

# Preference of white-tailed deer for corn hybrids and agricultural husbandry practices during the growing season

**JOSHUA A. DELGER**,<sup>1</sup> Department of Wildlife and Fisheries Sciences, Box 2140B, South Dakota State University, Brookings, SD 57007, USA [joshua\\_delger@nps.gov](mailto:joshua_delger@nps.gov)

**KEVIN L. MONTEITH**, Department of Biological Sciences, 921 South 8th Avenue, Stop 8007, Idaho State University, Pocatello, ID 83209, USA

**LOWELL E. SCHMITZ**, South Dakota Department of Game, Fish and Parks, 3305 West South Street, Rapid City, SD 57702, USA

**JONATHAN A. JENKS**, Department of Wildlife and Fisheries Sciences, Box 2140B, South Dakota State University, Brookings, SD 57007, USA

**Abstract:** Damage to field corn (*Zea mays*) by white-tailed deer (*Odocoileus virginianus*) can be substantial, resulting in millions of dollars lost annually. Numerous methods exist to minimize deer depredation, but all have met with varying degrees of success. Currently, little information is available on preference of white-tailed deer for corn hybrids during the growing season and how that preference might affect depredation patterns. We used adult female white-tailed deer in captivity to study the effect of herbicide treatments on deer-use (treatment versus no treatment) of corn in 2005 and to document preference among specific corn hybrids in 2006 and 2007 using manipulated corn food plots. In 2005, 67% of deer-feeding activity occurred in herbicide-treated areas; deer preferred to feed on the edges of food plots (78%). In 2006 and 2007, deer exhibited preferential patterns of feeding ( $P < 0.05$ ) among corn hybrids throughout the study period and during most phenological growth phases of corn plants. Deer preference was not related to physical characteristics of hybrids but was related to days to maturity and nutritional content. Deer preferred earlier maturing hybrids that contained higher levels of digestible dry matter. Wildlife managers and crop producers could use corn hybrids and husbandry practices desirable to deer (i.e., earlier maturing hybrids with higher digestibility and fertilizer and herbicide application) to reduce damage to field corn by altering type and placement of corn.

**Key words:** agriculture, corn, crop damage, depredation, digestibility, human–wildlife conflicts, *Odocoileus virginianus*, South Dakota, white-tailed deer

**WHITE-TAILED DEER** (*Odocoileus virginianus*) feed extensively on the numerous hybrids of field corn planted across agricultural regions of North America. Researchers in Missouri (Korschgen 1962), Kansas (Anderson 1964, Watt et al. 1967), Iowa (Mustard and Wright 1964), and Illinois (Nixon et al. 1989) determined that up to 80 to 90% of deer diets can be comprised of corn. Considering the high use of corn as primary forage, deer are consistently classified as the most severe wildlife problem for crop producers in the United States (McDowell and Pillsbury 1959, Conover and Decker 1991, McIvor and Conover 1994, Wywiałowski 1994). Conover (1997) conservatively estimated that annual losses of agricultural production to depredation by deer in the United States exceeded \$100 million.

Little information exists regarding variation in deer preference for specific corn hybrids,

despite the extensive use of corn as a source of food and cover by deer throughout the year (Larson et al. 1978, Murphy 1983, Kramlich 1985, Nixon et al. 1989, VerCauteren and Hygnstrom 1993). Crop depredation is a longstanding issue for corn producers and wildlife managers; however, preference by deer for specific corn hybrids during the growing season has not been investigated. Indeed, such information could lead to improved management efforts to alleviate economic loss and minimize human–wildlife conflicts. Recently, wildlife managers in South Dakota have observed deer bypassing corn food plots managed by the U.S. Fish and Wildlife Service to feed on corn in agricultural fields that were privately owned (W. Smith, Sand Lake National Wildlife Refuge, personal communication). Husbandry practices and planting of corn hybrids, both of which may affect preferential feeding by deer, commonly

<sup>1</sup>Badlands National Park, 25216 Ben Reifel Road, Box 6, Interior, SD 57750, USA

differ between private producers and agency-managed food plots.

Understanding how crop depredation can be mitigated is essential for managing deer in agricultural regions. Lethal means are typically most productive (Matschke et al. 1984, McDonald et al. 2007), but they are not always an option. Other options include fencing (Longhurst 1952, Caslick and Decker 1979, Palmer et al. 1985, Hygnstrom and Craven 1987, Craven and Hygnstrom 1988), chemical repellents (Craven 1983, Palmer 1983, Craven and Hygnstrom 1987, Craven and Hygnstrom 1988, Ward and Williams 2010), and scare devices (Matschke et al. 1984), but all tend to be either temporarily effective or cost prohibitive. Conover (1989) and Yoder (2002) recommended that landowners alter land-use patterns in response to deer damage. If deer exhibit preference for specific corn hybrids, utilizing strategically placed food plots of preferred hybrids could reduce deer depredation in areas adjacent to agricultural fields that are susceptible to deer damage.

Ingebrigtsen and McAninch (1989) reported that feeding preferences of deer for corn hybrids in winter were associated with higher ear heights above the ground and reduced husk coverage of the ear. Deer damage to corn, however, often peaks in mid- to late-July when corn is at the tasseling-silking stage of development and is most susceptible to crop losses (Shapiro et al. 1986, Dolbeer 1990, VerCauteren and Hygnstrom 1993, Stewart et al. 2007). VerCauteren and Hygnstrom (1993) recorded high deer use of corn and noted that the degree of susceptibility of corn to damage by deer was influenced by the physiological state of the plant during the growing season. High deer-use coincident with plant susceptibility during the growing season provides strong supporting evidence that depredation during this period is responsible for most of the crop losses associated with depredation on corn by deer (Dolbeer 1990, VerCauteren and Hygnstrom 1993, Stewart et al. 2007).

Although morphological traits of corn hybrids may influence preference (Ingebrigtsen and McAninch 1989), foraging decisions are more likely based on nutritional characteristics. Evidence from other studies indicates that summer forage selected by deer is typically high in digestibility compared with other

available forage (Snider and Asplund 1974, Waer et al. 1994, Barboza and Bowyer 2000, Sauve and Cote 2007); this is critical for concentrate selectors (i.e., animals that have a relatively small and simple rumen that best accommodates diets low in fiber), such as white-tailed deer (Hofmann 1989, Van Soest 1994). Moreover, energetic demands associated with lactation for reproductive females during summer emphasize the importance of a high-quality diet to maintain somatic reserves and support investment in reproduction (Barboza and Bowyer 2000, Barboza et al. 2009, Parker et al. 2009). Therefore, it is likely that nutritional characteristics of corn hybrids may be more strongly linked to deer-feeding preferences than to morphological traits of preferred plants.

In addition to the effects of morphological and nutritional characteristics of plants on preferential feeding and habitat use by deer (Massé and Côté 2009), the spatial configuration and size of habitat patches affect how individuals use their environment (Kie et al. 2002). White-tailed deer often are considered habitat generalists and are well-adapted to highly fragmented landscapes in agricultural regions with abundant habitat edge (Walter et al. 2009). Accordingly, deer-feeding often occurs near transitional edges between habitat patches (Leopold 1933, Hanley 1983, Williamson and Hirth 1985, Bonner and Fulbright 1999, Reyes and Vasseur 2003). Therefore, habitat configuration alone may influence preferential feeding by deer.

We measured preference of captive white-tailed deer for corn hybrids and husbandry practices (e.g., herbicidal treatment) using manipulated food plots during the growing season. In addition, we quantified physical and nutritional characteristics of corn hybrids to determine why specific hybrids may be more or less desirable to deer. We hypothesized that deer would exhibit preference for corn hybrids based on both physical and nutritional characteristics. We predicted that deer would prefer corn hybrids with greater ear height, and higher levels of protein and digestibility. Furthermore, we hypothesized that husbandry practices and distance to edge would affect deer preference. We predicted that deer would prefer to feed in corn plots where fertilizer was applied and voluntary weeds were controlled

by the application of herbicide, both of which should maximize growth of corn plants. Lastly, we predicted that deer would favor feeding nearest to the edge of the food plot compared to internal rows.

