THE EFFECT OF DEER BROWSING ON WHEAT YIELD

by

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ABSTRACT

White-tailed deer (*Odocoileus virginianus*) are overabundant in many areas of the country and increased deer numbers have caused damage to agronomic crops to increase. Winter wheat (*Triticum aestivum*) is a commonly grown crop and food source for white-tailed deer on the Delmarva Peninsula. The effect of deer browsing on corn and soybean yields has been documented, but research is lacking on the effect of deer browsing on wheat yield. In 2007-2009, I investigated the effect of browse timing and wheat type (bearded and unbearded) on wheat yield in Delaware. I placed 1680, 4.4 m^2 plots in the middle of 10 m distance classes starting from the forested edge out to 60 m. In 2007, I systematically assigned 1 of 2 treatments (i.e., no protection or protected at planting) to the plots. In 2008-2009, I added a third treatment: protected prior to heading. After head emergence, I conducted weekly browse surveys on all unprotected plots to determine browse rates. I collected weekly biomass samples to estimate the amount of wheat biomass removed by deer. I harvested a 1 m^2 area in the middle of each plot to determine the deer impact on yield. I also tested if browsing affects the test weight of wheat during 2008 and 2009. Browsing increased in intensity as head development progressed with most browsing occurring on the unbearded wheat. I found no interaction between wheat and treatment ($P > 0.10$) during the study. Unprotected plots yielded 195 kg/ha more wheat then protected plots in 2007 ($P = 0.08$). I found no difference between treatments for 2008 and 2009 ($P = 0.38$). Bearded wheat yielded 379 kg/ha higher in 2007 and 399 kg/ha higher in 2008 and 2009 than unbearded wheat ($P < 0.001$). I found no difference in test weight among treatments (P

= 0.42) or between wheat types (P = 0.997) in 2008 and 2009. My browse surveys demonstrated avoidance of bearding but the overall browsing was not intense enough to reduce yield. My results differed from past research documenting a reduction in yield but the lower deer density (~15 deer/km^2) on my study area was the likely cause of the difference.

Chapter 1

INTRODUCTION

White-tailed deer (*Odocoileus virginanus*) are overabundant in many areas of the country and increased deer numbers have caused human-wildlife conflicts to increase. White-tailed deer cause >$100 million of crop damage a year (Conover 1997). In a nationwide poll, Conover (1998) found that over 80% of farmers believed wildlife caused damage to their property and 23% reported damage >$1,000. White-tailed deer were blamed 53% of the time; the most of any wildlife species but the perception of damage may be different than the actual damage occurring to the crops. Monetarily the top 3 row crops produced in the United States are corn (*Zea mays*), soybean (*Glycine max*), and wheat (*Triticum aestivum*; Environmental Protection Agency 2009). The effect of deer browsing on corn and soybean yield has been documented (deCalesta and Schwendeman 1978, Garrison and Lewis 1987, Rogerson 2005, Colligan 2007, and Tzilkowski et al. 2002), but research is limited on the effect of deer browsing on wheat yield..

Wheat has 10 growth stages on the Zadoks scale: germination, seed growth, tillering, stem elongation, booting, inflorescence emergence, anthesis, milk development, dough development, and ripening (Crop Development Centre 2002). Germination occurs within the first week of planting, with seed growth following. Seed growth, when the plant begins to grow above ground, is the first point at which deer can impact wheat by browsing. As the plant continues to grow it reaches the tillering stage in late fall. Leaves are added onto the plant increasing the overall biomass during both pre and post winter dormancy. Deer browse on the plant by removing leaf biomass during tillering. Much of the research investigating wheat damage has occurred from germination through winter dormancy. After tillering the plant begins stem elongation in early spring. Stem elongation concludes with the development of a wheat head in a flag leaf, which is the boot stage. The wheat head then emerges in early May, which is inflorescence emergence. At this point, a difference exists depending on the type of wheat planted. Two types of wheat heads exist: bearded has awns, which are a bristle-like features located on the wheat head, and unbearded lacking awns. The plant develops quickly into the anthesis stage, the point when the plant releases pollen for reproduction. After pollination, the grain development begins in the wheat heads with milk development, when the grain is liquid-like. Dough development then occurs when the liquid solidifies into soft grain. Finally, grain ripening occurs when the grains harden and the wheat plant dries out and becomes brown. Deer browse on the leaves until after the anthesis stage when grain development occurs, at which time deer browse the head of the plant.

