	11.0	4.7	8.6	13.4	13.3	11.3	11.5	1.2
34	40	8	0	17.4	4.0	3.0	3.9	6.5	6.5	7.0	10.8	9.0	5.0
35	40	8	0	15.0	6.9	10.5	0.0	0.0	0.0	0.0	0.0	0.0	-6.9
36	40	8	0	14.5	8.5	11.0	15.2	14.7	14.4	14.4	13.8	13.2	4.7
37	80	0	1	19.8	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-9.1
38	80	0	1	15.8	8.3	8.0	10.9	11.4	9.8	1.3	1.3	0.0	-8.3
39	80	0	1	16.6	10.3	10.2	12.2	13.5	15.1	19.8	21.6	21.5	11.2
40	80	0	0	21.3	6.2	8.5	10.6	13.5	13.2	19.8	20.4	20.1	13.9
41	80	0	0	15.7	5.5	6.5	5.2	7.0	6.8	8.0	8.7	9.8	4.3
42	80	0	0	13.0	10.5	10.6	8.4	8.8	8.5	12.0	18.3	8.0	-2.5
43	80	4	1	15.1	14.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-14.9
44	80	4	1	21.3	10.1	6.2	7.1	6.6	0.0	0.0	0.0	0.0	-10.1
45	80	4	1	12.7	8.1	10.3	12.8	12.9	12.7	14.4	16.2	16.0	7.9
46	80	4	0	15.8	8.0	7.7	12.0	1.5	2.3	0.0	0.0	0.0	-8.0
47	80	4	0	15.2	6.7	6.8	8.6	8.6	8.7	6.7	8.8	0.0	-6.7
48	80	4	0	9.3	7.6	7.0	9.2	11.0	11.2	12.9	14.0	11.0	3.4
49	80	8	1	12.0	6.3	2.2	0.0	0.0	0.0	0.0	0.0	0.0	-6.3
50	80	8	1	14.0	6.0	10.2	12.0	11.5	12.6	11.0	0.0	0.0	-6.0
51	80	8	1	14.9	11.8	14.0	17.6	16.5	19.5	25.3	25.2	25.0	13.2
52	80	8	0	13.6	7.7	11.8	13.6	16.1	15.3	14.1	8.8	7.5	-0.2
53	80	8	0	17.0	4.5	10.8	11.8	9.9	9.7	19.0	18.5	18.4	13.9
54	80	8	0	16.7	12.3	12.4	8.8	11.9	12.1	11.2	6.5	4.3	-8.0

Table 8.11 - *Elymus* seedling count data where SHD = shade level, DPS = disturbance patch size, GRZ = grazing (0 = unmowed, 1 = mowed).

ID	SHD	DPS	GRZ	T0	W2	W4	W6	W8	W10	W12	W14	W16
7	40	0	1	0	0	2	2	2	2	2	2	0
8	40	0	1	0	2	1	5	2	1	1	1	0
9	80	0	1	0	0	0	0	0	0	0	0	0
10	0	4	1	0	0	1	0	0	0	0	0	0
11	40	4	1	0	1	0	0	0	0	0	1	0
12	40	4	1	0	0	0	2	0	1	1	0	0
19	40	4	0	0	0	1	1	0	0	0	0	0
20	80	4	0	0	0	1	1	1	0	0	0	0
21	80	4	0	0	0	0	0	0	0	0	0	0
22	80	8	0	0	1	0	0	0	1	1	1	0
23	40	0	0	0	0	0	1	1	1	1	1	1
24	0	4	1	0	4	0	0	0	1	1	2	1
31	40	8	1	0	0	0	2	1	1	1	1	1
32	0	8	0	0	0	3	2	2	2	4	2	1
33	0	8	0	0	0	0	2	1	1	1	1	1
34	40	4	0	0	2	0	1	2	2	2	2	2
35	0	8	0	0	0	0	1	3	2	2	2	2
36	40	8	0	0	0	0	2	1	2	2	2	2
43	80	0	1	0	0	0	2	0	0	0	0	0
44	0	0	0	0	0	2	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	0	0
46	40	4	1	0	0	0	1	1	0	0	0	0
47	80	4	1	0	0	2	2	1	1	1	0	0
48	80	4	1	0	1	1	1	1	0	0	0	0
55	0	8	1	0	0	1	1	1	2	2	1	0
56	40	8	1	0	0	2	0	0	0	0	0	0
57	80	8	1	0	1	0	0	0	0	0	0	0
58	0	4	1	0	1	1	1	1	2	2	1	1
59	40	4	0	0	0	1	1	2	2	3	3	1
60	80	4	0	0	0	1	1	1	1	1	1	1
67	40	8	0	0	8	0	2	1	1	1	1	1
68	80	8	0	0	0	1	1	1	1	1	1	1
69	0	0	1	0	0	2	3	2	2	2	2	2
70	80	8	0	0	0	0	1	1	2	2	2	2
71	40	0	0	0	0	0	5	5	4	4	3	3

72	0	4	0	0	0	1	1	3	3	3	3	3
79	40	0	0	0	0	0	0	0	0	0	0	0
80	80	0	0	0	0	1	1	1	1	1	1	0
81	80	0	0	0	0	0	0	0	0	0	0	0
82	80	4	1	0	0	0	0	0	0	0	0	0
83	0	4	0	0	2	0	0	0	0	0	0	0
84	0	4	0	0	0	0	0	0	0	0	0	0
91	80	8	1	0	0	1	1	0	0	0	0	0
92	80	8	1	0	0	0	0	3	0	0	0	0
93	40	8	0	0	1	0	1	1	0	0	0	0
94	0	8	1	0	1	2	0	0	2	2	2	1
95	0	8	1	0	2	1	1	1	1	1	1	1
96	40	8	1	0	3	1	1	2	1	1	1	1
103	80	0	1	0	0	3	3	2	1	1	2	2
104	0	0	0	0	0	1	3	1	2	2	2	2
105	80	0	0	0	0	3	3	2	2	2	2	2
106	0	0	1	0	0	1	2	5	4	5	5	5
107	0	0	1	0	0	3	6	3	5	5	5	5
108	40	0	1	0	1	0	6	5	6	6	6	6

Table 8.12 - *Elymus* seedling height data where SHD = shade level, DPS = disturbance patch size, GRZ = grazing (0 = unmowed, 1 = mowed).