### Research facilities

We conducted manipulative experiments using captive white-tailed deer at the Wildlife and Fisheries Sciences Research Facility at South Dakota State University in Brookings, South Dakota, USA. The facility encompassed approximately 4 ha in Brookings County (44° 20' N, 96° 47' W) and was enclosed with a 2.4-m woven wire fence (Monteith et al. 2009). Since 2004, the facility has been double-fenced with an additional 2.4-m-high fence to eliminate contact between wild and captive animals (Miller and Williams 2003). Elevation is 490 m above mean sea level and temperature ranged from -29° C in the winter to >38° C in summer, with a mean annual temperature of 8° C (Spuhler et al. 1971). Annual precipitation varied from 33 to 64 cm, and snowfall ranged from 64 to 114 cm (Spuhler et al. 1971). Facilities and procedures were in compliance with the guidelines of the Institutional Animal Care and Use Committee (2002) at South Dakota State University (Approval Number 02-A038), and followed guidelines for research on mammals provided by the American Society of Mammalogists (Gannon et al. 2007).

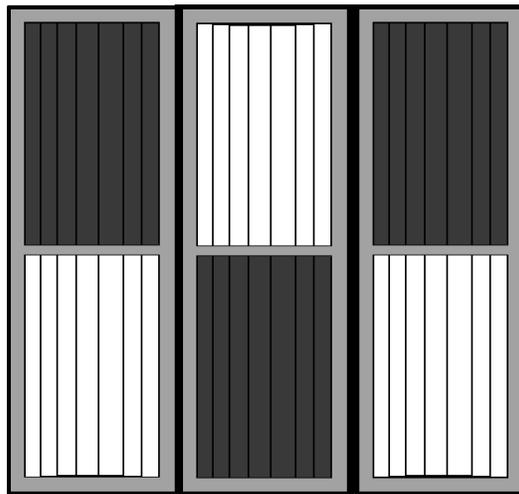
### Methods

We determined deer preference for corn hybrids and husbandry practices during the 2005 through 2007 growing seasons using female white-tailed deer that were reproductively active. We expected that reproductive females would exhibit preferential feeding patterns because of the energetic demands associated with lactation (Sadlier 1982, Monteith 2006), in addition to building energy reserves for the subsequent winter (Julander et al. 1961, Torgerson and Pfander 1971). Moreover, deer populations are typically skewed toward females, and therefore, females represent the majority of individuals within most deer populations (Monteith et al. 2007).

We constructed 3 enclosures, each 11.3 m × 39.3 m in size; plots were centered within grass buffers of 2.5 m in length along each side. We

planted 8 rows of corn in each plot, with 66 cm between each row, and we fertilized them at a rate of 112 kg of nitrogen/ha as urea (46-0-0) each year. All corn hybrids used were Roundup Ready Corn 2® (Monsanto Co., St. Louis, Mo.), which allowed for the application of glyphosate-based herbicides to control weeds during the growing season.

In 2005, we conducted trials to determine how deer-use of corn food plots was associated with herbicidal treatments and location within the plot. Each of 3 plots was separated into 2 sections with a 1-m buffer between them (Figure 1). One section of each plot received Roundup UltraMAX™ (Monsanto Co., St. Louis, Mo.) according to label specifications at a rate of 1.61 liters/ha approximately 1 month after plant emergence, while the other section received no herbicide application, allowing growth of weeds. Because we expected distance to the edge of food plots to affect feeding patterns by deer (Leopold 1933, Hanley 1983, Williamson and Hirth 1985, Bonner and Fulbright 1999), we recorded the row in which each feeding observation occurred with respect to its distance to the edge of the plot and evaluated deer preference for edge by comparing the total number of feeding observations by row. We used deer preference for location within the plot to determine hybrid placement the following 2

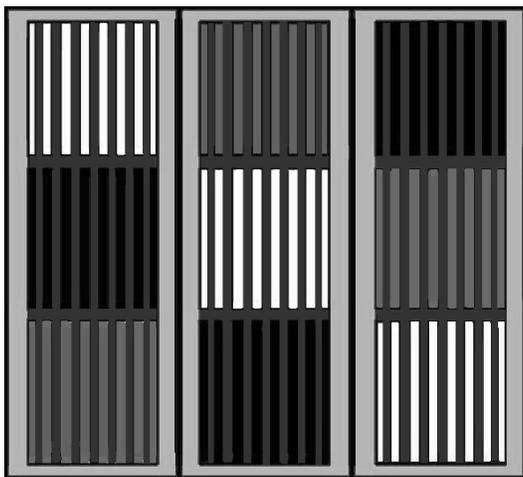


**Figure 1.** Depiction of corn study food plots during the 2005 growing season. Three subplots were adjacent to each other lengthwise. White areas represent herbicide treatment while dark gray areas represent no herbicide treatment; grass buffers are depicted as gray areas around the perimeter of subplots.

years of the study and control for the effect of edge on feeding preference.

During 2006 and 2007, we compared deer preference for 3 corn hybrids each year. In 2006, we compared Dekalb DKC44-92 (hybrid A), Dekalb DKC46-28 (hybrid B), and Dekalb DKC48-52 (hybrid C); maturity dates were 94, 96, and 98 days, respectively. The range of maturity rates represented what was commonly used by local producers in this region of South Dakota (R. Christensen, Monsanto Co., personal communication). For 2007, we compared an earlier maturing hybrid of 90 days (Dekalb DKC40-07 [hybrid D]) and a later maturing hybrid of 105 days (Dekalb DKC55-82 [hybrid E]) with the 94-day hybrid (Dekalb DKC44-92 [hybrid A]) used in 2006 to obtain a greater range in maturity dates. We applied herbicide at 4 and 7 weeks post-emergence to remove competing plants. The location of each hybrid in each plot was blocked systematically to control for the effect of proximity to edge on feeding preference; each hybrid was equally represented on the edge rows through the course of each year by systematically placing hybrids among each of the 3 plots (Figure 2). Therefore, availability of each hybrid was equal, and each hybrid was equally represented with respect to location in the 3 plots within each year.

We offered corn plants of study hybrids (*ad libitum*) to 4 reproductively active adult female



**Figure 2.** Depiction of corn study food plots during the 2006 and 2007 growing seasons. Three subplots were adjacent to each other lengthwise. Shaded lines represent systematic placement of planted corn hybrids; grass buffers are depicted as gray areas around the perimeter of subplots.

deer (i. e., lactating) a minimum of 2 weeks prior to data collection to allow rumen microbes to adapt to diets (Mautz et al. 1976). Besides the addition of corn plants, deer were maintained on a high-quality diet of shelled corn and pelleted soy hulls offered *ad libitum* (Monteith et al. 2009). To maximize feeding observations during preference trials, we removed the food supply of each deer 12 hours prior to trials (Waer et al. 1994). For each trial, adult female deer, along with fawns, were allowed into corn plots (2 adults/trial; Figure 3) for a period of 30 minutes during crepuscular periods when deer are most active (Hirth 1977, Monteith et al. 2007). Upon entering plots, we scattered research animals to eliminate bias associated with the entrance (Waer et al. 1994), and allowed 5 minutes for deer to acclimate to plots before the start of each trial. We observed animals from an elevated platform (3.7 m high) and recorded all deer activity, including the use of corn hybrids and plant parts eaten every 60 seconds in 2005, and every 30 seconds in 2006 and 2007. Each week, all deer were placed in each of the 3 plots during trials to avoid dependence among weekly observations because corn hybrids were arranged differently in each plot. We avoided allowing any plots to become over-browsed to meet the assumption that each corn hybrid was equally available relative to other hybrids within the plot without being influenced by previous preferential browsing (Johnson 1980). We determined preference based on the proportion of feeding observations relative to husbandry practice and row placement in 2005, and corn hybrids in 2006 and 2007. In 2005, we conducted trials on 10 sampling occasions from September 1 to 21 during the rapid and dry-down phases of corn development. In 2006, we collected data weekly for 11 weeks from July 3 to September 15; in 2007, we collected data weekly for 10 weeks from June 25 to August 31.