Previous research has investigated the impact of browsing by several species on wheat yield with varying results. Canada geese (*Branta canadensis*) reduced yields at all stages of wheat development from emergence through tillering in Michigan (Flegler et al. 1987), but other geese studies have indicated that wheat can be grazed without impact on yield depending on the intensity and timing of grazing (Fischer and Kahn 1966, Puckeridge and Donald 1967). Cervid browsing is less aggressive then geese, which browse by ripping at the plant possibly uprooting and killing the plant. Pronghorn antelope (*Antilicapra americana*) did not impact wheat yield in a winter grazing study (Torbit et al. 1993), whereas Vecellio et al. (1994) observed a reduction of 30% in yield because of white-tailed deer browse. Colligan (2007) documented wheat to be ~ 50% of the diet of white-tailed deer during the last month (i.e., June) of wheat development in Delaware. Although, these studies on cervids did determine that wheat could be impacted, the results are conflicting. Torbit et al. (1993) may not have detected a reduction in yield because his study focused on winter browse and wheat may be more vulnerable to yield reduction during later stages of development. Although Vecellio et al. (1994) documented deer decreased wheat yield, they conducted their research in Gettysburg National Park at an extremely high deer density (i.e., 136 deer/km^2 of forested land; Frost et al. 1994). Previous research has suggested that an ideal deer density to provide adequate viewing opportunities but limit deer/human conflicts is 15 deer/km^2 (Hansen and Beringer 1997). No research has examined the impact of deer around this density on wheat yield, which is needed to better understand the impact of deer browsing on wheat yield. Because the research results are conflicting and the research has been conducted at greater than normal deer densities, additional research is needed to elucidate the impact of white-tailed deer browse on wheat yield.

One factor that may influence whether deer browse affects yield is structure of the wheat head. Awns are a mechanism that plants use to reduce browsing by herbivores. Recently, some producers have suggested that bearded wheat may reduce deer browsing and increase the subsequent wheat yield, but nothing is known about the impact awns have on deer browse. Colligan (2007) demonstrated that deer are browsing wheat at the time when awns would be present on the wheat heads. If awns on wheat heads reduce deer browsing, then farmers may have a new strategy to decrease their crop damage from deer.

Research has examined the impact of an extremely high deer density (136 deer/km^2) on wheat yield but a lack of information exists about the impact of a lower deer density has on wheat yield. There is also a gap in research for the impacts of browsing during different growth stages, because research has not investigated the impact of browsing on growth stages after tillering (i.e., browsing during the spring). Because of this lack of research on later growth stages, nothing is known about how the different head structures of wheat may influence browsing. Understanding these variables can provide insight into how wheat yield may be affected. My objectives were to quantify the browsing rates on the two types of wheat heads, to determine if awns on wheat heads affected deer browsing and provided increased yield for farmers, and to determine if deer browsing at 15 deer/km^2 affects wheat yield.

CHAPTER 2

STUDY AREA

The research farm was located in Kent County, Delaware, 10 km south of Little Creek on the Delmarva Peninsula and is owned by Dr. Chester and Sally Dickerson (Rogerson 2005). The farm was 261 ha in size and approximately 80% crop fields (i.e., corn, wheat, and soybean) and 20% forested. Forested portions were primarily sweetgum (*Liquidambar styraciflua*), white oak (*Quercus alba*), red maple (*Acer rubrum*), and American holly (*Ilex opaca*). The fields used for agriculture ranged in size from 8-20 ha. Soil types present in these fields were Woodstown loam (Auic Hapludults), Sassafras sandy loam, Mattapex silt loam (Typic Hapludults), and Falsington loam (Typic Endoaquults; Colligan 2007). The crop rotation for a field was corn in year 1, soybeans in year 2, and wheat followed by soybeans in year 3. Wheat was planted in mid to late October after the full season soybeans were harvested. The average temperatures for October to July ranged from 6.1 ^{o}C to 26.4 ^{o}C and the average precipitation was 123 cm (National Climatic Data Center 2004). In 2007, a total of 78 cm of precipitation was recorded with an average temperature of 11.4 ^{o}C. In 2008, a total of 88 cm of precipitation was recorded with an average temperature of 12 ^{o}C. In 2009, a total of 80 cm of precipitation was recorded with an average temperature of 10.6 ^{o}C (K. Brinson, Delaware Environmental Observing System, unpublished data). The deer density for the management area was estimated at 15 deer/km^2 of deer habitat (Bowman 2006).

CHAPTER 3

METHODS

The farm staff planted wheat in the middle of October each year. I chose fields with 1 forested edge, planted uniformly with 1 type of wheat. I chose fields with 1 forested edge to avoid the increased browsing that occurs in field corners. I divided each field into 6 distance intervals from the field edge: 0-10 m, 10-20 m, 20-30 m, 30-40 m, 40-50 m, and 50-60 m. Within each distance interval, I established 4.6 m2 circular plots in the middle of the distance interval.

I systematically assigned 1 of 2 treatments to each of the plots in 2007: protected at planting or no protection. The protection at planting treatment allowed me to estimate wheat yield with no influence of deer browsing. The no protection plots allowed me to determine the influence of deer on wheat yield. To be certain browsing was not caused by geese, I checked for the presence of goose droppings in my plots approximately every 2 weeks during the year. I added a third treatment, protected prior to heading, in 2008 and 2009. The timing of the fence placement occurred while the wheat was in the boot stage, when the wheat head was in the flag leaf prior to emergence. The new treatment allowed me to estimate the differences between bearded and unbearded wheat yield and the influence of bearding on deer browsing. For protection treatments, I placed a 1.22 m welded wire fence around plots to keep deer from browsing the wheat. Browsing did not occur in any of the protected plots during the 3 years. Fields contained 20 (2007) or 30 (2008 and 2009) plots per distance interval, which resulted in 120 (2007) or 180 (2008 and 2009) plots per field. In 2007, I had 2 fields (i.e., 1 bearded and 1 unbearded), whereas in 2008 and 2009, I had 4 fields each year, (i.e., 2 bearded and 2 unbearded), which resulted in a total of 1680 plots for my study. I removed 71 plots (23 in 2007, 3 in 2008, and 45 in 2009) that had water damage or weeds present. Plots that had water damage were almost entirely dead, had decreases in height, and/or decreases in head density >25%. Plots with weeds were removed because of competition between plants and were characterized by one or more weeds covering >25% of the plot.

