Hair Sheep Production in Temperate, Deciduous Appalachian Silvopastures

by

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ABSTRACT

Silvopastoral management has potential to diversify and increase the output from livestock production systems. Silvopasture production offers solutions to many management issues associated with grazing systems in the Appalachian region. Several tree species have been proposed for silvopastures in humid temperate regions, but little data comparing animal performance from systems with different deciduous tree species are available. Forage and animal performance was compared from open systems (*i.e.*, no trees) with that from silvopastures containing 13-yr-old honeylocust (*Gleditsia triacanthos*) or black walnut (*Juglans nigra*) trees. Cool-season grass-legume pastures were rotationally stocked with hair sheep crosses from mid-June through September. The objective of this project was to determine carcass characteristics and meat quality of hair sheep crosses grazing honey locust or black walnut silvopastures in comparison with traditional pasture systems.

Forage production varied by year with black walnut having lower production, especially in the 2009 season with black walnut producing less forage compared to open pastures and honeylocust silvopastures ($P=0.0008$). Only small differences in forage nutritive value were observed. Total gains and average daily gains (ADG) did not differ by treatment in 2008, but during the 2009 season black walnut silvopastures produced half the total gains ($P=0.0427$) and ADG ($P=0.0513$) of open pastures and honeylocust silvopastures.

Carcass characteristics evaluated did not vary among treatments except hot carcass weight with black walnut having lower weights ($P=.0045$). Meat quality characteristics did not vary among treatments ($P>0.1$). Shear force and fat content showed great differences and varied by year ($P<0.05$). Overall, carcass and meat quality was similar for all treatments showing great promise for silvopastures.

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Chapter 1: Introduction and Overall Objectives

Introduction

The Appalachian physiographic region is dominated by grass-based agriculture due to its mountainous and rolling topography (Williams, 2002). Utilizing steep slopes for grazing presents management challenges such as erosion and poor animal nutrition. The region's steep terrain often limits nutrient inputs, in turn reducing forage production (Cheek et al., 2006). Many pastures often are overgrazed, further exacerbating nutrient losses and environmental quality issues. The Appalachian region, traditionally an area of subsistence agriculture, continues to lose full time farmers with each passing year. Agroforestry practices (such as silvopastures, riparian buffers, windbreaks, and forest farming) and the use of livestock breeds that complement the changing times offer hope to the agricultural future of the Appalachian region (Feldhake et al., 2010).

Cattle and sheep production have been the dominant livestock enterprises in this region, although the sheep numbers decreased in the United States especially in the Appalachian region from the 1950s to 2000s (USDA, 2011). Recently, sheep production in the Appalachian region has dramatically increased with the introduction of low-maintenance hair sheep breeds such as Katahdin and Dorper and increased marketing opportunities (Wildeus, 1997). Hair sheep offer many advantages for livestock producers because they require less management and input costs than traditional sheep breeds (Wildeus, 1997). Characteristics such as the ability to shed hair and high resistance parasite reduce maintenance labor and anthelminthic input costs (Wildeus, 1997). Hair sheep also have high lamb yields, with most ewes producing two or three lambs in a breeding season (Wildeus, 1997). Although the lambs are smaller than for traditional meat breeds, this has not been an issue due to the increased demand from the growing ethnic and religious markets (Wildeus, 1997). Due to these benefits and market conditions, hair sheep production is increasing within the Appalachian Region.

Silvopasture production, one of the five agroforesty practices, has potential to increase productivity, environmental quality, and economic viability of livestock production systems through the capture of multiple resources (Gold et al, 2000). Silvopastures are grazing systems in which forage species are managed in conjunction with trees (Clason and Sharrow, 2000). Tree management is critical and varies by tree species. In well designed and managed systems, trees modify the grazing micro-climate to the benefit of both the forage and the animals (Olson et al, 2000). Trees can also provide benefits through production of fruits, fodder, timber, and other products that create market opportunities or feed resources.(Clason and Sharrow, 2000) Trees can also provide important conservation services by stabilizing stream banks, reducing erosion, increasing water infiltration, and improving nutrient cycling and soil health (Gold et al, 2000). Silvopasture production offers solutions to many management issues associated with grazing systems in the Appalachian region and can complement the rise of the hair sheep industry.