We used compositional analysis (Aebischer et al. 1993) on deer-feeding data to determine if preference differed between row placement, and herbicide treatment and among corn hybrids. We completed compositional analysis with data combined by individual deer during the entire study season and performed separate analyses within 3 general categories based on phenological growth phases of the corn plants

for 2006 and 2007: early, rapid, and dry-down phases (Iowa State University 1993). Early phase was characterized by all stages of growth preceding the appearance of ears (stages VE through VT), rapid phase was characterized by the appearance and rapid growth of ears through full growth of ears (stages R1 through R4), and dry-down phase was characterized by full growth of ears and the onset of dry-down of the corn plant (stages R5 through physiological maturity). Following significance of the compositional analysis, we conducted pair-wise comparisons between corn hybrids using *t*-tests with Bonferroni corrections to maintain experiment-wise error (Zar 1999).

We measured ear heights and degree of husk coverage (Ingebrigtsen and McAninch 1989) for every plant in 2006 and every third plant in 2007 for each corn hybrid in every plot to determine if those physical traits differed among hybrids and were associated with deer-feeding preference. We measured ear heights from ground level to the base of the ear. Using analysis of variance (ANOVA), with Bonferroni corrections for pairwise comparisons (Zar 1999), we determined if ear heights differed among corn hybrids.

We collected samples of each corn hybrid during 4 weeks during the growing season of 2006 and 2007. For each hybrid, we collected parts of the corn plant that deer most readily consumed in our study; the majority of the sample was composed of corn kernels, but included some husk and leaf material, and was collected from a single plant within each of the 3 representative plots. Corn samples were analyzed at the Oscar E. Olson Biochemistry Laboratory (Brookings, S. Dak.) to determine moisture, ash, crude protein (CP), crude fat (ether extract), acid-detergent fiber (ADF), neutral-detergent fiber (NDF), starch, and sugar (dextrose) content. We estimated digestible dry matter (DDM) from an equation adapted from Robbins et al. (1987) and Hanley et al. (1992):

$$DDM = [(0.9231 e^{-0.0451 A} - 0.03 B) (NDF)] + [(-16.03 + 1.02 NDS) - 2.8 P],$$

where DDM = digestible dry matter, A = (lignin



**Figure 3.** A female white-tailed deer acclimating within one of the 3 corn-food plot enclosures during the preference study.

+ cutin) content as a percentage of the neutral detergent fiber (assumed constant),  $B$  = % biogenic silica content of monocots (assumed to be approximately zero), NDF = % neutral detergent fiber, NDS = % neutral detergent solubles (100 minus % NDF), and  $P$  = % reduction in protein digestion. We reported all nutritional data on a dry-matter basis and determined if nutritional characteristics differed among corn hybrids using multivariate analysis of covariance (MANCOVA), with days since planting as the covariate to control for changes in plant phenology (Zar 1999). Following a significant main effect in MANCOVA, we identified the variables most responsible for that effect using canonical correlation analysis (Johnson and Wichern 2002). We then identified variables using canonical analysis and included them as dependent variables in separate 1-way ANOVA with the same main effect (i.e., hybrid). We used  $\alpha \leq 0.10$  because we were more concerned with detecting differences in preference, as well as nutritional and morphological characteristics among corn hybrids, than the possibility of a Type I error. We used Systat 10.0 (Wilkinson 1990) for all statistical analyses.

## Results

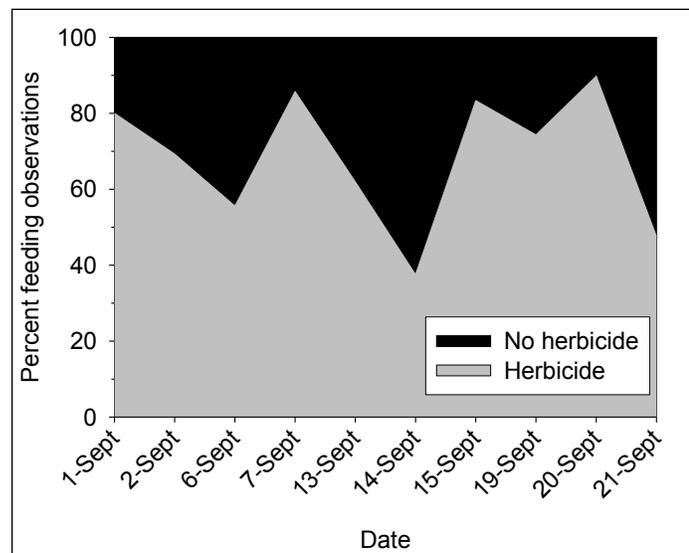
### Deer preference

In 2005, percentage use ( $\pm$ SE) of corn by deer foraging in herbicide-treated areas ( $69 \pm 6\%$ ) was significantly greater ( $\chi^2_1 = 8.9$ ,  $P < 0.05$ )

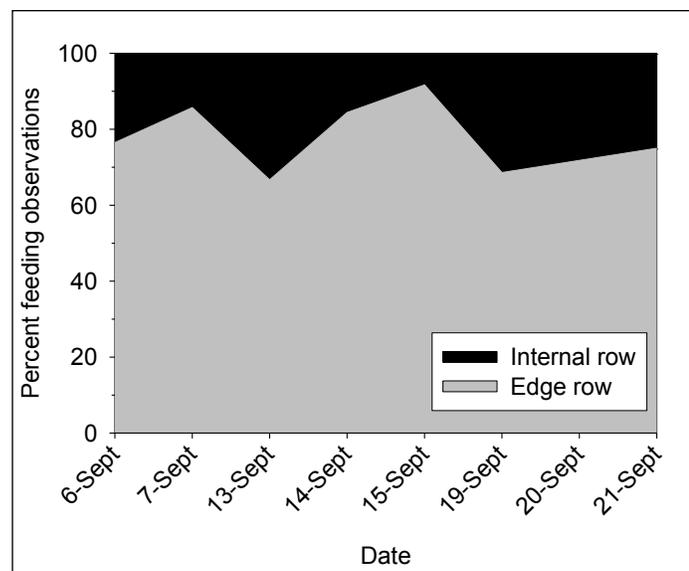
than that for untreated areas ( $32 \pm 6\%$ ; Figure 4). In addition, deer did not use internal corn rows in proportion to their availability ( $\chi^2_1 = 16.51, P < 0.01$ ). Although availability of internal rows was 3 times greater than edge rows (75% versus 25%, respectively), deer-feeding activity occurred primarily on edge rows ( $78 \pm 3\%$ ; Figure 5). Available corn was not depleted on edge rows at any point during the experiment. In addition, following the appearance of ears on corn plants, >75% of deer-feeding observations occurred on ears; the remaining use occurred on leaves of corn plants.

During 2006, mean ( $\pm$ SE) percentage of weekly feeding observations during the entire growing season for hybrid A (Dekalb DKC44-92), hybrid B (Dekalb DKC46-28), and hybrid C (Dekalb DKC48-52) was  $48 \pm 6.6$ ,  $33 \pm 6$ , and  $35 \pm 6$ , respectively. Deer exhibited preference ( $\chi^2_2 = 11, P < 0.05$ ) among corn hybrids when data were combined during the entire growing season, with hybrid A most preferred over other hybrids (Figure 6a). When considered with respect to plant growing phase, preference among corn hybrids occurred during the early- ( $\chi^2_2 = 4.83, P = 0.09$ ) and rapid-growth phases ( $\chi^2_2 = 6, P = 0.06$ ), but not during the dry-down phase ( $\chi^2_2 = 5, P = 0.12$ ; Figure 6a). During both early- and rapid-growth phases, hybrid A was preferred, and hybrid A continued to receive the highest deer-use during the dry-down phase (Figure 6a).