ID	SHD	DPS	GRZ	T0	W2	W4	W6	W8	W10	W12	W14	W16	HT CHG 16	HT CHG 12	HT CHG 8
1	0	8	1	0.0	1.1	7.7	0.0	0.0	4.0	5.0	6.2	0.0	0.0	5.0	0.0
2	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0	4	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0	8	1	0.0	0.0	3.5	8.0	8.3	8.9	5.6	8.2	0.0	0.0	5.6	8.3
5	0	4	1	0.0	0.4	6.0	4.0	5.3	7.2	13.0	5.3	5.2	5.2	13.0	5.3
6	40	0	0	0.0	0.0	0.0	8.0	7.8	6.7	8.7	8.5	4.2	4.2	8.7	7.8
7	0	4	0	0.0	0.0	4.6	6.5	6.4	6.2	4.4	6.1	5.6	5.6	4.4	6.4
8	0	0	1	0.0	0.0	5.8	6.5	7.4	8.4	7.6	8.6	5.7	5.7	7.6	7.4
9	0	8	0	0.0	0.0	0.0	7.5	6.6	6.8	6.8	5.9	5.9	5.9	6.8	6.6
10	0	0	0	0.0	0.0	7.1	5.5	7.3	7.0	7.3	7.8	6.2	6.2	7.3	7.3
11	0	0	1	0.0	0.0	6.2	7.0	8.9	8.6	9.7	10.4	9.2	9.2	9.7	8.9
12	0	8	0	0.0	0.0	7.0	6.0	5.1	5.8	4.3	5.0	10.6	10.6	4.3	5.1
13	0	0	1	0.0	0.0	8.6	6.5	9.6	10.3	11.4	10.5	11.3	11.3	11.4	9.6
14	0	8	1	0.0	0.8	9.1	8.3	9.0	12.4	13.7	14.3	13.2	13.2	13.7	9.0
15	40	8	0	0.0	1.0	0.0	8.2	4.8	0.0	0.0	0.0	0.0	0.0	0.0	4.8
16	40	4	1	0.0	0.7	0.0	0.0	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0
17	40	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	40	4	1	0.0	0.0	0.0	14.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
19	40	4	0	0.0	0.0	5.1	9.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	40	8	1	0.0	0.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	40	0	1	0.0	0.0	8.2	5.6	9.6	8.8	7.8	9.1	0.0	0.0	7.8	9.6
22	40	4	1	0.0	0.0	0.0	6.0	0.0	6.1	12.5	0.0	0.0	0.0	12.5	0.0
23	0	4	0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0	0	0	0.0	0.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	40	4	0	0.0	5.7	0.0	6.5	8.4	8.2	5.4	7.9	7.8	7.8	5.4	8.4
26	80	8	0	0.0	0.0	0.0	10.4	9.0	8.1	9.8	12.2	8.4	8.4	9.8	9.0
27	0	4	1	0.0	0.0	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	80	0	0	0.0	0.0	9.2	5.2	9.2	8.8	10.1	10.5	4.2	4.2	10.1	9.2
29	80	8	0	0.0	2.5	0.0	0.0	0.0	4.4	5.3	3.2	0.0	0.0	5.3	0.0
30	0	8	0	0.0	0.0	0.0	6.2	7.1	8.4	8.8	8.3	7.9	7.9	8.8	7.1
31	80	4	1	0.0	1.0	4.8	4.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
32	80	4	0	0.0	0.0	5.1	7.7	6.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0
33	40	8	1	0.0	4.2	5.5	6.0	6.7	10.2	10.0	10.0	9.9	9.9	10.0	6.7
34	40	8	1	0.0	0.0	0.0	7.5	8.4	10.6	10.7	9.5	9.3	9.3	10.7	8.4
35	40	8	0	0.0	1.5	0.0	7.0	12.7	13.0	13.5	13.5	13.1	13.1	13.5	12.7

36	80	0	1	0.0	0.0	6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	80	4	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38	80	8	1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	80	4	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	80	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	0	4	1	0.0	2.0	0.0	0.0	0.0	12.7	5.6	5.6	19.6	19.6	5.6	0.0
42	40	8	0	0.0	0.0	0.0	6.6	9.7	6.2	6.4	10.6	4.2	4.2	6.4	9.7
43	80	0	1	0.0	0.0	0.0	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44	40	4	0	0.0	0.0	5.0	7.0	10.5	11.2	8.1	8.5	5.9	5.9	8.1	10.5
45	80	8	1	0.0	0.0	5.9	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46	80	4	1	0.0	0.0	5.7	7.3	3.5	3.3	2.8	0.0	0.0	0.0	2.8	3.5
47	80	8	1	0.0	0.0	0.0	0.0	8.2	0.0	0.0	0.0	0.0	0.0	0.0	8.2
48	40	0	1	0.0	2.1	0.0	9.6	9.3	9.0	9.8	11.2	8.2	8.2	9.8	9.3
49	80	0	0	0.0	0.0	8.0	8.5	9.8	6.2	7.9	4.9	0.0	0.0	7.9	9.8
50	80	0	1	0.0	0.0	5.8	5.3	4.9	7.0	6.4	5.8	5.5	5.5	6.4	4.9
51	80	4	0	0.0	0.0	0.0	7.8	8.2	10.4	6.8	6.9	5.5	5.5	6.8	8.2
52	40	0	1	0.0	1.5	3.7	6.1	4.4	3.5	4.3	5.2	0.0	0.0	4.3	4.4
53	40	0	0	0.0	0.0	0.0	9.4	9.0	9.1	7.7	8.2	7.7	7.7	7.7	9.0
54	80	8	0	0.0	0.0	0.0	13.1	4.1	4.5	6.0	6.3	7.5	7.5	6.0	4.1

Table 8.13 - *Panicum* plug data where SHD = shade level, DPS = disturbance patch size, GRZ = grazing (0 = unmowed, 1 = mowed).

