FACTORS AFFECTING WHITE-TAILED DEER BROWSING RATES ON EARLY GROWTH STAGES OF SOYBEAN CROPS

by

Gregory M. Colligan

A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Master of Science in Wildlife Ecology

Fall 2007

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Deer damage to soybean crops is a concern for soybean producers on the Delmarva Peninsula. Although researchers have documented decreases in the intensity of deer browse on soybean plants as the growing season progresses, an understanding of the mechanisms driving the decrease in deer browse is necessary for reduction and mitigation of deer damage to soybean crops. I tested 4 hypotheses to determine why deer browse rates decreases 3 weeks after plant emergence: plant phenology affects plant palatability, diet change occurs, deer damage induces a plant response making soybean leaves less palatable, and deer consume fewer leaves but the same amount of leaf biomass as the season progresses. I recorded deer browse in double and single crop soybean fields in Little Creek, Delaware during the 2005 – 2006 growing seasons. To test if plant phenology affected deer browse, I conducted a forage analysis of soybean leaves at different growth stages. Although forage quality components were variable across the growing season, white-tailed deer dietary requirements were met or exceeded in all cases expect one. I compared deer diet composition using microhistological analyses across the early soybean growing season. By late-May, crops constituted >76% of the items documented in deer diets. The proportion of soybeans in the diet increased from 13% to 37% from late-May to early-July. I tested for an induced plant response by comparing the browse rates of plots that were protected from deer browsing until 4 weeks after plant emergence to plots that received no protection and were browsed sometime in during the 1st 4 weeks. Although I documented greater browse rates in the protected plots, I also
documented that protected plots had taller plants suggesting that deer may have been attracted to the taller plants. The amount of soybean leaf biomass deer were consuming across the growing season was variable but did not decrease from the early to late growth stages of soybeans. Decreasing trends in deer browse, during the early part of the growing season, as reported by other authors were likely the result of how other authors determined browse rates. My research indicates that deer browse does not decrease 3 weeks after plant emergence. When browse rates are standardized by using consumed biomass per week, deer browse on soybean plants is continuous across the growing season. If deer continue to consume leaf biomass at a relatively constant rate as the plants grow more leaves, the impact on plant and the visibility of deer browsing to the agricultural producers will decrease across the season.
Chapter 1
INTRODUCTION

The white-tailed deer (*Odocoileus virginanus*) diet in agricultural landscapes is typically dominated by agronomic crops (Nixon et al 1991). The heterogenous row crop landscape and variable planting and harvesting chronology of agricultural landscapes provide deer with a plethora of highly palatable food sources year-round. Availability and use of agricultural crops has caused deer abundance to exceed the cultural carrying capacity in rural landscapes (Conover 1994, Conover 1997). Most agricultural producers reported that deer caused significant economic damage to crops (Conover 1994). Conover (1997) conservatively estimated that deer are responsible for $100 million in damage to agricultural productivity annually in the US.

Soybean (*Glycine max*) crops are a preferred food item by deer; and in some parts of the Southeast agriculture producers have stopped planting soybeans because deer damage is severe and unavoidable (Wallace et al. 1996). Most deer browsing on soybeans plants occurs during early growth stages (DeCalesta and Schwenderman 1978, Garrison and Lewis 1987, Rogerson 2005). Although browse intensity decreases as the growing season progresses (Lyon and Scanlon 1987, Rogerson 2005), the reason for this decrease is unknown. Rogerson (2005) proposed 4 hypotheses for why deer browse on soybeans...
declined 3 weeks after plant emergence. First, soybean plants may become less palatable in the reproductive growth stages. Second, deer may switch to alternate food sources as the growing season progresses. Third, deer browse on soybean plants may induce plant responses making soybean leaves less palatable. Fourth, deer may continue to consume the same amount of leaf biomass, but an increase in the biomass of individual leaves caused deer to remove fewer leaves. Determining the validity of these hypotheses may provide further insight for new management techniques needed to reduce deer damage to soybean crops.