During 2007, mean ( $\pm$ SE) percentage of weekly feeding observations during the entire growing season for hybrid A, hybrid D (Dekalb DKC40-07), and hybrid E (Dekalb DKC55-82) was  $46 \pm 4$ ,  $40 \pm 7$ , and  $41 \pm 4$ , respectively.

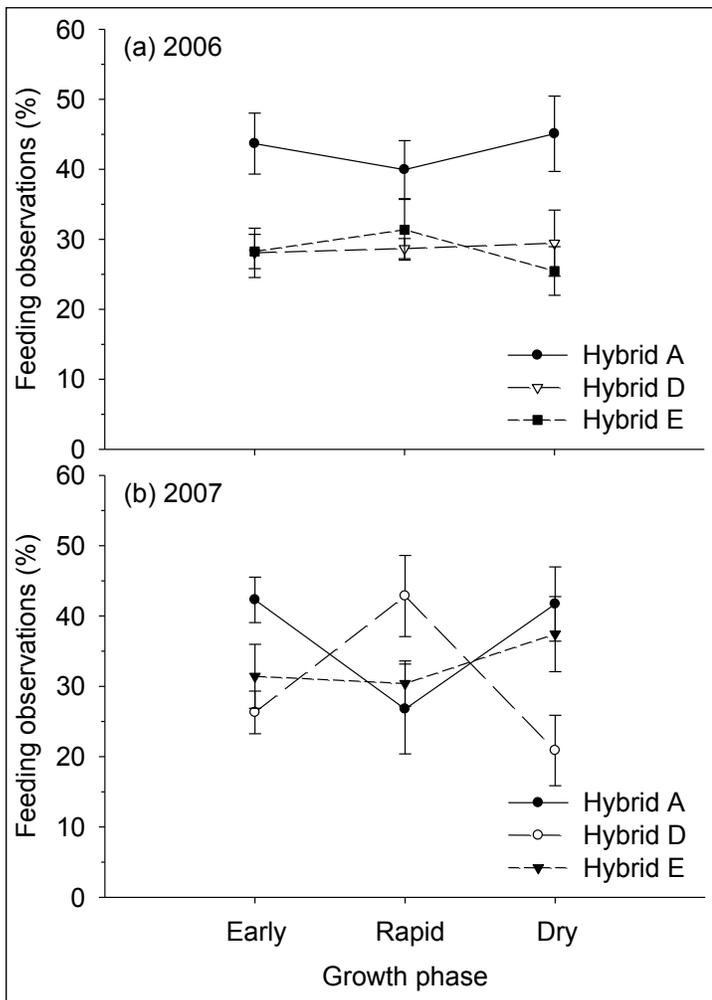


**Figure 4.** Percentage of feeding observations of captive white-tailed deer in portions of corn food plots that received herbicide treatment compared to areas left untreated during the 2005 growing season.



**Figure 5.** Percentage of feeding observations of captive white-tailed deer in internal and edge rows of corn food plots during the 2005 growing season. Availability of internal rows was 3 times greater than edge rows.

Overall in 2007, deer exhibited preferential feeding patterns among corn hybrids ( $\chi^2_2 = 7, P < 0.05$ ), with hybrid A being most preferred (Figure 6b). Within the phenological-growth phases, preferential feeding occurred during the early-growth phase ( $\chi^2_2 = 7, P < 0.05$ ), but was not detected during rapid-growth ( $\chi^2_2 = 3,$



**Figure 6.** Percentage of feeding observations during weekly preference trials of captive white-tailed deer ( $n = 4$  per year) on corn hybrids that were combined relative to phenological growth phases of corn plants during the (a) 2006 and (b) 2007 growing seasons. Data are means  $\pm$  SE.

$P = 0.22$ ) or dry-down ( $\chi^2_2 = 4$ ,  $P = 0.17$ ) phases (Figure 6b). Hybrid A was the preferred hybrid during the early-growth phase, while hybrid D experienced the least amount of feeding activity (Figure 6b). During rapid growth, the majority of feeding observations occurred on hybrid D, followed by hybrid E, and then hybrid A; feeding pressure during the dry-down phase was highest on hybrid A, followed by hybrid E, and then hybrid D (Figure 6b).

### Nutritional and physical characteristics

In 2006, nutritional characteristics differed (Wilk's  $\Lambda = 0.26$ ,  $F_{14,34} = 2.33$ ,  $P = 0.02$ ) among

corn hybrids; canonical correlation analysis indicated that moisture content and digestible dry matter (DDM) were responsible for that difference. Moisture content, however, was similar among hybrids ( $F_{2,32} = 0.3$ ,  $P = 0.76$ ; Figure 7a). In contrast, DDM differed among corn hybrids during the growing season ( $F_{2,32} = 3$ ,  $P = 0.08$ ) with the most preferred hybrid (hybrid A) having the highest DDM (Figure 8a). In 2007, nutritional characteristics among corn hybrids also differed (Wilk's  $\Lambda = 0.34$ ,  $F_{14,34} = 1.7$ ,  $P = 0.1$ ); canonical correlation analysis indicated that moisture and DDM accounted for differences among hybrids. As in 2006, DDM differed ( $F_{2,32} = 2.6$ ,  $P = 0.09$ ) among hybrids and was highest for hybrid A (Figure 8b). Overall moisture was higher for hybrid E ( $F_{2,32} = 3.51$ ,  $P = 0.04$ ), the latest maturing hybrid (Figure 7b).

In 2006, ear height ( $\pm$ SE) differed ( $F_{2,4052} = 448$ ,  $P < 0.001$ ) among corn hybrids, but was similar ( $P = 0.5$ ) between hybrid C and hybrid B, and was significantly lower for hybrid A ( $P < 0.001$ ; Figure 9).

Ear height also differed ( $F_{2,1169} = 33$ ,  $P < 0.001$ ) among corn hybrids in 2007, but was similar ( $P = 0.7$ ) for hybrid E and hybrid A, and significantly less for hybrid D ( $P < 0.001$ ; Figure 9). Husk covered the ears of all hybrids during both 2006 and 2007 growing seasons; hence, no differences were documented relative to corn hybrid.

### Discussion

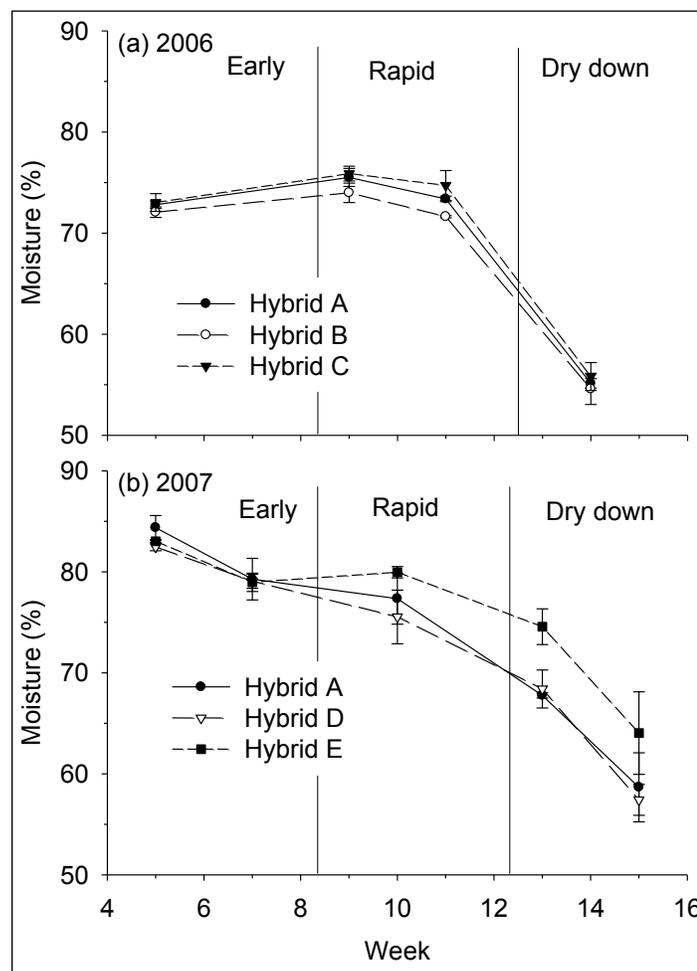
Government agencies are obligated to control wildlife damage on behalf of the public (Fagerstone and Clay 1997, Austin et al. 1998), and with significant annual agricultural losses resulting from deer feeding activity (Conover 1997), knowledge of preferential feeding habits