ID	SHD	DPS	GRZ	T0	W2	W4	W6	W8	W 10	W 12	W 14	W 16	HT CHG 16
109	80	8	1	65.4	65.5	78.6	79.2	77.1	74.8	64.0	53.1	56.0	-9.5
110	80	8	1	32.5	42.8	67.7	69.0	70.2	75.2	60.1	62.3	57.0	14.2
111	40	0	1	60.3	59.1	58.5	55.6	48.0	42.0	45.5	44.7	52.7	-6.4
115	0	8	0	60.1	57.8	56.6	51.1	43.7	55.3	41.8	54.3	42.0	-15.8
116	80	0	1	69.3	58.0	54.9	54.4	45.7	41.7	41.6	32.5	43.0	-15.0
117	0	0	1	63.8	50.6	45.7	44.3	41.0	53.0	59.7	49.9	57.5	6.9
121	80	0	0	67.8	67.5	64.9	61.6	71.6	69.8	85.9	72.6	50.9	-16.6
122	0	0	0	64.6	51.5	55.0	55.2	55.5	54.8	48.5	47.8	54.2	2.7
123	80	4	0	62.6	69.5	66.7	84.6	100.8	100.3	68.6	68.3	67.3	-2.2
127	0	0	1	64.7	65.3	63.2	65.5	61.5	55.5	57.6	58.5	58.9	-6.4
128	40	0	0	62.3	72.3	66.5	65.9	58.4	61.9	62.4	57.5	65.0	-7.3
129	40	4	0	58.5	54.5	54.2	54.7	52.0	46.2	46.0	45.0	52.9	-1.6
133	0	8	1	51.8	63.3	51.9	55.4	61.9	60.6	46.5	45.0	54.2	-9.1
134	0	4	1	34.1	33.5	32.7	33.5	40.1	53.6	0.0	0.0	0.0	-33.5
135	0	4	0	69.5	66.3	66.1	62.9	62.7	62.3	69.9	54.5	56.1	-10.2
139	0	0	0	48.5	33.0	37.5	49.7	53.8	67.1	67.5	67.4	67.1	34.1
140	40	4	1	54.0	53.9	53.3	53.7	54.2	65.7	47.0	48.1	52.4	-1.5
141	80	4	0	50.0	55.2	54.6	50.9	51.1	43.5	44.1	0.0	0.0	-55.2
145	0	4	1	55.9	67.1	67.0	67.9	66.9	66.6	59.0	57.3	60.3	-6.8
146	40	0	0	66.7	66.7	66.4	33.0	25.2	32.4	39.4	24.8	67.3	0.6
147	40	8	1	54.7	57.5	56.8	64.5	71.9	86.3	64.4	55.8	68.8	11.3
151	80	4	1	57.0	55.6	42.8	52.4	56.2	52.7	48.4	0.0	0.0	-55.6
152	80	0	1	62.0	64.4	59.5	61.6	32.3	22.7	0.0	0.0	0.0	-64.4
153	0	4	1	61.4	61.7	57.6	58.6	48.0	46.5	55.3	62.6	55.3	-6.4
157	40	4	0	54.9	62.0	61.1	61.8	61.9	61.8	46.2	46.1	48.9	-13.1
158	0	0	1	48.6	48.5	50.6	48.8	49.5	49.7	50.7	49.0	47.0	-1.5
159	0	8	1	67.6	76.1	75.1	75.4	51.7	0.0	0.0	0.0	0.0	-76.1
163	80	0	0	57.5	43.0	59.7	10.0	15.2	0.0	0.0	0.0	0.0	-43.0
164	0	8	0	59.6	71.2	73.7	73.5	73.9	71.5	49.2	49.3	73.7	2.5
165	80	0	0	51.5	46.8	39.5	35.5	24.0	21.2	0.0	0.0	0.0	-46.8
169	40	4	0	55.7	55.9	56.2	56.3	82.1	63.9	59.9	49.3	0.0	-55.9
170	0	8	0	28.5	12.5	29.2	55.4	0.0	0.0	0.0	0.0	0.0	-12.5
171	40	4	1	56.9	60.7	51.8	54.0	63.0	63.9	48.5	52.4	51.3	-9.4
175	80	4	1	48.0	57.4	47.5	21.5	0.0	0.0	0.0	0.0	0.0	-57.4
176	80	4	1	48.0	47.5	48.1	46.2	63.6	46.1	25.5	25.7	0.0	-47.5

177	80	8	0	51.5	66.4	69.4	68.9	70.3	70.4	69.7	0.0	49.0	-17.4
181	40	0	1	66.2	66.6	71.0	71.0	58.0	57.9	64.6	48.5	67.0	0.4
182	80	8	0	55.9	66.7	71.1	71.2	47.4	47.3	49.8	48.7	40.2	-26.5
183	80	0	1	60.8	68.5	67.6	52.5	55.6	59.7	57.1	66.8	38.5	-30.0
187	0	4	0	53.3	62.6	57.5	61.1	61.6	65.1	60.7	60.2	67.5	4.9
188	40	0	1	63.9	68.1	68.2	65.5	66.7	66.1	44.5	41.1	45.2	-22.9
189	80	8	1	64.4	82.0	55.9	60.7	74.5	86.3	42.2	67.0	36.9	-45.1
193	0	0	0	62.1	61.0	64.0	63.2	63.8	64.4	57.0	58.1	63.0	2.0
194	80	4	0	60.4	68.1	67.9	47.7	47.8	48.5	46.5	0.0	0.0	-68.1
195	40	0	0	67.7	72.0	73.5	68.2	65.5	66.5	64.5	56.0	67.0	-5.0
199	40	8	1	57.1	58.9	59.5	58.9	60.0	59.8	60.1	49.0	59.7	0.8
200	40	8	0	59.9	68.0	67.5	68.2	67.4	66.9	67.0	65.5	64.4	-3.6
201	40	8	0	47.6	34.6	52.0	52.6	51.9	47.8	30.2	28.5	34.0	-0.6
205	40	8	0	52.5	54.0	37.2	51.6	51.8	50.1	49.5	28.0	50.9	-3.1
206	40	4	1	44.2	51.7	49.5	51.8	51.6	51.4	51.2	47.5	53.2	1.5
207	40	8	1	65.1	74.6	74.0	77.3	65.4	62.6	51.0	48.3	47.9	-26.7
211	0	8	1	64.3	66.7	66.3	66.5	67.4	52.7	47.3	47.6	52.4	-14.3
212	80	8	0	67.1	75.0	63.5	60.5	58.4	57.0	59.5	58.3	56.5	-18.5
213	0	4	0	50.1	56.5	46.9	57.4	66.5	66.0	67.0	67.5	67.9	11.4

Table 8.14 - *Panicum* seedling count data where SHD = shade level, DPS = disturbance patch size, GRZ = grazing (0 = unmowed, 1 = mowed).