Combining silvopastures with hair sheep production offers many opportunities for diversifying farm production, increasing conservation benefits, and possibly increasing animal and consumer health. Knowledge of these systems and their management options in the Appalachians is limited, leaving many livestock producers reluctant to pursue these grazing systems. Few data comparing animal performance in grazing systems with different deciduous tree species are available. The objective of this project was to determine forage production and nutritive value, animal gain, and carcass quality of hair sheep grazing honey locust or black walnut silvopastures in comparison with traditional pasture systems.

Objectives

The study's hypothesis was that incorporating deciduous trees into temperate Appalachian pastures benefits animal production and health and forage utilization. To test this hypothesis, my objectives were to:

- Conduct a literature review to establish previous knowledge of silvopasture systems.
- Determine research needed to supplement or fill knowledge gaps regarding silvopasture systems.
- Measure and compare forage production, utilization, and nutritive value among honeylocust silvopasture, black walnut silvopasture, and open pasture systems.
- Measure animal gain and plasma metabolites across field treatments.
- Measure meat quality and characteristics across field treatments.
- Quantify the relationship between animal gain and plasma metabolites as a function of forage nutritive value and utilization.
- Quantify the relationship between carcass quality and characteristics as a function of forage nutritive value and utilization.
- Determine implications of data to future research and management.

Chapter 2: Literature Review

Objectives

To review and synthesize the literature regarding silvopastures, focusing on forage and livestock production.

Looking to the Past

Agricultural practices found in the Appalachian region began as “forest fallowing” or “slash and burn” (Otto, 1987). In “forest fallowing,” trees were often girdled and left to die prior to clearing the forest floor for crop production (Otto, 1987). In “slash and burn” systems, the trees were cut and the area burned to clear the land; the crops that followed utilized the soil nutrients that the forests had built and cycled for centuries (Otto, 1987). The native Cherokee practiced this type of agriculture centuries before white settlers came to the mountains (Williams, 2002). The Cherokee often burned and cleared areas to promote grazing for the buffalo, elk, deer and other wildlife they hunted (Williams, 2002). Cherokee women also tended the “three sisters” – corn, beans, and squash – in small agriculture fields (Veteto, 2008). Eventually European settlers made their way to the mountains, with many following routes established by great adventurers such as Daniel Boone (Veteto, 2008). Germans, English, and Scots or Scotch-Irish settled in various pockets of the mountains forging their own ways of survival (Veteto, 2008). The settlement of the mountains by these various peoples brought about a blending of agricultural practices and concepts, including those techniques used by the Cherokee (Veteto, 2008)

The concept of the open range is most typically associated with the western United States, where range wars left many dead in a grab for the existing grassland resources (Cheek et al., 2006). However, such practices were heavily utilized in the Appalachian region until the early 20th century (Cheek et al., 2006). The traditional grazing system of the Appalachian Mountains was an open range system with cattle, sheep, and hogs freely grazing under trees and in meadow pastures of the mountains (Williams, 2002). Farmers marked their livestock, often with ear notches, and gathered their livestock when ready for market or butchering (Cheek et al., 2006). The mast produced by chestnut, oak, and other trees was utilized by livestock, allowing them to fatten with minimal grain feeding (Cheek et al., 2006). Sheep and cattle were turned loose to graze on ground cleared through slash-and-burn practices and brought in to be fed in the winter (Cheek et al., 2006). Fences were not used to keep livestock within a given area, but rather to keep livestock out of crop fields (Cheek et al., 2006). The system was honored in the mountains and there were few complaints when wandering livestock were found on an individuals' property (Cheek et al., 2006).