At the anthesis stage, I began to estimate biomass removal weekly in the center of a 1 m^2 area of the unprotected plots. I estimated removal by counting the number of heads present and the number of heads browsed upon in each plot. I measured the amount of biomass removed on 120 plots in 2007, 240 plots in 2008, and 240 plots in 2009. I removed 33 plots due to water and weeds (13 in 2007, 1 in 2008, and 19 in 2009). Next, I randomly collected 30 plants at each distance class in each field outside of my plots to obtain a representative sample of the plants in that field. I stratified my sample by distance class and field since plants mature at different rates depending on field and location in the field. I placed these plants in a paper bag and dried them for 7 days at 43.3 $^{\circ}C$ in a plant drier to obtain a standard moisture content. I weighed the wheat heads to ±0.01 g and then calculated the average head weight for each distance class in each field. I multiplied these averages by the number of heads removed in each plot. By doing this, I was able to estimate the biomass removed in each plot during a week and to determine if removal rates change as the wheat plant gets closer to maturity. If I only counted the number of heads being removed, I would not know if deer are eating more or less of the plant because wheat heads increase in weight throughout the growth stages. I harvested the plots when the wheat reached maturity in late June or early July, which was when the wheat kernels were hard enough to be captured by the thresher. I harvested a 1 m^2 area in the center of each plot by cutting the base of the wheat plant by hand and obtained the wheat grains by running the plants through a thresher. I then dried the grain for 7 days in paper bags at 43.3 ^{o}C in a plant drier and weighed the grain in each bag to ± 2 g.

Wheat quality may be compromised by damage to the plant, such as leaf removal or extreme weather conditions, during several growth stages. Extensive damage to the plant can prevent the development of kernels that have the nutrient content needed by processors for food production (i.e. protein content and bread production). Wheat quality cannot be determined by exclusively looking at wheat yield. To test wheat quality, a test weight for the wheat is obtained by processors. Test weight measures a known volume of wheat and compares its weight to the standard wheat weight at that volume. Obtaining a test weight provides a quality estimate for the wheat. If the wheat does not meet a certain quality, the farmer does not receive full price for the wheat. To obtain my test weight estimates, I weighed a volume of 100mL for each plot to ± 0.01 g. If a plot did not have enough wheat to measure 100mL, then I used a 50mL volume. I then compared that weight estimate to the standard bushel weight of 4040 kg/ha (Hellevang 1995). Farmers were penalized when their test weight was lower than 3900 kg/ha.

I conducted all analyses with SAS (version 9.1, Cary, NC) and an alpha level of 0.10. For the 2007 data, I used a two-way ANOVA, blocking on distance, with the main effects of treatment (i.e., no protection or protection for the entire season) and wheat type (i.e., bearded or unbearded) to detect differences in wheat yield. For the 2008 and

2009 data, I used a two-way ANOVA, blocking on distance and year, with the main effects of treatment and wheat type to detect differences in wheat yield and test weight.

CHAPTER 4

RESULTS

Overall biomass removed was greater in 2007 with ~ 4 times the amount of biomass removed than in 2008 and 2009. In 2007, I observed almost no biomass removed on bearded wheat compared to a peak of >25 kg/ha biomass removed for unbearded wheat (Figure 1). In 2008 and 2009, I observed similar biomass removal between the 2 types of wheat for weeks 1 and 2 of the survey period; however, during week 3 in both years, deer browsed the unbearded wheat 4-6 times more than the bearded wheat (Figure 2). By week 4 of the survey, both wheat types had similar removal rates (Figure 2).

In 2007, I observed no interaction effect between treatments and wheat type ($F_{1, 208} = 0.21$, $P = 0.645$). I did detect a difference in wheat yield between treatments ($F_{1, 208} = 3.05$, $P = 0.082$) and types ($F_{1, 208} = 10.68$, $P = 0.001$). No protection plots ($\bar{x} = 4186$, SE = 103) had 194 kg/ha greater yield than the full protection plots ($\bar{x} = 3992$, SE = 89, Figure 3). Plots with bearded wheat ($\bar{x} = 4274$, SE = 88) had 379 kg/ha greater yield than unbearded plots ($\bar{x} = 3895$, SE = 101, Figure 4). In 2008 and 2009, I also observed no interaction effect between treatments and wheat type ($F_{2, 1381} = 0.17$, $P = 0.846$), and I did not detect a difference in treatments (full protection $\bar{x} = 3889$, SE = 83, spring protection $\bar{x} = 3790$, SE = 73, and no protection treatments $\bar{x} = 3758$, SE = 75; $F_{2, 1381} = 0.97$, $P = 0.378$, Figure 5). Wheat yield differed between wheat types with bearded ($\bar{x} = 4027$, SE = 60) yielding 399 kg/ha greater then unbearded ($\bar{x} = 3628$, SE = 64; $F_{1, 1381} = 31.98$, $P < 0.001$, Figure 6). I observed no interaction effect between treatments and wheat type for test weight ($F_{2, 1372} = 0.88$, $P = 0.417$). I observed no difference in test weight among treatments ($F_{2, 1372} = 0.82$, $P = 0.441$) or between types of wheat ($F_{1, 1372} = 0.00$, $P = 0.998$).