Rogerson (2005) suggested that soybeans may become less palatable to deer as plant mature from vegetative to reproductive stages. Lyon and Scanlon (1987) observed more deer in soybean fields during vegetative growth stages compared to reproductive growth stages. As soybean plants matured toward the reproductive growth stages, Lyon (1984) documented that soybeans occurred in deer diets with decreasing frequency, which suggested deer ate fewer soybean leaves later in the growing season. Conversely, by examining rumen contents, Nixon et al. (1991) documented that deer feed on soybean crops for the entire growing season.

Rogerson (2005) suggested that the availability of different food sources, primarily other row crops, may influence deer browse rates on soybean plants. Certain row crops are likely more attractive to deer at particular times during the growing season than others. On my study area wheat (Triticum aestivum), corn (Zea mays), and soybean
are simultaneously available for deer to feed on during the early part of the soybean growing season. Nixon et al. (1991) documented the importance of wheat for deer in agricultural landscapes in early-spring. Corn also becomes a preferred food item during the silking-tasseling growth stages (VerCauteren and Hygnstrom 1993, Nixon et al 1991). Deer prefer to eat wheat (Hartman 1972) and corn (VerCauteren and Hygnstrom 1993, Nixon et al 1991) when those crops are at particular growth stages. The availability of these crops at those preferred growth stages may influence deer browsing on soybeans.

Rogerson (2005) hypothesized that defoliation of soybean plants by deer may elicit a chemical response thereby decreasing the palatability of the remaining leaves. Previous research indicated chemical changes occurred within soybean plants in response to insect herbivory (Klubertanz et al 1996, Peterson and Higley 1996). Kogan and Fisher (1991) found that some chemical changes induced by insect defoliation defended the plant against subsequent defoliation. However, the mode of feeding for insects and deer is different, deer tend to eat whole leaves, whereas insects feed by chewing portions of leaves or sucking the phloem. Research investigating soybean plant reaction to leaf clipping, as it relates to vegetative growth and plant chemical reaction is nonexistent.

A reduction in browse rates could result from leaves increasing in size across the growing season (Rogerson 2005). Deer tend to browse soybean leaves from the top of the plant and the upper most leaves are generally thicker than leaves at lower nodes, which results in greater individual leaf weights (Lugg and Sinclair 1980). Additionally, both
leaf expansion rates and individual leaf area of individual soybean leaves increase across vegetative growth stages (Leadley and Reynolds 1989). New soybean leaves are thicker, larger, and grow faster than older leaves so deer have to consume fewer leaves to become satiated as the growing season progresses.

The mechanisms driving the decrease in browse activity need to be investigated because determining the mechanism may allow the formulation of new strategies for reducing deer damage to soybean. My objectives were to determine if a decrease in browse rates was caused by:

1. soybean plants becoming less palatable as the plants matured from vegetative to reproductive stages
2. a shift in deer diets
3. deer browsing inducing a soybean plant response making the leaves less palatable
4. changes in individual leaf biomass
Chapter 2

STUDY SITE

The study site was located on the Delmarva Peninsula on the coastal plain of Delaware, 10 km south of Little Creek, Delaware on Route 9. The farm was owned and operated by Dr. Chester and Sally Dickerson and was representative of farms found on the Delmarva Peninsula (Rogerson 2005). Agricultural fields comprised 80% of the farm with the remaining 20% being forested. Fields used for crop production ranged from 8-20 ha. The soils on the study site relevant to crop production were Woodstown loam (Aquic Hapludults), Sassafras sandy loam, and Mattapex silt loam (Typic Hapludults), and Falsington loam (Typic Endoaquults). The row crops produced on my study area were soybean, corn, and wheat. Single crop soybeans were planted on 1 June 2005 (Asgrow, AG3905RR) and 10 May 2006 (Asgrow, AG2801RR) and harvested on 3 November 2005 and 16 October 2006. Double crop soybeans were planted after the wheat harvest on 15 July 2005 (Asgrow, AG4201RR) and 11 July 2006 (Pioneer, P94M30RR) and harvested in the fall on 7 December 2005 and 10 November 2006. Sweetgum (Liquidambar styraciflua), sycamore (Platanus occidentalis), red maple (Acer rubrum), white oak (Quercus alba), pin oak (Quercus palustris) and American holly (Ilex opaca) dominated the forest portions of the study site (Rogerson 2005). The study site averaged a maximum and minimum temperature of 26.6° C and 15.6° C, respectively,
and averaged 10.5 cm of precipitation during the growing season (May–October; National Climatic Data Center 2005).
Chapter 3