The open range grazing practices of the Appalachian region began to decline in the 1930s as the government purchased much of the mountainous lands to form national forests (Williams, 2002). At the same time, new laws were passed obligating owners to keep livestock fenced in on their own property (Cheek et al., 2006). In addition, U.S. agriculture underwent a revolution following World War II, as large-scale monoculture production of corn and other grain commodities became the norm (Williams, 2006). Change also came to isolated Appalachian communities as mining and furniture industries, seeking the region's resources, brought factories and mechanization

(Williams, 2006). Prior to this, subsistence farming was not a choice for the people of the mountains, but a necessity for life (Cheek et al., 2006). Now with industry jobs available and large-scale commodity farms providing food for the nation, Appalachian people did not have to farm to survive; many chose not to farm and others sought farming as a part-time enterprise for extra money or to maintain their way of life (Williams, 2006).

Today's livestock systems in Appalachia are vastly different from those of the past (Cheek et al., 2006). Livestock species and numbers and their distribution have shifted dramatically over time because feeding operations have moved to other region of the United States where available grain and industrial production practices provide economies of scale (Cheek et al., 2006). These changes, accompanied by advances in livestock genetics and nutrition, have resulted in greatly increased animal size and meat quality (Cheek et al., 2006). Thus, many of the smaller, heartier breeds adapted to the open range system and capable of surviving on limited feed resources have disappeared, while many of today's livestock breeds would fare poorly in the open range system given their higher feed requirements (Cheek et al., 2006). Not all changes to the region's livestock systems come from changes in production practices, however. Pressures from growing coyote populations, increasing parasite burdens, coupled with anthelminthic resistance, and a declining demand for lamb also dramatically reduced sheep numbers in the Appalachians in the latter half of the 20th century (USDA, 2011). As a result of these changes, much of the land resource has changed; many fields once used for agriculture have completely reforested (Veteto, 2008).

Cattle production now is the primary livestock enterprise in Appalachia (Cheek et al., 2006). Farmers typically use cleared fenced pastures that have been maintained for more than 50 years. The typical forage systems have low diversity, made up of predominantly tall fescue- [*Festuca arundinacea* Schreb. syn. *Lolium arundinaceum* (Schreb.) Darbysh.] and clover- (*Trifolium* spp.) based pastures (Veteto, 2008). The interrelations used and captured by the earlier open range systems are now almost completely forgotten, and many producers now spend much of their time fighting invading woody (tree and shrub) species in their hay and pasture fields (Cheek et al., 2006).

Such modern production systems have their basis in cheap available energy, but the productive efficiency per unit of energy input is quite low (Heitschmidt et al, 1996). This inefficiency, coupled with greater global demands for agricultural products has created a consequent strain on natural resources (Matson, 1997). This tension between production and conservation has caused many to question current agriculture practices and to look to nature for "new" production ideas (Buergler, 2004). In this context, "sustainable agriculture" has entered the lexicon, but the term's meaning is completely subject to interpretation. Broadly stated, sustainable agriculture should enhance environmental quality and the resource base, provide food and fiber needs for the world's population, be economically viable, and enhance the quality of life for producers and society (ASA, 1989). Fulfilling these requirements can be difficult; however, one practice being examined as a tool for sustainable agriculture, agroforestry, offers great promise for this endeavor.

Sustainability through Agroforestry

Agroforestry practices create multidimensional systems that integrate current agricultural practices and natural systems. Agroforestry combines trees with crop and/or livestock production in an intensive management system (Garrett, 1997). Agroforestry capitalizes on the biological interactions and temporal partitioning created by the combination of the system components (Garrett, 1997). Agroforestry involves polyculture production, offering diverse product streams and potential for over-yielding (Fisher, 2011). Over-yielding is the increase in productivity (over a monoculture crop) attained on a given land area by including multiple products (food, ornamentals, and timber) on the land base (Vaughan & Munsell, 2009). Even though a crop may have lower yield in an agroforestry system than in a monoculture system, the total production coming from the same unit of land is greater because multiple products are being produced (Vaughan & Munsell, 2009). Agroforesty systems capture multiple resources and use them with greater efficiency in time and space because different species utilize resources in different seasons, with various rates of efficiency, and at assorted vertical and horizontal positions in the environment (Gold et al., 2000). Simplified, monocultural production systems place all efforts into one crop, potentially increasing both environmental and economic risk (Olson et al, 2000). In contrast, agroforestry systems rely on greater complexity to better use the available resources on a given site and frequently produce more than a single product (Garrett, 1997).