ID	SHD	DPS	GRZ	T0	W2	W4	W6	W8	W10	W12	W14	W16
115	0	0	1	0	0	0	0	0	0	0	0	0
116	0	0	1	0	0	0	0	0	0	0	0	0
117	0	0	1	0	0	0	0	0	0	0	0	0
118	0	0	0	0	0	0	0	0	0	0	0	0
119	0	0	0	0	0	0	0	1	2	2	1	0
120	0	0	0	0	1	0	0	0	0	0	0	0
127	0	4	1	0	5	2	1	1	1	1	1	1
128	0	4	1	0	0	0	0	0	0	0	0	0
129	0	4	1	0	0	1	0	0	0	0	0	0
130	0	4	0	0	3	0	0	0	0	0	0	0
131	0	4	0	0	0	0	0	0	0	0	0	0
132	0	4	0	0	1	0	0	0	0	0	0	0
139	0	8	1	0	2	0	0	0	0	0	0	0
140	0	8	1	0	0	1	0	0	0	0	0	0
141	0	8	1	0	0	1	1	1	1	1	0	0
142	0	8	0	0	1	0	0	0	1	1	1	0
143	0	8	0	0	0	1	3	0	0	0	0	0
144	0	8	0	0	0	1	0	1	1	1	1	1
151	40	0	1	0	0	0	0	0	0	0	0	0
152	40	0	1	0	0	0	0	0	0	0	0	0
153	40	0	1	0	0	0	0	0	0	0	0	0
154	40	0	0	0	0	0	0	0	0	0	0	0
155	40	0	0	0	0	0	0	0	0	0	0	0
156	40	0	0	0	0	0	0	0	0	0	0	0
163	40	4	1	0	1	0	1	0	1	1	1	1
164	40	4	1	0	0	0	0	0	0	0	0	0
165	40	4	1	0	0	0	0	0	2	0	0	0
166	40	4	0	0	1	1	0	0	0	0	0	0
167	40	4	0	0	0	0	0	0	0	0	0	0
168	40	4	0	0	0	0	1	0	0	0	0	0
175	40	8	1	0	0	1	1	1	1	1	1	1
176	40	8	1	0	0	0	0	0	0	0	0	0
177	40	8	1	0	0	1	1	0	0	0	0	0
178	40	8	0	0	1	0	0	0	0	0	0	0
179	40	8	0	0	0	0	0	0	0	0	0	0
180	40	8	0	0	0	0	0	0	0	0	0	0
187	80	0	1	0	0	0	0	0	0	0	0	0

188	80	0	1	0	0	0	0	1	0	0	0	0
189	80	0	1	0	0	0	0	0	0	0	0	0
190	80	0	0	0	0	0	0	0	0	0	0	0
191	80	0	0	0	0	0	0	0	0	0	0	0
192	80	0	0	0	0	0	0	0	0	0	0	0
199	80	4	1	0	0	0	0	0	0	0	0	0
200	80	4	1	0	1	0	0	0	0	0	0	0
201	80	4	1	0	0	0	1	0	0	0	0	0
202	80	4	0	0	0	8	8	0	0	0	0	0
203	80	4	0	0	0	0	0	0	0	0	0	0
204	80	4	0	0	0	0	1	3	0	0	0	0
211	80	8	1	0	1	0	0	0	0	0	1	1
212	80	8	1	0	2	0	0	0	3	3	3	3
213	80	8	1	0	0	0	0	0	0	0	0	0
214	80	8	0	0	1	0	0	0	0	0	0	0
215	80	8	0	0	1	2	2	1	1	1	1	1
216	80	8	0	0	0	0	0	0	0	0	0	0

Table 8.15 - *Panicum* seedling height data where SHD = shade level, DPS = disturbance patch size, GRZ = grazing (0 = unmowed, 1 = mowed).

ID	SHD	DPS	GRZ	T0	W2	W4	W 6	W 8	W 10	W 12	W 14	W 16	HT CHG 16
115	0	0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
116	0	0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
117	0	0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
118	0	4	0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
119	0	4	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
120	0	4	0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
127	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
128	0	0	0	0.0	0.0	0.0	0.0	6.8	6.9	11.2	11.5	0.0	0.0
129	0	0	0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
130	0	8	1	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
131	0	8	1	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
132	0	8	1	0.0	0.0	2.0	4.3	7.5	14.3	14.7	0.0	0.0	0.0
139	0	4	1	0.0	1.4	6.2	8.0	4.5	5.8	5.9	6.5	6.3	6.3
140	0	4	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
141	0	4	1	0.0	0.0	4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
142	0	8	0	0.0	0.6	0.0	0.0	0.0	2.1	2.4	2.1	0.0	0.0
143	0	8	0	0.0	0.0	1.4	7.4	0.0	0.0	0.0	0.0	0.0	0.0
144	0	8	0	0.0	0.0	1.3	0.0	4.0	6.0	6.0	4.4	6.3	6.3
151	40	0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
152	40	0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
153	40	0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
154	40	4	0	0.0	1.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
155	40	4	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
156	40	4	0	0.0	0.0	0.0	5.6	0.0	0.0	0.0	0.0	0.0	0.0
163	40	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
164	40	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
165	40	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
166	40	8	1	0.0	0.0	4.4	7.4	9.8	10.0	7.9	7.0	3.5	3.5
167	40	8	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
168	40	8	1	0.0	0.0	2.0	4.7	0.0	0.0	0.0	0.0	0.0	0.0
175	40	4	1	0.0	2.5	0.0	2.8	0.0	5.5	6.0	3.2	4.0	4.0
176	40	4	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
177	40	4	1	0.0	0.0	0.0	0.0	0.0	5.2	0.0	0.0	0.0	0.0
178	40	8	0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
179	40	8	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

180	40	8	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
187	80	0	1	0.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
188	80	0	1	0.0	0.0	0.0	0.0	8.2	0.0	0.0	0.0	0.0	0.0
189	80	0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
190	80	4	0	0.0	0.0	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0
191	80	4	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
192	80	4	0	0.0	0.0	0.0	7.5	0.0	0.0	0.0	0.0	0.0	0.0
199	80	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
200	80	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
201	80	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
202	80	8	1	0.0	1.5	6.8	0.0	0.0	0.0	0.0	4.4	4.3	4.3
203	80	8	1	0.0	0.8	0.0	0.0	0.0	6.0	7.9	8.0	8.3	8.3
204	80	8	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
211	80	4	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
212	80	4	1	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
213	80	4	1	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0
214	80	8	0	0.0	0.8	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
215	80	8	0	0.0	1.6	0.0	6.0	8.0	10.2	12.1	13.2	11.5	11.5
216	80	8	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 8.16 - *Panicum* height data where SHD = shade level, DPS = disturbance patch size, GRZ = grazing (0 = unmowed, 1 = mowed).