of deer is crucial to identifying management practices to alleviate such losses. Deer forage selectively and generally have diverse diets (Swift 1948, Vangilder et al. 1982, Jenks et al. 1990). Although deer seek forage diversity during summer months (Vangilder et al. 1982), we expected that within forage species, those most nutritiously beneficial to deer would be preferred. During our manipulative experiment, female white-tailed deer greatly preferred corn plots where competing vegetation was controlled by herbicidal treatment (Figure 4), preferred feeding on the edge of corn plots (Figure 5), and preferred hybrids that matured earlier and were more digestible (Figure 6). Our results indicate that strategically placed food plots with preferred hybrids and husbandry practices to shortstop (Schmitz 2000) deer before reaching corn fields of private producers may be an effective management strategy for reducing depredation.

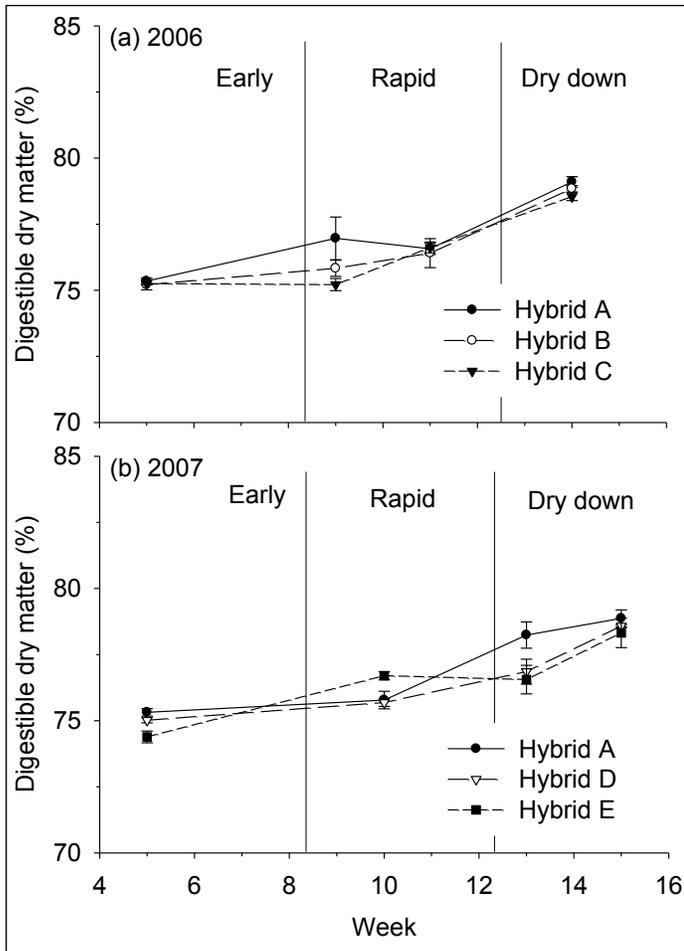
Application of fertilizer improves growth of vegetation, and herbicide application eliminates weeds competing for soil nutrients, water, and light. Patterson and Fuchs (2001) reported that fertilizer application to managed grasslands in Scotland abated conflicts between farmers and geese (*Anser brachyrhynchus*) by reducing damage to agricultural crops. Ball et al. (2000) witnessed increased browsing pressure by moose (*Alces alces*) on stands of young, fertilized forest compared to unfertilized control plots in northern Sweden. Additionally, Bayoumi and Smith (1976) reported heavier use by elk (*Cervus elaphus*) of plots that were nitrogen-fertilized on winter range in Utah. Likewise, female white-tailed deer exhibited strong preference for corn in corn plots treated with herbicide compared to those areas left untreated (Figure 4); however, further research pertaining to deer-use of fertilized plots would

be warranted because the effect of fertilizer on deer preference was not examined. Corn plants grew thicker and taller as a result of herbicide treatments, whereas in the areas left untreated, corn plants experienced much less growth, thereby creating lower visibility for deer within treated areas. Assuming that visibility is important to deer while feeding, we would have expected this facet of herbicide treatment to corn plots to lower its attractiveness.

Corn hybrids with faster maturity rates were preferred by white-tailed deer over later maturing hybrids. Earlier maturing hybrids used in both years experienced the highest levels of deer use. Earlier maturing hybrids grow at a faster rate, allowing deer access to more nutrients (Short 1971, Blair et al. 1977, Lesage et al. 2000), and, thus, have less cell-



**Figure 7.** Percentage moisture of corn hybrids relative to week since planting and phenological growth phase during the (a) 2006 and (b) 2007 growing seasons. Data are means  $\pm$  SE.



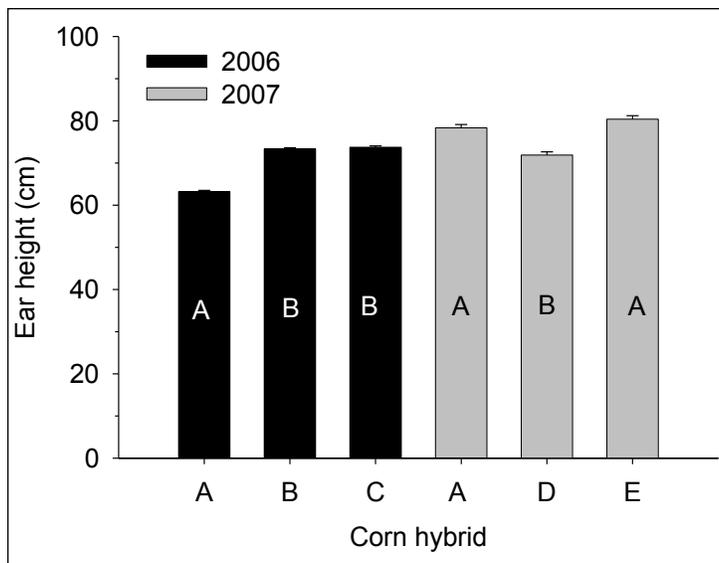
**Figure 8.** Percentage digestible dry matter of corn hybrids relative to week since planting and phenological growth phase during the (a) 2006 and (b) 2007 growing seasons. Data are means  $\pm$ SE.

wall components and more cell solubles. Cell solubles are approximately 98% digestible in the ruminant digestive tract (Van Soest 1967, Short and Reagor 1970). Cell solubles are immediately available to rumen microorganisms and provide more energy and other nutrients per unit time than cell walls that are more slowly fermented (Snider and Asplund 1974). Fermentation of earlier maturing and highly digestible hybrids would result in larger amounts of volatile fatty acids, particularly propionic acid (Short 1971, Hoppe 1977). Propionic acid is the most important single source of glucose carbon that can be used in gluconeogenesis by ruminants (Van Soest 1994). The requirement for glucose is highest among lactating females because it is the main source of lactose in milk (Van Soest 1994),

which supports preferential feeding by reproductive females for earlier maturing and highly digestible hybrids.