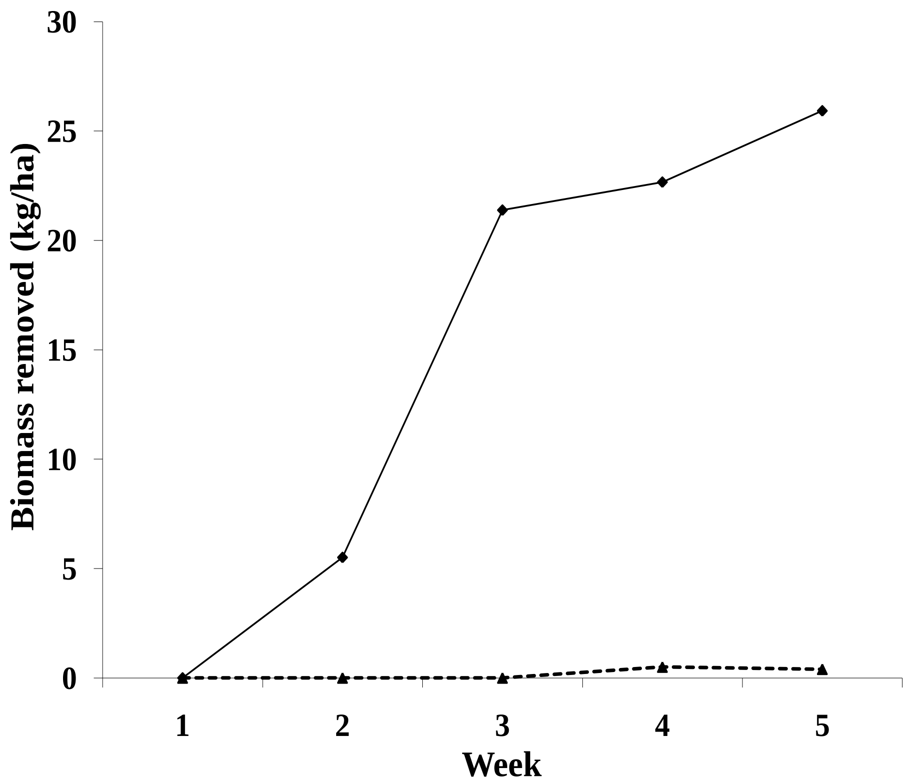

Figure 1. Weekly biomass removal estimates for two types of wheat heads (i.e., bearded and unbearded) from browse surveys conducted in Little Creek, Delaware, 2007. Week 1 represents the first week after I placed the spring fence treatment during the boot stage of wheat development and Week 5 represent the week before I harvested the plots. Total biomass removed did not exceed 0.01% of the overall yield for either type of wheat.

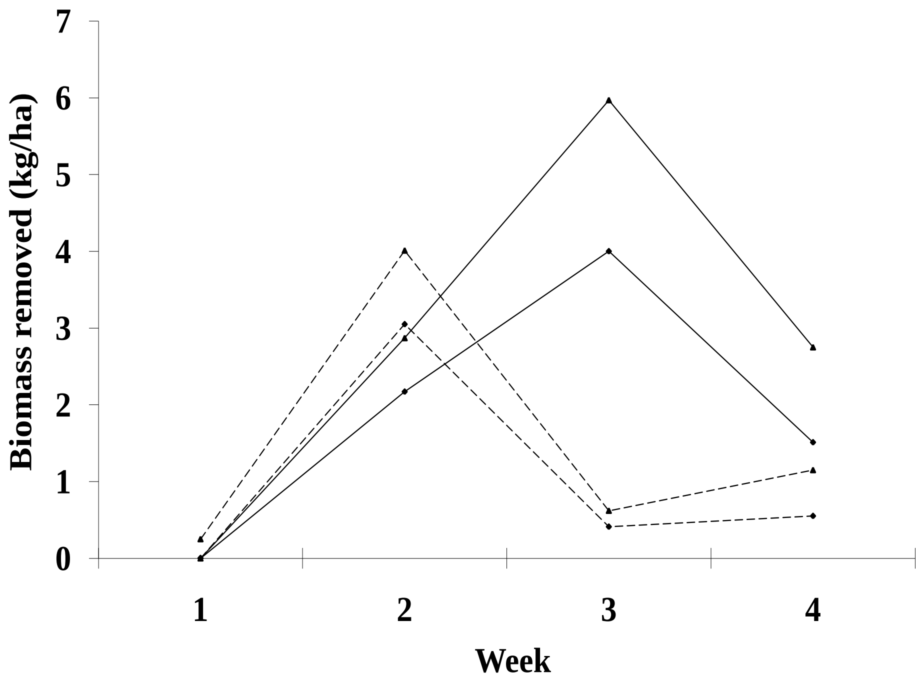

Figure 2. Weekly biomass removal estimates for two types of wheat heads (i.e., bearded 2008 bearded 2009,, unbearded 2008, and unbearded 2009) from browse surveys conducted in Little Creek, Delaware, 2008 and 2009. Week 1 represents the first week after I placed the spring fence treatment during the boot stageof wheat development and Week 4 represent the week before I harvested the plots. Total biomass removed did not exceed 0.01% of the overall yield for either type of wheat.