METHODS

I conducted my research in 1 double crop and 1 single crop soybean field annually. Based on observations by the agricultural producer and Rogerson (2005), I selected fields that had historically high deer use. I selected fields bordered by only 1 forest edge, which were typical of farm fields on the Delmarva Peninsula. In each selected field, I systematically placed 4.6 m$^2$ circular plots (diameter = 2.4m) at the midpoint of 6 distance intervals (0-10, 11-20, 21-30, 31-40, 41-50, and 51-60m) from the forest/field edge into each field. I spaced plots in the same distance class 2 m apart from plot edge to edge. I systematically assigned a treatment to each plot: protected before emergence until 4 weeks after emergence, never protected, or protected before emergence and for the entire growing season. I protected the plots that were assigned a protection treatment using 1.22 m high welded wire fences. Fences were large enough to provide a 0.5m buffer around the centralized 1m$^2$ plots to prevent effects from deer browsing next to fences or differences in sunlight exposure. The plots that I protected for the entire growing season were used for the continuation of Rogerson’s (2005) yield study and are not mentioned in this study again. In 2005, I had 5 replicates of each treatment within each distance interval for a sample size of 60 in each field (i.e., 90 including plots used for the continuation of the yield study). Due to the amount of browse observed in 2005, I
doubled the number of replicates within each treatment in 2006 for a sample size of 120 in each field (i.e., 180 including plots used for the continuation of the yield study).

**Browse Rates**

To determine all aspects of my objectives, I estimated soybean leaf browse rates across the growing season. I estimated browse rates by calculating the proportion of leaves browsed within each plots, so that my results could be compared to those of Rogerson (2005). Soybean leaves are compound leaves, comprised of 3 leaflets. I considered a leaf browsed when the entire leaf (i.e., all 3 leaflets) was eaten, which was always the case. To determine the the proportion of leaves browsed within each plot I divided the number of leaves eaten by the total number of leaves available in each plot. I counted the number of leaves browsed every 7-10 days in a centralized 1 m\(^2\) (within each 4.6 m\(^2\) plot) starting 1 week after plant emergence and ending approximately at the reproductive growth stage 6 (R6) when plant leaves begin to senesce (i.e., approximately 8-10 weeks after emergence). I estimated the total number of leaves in each plot by determining the average number of leaves per plant and multiplying it by the number of plants in each plot. To account for variation in plant growth with respect to distance class, each week I randomly selected 10 plants at each distance class. I counted the number of leaves on each plant and calculated the average number of leaves per plant for each distance class, each week. Each week, I calculated the average number of leaves per
plot by multiplying the number of plants per plot by the average number of leaves per plant, for each distance class. I calculated the proportion of leaves browsed per plot by dividing the average number of leaves per plot by the number of leaves browsed. Additionally, I measured the average height of plants in each plot, each week. I investigated differences in weekly browse rates using a repeated measures ANOVA blocking on distance class for each field type (i.e., double and single crop fields) and year. I used a least squares means test as a mean separate test if differences were detected.

**Deer Population Estimates**

I used cameras triggered by infrared monitors to estimate the deer population on the farm using methods described by Jacobson (1997). I systematically placed the 5 camera sites at a density of 1 camera per 52 ha. I used the same sites as those previously described by Rogerson (2005). I located sites on or within 25 m of field edges. I pre-baited sites with whole-kernel corn for 1 week before beginning my surveys. I conducted the camera survey from August 15th – 29th and August 10th -23rd in 2005 and 2006, respectively. I maintained at least 11 kg of whole-kernel corn at the bait sites during my surveys. I set the cameras to take pictures in 3 minute intervals and were checked every 2-3 days.
Plant Phenology