ID	SHD	DPS	GRZ	T0	W2	W4	W6	W8	W 10	W 12	W 14	HT CHG 14
1	0	0	1	21.4	32.5	44.4	59.8	55.1	60.1	51.8	55.8	34.4
2	0	0	1	21.3	34.6	49.0	55.5	60.8	61.8	57.6	61.3	40.0
3	0	0	1	14.8	43.0	52.3	71.2	62.4	63.0	50.5	51.4	36.6
4	0	4	1	26.6	28.8	53.5	64.4	60.3	65.5	57.3	52.7	26.1
5	0	4	1	16.8	33.8	54.9	62.9	54.7	63.1	51.7	49.9	33.1
6	0	4	1	22.8	63.4	60.5	76.9	50.1	59.0	51.1	53.8	31.0
7	0	8	1	21.6	44.0	50.3	66.9	62.0	78.9	63.1	65.7	44.1
8	0	8	1	41.5	39.5	57.3	82.2	72.2	75.4	63.4	73.9	32.4
9	0	8	1	15.1	39.9	56.0	87.4	69.1	78.1	61.1	62.2	47.1
10	0	0	0	22.8	29.0	62.0	76.0	78.8	78.5	87.6	82.3	59.5
11	0	0	0	27.0	46.5	61.2	77.1	85.3	86.2	84.2	81.7	54.7
12	0	0	0	15.0	37.2	48.0	62.3	71.4	88.1	82.8	88.9	73.9
13	0	4	0	31.2	31.0	42.9	64.1	63.3	64.2	76.2	72.8	41.6
14	0	4	0	15.0	39.0	50.2	65.2	71.0	72.5	75.1	73.4	58.4
15	0	4	0	25.3	55.0	73.1	75.2	83.6	77.5	77.2	97.7	72.4
16	0	8	0	25.6	49.0	60.5	81.2	81.2	86.2	94.7	92.5	66.9
17	0	8	0	16.4	36.2	71.5	85.9	86.5	94.0	96.4	88.6	72.2
18	0	8	0	23.0	34.6	72.2	85.3	83.3	99.0	95.7	93.5	70.5
19	40	0	1	22.3	28.4	57.1	75.5	55.8	65.4	57.0	61.1	38.8
20	40	0	1	25.0	45.5	62.6	92.2	56.5	66.5	82.0	59.0	34.0
21	40	0	1	28.6	33.5	49.8	76.7	74.5	86.3	53.6	49.9	21.3
22	40	4	1	22.3	28.4	57.1	75.5	55.8	65.4	57.0	61.1	38.8
23	40	4	1	25.0	45.5	62.6	92.2	56.5	66.5	82.0	59.0	34.0
24	40	4	1	28.6	33.5	49.8	76.7	74.5	86.3	53.6	49.9	21.3
25	40	8	1	37.3	39.0	61.0	86.2	82.8	101.1	66.5	68.1	30.8
26	40	8	1	16.3	39.6	57.7	83.7	61.9	72.6	57.4	63.5	47.2
27	40	8	1	18.6	38.6	58.3	98.5	85.9	93.8	59.2	84.3	65.7
28	40	0	0	18.8	40.8	63.0	68.8	83.0	77.0	99.2	85.7	66.9
29	40	0	0	27.7	42.0	53.5	94.2	90.2	117.0	104.2	86.5	58.8
30	40	0	0	19.6	24.1	56.4	78.8	86.5	99.6	110.5	92.8	73.2
31	40	4	0	18.8	40.8	63.0	68.8	83.0	77.0	99.2	85.7	66.9
32	40	4	0	27.7	42.0	53.5	94.2	90.2	117.0	104.2	86.5	58.8
33	40	4	0	19.6	24.1	56.4	78.8	86.5	99.6	110.5	92.8	73.2
34	40	8	0	25.6	37.0	59.0	88.2	81.7	108.2	115.6	81.1	55.5
35	40	8	0	22.8	33.2	115.0	81.0	90.4	92.8	85.5	86.9	64.1