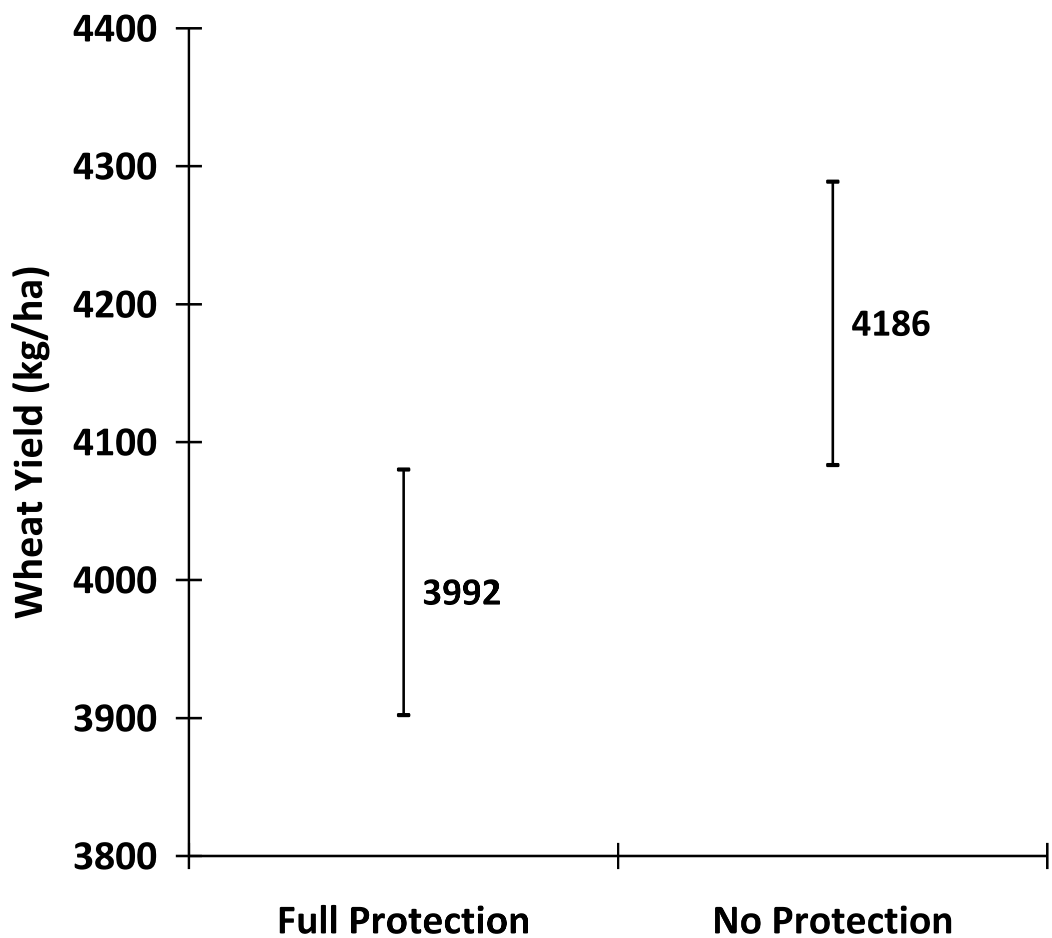

Figure 3. Wheat yield by treatment collected from Little Creek, Delaware, 2007. Full protection represents plots that had a fence place around the plot from planting till harvest and no protection represents those plots that had no fence protection.