To test the hypothesis that browse rate decrease was caused by soybean plants becoming less palatable as the plants matured from vegetative to reproductive stages, I monitored forage quality. I compared the forage quality of soybean leaves by growth stage across the growing season in double crop and single crop fields. I randomly selected 5 plants 0-25 m from the forest/field edge and clipped leaves from the uppermost portion of the plants, mimicking deer browse. For each replicate, I clipped enough leaves to fill a 1 quart bag. I sent the samples to Cumberland Valley Analytical Services (CVAS), Hagerstown, Maryland for standard forage quality analyses. Immediately upon clipping, I placed samples in a cooler and kept them cool thereafter to maintain sample integrity. I used crude protein (CP), calcium (Ca), phosphorous (P), sodium (Na), and digestibility in the form of acid detergent fiber (ADF) and neutral detergent fiber (NDF) to evaluate the forage quality of soybean leaves for different plant growth stages (Campbell et al. 2002). To investigate differences in forage quality of soybean leaves across the growing season, I used a one-way ANOVA for each field type. If I detected differences, I used a Fisher’s Protected Least Significant Difference (LSD) as a means separation test.
**Diet Change**

To test the hypothesis that the browse rate decrease was caused by a diet shift, I monitored deer diets using microhistological analysis. I collected deer fecal samples weekly (17 May 2006 – 17 July 2006) from the study site. This time period covered the time from before single crop soybeans were planted to just before emergence of double crop soybeans. I choose to stop sampling before double crop soybean emergence to prevent any influence on diet that double crop soybeans may have had. Each week I collected and froze 8-12 pellets from 10-12 different piles of fresh scat. I collected pellets from the woodlot adjacent to the single crop soybean field. This woodlot was equidistant from my full season soybean field, a field planted in corn, and a field planted in wheat. I combined 1 week samples (all pellets collected for a given week) into 2 week intervals to attain appropriate sample sizes (Holechek and Vavra 1981). I sent samples to the Washington State University Wildlife Habitat Nutrition Laboratory, Pullman, Washington (WSHNL), which conducted a food-habitat diet composition for each composite sample. Samples were analyzed by forage class (crops, grass, forbs, and shrubs) and major forage plants (> 5% in diet). For each sample, 8 slides were made and viewed 25 times, for a total of 200 views per sample. From these views, the percent of each forage class and specific plants in the diet was estimated.

**Induced Plant Response**

To test the hypothesis that the browse rate decrease was caused by deer browsing inducing a soybean plant response making the leaves less palatable, I protected plots from planting until 4 weeks after plant emergence. Although this approach would not allow
me to determine the mechanism of reduction in palatability, it did allow me to determine if this mechanism occurred. If deer browse did elicit a response by the plant that decreased plant palatability in the weeks following fence removal (5, 6, and 7), I expected to see more browse in the plots that were protected for 4 weeks compared to the control plots. For this analysis, I had 2 treatments: unprotected plots that were browsed during weeks 1-4 and plots protected from browse until week 4. During weeks 5-7, I compared the proportion of leaves browsed per plot for the 2 treatments using one-way ANOVAs for each week, field type, and year. Based on Rogerson (2005), I suspected that protection treatment plants might be taller than unprotected plants. If protected plants were taller, their height may have influenced deer browsing. Therefore, if I detected a difference in browse rates between the treatments, I compared the plant heights of the 2 treatments during weeks 4-7 using one-way ANOVAs for each week, field type, and year.

**Leaf Biomass**

To test the hypothesis that the browse rate decrease was caused by changes in individual leaf biomass, I monitored the amount of biomass removed by browsing. To estimate the amount of available soybean leaf biomass each week, I clipped 1 completely unrolled leaf, at the highest node, from 30 random plants within each distance class mimicking deer browse. I dried the clippings at 43°C for 2 weeks. I weighed the dried clippings and divided the weight of the sample by 30 to determine the average weight of 1
leaf. I estimated consumed biomass for each week by multiplying the number of leaves browsed in the unprotected plots by the average dry leaf weight within each distance class. I investigated differences in weekly browse rates using a repeated measures ANOVA blocking on distance class for each field type and year. I used a least squares means test as a mean separate test if differences were detected.
Chapter 4

RESULTS

Browse Rates

In 2005, browse rates did not differ among weeks in the double crop field ($F_{6, 162} = 0.61, P = 0.721$) or in the single crop fields ($F_{6, 174} = 1.30, P = 0.261$). In the 2006 double crop field, browse rates were over 20 times greater 1 week after plant emergence ($F_{6, 354} = 5.81, P < 0.001$) than for any of the subsequent weeks (Figure 1). In the 2006 single crop field, week 1 browse rates were more than double those of weeks 3 through 7 ($F_{6, 354} = 3.79, P = 0.001$; Figure 2).