36	40	8	0	30.2	48.3	56.2	115.0	120.5	111.5	91.5	92.5	62.3
37	80	0	1	22.4	39.3	62.9	90.4	64.1	73.2	64.0	84.5	62.1
38	80	0	1	38.3	41.4	52.4	83.1	75.5	75.9	70.6	68.2	29.9
39	80	0	1	12.6	38.4	59.4	91.0	57.0	77.0	64.2	73.1	60.5
40	80	4	1	23.0	37.7	59.4	89.3	65.4	72.3	61.9	66.0	43.0
41	80	4	1	26.1	51.5	69.3	96.5	57.8	82.1	76.7	75.3	49.2
42	80	4	1	17.0	43.6	54.1	87.0	52.3	71.1	70.5	69.7	52.7
43	80	8	1	16.5	34.0	59.4	92.3	66.1	75.2	73.1	62.0	45.5
44	80	8	1	23.8	39.5	53.4	92.3	72.7	72.2	57.8	63.7	39.9
45	80	8	1	13.9	38.3	49.5	90.2	57.7	70.9	60.9	66.7	52.8
46	80	0	0	31.1	44.0	65.1	99.3	129.5	110.9	108.8	89.1	58.0
47	80	0	0	27.9	43.6	51.2	90.8	82.8	95.3	99.7	82.8	54.9
48	80	0	0	21.1	49.0	61.2	116.0	115.3	135.4	105.9	92.0	70.9
49	80	4	0	22.0	41.0	60.0	69.0	91.7	95.0	88.5	91.1	69.1
50	80	4	0	19.9	43.3	50.9	82.9	88.5	94.5	96.0	104.9	85.0
51	80	4	0	26.3	50.5	59.4	93.8	89.0	117.7	105.3	87.2	60.9
52	80	8	0	20.8	30.4	63.8	94.8	78.2	97.6	90.4	99.8	79.0
53	80	8	0	17.5	24.5	55.0	71.4	84.7	96.5	106.8	101.5	84.0
54	80	8	0	24.8	40.9	41.4	78.0	85.6	93.2	99.2	92.8	68.0
55	0	0	1	20.3	37.9	50.3	50.8	60.9	63.9	52.3	50.6	30.3
56	0	0	1	31.2	26.9	54.8	62.4	52.0	65.3	60.4	67.3	36.1
57	0	0	1	25.3	46.1	51.0	76.8	50.1	61.2	54.7	74.5	49.2
58	0	4	1	22.5	38.4	50.5	59.6	57.1	55.0	56.5	54.3	31.8
59	0	4	1	19.5	37.6	58.6	54.0	54.3	66.3	51.3	57.8	38.3
60	0	4	1	24.4	52.3	61.0	77.7	52.4	66.1	57.3	60.6	36.2
61	0	8	1	34.0	51.2	61.8	70.3	64.6	78.5	61.5	55.9	21.9
62	0	8	1	21.0	40.5	62.8	87.7	65.5	71.5	62.1	60.9	39.9
63	0	8	1	18.3	40.7	63.3	74.0	64.8	71.6	51.8	51.3	33.0
64	0	0	0	18.8	35.0	44.4	65.1	78.8	77.5	82.8	81.2	62.4
65	0	0	0	22.3	33.4	50.4	61.2	70.7	72.0	78.7	83.7	61.4
66	0	0	0	16.8	36.3	51.6	71.8	71.3	86.1	82.8	83.2	66.4
67	0	4	0	28.4	32.0	48.1	61.5	68.5	63.0	80.2	74.9	46.5
68	0	4	0	19.3	37.7	52.7	70.0	70.8	77.0	86.4	75.1	55.8
69	0	4	0	24.0	56.8	64.5	75.9	80.8	86.9	95.5	85.0	61.0
70	0	8	0	37.6	47.3	54.3	68.7	90.6	82.5	90.3	92.9	55.3
71	0	8	0	25.9	32.7	54.3	75.0	84.2	92.3	88.5	92.9	67.0
72	0	8	0	25.0	50.0	64.3	77.0	77.5	88.9	100.8	117.5	92.5
73	40	0	1	31.8	44.8	60.0	76.9	53.6	61.7	58.4	59.3	27.5
74	40	0	1	20.5	39.7	62.6	93.3	67.4	70.4	58.8	63.1	42.6
75	40	0	1	34.3	40.0	46.4	77.7	63.0	72.0	65.3	64.7	30.4

76	40	4	1	31.8	44.8	60.0	76.9	53.6	61.7	58.4	59.3	27.5
77	40	4	1	20.5	39.7	62.6	93.3	67.4	70.4	58.8	63.1	42.6
78	40	4	1	34.3	40.0	46.4	77.7	63.0	72.0	65.3	64.7	30.4
79	40	8	1	25.6	34.5	57.7	83.2	62.5	77.5	66.6	57.4	31.8
80	40	8	1	19.8	40.2	54.5	76.5	52.8	66.3	60.3	61.3	41.5
81	40	8	1	23.1	44.8	54.9	91.4	81.1	91.3	59.6	70.2	47.1
82	40	0	0	21.0	40.5	47.3	77.9	72.2	91.3	76.8	90.4	69.4
83	40	0	0	17.8	44.0	68.3	103.4	98.0	126.4	128.6	78.4	60.6
84	40	0	0	23.7	40.5	43.5	70.8	87.3	107.9	107.0	100.1	76.4
85	40	4	0	21.0	40.5	47.3	77.9	72.2	91.3	76.8	90.4	69.4
86	40	4	0	17.8	44.0	68.3	103.4	98.0	126.4	128.6	78.4	60.6
87	40	4	0	23.7	40.5	43.5	70.8	87.3	107.9	107.0	100.1	76.4
88	40	8	0	21.3	19.0	54.2	94.1	102.4	122.7	95.7	95.5	74.2
89	40	8	0	26.6	44.2	85.5	76.4	84.8	89.2	91.9	80.2	53.6
90	40	8	0	21.5	33.1	60.5	91.0	117.9	129.0	103.6	78.9	57.4
91	80	0	1	18.2	38.4	48.3	79.5	75.9	76.4	64.8	77.5	59.3
92	80	0	1	14.9	30.3	51.9	79.6	54.8	74.6	58.3	68.2	53.3
93	80	0	1	13.0	50.2	61.8	90.8	56.0	85.4	69.2	74.7	61.7
94	80	4	1	22.9	52.2	56.8	96.8	64.8	71.5	68.5	75.3	52.4
95	80	4	1	22.4	45.3	59.1	99.5	53.2	87.8	75.5	74.9	52.5
96	80	4	1	15.6	32.4	54.2	89.6	59.0	78.7	70.5	81.9	66.3
97	80	8	1	23.4	45.8	63.5	101.8	89.2	78.5	68.0	75.0	51.6
98	80	8	1	17.6	39.4	58.0	75.8	58.0	71.3	67.5	61.1	43.5
99	80	8	1	24.2	40.6	58.4	79.4	52.3	68.6	51.8	91.5	67.3
100	80	0	0	20.0	35.8	50.8	89.9	82.1	107.8	105.3	126.5	106.5
101	80	0	0	18.5	28.8	51.0	77.2	73.6	89.0	104.8	96.2	77.7
102	80	0	0	16.9	53.5	58.5	100.3	119.5	121.3	110.2	77.9	61.0
103	80	4	0	32.8	40.1	66.8	86.4	78.5	94.2	95.7	83.4	50.6
104	80	4	0	20.5	48.2	52.1	90.9	95.0	97.6	96.3	97.5	77.0
105	80	4	0	19.3	42.8	58.5	95.0	93.7	107.7	106.4	86.8	67.5
106	80	8	0	23.0	41.5	51.1	92.9	79.0	112.9	132.9	97.4	74.4
107	80	8	0	22.1	43.8	64.5	104.8	85.4	117.1	102.1	100.5	78.4
108	80	8	0	15.4	28.1	51.4	90.8	92.5	102.1	106.5	79.2	63.8
109	0	0	1	39.3	38.5	52.5	72.3	65.6	70.8	57.5	62.1	22.8
110	0	0	1	21.5	47.8	50.0	74.0	60.5	64.0	59.9	69.8	48.3
111	0	0	1	25.0	43.5	52.4	73.0	59.4	61.0	54.1	55.0	30.0
112	0	0	0	24.5	39.0	60.4	76.3	85.0	80.6	90.7	84.3	59.8
113	0	0	0	28.2	38.8	50.9	64.1	68.0	75.1	78.1	79.0	50.8
114	0	0	0	29.4	49.5	56.5	76.3	77.7	77.3	86.3	85.7	56.3
115	40	0	1	20.7	39.7	49.6	66.7	67.2	79.8	56.7	62.4	41.7