Typically, diets selected by deer during summer are high in digestible energy to support the demands of nursing young (Crawford 1982, Sadlier 1982, Parker et al. 2009) and the accumulation of somatic reserves for the following winter (Torgerson and Pfander 1971). Plants higher in digestibility, protein, fats, and starch are preferred by concentrate selectors during most of the year (Hofmann 1989), whereas plants with higher fiber content are more likely to be avoided because of higher cellulose and lignin-cutin content, resulting in lower digestibility (Robbins et al. 1975). Net available energy of feed materials is inversely related to cellulose content (Short 1966). Digestion of cellulose is a time-consuming process (Torgerson and Pfander 1971) wherein increased rates of turnover required for sufficient digestion of cellulose is limited for small ruminants (Hofmann 1989, Clauss et al. 2007). In 2006, DDM

was generally higher for hybrid A compared with the other 2 hybrids, and accordingly, deer preference for hybrid A was consistent over the entire growing season. Conversely, during 2007, hybrid A was preferred during the early growth stage and dry-down period, but hybrid D was preferred during the rapid-growth stage. In correspondence with the changes in feeding preference between hybrid A and D, hybrid A exhibited greater levels of DDM during the early growth and dry-down stages, but not during the rapid-growth stage (Figure 8). These results support the capabilities of selective foragers, such as white-tailed deer, to seek out and detect small differences in dietary quality. Moreover, corn hybrids manufactured to increase forage yields at the expense of grain yields (i.e.,



**Figure 9.** Ear heights (cm) of corn hybrids during 2006 and 2007. Data are means  $\pm$ SE. Significant differences between hybrids within year are indicated by different letters within bars (based on ANOVA with Bonferroni correction).

silage corn) will likely be less favorable for small ruminants, such as white-tailed deer, that forage very selectively compared to large domestic ruminants that are more adapted to diets higher in fiber (Hanley 1982, Hanley and Hanley 1982, Hoppe 1977, Ivan et al. 2005).

Moisture content among corn hybrids differed during the second year of our study due to a wider range of maturity rates; however, moisture content was not related to deer-feeding patterns. Clear patterns were apparent among hybrids, as slower maturing hybrids retained moisture later in the growing season (Figure 7). As a result, slower maturing hybrids began to receive increased feeding pressure later in the growing season, but total feeding observations on corn were considerably lower at that time. Additionally, height of ears on hybrids was not related to deer preference (Figure 9). Although ear heights differed among corn hybrids, the preferred hybrid in 2006 exhibited the lowest ear heights; however, in 2007, ear height of the preferred hybrid was not different from the hybrid with the highest ear heights. Ingebrigtsen and McAninch (1989) suggested that feeding preference of deer on corn hybrids in winter was related primarily to higher ear heights. We believe that snow depth could be a major factor in winter food plots because

higher ear heights improve accessibility to deer. Although ear height may correlate with preference during the winter (Ingebrigtsen and McAninch 1989), it is unlikely to be the factor sought by deer during the growing season.

### Management implications

Considering the preferential use of corn hybrids and husbandry practices (e.g., herbicide and fertilizer treatments) by white-tailed deer, deer depredation could be reduced by altering land-use practices to either increase or deter the use of corn by deer, depending upon the desired outcome.

Managers could strategically place food plots with preferred corn hybrids (i.e., high in DDM) to shortstop (Schmitz 2000) deer before proceeding to private producer fields. Moreover, fertilizer and herbicide treatments can alter feeding patterns of wildlife (Ball et al. 2000, Patterson and Fuchs 2001). White-tailed deer preferred to feed in plots that received herbicide application; therefore, we recommend that managed food plots include fertilizer and herbicide applications to maximize growth of corn and control competing plants. Because deer preferred to feed on the edge of corn plots (Figure 5), strategies to increase the amount of easily accessible edge rows may improve deer-use of all corn within a plot area, particularly for large corn plots (Bonner and Fulbright 1999). Corn plot placement should about the best habitat and travel corridors available to exploit this edge habitat, as well. Private producers could plant hybrids less preferred by deer on the edges of fields to minimize depredation.

Plants are most susceptible to damage, and deer-use often peaks as field corn enters the tasseling-silking stage and the onset of kernel development (VerCauteren and Hygnstrom 1993). During this time, efforts should be focused on minimizing deer-feeding (depredation) in cornfields of private producers. Manipulation of

planting dates with corn hybrids in plots used to shortstop deer may enhance the availability of preferred plants during this critical period and focus feeding pressure within food plots. Moreover, using corn hybrids with similar or faster maturity rates, but with superior nutritional quality, compared to field corn of private producers should also help to minimize depredation experienced by producers.

### Acknowledgments

We thank the technicians who assisted with this project, including K. B. Monteith, R. Steffen, R. Scott, Y. Redeuilh, J. Hanson, and J. S. Delger. We acknowledge A. Bly from the South Dakota State University Plant Science Department for assistance with establishing and maintaining our research plots. We thank Olsen Biochemistry Laboratory and N. Thiex at South Dakota State University for assistance with sample analyses, and R. Pritchard and D. Thudukurthy at the South Dakota State University Department of Animal and Range Sciences for assistance with sample preparation. We thank T. Grovenburg, D. Hubbard, G. Schroeder, C. Peterson, and R. Long, for providing comments on earlier drafts. A. Smith from South Dakota Game, Fish and Parks also provided guidance on this project. Funding was provided by Federal Aid to Wildlife Restoration Funds (Project No. 7588) administered through South Dakota Game, Fish and Parks, the Berryman Institute, South Dakota Agricultural Experiment Station, Whitetail's Unlimited (Big Sioux chapter), and a Griffith Faculty Research Award (College of Agricultural and Biological Sciences, SDSU) presented to J. A. Jenks. Hybrid seed corn was provided through R. Christensen at Monsanto Company.

### Literature cited

- Aebischer, N. J., P. A. Robertson, and R. E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. *Ecology* 74:1313–1325.
- Anderson, D. D. 1964. The status of deer in Kansas. University of Kansas Museum of Natural History Miscellaneous Publication 39, Lawrence, Kansas, USA.
- Austin, D. D., P. J. Urness, and D. Duersch. 1998. Alfalfa hay crop loss due to mule deer depredation. *Journal of Range Management* 51:29–31.
- Ball, J. P., D. Kjell, and P. Sunneson. 2000. Response of an herbivore community to increased food quality and quantity: an experiment with nitrogen fertilizer in a boreal forest. *Journal of Applied Ecology* 37:247–255.
- Barboza, P. S., and R. T. Bowyer. 2000. Sexual segregation in dimorphic deer: a new gastrocentric hypothesis. *Journal of Mammalogy* 81:473–489.
- Barboza, P. S., K. L. Parker, and I. D. Hume. 2009. Integrative wildlife nutrition. Springer-Verlag, Heidelberg, Germany.
- Bayoumi, M. A., and A. D. Smith. 1976. Response of big game winter range vegetation to fertilization. *Journal of Range Management* 29:44–48.
- Blair, R. M., H. L. Short, and E. A. Epps Jr. 1977. Seasonal nutrient yield and digestibility of deer forage from a young pine plantation. *Journal of Wildlife Management* 41:667–676.
- Bonner, J. P., and T. E. Fulbright. 1999. Spatial use of warm-season food plots by white-tailed deer. *Journal of Range Management* 52:45–50.
- Caslick, J. W., and D. J. Decker. 1979. Economic feasibility of a deer-proof fence for apple orchards. *Wildlife Society Bulletin* 7:173–175.
- Clauss, M., A. Schwarm, S. Ortmann, W. J. Streich, and J. Hummel. 2007. A case of non-scaling in mammalian physiology? Body size, digestive capacity, food intake, and ingesta passage in mammalian herbivores. *Comparative Biochemistry and Physiology, Part A* 148:249–265.
- Conover, M. R. 1989. Relationships between characteristics of nurseries and deer browsing. *Wildlife Society Bulletin* 17:414–418.
- Conover, M. R. 1997. Monetary and intangible valuation of deer in the United States. *Wildlife Society Bulletin* 25:298–305.
- Conover, M. R., and D. J. Decker. 1991. Wildlife damage to crops: perceptions of wildlife professionals in 1957 and 1987. *Wildlife Society Bulletin* 19:46–52.
- Craven, S. R. 1983. Deer. Pages D-23–33 in R. M. Timm, editor. Prevention and control of wildlife damage. Great Plains Agricultural Council, University of Nebraska, Lincoln, Nebraska, USA.
- Craven, S. R., and S. E. Hygnstrom. 1987. Controlling deer damage in Wisconsin. University of Wisconsin—Extension Publication G3083. Madison, Wisconsin, USA.
- Craven, S. R., and S. E. Hygnstrom. 1988. Electrical fences and commercial repellents for reduc-