Plant Phenology

Crude protein (double crop: $F_{5, 24} = 14.19, P < 0.001$; single crop: $F_{4, 25} = 83.34, P < 0.001$; Figure 3), percent calcium (double crop: $F_{5, 24} = 10.64, P < 0.001$; single crop: $F_{4, 25} = 10.76, P < 0.001$; Figure 4), and percent phosphorous (double crop: $F_{5, 24} = 6.84, P < 0.001$; single crop: $F_{4, 25} = 26.30, P < 0.001$; Figure 5), differed by growth stage for the double and single crop fields. Sodium did not differ by growth stages for double or single crop fields (double crop: $F_{5, 24} = 1.11, P = 0.379$; single crop: $F_{4, 25} = 0.31, P = 0.868$; Figure 6). Crude protein, calcium, and phosphorous values exceeded the minimum requirement for deer across all growth stages in both double crop and single crop fields. Although sodium did not meet the minimum requirement for maintenance and antlers
(Hellgren and Pitts 1997) for the R2 growth stage in the single crop field, R2 was not statistically different than other growth stages in that field and all other growth stages exceeded the minimum requirements. Acid detergent fiber (ADF) differed by growth stage in double crop ($F_{5, 24} = 3.40, P = 0.018$) and single crop fields ($F_{4, 25} = 15.30, P < 0.001$; Figure 7). Neutral detergent fiber (NDF) also differed by growth stages in the single crop ($F_{4, 25} = 2.77, P = 0.049$) and the double crop fields ($F_{5, 24} = 5.05, P = 0.003$; Figure 7)

**Diet Change**

In the 1st sampling period, deer diets were primarily comprised shrubs and forbs. Oak (*Quercus spp.*; 26.3%), dwarf sumac (*Rhus copallina*; 5.0%), and blackberry (*Rubus spp.*; 5.0%) were important shrub food sources. Coreopsis beggarticks (*Bidens polylepis*), spotted touch-me-not (*Impatiens campensis*), small white morning glory (*Ipomoea lacunose*), smartweed (*Polygonum spp.*), common greenbrier (*Smilax rotundifolia*), and white clover (*Trifolium repens*) were important forb food sources. After the 1st sampling period, shrubs and forbs comprised, <13% of the deer diet (Table 1). Row crops consisted of ≥77% of the diet after the first sampling period (Table 1). Wheat and soybean crops were the most common food items in deer diets during sampling periods 2-4 (Table 1).
**Induced Plant Response**

Browse rates during weeks 5-7 did not differ between plots protected for 4 weeks and unprotected plots for single crop field in 2005 and double crop fields in 2005 or 2006 (Table 2). In the 2006 single crop field, browse rates were greater in week 5 for plots protected for 4 weeks compared to unprotected plots, whereas browse rates were similar between treatments in weeks 6-7 (Figure 8). The difference in plant height between the treatments decreased from weeks 4 to 7 until by week 7 plant height did not differ between the treatments (Table 3).

**Leaf Biomass**

The amount of biomass removed by deer in the double crop field did not differ by week in 2005 ($F_{6,162} = 0.78, P = 0.583$) or 2006 ($F_{6,354} = 0.92, P = 0.482$) but did differ by week in the single crop field in 2005 ($F_{6,174} = 2.44, P = 0.027$) and 2006 ($F_{6,354} = 5.87, P < 0.001$; Figure 9). In week 7, biomass consumed was more than triple that of any other week in the 2005 single crop field (Figure 9). Week 5 had more than double the amount of consumed biomass as any other week, and week 3 had about half the consumed biomass in the 2006 single crop field (Figure 9).