116	40	0	1	37.5	45.4	53.4	77.5	55.4	63.3	56.1	59.5	22.0
117	40	0	1	20.9	40.3	60.6	87.0	69.1	76.1	65.8	67.9	47.0
118	40	0	0	29.7	46.0	56.3	81.8	90.6	101.8	111.7	90.6	60.9
119	40	0	0	23.4	39.0	64.0	112.0	110.3	127.6	109.4	96.5	73.1
120	40	0	0	21.3	41.4	68.0	94.2	102.2	100.0	125.4	115.1	93.8
121	80	0	1	30.5	50.0	61.4	103.9	71.3	87.8	65.8	74.6	44.1
122	80	0	1	24.8	50.9	57.0	87.9	68.1	80.1	56.3	84.3	59.5
123	80	0	1	28.0	44.2	66.1	105.7	63.8	82.9	55.3	82.0	54.0
124	80	0	0	23.2	53.5	76.5	98.2	107.0	128.3	111.4	106.5	83.3
125	80	0	0	32.1	38.6	72.0	101.0	99.0	122.5	123.3	115.2	83.1
126	80	0	0	27.5	57.4	63.5	93.2	112.7	114.6	107.4	110.0	82.5

Table 8.17 - *Phalaris* percent coverage data where SHD = shade level, DPS = disturbance patch size, GRZ = grazing (0 = unmowed, 1 = mowed).

ID	SHD	DPS	GRZ	T0	W2	W4	W6	W8	W10	W12	W14	% CHG 14
1	0	0	1	NA	70	75	95	90	95	90	95	25
2	0	0	1	NA	30	65	75	75	90	95	90	60
3	0	0	1	NA	80	90	90	85	85	80	85	5
4	0	0	0	NA	90	85	95	90	90	90	90	0
5	0	0	0	NA	90	90	95	90	95	95	90	0
6	0	0	0	NA	80	75	80	95	95	80	80	0
7	0	0	1	NA	80	75	90	85	75	75	90	10
8	0	0	1	NA	40	75	75	80	90	85	90	50
9	0	0	1	NA	80	85	85	75	80	85	90	10
10	0	0	0	NA	70	85	90	95	90	90	90	20
11	0	0	0	NA	90	90	95	95	95	100	100	10
12	0	0	0	NA	80	60	70	90	90	80	85	5
13	0	4	1	NA	40	70	85	60	75	75	80	40
14	0	4	1	NA	85	90	90	95	90	85	85	0
15	0	4	1	NA	75	70	75	75	75	80	80	5
16	0	4	0	NA	80	85	95	95	95	90	90	10
17	0	4	0	NA	90	95	100	95	95	60	75	-15
18	0	4	0	NA	70	70	85	90	85	85	80	10
19	0	4	1	NA	50	80	85	75	70	85	85	35
20	0	4	1	NA	80	80	90	90	90	90	90	10
21	0	4	1	NA	75	70	75	80	80	60	75	0
22	0	4	0	NA	40	60	85	80	80	80	85	45
23	0	4	0	NA	80	80	95	85	90	85	85	5
24	0	4	0	NA	60	60	75	60	60	80	85	25
25	0	8	1	NA	70	95	90	75	90	85	90	20
26	0	8	1	NA	90	90	95	85	85	75	60	-30
27	0	8	1	NA	70	60	75	60	75	75	75	5
28	0	8	0	NA	30	90	85	60	75	85	90	60
29	0	8	0	NA	80	80	95	85	85	80	80	0
30	0	8	0	NA	75	75	75	85	95	90	95	20
31	0	8	1	NA	70	75	90	75	80	80	80	10
32	0	8	1	NA	60	90	95	70	85	50	60	0
33	0	8	1	NA	40	30	50	70	80	80	80	40
34	0	8	0	NA	80	95	90	85	90	80	85	5

35	0	8	0	NA	50	75	85	80	90	85	85	35
36	0	8	0	NA	50	50	70	60	85	85	90	40
37	40	0	1	NA	60	80	90	85	90	85	85	25
38	40	0	1	NA	90	90	95	60	80	90	90	0
39	40	0	1	NA	80	90	90	95	95	90	85	5
40	40	0	0	NA	60	80	80	85	90	85	85	25
41	40	0	0	NA	90	85	95	80	80	90	90	0
42	40	0	0	NA	80	85	90	95	95	95	95	15
43	40	0	1	NA	80	80	85	90	90	75	85	5
44	40	0	1	NA	85	95	85	80	85	90	80	-5
45	40	0	1	NA	90	95	85	90	95	85	85	-5
46	40	0	0	NA	80	85	90	95	90	90	90	10
47	40	0	0	NA	75	90	95	85	85	85	90	15
48	40	0	0	NA	80	95	95	90	90	80	85	5
49	40	4	1	NA	50	70	70	60	85	65	60	10
50	40	4	1	NA	85	95	90	90	85	85	80	-5
51	40	4	1	NA	90	90	95	90	90	85	90	0
52	40	4	0	NA	80	85	80	75	75	85	90	10
53	40	4	0	NA	85	85	95	90	95	95	90	5
54	40	4	0	NA	75	80	95	10 0	10 0	100	90	15
55	40	4	1	NA	80	80	85	70	90	75	85	5
56	40	4	1	NA	90	90	90	90	95	85	80	-10
57	40	4	1	NA	80	85	90	85	85	85	85	5
58	40	4	0	NA	85	95	10 0	95	85	85	90	5
59	40	4	0	NA	85	95	95	90	90	90	85	0
60	40	4	0	NA	70	80	90	10 0	90	90	95	25
61	40	8	1	NA	70	65	80	85	90	90	90	20
62	40	8	1	NA	70	85	85	80	80	75	85	15
63	40	8	1	NA	50	50	80	50	90	90	90	40
64	40	8	0	NA	60	75	90	90	80	85	90	30
65	40	8	0	NA	75	80	85	75	85	85	90	15
66	40	8	0	NA	65	90	95	90	85	85	85	20
67	40	8	1	NA	60	70	75	75	80	85	80	20
68	40	8	1	NA	70	85	85	80	80	85	80	10
69	40	8	1	NA	80	85	85	80	95	85	95	15
70	40	8	0	NA	60	75	80	80	75	80	80	20
71	40	8	0	NA	75	85	80	80	85	70	75	0
72	40	8	0	NA	75	75	95	95	85	80	85	10