- ing deer damage in cornfields. *Wildlife Society Bulletin* 16:291–296.
- Crawford, H. S. 1982. Seasonal food selection and digestibility by tame white-tailed deer in central Maine. *Journal of Wildlife Management* 46:974–982.
- Dolbeer, R. A. 1990. Ornithology and integrated pest management: red-winged blackbirds *Agelaius phoeniceus* and corn. *Ibis* 132:309–322.
- Fagerstone, K. A., and W. H. Clay. 1997. Overview of USDA animal damage control efforts to manage overabundant deer. *Wildlife Society Bulletin* 25:413–417.
- Gannon, W. L., R. S. Sikes, and the Animal Care and Use Committee of the American Society of Mammalogists. 2007. Guidelines of the American Society of Mammalogists for the use of wild animals in research. *Journal of Mammalogy* 88:809–823.
- Hanley, T. A. 1982. The nutritional basis for food selection by ungulates. *Journal of Range Management* 35:146–151.
- Hanley, T. A. 1983. Black-tailed deer, elk, and forest edge in a western cascades watershed. *Journal of Wildlife Management* 47:237–242.
- Hanley, T. A., and K. A. Hanley. 1982. Food resource partitioning by sympatric ungulates on Great Basin rangelands. *Journal of Range Management* 35:152–158.
- Hanley, T. A., C. T. Robbins, A. E. Hagerman, and C. McArthur. 1992. Predicting digestible protein and digestible dry matter in tannin-containing forages consumed by ruminants. *Ecology* 73:537–541.
- Hirth, D. H. 1977. Social behavior of white-tailed deer in relation to habitat. *Wildlife Monographs* 53:1–55.
- Hofmann, R. R. 1989. Evolutionary steps of ecophysiological adaptation and diversification of ruminants: a comparative view of their digestive system. *Oecologia* 78:443–457.
- Hoppe, P. P. 1977. Rumen fermentation and body weight in African ruminants. *Proceedings of the International Congress of Game Biologists* 13:141–150.
- Hygstrom, S. E., and S. R. Craven. 1987. Home range responses of white-tailed deer to crop protection fences. *Proceedings of the Eastern Wildlife Damage Control Conference* 3:128–131.
- Ingebrigtsen, D. K., and J. B. McAninch. 1989. Factors affecting deer use of corn in winter. *Proceedings of the Eastern Wildlife Damage Control Conference* 4:173–181.
- Iowa State University. 1993. How a corn plant develops, Cooperative Extension Service Special Report 48, <<http://maize.agron.iastate.edu/corngrows.html#v9mg>>, Ames, Iowa. Accessed January 12, 2011.
- Ivan, S. K., R. J. Grant, D. Weakley, and J. Beck. 2005. Comparison of a corn silage hybrid with high cell-wall content and digestibility with a hybrid of lower cell-wall content on performance of holstein cows. *Journal of Dairy Science* 88:244–254.
- Jenks, J. A., D. M. Leslie Jr., and R. L. Lochmiller. 1990. Food habits and nutritional condition of white-tailed deer and cattle. Oklahoma Department of Wildlife Conservation, Final Report, PR Project W-142-R, Oklahoma City, Oklahoma, USA.
- Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. *Ecology* 61:65–71.
- Johnson, R. A., and D. W. Wichern. 2002. Applied multivariate statistical analysis. Prentice Hall, Upper Saddle River, New Jersey, USA.
- Julander, O., W. L. Robinette, and D. A. Jones. 1961. Relation of summer range condition to mule deer herd productivity. *Utah Cooperative Wildlife Research Unit* 25:54–60.
- Kie, J. G., R. T. Bowyer, M. C. Nicholson, B. B. Boroski, and E. R. Loft. 2002. Landscape heterogeneity at differing scales: effects on spatial distribution of mule deer. *Ecology* 83:530–544.
- Korschgen, L. J. 1962. Food of Missouri deer with some management implications. *Journal of Wildlife Management* 26:164–172.
- Kramlich, T. J. 1985. Evaluation of seasonal habitat use by white-tailed deer in eastern South Dakota. Thesis, South Dakota State University, Brookings, South Dakota, USA.
- Larson, T. J., O. J. Rongstad, and F. W. Terbilcox. 1978. Movement and habitat use of white-tailed deer in southcentral Wisconsin. *Journal of Wildlife Management* 42:113–117.
- Leopold, A. 1933. *Game management*. Scribners, New York, New York, USA.
- Lesage, L., M. Crête, J. Huot, and J. Ouellet. 2000. Quality of plant species utilized by northern white-tailed deer in summer along a climatic gradient. *Ecoscience* 7:439–451.
- Longhurst, W. M. 1952. Survey of California deer herds, their ranges and management prob-