**Population Estimation**

During the 2005 growing season, I estimated that 176 deer (10 bucks, 115 does, and 51 fawns) were using the farm. In the 2006 growing season, I estimated that 58 deer were using the farm: 23 bucks, 26 does, and 9 fawns.
Figure 1. Mean proportion of soybean leaves browsed by week in double crop fields in Little Creek, Delaware, 2005 and 2006. Values sharing the same letter are not significantly different.
Figure 2. Mean proportion of soybean leaves browsed by week in single crop fields in Little Creek, Delaware, 2005 (P = 0.721) and 2006 (P < 0.001). Values sharing the same letter are not significantly different.
Figure 3. Mean percent of crude protein in single crop and double crop soybean leaves by growth stage in Little Creek, Delaware, 2006.
Figure 4. Mean percent dry matter calcium in single crop and double crop soybean leaves by growth stage in Little Creek, Delaware, 2006.
Figure 5. Mean percent of dry matter phosphorous in single crop and double crop soybean leaves by growth stage in Little Creek, Delaware, 2006

Spring Requirement (Grasman and Hellgren 1993)
Figure 6. Mean percent of dry matter sodium in single crop and double crop soybean leaves by growth stage in Little Creek, Delaware, 2006.
Figure 7. Mean digestibility values for (a) ADF and (b) NDF for double and single crop soybean leaves by growth stage, in Little Creek, Delaware, 2006.
Table 1. Diet composition by forage class for white-tailed deer in Little Creek, Delaware, 2006.

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* Refers to the 2 weeks before single crop soybean was planted
Figure 8. Mean browse rates (a) and plant heights (b) for protected and unprotected plots in the single crop soybean field in Little Creek, Delaware, 2006.
Table 2. Average browse rates (proportion of leaves browsed) for plots that received a protection treatment and plots that were unprotected and browsed in weeks 1-4 in a single crop and double crop fields, Little Creek, Delaware, 2006

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<td>6</td>
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<td>0.005</td>
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<td>0.0254</td>
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<td></td>
<td>2006</td>
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<td>0.0048</td>
<td>0.052</td>
<td>0.0112</td>
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<td></td>
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<td>0.0046</td>
<td>0.020</td>
<td>0.0058</td>
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<td>7</td>
<td>0.002</td>
<td>0.0015</td>
<td>0.002</td>
<td>0.0015</td>
</tr>
</tbody>
</table>

\[^\text{1}]\text{NA} = \text{no analysis for weeks when no browse was observed for either treatment}
Table 3. Average heights (m) of plots that received a protection treatment and plots that were unprotected and browsed in weeks 1-4 in a single crop field, Little Creek, Delaware, 2006.

<table>
<thead>
<tr>
<th>Week</th>
<th>n</th>
<th>Protected</th>
<th></th>
<th></th>
<th></th>
<th>Unprotected</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>x</td>
<td>SE</td>
<td>n</td>
<td>x</td>
<td>SE</td>
<td>F_{1, 76}</td>
<td>P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>54</td>
<td>0.207</td>
<td>0.0028</td>
<td>29</td>
<td>0.191</td>
<td>0.0036</td>
<td>13.11</td>
<td>&lt;0.001</td>
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<td></td>
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<tr>
<td>5</td>
<td>54</td>
<td>0.353</td>
<td>0.0047</td>
<td>29</td>
<td>0.329</td>
<td>0.0058</td>
<td>12.71</td>
<td>&lt;0.001</td>
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<td>29</td>
<td>0.386</td>
<td>0.0082</td>
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<td>0.0094</td>
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<td>2.77</td>
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</table>

^n does not equal 60 due to inundation of some plots that altered plant growth
Figure 9. Estimated weekly soybean leaf biomass (g m$^{-2}$) removed in double (a) and single (b) crop soybean fields by week, Little Creek, Delaware, 2005 and 2006.
Chapter 5
DISCUSSION

Browse Rates

My results in 2006 were similar to authors whom observed decreasing browse rates across the growing season (Rogerson 2005, Garrison and Lewis 1987, DeCalesta and Schwenderman 1978). The periods of greatest deer browse that I documented were more focused than those described by Garrison and Lewis (1987) and Rogerson (2005). I observed the greatest browse rates (proportion of leaves browsed) during the first 2 weeks after plant emergence. Garrison and Lewis (1987) found that browse intensity was greatest in the first 4 weeks after plant emergence, whereas Rogerson (2005) found that browse intensity was greatest in the 1st 3 weeks after plant emergence.