Agroforestry includes five major practices: windbreaks, riparian buffers, forest farming, alley cropping, and silvopastures (Shultz et al., 1994; Clason and Sharrow, 2000; Gold et al., 2000, Hill and Buck, 2000; Garrett et al., 2004). The five practices, briefly described (Shultz et al., 1994; Clason and Sharrow, 2000; Gold et al., 2000, Hill and Buck, 2000; Garrett et al., 2004) are:

I. Windbreaks – rows of trees planted around crop fields and pastures. Windbreaks can increase crop production and animal comfort and reduce erosion by decreasing wind speed and wind damage around production fields.

II. Riparian buffers – zones of trees planted along streams. Used to create wildlife habitat, cool water temperatures, and filter nutrients, advanced buffers not only protect the environment but also can be used to grow a variety of edibles and marketable products.

III. Forest farming – the production of shade-tolerant crops and medicinals such as mushrooms and ginseng under full tree canopies. Forest farming practices range from intensive agricultural production to emulated wild systems.

IV. Alley cropping – growing row crops (typically commodity crops such as grains) in the alleys between tree production rows. Deciduous fruit nut trees are most commonly used in these systems.

V. Silvopastures – integrated tree, forage, and livestock production systems. Livestock convert the forage to annual, marketable products and both forages and animals may receive benefits from trees modifying the microclimate.

Silvopastures

Silvopastures offer many opportunities for landowners through product stream diversification and environmental conservation. Silvopastures can provide annual income through tree products such as fruits, nuts and fodders, and long-term returns through the sale of fuelwood, posts, or high-quality timber (Garrett, 1997). Tree production also offers benefits through aesthetic appeal, conservation services and microclimate alterations (Garrett, 1997). Livestock and forage production of silvopasture systems offers additional sources of annual revenue to landowners and properly managed livestock can serve as a tool to optimize forage–tree interactions (Clason and Sharrow, 2000). Silvopastures offer many environmental benefits including erosion control, increase infiltration, and microclimate alterations (Feldhake et al., 2010). Properly managed, microclimatic alterations by trees can offer many possible benefits to the understory vegetation, with consequence to the grazing ruminant (Clason and Sharrow, 2000). Silvopastures offer land managers options to create multi-dimensional production systems with over-yielding potential.

Silvopastures can be established in two main ways, either by planting trees within an existing pasture or thinning existing woodland (Garrett, 2004). There are many different management considerations such as component selection, tree protection, and tree density. Maintaining proper levels of light for forage requires pruning and thinning of trees on a regular basis (Garrett, 2004). When thinning woodlands for silvopastures, soil characteristics need to be assessed because woodlands often are found on poor soils that may require much lime and fertilization to support common forage crops (Garrett, 2004). Tree arrangement depends greatly on the type of trees as planting configuration can affect tree form and pruning requirements (Fike et al., 2004). Tree density for establishment into pastures should be four to six times the number needed at the end of crop rotation (Fike et al., 2004). However, spacing and actual tree density varies based on tree and growth habit with pines requiring higher planting densities and pruning (Fike et al., 2004). Thinning woodlands for silvopasture offers the ability to implement timber stand improvement; however, success of thinning woodland for a silvopasture can be difficult (Garrett, 2004). For example, Feldhake et al. (2010) established a silvopasture from a deciduous forest by removing 22% of forest canopy, which allowed 47% penetration of daily incident photosynthetically active radiation (PAR) to the forage understory. Forage production in the silvopasture was 59% of the production in open pastures (Feldhake et al., 2010).