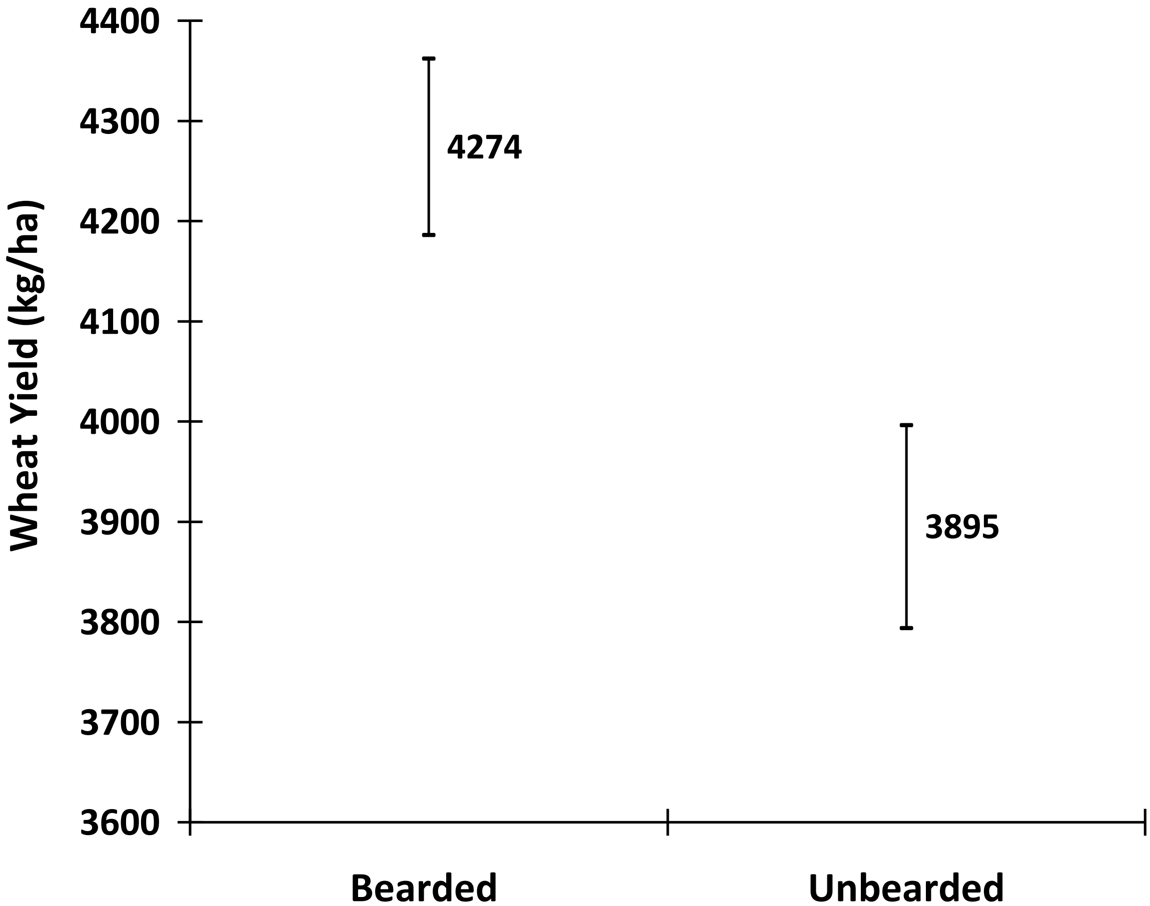

Figure 4. Wheat yield by wheat type collected from Little Creek, Delaware, 2007. Bearded represents the wheat that had awns located on the wheat head and unbearded represents the wheat that lacked awns.

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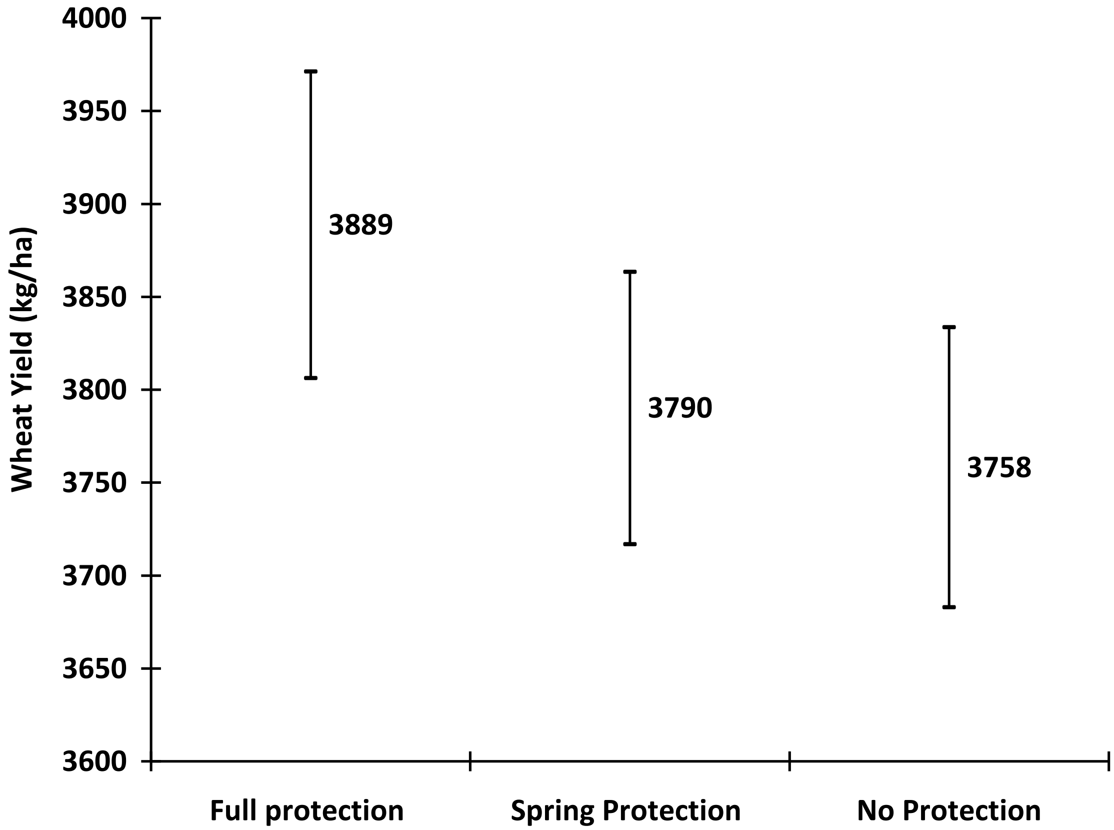

Figure 5. Wheat yield by treatment collected from Little Creek, Delaware, 2008 and 2009. Full protection represents plots that had a fence place around the plot from planting till harvest, Spring protection represents plots that were protected from just prior to heading till harvest, and no protection represents those plots that had no fence protection from planting till harvest.