Indistinguishable differences in weekly browse rates in 2005 may have resulted from lower overall browse rates relative to those of the 2006 season. These lower browse rates may have been attributable to smaller sample sizes, which resulted in a more narrow spatial distribution of plots parallel to the field edge. Additionally, the 2005 double crop field was subject to abnormally high human activity associated with the construction of a new electric power line adjacent to my study plots. Activity in this field likely resulted in lower deer use of the field relative to fields with less activity.

The inconsistencies in the estimated population from 2005 to 2006 can be partially attributed to crop rotation, heavy landscape fragmentation, and deer use of the landscape.
with respect to these factors. More importantly, in 2006, malfunctioning cameras likely influenced my population estimates. Because these estimates are largely based on buck to doe ratios and the number of doe observed, it is difficult to determine how the malfunctioning cameras influenced my population estimates. Although more browse was generally observed in 2006 than in 2005, the remote camera survey indicates that fewer deer were using the farm in 2006.

**Plant Phenology**

Decreasing leaf browse rates may be the result of leaves becoming less palatable as soybean plants mature (Rogerson 2005 and Lyon and Scanlon 1987). Although I found significant variation in forage quality components for different growth stages, the nutrient requirements for white-tailed deer were met or exceeded in all cases except one (Ullrey et al. 1973, Grasman and Hellgren 1993, Asleson et al. 1996, and Hellgren and Pitts 1997). Although the sodium requirement was not met in the single crop R2 growth stage, all other growth stages exceeded the minimum requirement (Hellgren and Pitts 1997; Table 3). ADF and NDF are the primary analyses for determining forage quality in terms of digestion. ADF is a measure of the amount cellulose and lignin, and is used to calculate energy content. NDF measures the total fiber of forage, and can be used to determine intake rates. In terms of cattle, high quality forage like Alfalfa (pre-bud) has an ADF value of 28% and a NDF value of 38% (Jeranyama and Garcia 2004). The ADF and
NDF values for soybean leaves that I observed were lower than those reported by Jeranyama and Garcia (2004) for high quality cattle forage. Deer are more efficient digesters than cattle (Blankenship et al. 1982); thus, the NDF and ADF values that I observed indicated that soybean leaves are high quality deer forage with respect to digestibility. ADF and NDF did not show an increasing trend which would be expected if leaves were becoming less digestible as the growing season progressed (Moen 1985). The double crop field showed a decrease in ADF and NDF, suggesting that leaves were becoming more palatable as plants matured. My results suggest that decreasing browse rates during the early growing season are not related changes in leaf palatability associated with soybean plant phenology, likely because deer consume new leaves from the uppermost portion of the plant.

Diet Change

The agricultural landscape of the Delmarva Peninsula offers an abundance of highly palatable food items for deer. Rogerson (2005) hypothesized that diet change may have contributed to the decrease in deer browse on soybean plants that he observed 3 weeks after plant emergence. Like other authors (Nixon et al. 1991), I documented deer feeding on all 3 crop types. From soybean plant emergence, soybeans were found in deer diets with increasing frequency as the growing season progressed. Using the same microhistological techniques, Lyon (1984) found that the proportion of deer diets
comprised of soybean crops decreased as the growing season progressed. In contrast to Lyon (1984), my data did not indicate that deer were switching from feeding on soybean to others crops or native forages during the first 7 weeks after plant emergence. I only collected diet samples during the part of the growing season when double crop soybean was unavailable to deer in order to prevent indistinguishable diet components (double and single crop soybeans) from confounding the results. Therefore conclusions can not be drawn regarding how diet change may or may not affect deer browse on double crop soybean crops. It is plausible that diet change could explain the lower browse rates on double crop soybean compared to single crops soybeans.