The research conducted on silvopastures has been focused mainly on pine (*Pinus* spp.) in the plantations of the southern United States and New Zealand (Garrett, 2004). Southern pine plantations are ideal for silvopasture systems as the producers already understand the management inputs required for tree production (Clason, 1999). Adding livestock to these systems can assist with vegetation management and provide an annual income (Clason, 1999), greatly improving system economics. For example, Clason (1999) compared the output of silvopastures containing coastal bermudagrass (*Cynodon dactylon* L.), Pensacola bahiagrass (*Paspalum notatum* Flugge) or common bermudagrass with timber-only (loblolly- (*Pinus taeda* L.) shortleaf pine (*Pinus echinata* Mill)) plantation systems. After 11 years, the forage management treatments on average produced 38 m^3 ha^{-1} in lumber volume growth compared to 25 m^3 ha^{-1} in lumber volume growth for the traditional system, which was similar to other pine plantations (Clason, 1999). The mean five-year timber revenue for the silvopasture treatments was $5,283 ha^{-1}, $1,457 more than the timber only treatment.

Limited research has been completed on temperate silvopasture systems leaving many questions regarding management needs, productivity, and profitability. The Appalachian region has much potential for silvopasture development as agriculture and forestry dominate the region's rural economies (Feldhake et al., 2010). Component selection and management for an Appalachian silvopasture must give careful consideration to the many interactions among trees, forages, and livestock. While many silvopasture systems have been proposed, creating new systems, particularly with deciduous trees for the Appalachian Regions, entails some level of risk given that they have received only limited research and producer experience is minimal.

Tree Selection for Temperate Appalachian Silvopasture Systems

Selecting tree species for silvopasture systems requires thorough understanding of a tree species' characteristics, its suitability to the environment of interest, and the possible interactions with other components of the system (Clason and Sharrow, 2000). Desirable silvopasture trees should have great economic potential, or provide services that enhance the silvopasture system, or both (Clason and Sharrow, 2000). Species that develop leaves later in the growing season and that are deep rooted and drought resistant can minimize competition for light and nutrients in temperate, deciduous hardwood systems. With proper selection and management, trees may alter the microclimate to the benefit of the understory and grazing animals (as noted above), and in the case of leguminous trees may add resources such as N and other minerals back to the system.

Temperate hardwood silvopastures research mainly has focused on nut orchards (e.g., pecans or walnuts). These tree production systems can be readily adapted to silvopasture development (Garrett, 2004). The Center for Agroforestry at the University Missouri has pursued much research on silvopastures especially using black walnut (*Juglans nigra* L.) as a dual purpose tree for high quality timber and nut production (Garrett, 2004). Black walnut's advantages include high timber value, perennial nut crop production, a deep penetrating tap root, and compound leaf structure with early leaf drop (Buergler et al., 2005). Among agroforestry practices incorporating black walnut, silvopastures are viewed as the most promising (Scott and Sullivan, 2007).

Using black walnut requires specific management considerations, especially in terms of forage selection. Black walnut produces juglone, an allelopathic compound that reduces the productivity of many plant species including many legumes and members of the Solanum family (Scott and Sullivan, 2007). Most forage grasses are insensitive to juglone (Scott and Sullivan, 2007), but specific management such as length of time that legumes can be used and space between trees should be taken into account for legume sensitivity to this allelochemical (Scott and Sulllivan, 2007).

Forage species and management can have significant effects on timber and nut crop yields and quality. For example, the site index in a 26-yr-old black walnut (*Juglans nigra* L.) stand was much lower with tall fescue in the understory than with Kentucky bluegrass (*Poa pratensis* L.) (Ares and Brauer, 2004). Site index, the height of trees at 50 years, was 5 m greater with the bluegrass understory than compared to trees with tall fescue understory (Ares and Brauer, 2004).