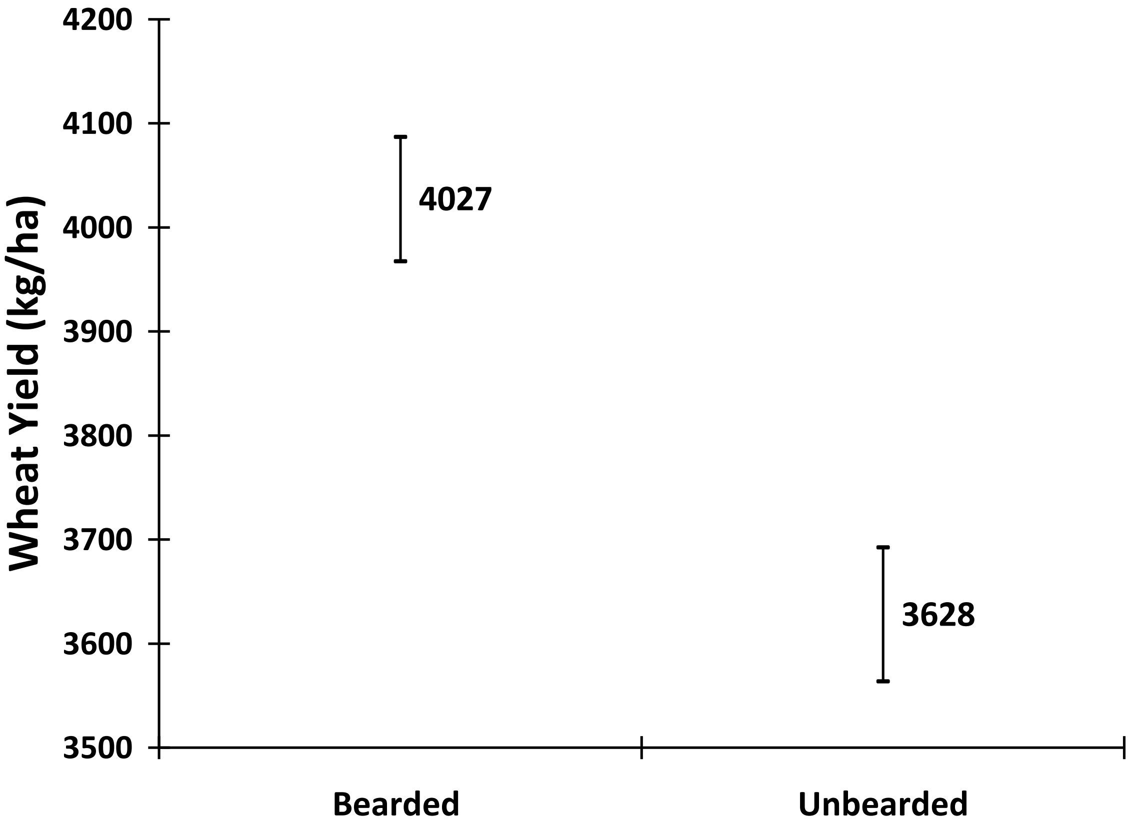

Figure 6. Wheat yield by wheat type collected from Little Creek, Delaware, 2008 and 2009. Bearded represents the wheat that had awns located on the wheat head and unbearded represents the wheat that lacked awns.

CHAPTER 5

DISCUSSION

My surveys demonstrated that bearding might deter deer browsing at the last growth stages of wheat. In 2007, removal rates differed with low removal rates for the bearded wheat compared to unbearded for all weeks of the survey. In 2008 and 2009, wheat types differed in removal rates in week 3, which may be when deer are avoiding the bearded wheat. During week 3, the wheat plant is in its last growth stages and has begun to dry and turn brown. The palatability of the plant may have changed and the awns may become more of an irritant as they dry. This irritation has been documented by Winter and Honess (1952), who found bearded wheat to be the cause of death for mule deer (*Odocoileus hemionus*) in Wyoming. During this case the awns lodged themselves into the gums of the deer and inflamed the abomasums, causing mastication and digestion to be disrupted. Deer can tolerate some browsing of awns but may switch to a different food source at a certain irritation level. The time at which awns dry out and become more of an irritant also coincides with the emergence and early growth stages of soybeans in neighboring fields. The newly emerged plants may be a better source of nutrients for deer. Colligan (2007) reported an increase in the percentage of soybeans in white-tailed deer diet at this time and Rogerson (2005) also detected the greater browse rates on soybeans at this point in wheat development. The increase in availability of newly emerged vegetation and the drying out of the wheat may explain why deer seem to avoid bearded wheat.