**Induced Plant Response**

Rogerson (2005) hypothesized that plants that have been browsed by deer become less palatable following the initial browsing event. Although, research indicates chemical changes occurring within soybean plants in response to insect herbivory (Klubertanz et al. 1996, Peterson and Higley 1996), the manner in which insects feed is different than deer. Deer tend to eat whole leaves (Rogerson 2005), whereas insects feed by chewing leaves or sucking phloem. I observed less browse in unprotected plots than in protected plots in the 2006 single crop field (Figure 7), which suggested a plant reaction may have decreased browse rates. In addition to decreased browse, I also observed that plants in the protected plots were taller than those in the unprotected plots. Anderson (1994)
documented that taller herbaceous plants (*Trillium grandiflorum*) are more attractive to deer than shorter plants of the same species. Browse rates followed the same pattern as plant height for plots that had previously been protected. When plant height was greater in the protected treatment plots than in the control plots the same was true for browse rates, as the growing season progressed and plant heights were no longer different between treatments, differences in browse rates also diminished. Deer preference for taller plants over shorter plants is a more plausible explanation for the observed differences in browse rates.

**Leaf Biomass**

Rogerson (2005) suggested that decreased browse rates may have resulted from increased individual leaf biomass. As the season progresses deer may have to eat fewer leaves to consume the same amount of biomass. Soybean leaves grow progressively larger between V1 and V6 (Leadley and Reynolds 1989), and leaves on the uppermost nodes are thicker and weigh more (Lugg and Sinclair 1980). Double crop fields in 2005 and 2006 did not show significant differences in the amount of biomass consumed across the growing season (Figure 9). Although, I observed differences in the amount of biomass consumed between weeks for both single crop fields, only 1 week was different in 2005 and 2 weeks in 2006. More importantly, the amount of consumed biomass observed did not show a clear trend across the growing season. If browse rates were
actually decreasing I would have expected to see the amount of biomass consumed decreasing across the growing season.

Conclusions

Other authors have indicated that deer browse rates on soybean decreases at or before the 3rd week after plant emergence. My research indicates that deer continue to browse soybean plants across the growing season. The significant decrease in browse rates described by other authors is likely a function of how browse was measured. Measuring browse rates using either the proportion of leaves browsed per plant, number of plants browsed, or the number leaves browsed per plot both have major draw backs, as these methods both result in skewed data because as the growing season progresses the number of leaves per plant and the size of individual leaves increase, and plant density can be variable. If deer continue to eat the same amount of leaf matter across the growing season, either of the aforementioned methods would indicate decrease in browse. The consumed biomass method that I used is more accurate for comparing browse rates across time than other methods (ie. number of leaves browsed, number of plants browsed), because it is less subject to natural variation and changing morphology within soybean leaves across the growing season. The consumed biomass portion of this study leads me to conclude that the most plausible explanation for deer browse rates decreasing 3 weeks after plant emergence is that deer browse does not decrease and deer continue to consume
the same amount of leaf matter. The increased number of available soybean leaves makes deer browse more cryptic latter in the growing season compared to early in the growing season, and may lead soybean growers to over estimate the amount of deer damage that they actually have.
When quantifying deer damage to soybean crops, browse rates should be standardized by the amount of biomass removed for a period. Soybean plants are more susceptible to being killed by deer browse early in the growing season when the amount of biomass per plant is lowest. In the early part of the growing season, deer remove more biomass per plant than later in the season. Deer damage to soybean crops may look misleadingly severe in the first 3 weeks after plants emerge. Deer browse on soybeans is continuous across the growing season, but as the growing season progresses browse becomes less apparent to landowners and less detrimental to the plants. In areas with moderate deer densities, plants recover from early season browsing becoming bushier and increasing yield as the result of deer browse (Rogerson 2005). In cases where crop protection is necessary, protection treatments may only need to be used until plants have accumulated enough leaf biomass to sustain browsing. Although mitigation techniques can be effective in the short-term, maintaining healthy, low density deer populations may be the most cost effective tool in mitigating deer damage on soybean crops.
LITERATURE CITED


Rogerson, J.E. 2005. The effect of protection and distance from the forest edge on soybean yield due to white-tailed deer browsing. M.S. Thesis, University of Delaware, Newark, USA.