Managing trees for different outcomes has implications for both tree and forage production. Finding the balance between management for nut products or timber production can be very difficult as nut production requires crown development and timber production requires pruning to produce less branching and a straight trunk (Reid et al, 2007). Kurtz et al (1984) found that black walnut trees planted at 12-m X 3-m spacing with boles trimmed to 3 m provided the best of both worlds for nut and timber production. Garrett and Harper (1999) found that sacrificing log length for greater crown area allowed for the greatest internal rates of return and net present value due to greater nut production (at the expense of livestock production). However, this analysis assumes a ready market for the nuts produced.

Two other promising tree species for Appalachian silvopastures include honeylocust (*Gleditsia triacanthos* L.) and black locust (*Robinia pseudoacacia* L.). As with black walnuts, these trees are native to the region and productive during late spring and summer. In addition, these trees may provide timber products and ecosystem services such as N fixation that can increase system productivity. The remaining discussion will be limited to honeylocusts as black locusts are not part of this study.

At first glance, honeylocusts may seem an unlikely choice for silvopastures. The tree produces no (currently) marketable products and its timber has little economic value. However, honeylocusts have some potential as a fodder crop. High-sugar honeylocust varieties such as 'Millwood' and 'Calhoun' have been selected for their ability to produce abundant, nutritious pods that can serve as a feed supplement for ruminants (Scanlon, 1980). Johnson (2011) found the nutritional value of whole, ground Millwood seedpods was comparable to that of ground whole-ear dent corn or oat grain. Smith (1950, as cited by Johnson, 2011) reported that honeylocust pods had up to 35% sugar with yields similar to an equivalent acreage of oats. A high-energy fall fodder crop could be a valuable resource as a livestock feed. However, little research has been conducted on the nutritional utility for livestock (as whole pods or in mixed rations). Of honeylocust cultivars, Millwood has the highest pod sugar concentrations (Gold and Hanover, 1993; Wilson, 1991). The browse from honeylocusts also is nutritious (Addlestone et al., 1999; Baertsche et al, 1986; Wilson, 1991), may contain tannins, and could thus improve protein nutrition (Barry and McNabb, 1999). Honeylocust fodder also is highly desired by grazing livestock (personal observation), although some authors have found establishment problematic (Burner et al., 2005).

In addition to providing desirable products, honeylocust trees have favorable morphology and phenology for cool-season forage systems. Honeylocust trees have pinnate leaf structure; the leaves develop in late spring and drop early in the fall, reducing light competition (Wilson, 1991). The tree also has a deep, penetrating taproot like the black walnut and may fix nitrogen (Bryan, 1996). This latter point has been the subject of some debate, as the plant does not nodulate (Bryan, 1996). However, evidence from Bryan (1996) indicates the plant is a primitive legume and does fix limited amounts of nitrogen.

One morphological trait, thorn production, can be a liability, because the tree's thorns can present a hazard to humans, livestock, and tires. Thorns are not considered a limitation by all producers, however, as they do reduce livestock predation on the trunk of the tree (Gold and Hanover, 1993). Thornless trees can be produced, and this requires grafting bud wood from thornless zones (above the bole) of the trees (Chase, 1949). Grafting also is the primary mode for expanding numbers of high-sugar varieties since the seeds do not breed true; typically the graft material for high-sugar clone propagation is taken from thornless zones (Chase, 1947).

Limited research has been completed on honeylocust as a silvopasture tree. Johnson (2011) investigated the nutritive value of Millwood honeylocust pods and found ground pod to be a highly nutritious fodder, with moderate levels of fiber and high digestibility. Buergler et al. (2005) examined honeylocust in an emulated silvopasture for its effects on forage production. Under honeylocust pastures greater amounts of legume and lesser amounts dead herbage were found (Buergler et al., 2005). As a result of increase legumes under honeylocust, a pattern of greater crude protein in forage under honeylocusts was observed (Buergler et al., 2006). The use this tree of honeylocust in silvopasture systems can increase through specific recommendations and management derived from further research.