73	80	0	1	NA	70	80	95	90	85	80	85	15
74	80	0	1	NA	40	70	75	80	85	80	75	35
75	80	0	1	NA	90	95	90	80	85	85	80	-10
76	80	0	0	NA	80	95	95	90	85	85	90	10
77	80	0	0	NA	80	75	95	90	85	80	85	5
78	80	0	0	NA	65	75	90	95	75	85	75	10
79	80	0	1	NA	80	75	95	95	90	90	90	10
80	80	0	1	NA	40	60	80	85	85	90	75	35
81	80	0	1	NA	80	95	95	85	85	90	80	0
82	80	0	0	NA	80	85	95	90	85	85	90	10
83	80	0	0	NA	60	70	85	90	90	90	80	20
84	80	0	0	NA	70	75	90	95	60	80	60	-10
85	80	4	1	NA	80	90	100	85	85	75	80	0
86	80	4	1	NA	75	80	90	75	75	70	85	10
87	80	4	1	NA	70	80	95	75	80	90	85	15
88	80	4	0	NA	75	85	95	95	90	90	85	10
89	80	4	0	NA	75	80	85	95	90	75	80	5
90	80	4	0	NA	70	85	90	80	85	75	85	15
91	80	4	1	NA	95	90	100	85	75	80	80	-15
92	80	4	1	NA	75	80	95	75	85	85	90	15
93	80	4	1	NA	70	80	95	80	90	90	90	20
94	80	4	0	NA	75	60	90	90	85	80	85	10
95	80	4	0	NA	80	90	90	95	90	95	95	15
96	80	4	0	NA	85	90	95	95	90	85	90	5
97	80	8	1	NA	80	90	95	85	90	85	90	10
98	80	8	1	NA	80	60	75	80	85	80	80	0
99	80	8	1	NA	60	60	75	80	75	90	85	25
100	80	8	0	NA	70	85	85	90	75	85	85	15
101	80	8	0	NA	5	5	10	30	65	85	75	70
102	80	8	0	NA	70	75	90	90	85	85	75	5
103	80	8	1	NA	70	85	95	85	90	80	85	15
104	80	8	1	NA	60	60	80	80	85	80	80	20
105	80	8	1	NA	70	70	85	80	85	80	80	10
106	80	8	0	NA	60	75	90	90	75	80	90	30
107	80	8	0	NA	60	50	75	80	60	75	75	15
108	80	8	0	NA	65	75	85	90	80	85	80	15
109	0	0	1	NA	90	80	95	95	95	90	90	0
110	0	0	1	NA	90	90	90	90	95	95	95	5
111	0	0	1	NA	90	85	85	85	85	90	85	-5

112	0	0	0	NA	85	90	95	90	85	85	90	5
113	0	0	0	NA	80	80	90	95	95	95	90	10
114	0	0	0	NA	85	70	85	90	85	85	85	0
115	40	0	1	NA	60	75	80	70	90	80	85	25
116	40	0	1	NA	80	90	80	80	75	85	85	5
117	40	0	1	NA	60	85	90	90	95	85	90	30
118	40	0	0	NA	85	80	90	90	75	90	85	0
119	40	0	0	NA	85	80	85	90	95	85	90	5
120	40	0	0	NA	75	85	95	95	95	90	90	15
121	80	0	1	NA	60	70	95	85	90	85	90	30
122	80	0	1	NA	90	80	85	90	90	90	90	0
123	80	0	1	NA	80	80	85	80	85	85	85	5
124	80	0	0	NA	75	80	95	90	90	90	90	15
125	80	0	0	NA	55	50	75	90	90	90	85	30
126	80	0	0	NA	75	75	90	95	90	90	100	25

Table 8.18 – Light readings taken for each plot. Means and standard errors were calculated for each shade level.

Plot I.D.	Light Reading (umol) 7/15/09	Light Readin g (umol) 7/28/09	Light Readin g (umol) 8/12/09	Mean
0%1	1132.9	778.0	1057.6	989.5
0%1	1093.0	788.2	1179.0	1020.1
0%1	1051.0	180.8	1110.9	780.9
0%2	1112.0	820.5	1132.9	1021.8
0%2	1114.7	795.1	1173.9	1027.9
0%2	1055.0	765.6	1169.0	996.5
0%3	1258.0	761.8	1082.2	1034.0
0%3	1158.0	803.3	1176.4	1045.9
0%3	1056.0	195.8	1119.9	790.6
0%C	1037.5	813.7	1195.0	1015.4
0%C	1098.0	182.2	1018.1	766.1
0%C	1111.2	831.2	1125.4	1022.6
40%1	324.8	353.5	579.0	419.1
40%1	474.6	393.8	561.6	476.7
40%1	458.0	340.1	594.6	464.2
40%2	467.0	316.4	586.9	456.8
40%2	427.0	355.6	559.3	447.3
40%2	503.9	434.7	598.4	512.3
40%3	446.2	328.0	581.4	451.9
40%3	397.0	290.5	535.3	407.6
40%3	497.0	429.2	613.2	513.1
40%C	406.1	405.7	494.6	435.5
40%C	474.7	355.9	553.8	461.5
40%C	507.1	442.4	571.8	507.1
80%1	361.3	339.9	230.3	310.5
80%1	315.5	360.2	228.4	301.4
80%1	218.0	190.6	254.5	221.0
80%2	256.1	154.8	152.0	187.6
80%2	247.1	168.2	237.5	217.6
80%2	215.5	359.3	254.3	276.4
80%3	354.5	388.6	224.0	322.4
80%3	250.4	161.5	258.4	223.4
80%3	234.8	205.8	236.3	225.6
80%C	226.8	429.3	272.5	309.5

80%C	263.7	391.8	216.8	290.8
80%C	230.1	162.5	217.5	203.4