Unbearded wheat was developed because of the inefficient threshing of bearded wheat. Farmers began to use the unbearded type of wheat because it made wheat harvest more efficient. With the improvements in the agriculture field and the use modern threshers, farmers could alter their wheat selections with improved harvesting efficiency (Schlehuber and Tucker 1967). I found that bearded wheat yielded greater than unbearded wheat. The fact that seed companies are implying the bearding on the wheat heads deters deer browsing may come from the increased yield that is associated with the bearded wheat. The bearded type of wheat may also be better suited to the climate or soil of the study farm, which caused it to produce higher yields. Bearding has been found to improve wheat yields in areas with extreme heat and drought (Blum 1985), but I did not have these extremes over the 3 years of my study. The lack of extreme weather conditions and the fact that bearded wheat still had greater yield over the 3 years suggests that there may be something more than just drought adaptation influencing yield.

Browsing by other species has been shown to decrease wheat yield. Cattle (Carver et al. 2001 and Holman et al. 2009), Hessian fly (*Mayetiola destructor*; Buntin 1999), and the cereal leaf beetle (*Oulema melanopus*; Buntin 2004) have reduced yields by 23%, 41%, and 13%, respectively. Weather events can also play a role in the lowering yield, with hail reducing yields up to 54% (Lauer 2000). Deer browsing on wheat has reduced wheat yields by up to 30% at high densities (136 deer/km^2; Vecellio et al. 1994), but I did not have any reduction of yield in my study at a density of 15 deer/km^2. In 2007, browsed plots had greater yield than unbrowsed plots. Garrison and Lewis (1987) and Rogerson (2005) also found an increase in soybean yield from deer browse if browse intensity did not surpass a threshold. Garrison and Lewis (1987) believed this threshold to be removal of < ~33% of the soybean plant. A threshold could exist if the plants produce more biomass then necessary for optimum yield production. An increased yield would be caused by the removal of only small amounts of biomass. This limited removal may trigger compensational growth in the plants and would cause the plant to grow more biomass than originally would have been grown, possibly increasing the overall potential yield. I did not see a yield increase in 2008 and 2009, nor did I observe any negative effect on yield. Fischer and Kahn (1966) and Puckeridge and Donald (1967) both documented wheat to produce more vegetative biomass than is needed for optimum yield. The production of additional biomass could explain why a browse threshold for damage could exist. The browse intensity may need to be great enough to remove the additional biomass produced to affect wheat yield. The lack of browse intensity may also explain why I did not find a significant reduction in test weight for any of the treatments. The quality of the grain was not compromised through browsing because the wheat plant produced enough biomass to supply the proper nutrients needed for grain production even with browsing. Wheat quality was not reduced by cattle even though a yield reduction occurred (Carver et al. 2001 and Holman et al. 2009), so extreme grazing may be necessary to compromise wheat quality.

The visibility of wildlife, especially larger, easily seen species, may have an impact on the farmer's accuracy in estimation of crop damage. Perception of damage may cause farmers to inaccurately estimate yield losses because they may be consistently seeing wildlife feeding on crops and believe they are having a greater affect on yield than is actually occurring. Tzilkowski et al. (2002) in a farmer survey paired with a damage estimation by researchers on the surveyed farms, found that the overall trend of farmer's ability to estimate damage was close to the damage estimated by the researchers. Tzilkowski et al. (2002) did note that even though the trend between farmers estimates of damage and actual damage was similar, they observed a large variation among individual farmers ability to accurately estimate the damage occurring on their farms. Studies have shown that wildlife browsing on crops can occur without the reduction of yield by Rogerson (2005), Garrison and Lewis (1987), and my study. Actual on the ground estimates may need to occur when farmers are reporting crop damage to understand if wildlife damage is actually occurring, or if the farmer only believes there is damage because of the presence of wildlife.

Even with the greater overall browse rate in 2007 and the increased browsing on unbearded wheat in all 3 years, I did not have sufficient browse intensity to cause a reduction in yield for either type of wheat. Although browse differences existed between wheat types, especially in 2007, the actual reduction in yield from browsing was ~ 0.01% of the overall yield so if bearding deters browsing the gain in yield was still minute. My findings do not support the hypothesis of Torbit et al (1993) that browsing during later growth stages would be more influential in decreasing wheat yield. To observe the significant yield reductions reported by Vecellio et al. (1994), the removal of wheat would have to be at an extreme intensity, which may only be met at a high deer density or if absolutely no other browse is available. Future investigations may want to focus on determining the intensity of head removal needed to affect wheat yield.

CHAPTER 6

MANAGEMENT IMPLICATIONS

Deer do not seem to be the driving force in yield variation, so other variables (i.e., weather and/or wheat variety) may play a more important role in determining wheat yield. For the 3 years of my study deer did not have a negative impact on wheat yield. The current deer density, ~15 deer/km^2, does not need to be lowered to regulate wheat damage. Managers may want to consider other indicators such as damage to other crops (i.e., corn or soybean) to determine an acceptable deer density for the area. In regards to wheat type, bearded wheat did not have a significant impact on wheat yield through the reduction of deer browsing, but since I found a greater underlying yield with the bearded wheat on my study farm, selection of wheat variety may be the most important role in potential yield for the farm. I recommend that selection of wheat type and variety should be made to best suit the climate and soil where planting will occur.

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