- lems. California Department of Fish and Game Bulletin 6. Sacramento, California, USA.
- Massé, A., and S. D. Côté. 2009. Habitat selection of a large herbivore at high density and without predation: trade-off between forage and cover. *Journal of Mammalogy* 90:961–970.
- Matschke, G. H., D. S. deCalesta, and J. D. Harder. 1984. Crop damage and control. Pages 647–654 in L. K. Halls, editor. *White-tailed deer ecology and management*. Stackpole, Harrisburg, Pennsylvania, USA.
- Mautz, W. W., H. Silver, H. B. Holter, H. H. Hayse, and W. E. Urban Jr. 1976. Digestibility and related nutritional data for several northern deer browse species. *Journal of Wildlife Management* 40:630–638.
- McDonald, J. E., Jr., D. E. Clark, and W. A. Woytek. 2007. Reduction and maintenance of a white-tailed deer herd in central Massachusetts. *Journal of Wildlife Management* 71:1585–1593.
- Mc Dowell, R. D., and H. W. Pillsbury. 1959. Wildlife damage to crops in the United States. *Journal of Wildlife Management* 23:240–241.
- McIvor, D. E., and M. R. Conover. 1994. Perceptions of farmers and non-farmers toward management of problem wildlife. *Wildlife Society Bulletin* 22:212–219.
- Miller, M. W., and E. S. Williams. 2003. Horizontal prion transmission in mule deer. *Nature* 425:35–36.
- Monteith, K. L. 2006. Sexual segregation in white-tailed deer: intersexual divergence in digestive function, morphology, and behavior. Thesis. South Dakota State University, Brookings, South Dakota, USA.
- Monteith, K. L., L. E. Schmitz, J. A. Jenks, J. A. Delger, and R. T. Bowyer. 2009. Growth of male white-tailed deer: consequences of maternal effects. *Journal of Mammalogy* 90:651–660.
- Monteith, K. L., C. L. Sexton, J. A. Jenks, and T. R. Bowyer. 2007. Evaluation of techniques for categorizing group membership of white-tailed deer. *Journal of Wildlife Management* 71:1712–1716.
- Murphy, R. K. 1983. Deer movements and habitat use of irrigated agricultural lands in central Wisconsin. Thesis. University of Wisconsin, Stevens Point, Wisconsin, USA.
- Mustard, E. W., and V. Wright. 1964. Food habits of Iowa deer. P-R Program, Iowa Conservation Commission, Des Moines, Iowa, USA.
- Nixon, C. M., L. P. Hansen, P. A. Brewer, and J. E. Chelsvig. 1989. Ecology of white-tailed deer in an intensely farmed region of Illinois. *Wildlife Monographs* 118:1–77.
- Palmer, W. L. 1983. Evaluation of white-tailed deer repellents. *Wildlife Society Bulletin* 11:164–166.
- Palmer, W. L., J. M. Payne, R. G. Wingard, and J. L. George. 1985. A practical fence to reduce deer damage. *Wildlife Society Bulletin* 13:240–245.
- Parker, K. L., P. S. Barboza, and M. P. Gillingham. 2009. Nutrition integrates environmental responses of ungulates. *Functional Ecology* 23:57–69.
- Patterson, I. J., and R. M. E. Fuchs. 2001. The use of nitrogen fertilizer on alternative grassland feeding refuges for pink-footed geese in spring. *Journal of Applied Ecology* 38:637–646.
- Reyes, G., and L. Vasseur. 2003. Factors influencing deer browsing damage to red spruce (*Picea rubens*) seedlings in coastal red spruce-balsam fir stands of southwestern Nova Scotia. *Forest Ecology and Management* 186:349–358.
- Robbins, C. T., P. J. Van Soest, W. W. Mautz, and A. N. Moen. 1975. Feed analyses and digestion with reference to white-tailed deer. *Journal of Wildlife Management* 39:67–79.
- Robbins, C. T., S. Mole, A. E. Hagerman, and T. A. Hanley. 1987. Role of tannins in defending plants against ruminants: reduction in dry matter digestion? *Ecology* 68:1606–1615.
- Sadlier, R. M. F. S. 1982. Energy consumption and subsequent partitioning in lactating black-tailed deer. *Canadian Journal of Zoology* 60:382–386.
- Sauve, D. G., and S. D. Cote. 2007. Winter forage selection in white-tailed deer at high density: balsam fir is the best of a bad choice. *Journal of Wildlife Management* 71:911–914.
- Schmitz, L. E. 2000. Development of lure forages for minimizing winter depredation by deer in South Dakota. Thesis, South Dakota State University, Brookings, South Dakota, USA.
- Shapiro, C. A., T. A. Peterson, and A. D. Flowerday. 1986. Yield loss due to simulated hail damage on corn: a comparison of actual and predicted values. *Agronomy Journal* 78:585–589.
- Short, H. L. 1966. Methods for evaluating forages for wild ruminants. *Transactions of the North American Wildlife and Natural Resources Conference*. 31:122–128.

- Short, H. L. 1971. Forage digestibility and diet of deer on southern upland range. *Journal of Wildlife Management* 35:698–706.
- Short, H. L., and J. C. Reagor. 1970. Cell wall digestibility affects forage value of woody twigs. *Journal of Wildlife Management* 34:964–967.
- Snider, C. C., and J. M. Asplund. 1974. In vitro digestibility of deer foods from the Missouri Ozarks. *Journal of Wildlife Management* 38:20–31.
- Spuhler, W., W. F. Lytle, and D. Moe. 1971. Climate of South Dakota. South Dakota State University Agricultural Experiment Station Bulletin 582. Brookings, South Dakota, USA.
- Stewart, C. M., W. J. McShea, and B. P. Piccolo. 2007. The impact of white-tailed deer on agricultural landscapes in 3 National Historical Parks in Maryland. *Journal of Wildlife Management* 71:1525–1530.
- Swift, R. W. 1948. Deer select most nutritious forages. *Journal of Wildlife Management* 12:109–110.
- Torgerson, O., and W. H. Pfander. 1971. Cellulose digestibility and chemical composition of Missouri deer foods. *Journal of Wildlife Management* 35:221–231.
- Vangilder, L. D., O. Torgerson, and W. R. Porath. 1982. Factors influencing diet selection by white-tailed deer. *Journal of Wildlife Management* 46:711–718.
- Van Soest, P. J. 1967. Development of a comprehensive system of feed analysis and its application to forages. *Journal of Animal Science* 26:119–128.
- Van Soest, P. J. 1994. Nutritional ecology of the ruminant. Cornell University Press, Ithaca, New York, USA.
- VerCauteren, K. C., and S. E. Hygnstrom. 1993. White-tailed deer home range characteristics and impacts relative to field corn damage. *Proceedings of the Great Plains Wildlife Damage Control Workshop* 11:218–219.
- Waer, N. A., H. L. Stribling, and M. K. Causey. 1994. Preference for selected forage plantings by captive white-tailed deer. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 48:55–68.
- Walter, W. D., K. C. VerCauteren, H. C. Campa III, W. R. Clark, J. W. Fischer, S. E. Hygnstrom, N. E. Mathews, C. K. Nielsen, E. M. Schaubert, T. R. Van Deelen, and S. R. Winterstein. 2009. Regional assessment on influence of landscape configuration and connectivity on range size in white-tailed deer. *Landscape Ecology* 24:1405–1420.
- Ward, J. S., and S. C. Williams. 2010. Effectiveness of deer repellents in Connecticut. *Human–Wildlife Interactions* 4:56–66.
- Watt, P. G., G. L. Miller, and R. J. Robel. 1967. Food habits of white-tailed deer in northeastern Kansas. *Transactions of the Kansas Academy of Science* 70:223–240.
- Wilkinson, L. 1990. SYSTAT: the system for statistics. SYSTAT Inc. Evanston, Illinois, USA.
- Williamson, S. J., and D. H. Hirth. 1985. An evaluation of edge use by white-tailed deer. *Wildlife Society Bulletin* 13:252–257.
- Wywiałowski, A. P. 1994. Agricultural producers' perceptions of wildlife-caused losses. *Wildlife Society Bulletin* 22:370–382.
- Yoder, J. 2002. Deer-inflicted crop damage and crop choice in Wisconsin. *Human Dimensions of Wildlife* 7:179–196.
- Zar, J. H. 1999. Biostatistical analysis. Prentice Hall. Upper Saddle River, New Jersey, USA.
- 
-

**JOSHUA A. DELGER** (left) is a wildlife technician at Badlands National Park in southwestern South Dakota. He received his B.S. and M.S. degrees in wildlife and fisheries sciences from South Dakota State University. He is currently involved with research and the management of endangered black-footed ferrets and state-threatened swift fox. He also is studying the reproduction, home ranges, and spread of disease in mule deer and bighorn sheep in the Badlands region of South Dakota. His research interests include large and small mammal ecology, population dynamics, and ungulate nutrition.



**KEVIN L. MONTEITH** (center) is a doctoral candidate in biological sciences at Idaho State University. He received his B.S. and M.S. degrees in wildlife and fisheries sciences from South Dakota State University and is currently studying the population dynamics and reproductive ecology of mule deer in the Sierra Nevada of California. His research interests include the population dynamics and the reproductive and nutritional ecology of large mammals.

**LOWELL E. SCHMITZ** (right) is a wildlife biologist with the South Dakota Department of Game, Fish and Parks. He received his B.S. degree from Moorhead State University (Minnesota), and his M.S. and Ph.D. degrees in wildlife and fisheries sciences from South Dakota State University. His research interests are in large mammal ecology, and he currently is studying the nutritional condition and mortality of elk in the Black Hills of South Dakota.

**JONATHAN A. JENKS** is distinguished professor of wildlife and fisheries sciences at South Dakota State University. He obtained his B.S. degree in wildlife from Unity College in Maine, M.S. degree in wildlife management from the University of Maine, and Ph.D. degree in wildlife and fisheries ecology from Oklahoma State University. He has been the academic advisor and provided oversight on all research activities at SDSU's captive deer research facilities since its inception in 1997. His research interests include ungulate ecology, predator–prey relationships, population dynamics, and landscape ecology.