Forage Production and Nutritive Value in Temperate Hardwood Silvopastures

Forage production and nutritive value can be affected by slight changes in environmental and microclimatic conditions. Microclimate modifications over time occur due to changes in tree growth and form. Understanding the interactions of trees and forages and how changes in tree morphology affect these interactions can aid the decision making process for silvopasture systems managers.

Reports on forage productivity in silvopastures can vary markedly. Buergler et al (2005) found that in a young silvopasture (with 7- to 8-yr-old trees), cool-season forage yield was increased about 15% under medium density plantings with roughly 370 trees per ha. Kallenbach et al. (2010) found that trees had no negative effect on stockpiled tall fescue production when the area around the trees was not excluded from grazing during winter under multiple hardwood tree species. However, Kallenbach et al. (2006) found on average 20% decrease in forage production per unit area when annual rye (*Lolium perenne* L.) and cereal rye *(Secale cereale* L.) were grown under black walnut and loblolly pine trees. This was largely because forage growth near the trees was reduced by 40–60%. Similarly, Bamboo et al. (2009) found that open ‘Argentine’ bahiagrass *(Paspalum notatum Flügge.)* pastures overseeded with annual cool-season species

(‘Jumbo’ ryegrass *(Lolium multiflorum Lam.),* ‘Dixie’ crimson clover (*Trifolium incarnatum L.)*, and ‘Cherokee’ red clover (*Trifolium pratense L.)* had 28% to 35% greater yield compared to those forages grown under trees. These results may seem surprising, as one might anticipate that the temperature reductions associated with shade in a hot environment would benefit cool-season forage growth. However, the forages were grown during the cool season, when reduced temperatures may not have been beneficial. As well, factors such as light interception and soil moisture could have affected these results, and light would potentially limit forage production in winter months. These conflicting findings support the point that forage yield is dependent on many environmental factors, and silvopasture management must account for these variables to maintain productivity.

The effect of trees on photosynthetic capacity can vary greatly depending upon many environmental and management factors (Peri et al., 2003). Even with reduced light, forage yield may not be affected negatively. For example, Feldhake et al. (2008) found no decrease in yield under black locust trees spaced 1.5 meters by 12 meters despite forages growing under tree canopies receiving as little as one fifth the photosynthetically active radiation (PAR) received by forages in open alley centers. This, coupled with the lack of yield difference between open and silvopasture systems, suggests greater light use efficiency by the forage crop and much greater light use efficiency in the silvopasture given the additional production of trees. However, clovers were less abundant under tree treatments (Felhake et al., 2008).

Light levels also have impacts on plant morphology. Lin et al. (2001) tested the productivity and morphology of potted forages grown under different levels of light attenuated with shade cloth. Leaf area of 30 species of forages were increased anywhere from 13% to 126% under 50% shade; at 80% shade the leaf area of grasses increased anywhere from 19% to 220%. Internodal lengths of both grasses and legumes were greater under shade (Lin et al., 2001). By altering canopy characteristics, such responses may have implications for intake and nutrition of grazing animals.

Forage nutritive value can be directly affected by shade and other microclimate factors. Possible benefits of include greater forage nutritive value. For example, Buxton (1996) reported that with each 1^{o}C increase in temperature, digestibility of cool-season grasses decreases by 3-7 g kg $^{-1}$. However, fibers may be increased with low light levels. For example, Lin et al. (2001) tested response to shade for 30 forages grown under shade cloth, hypothesizing that decreasing concentrations of non-structural carbohydrates caused by increasing shade would increase cell wall contents (Lin et al., 2001). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) concentrations of most species were increased or unaffected by shade, with an overall effect of lower forage digestibility (Lin et al., 2001). Crude protein (CP) concentrations were greater in several species including orchardgrass *(Dactylis glomerata* L.*),* timothy (*Phleum pratense* L.), smooth bromegrass *(Bromus inermis* L.*),* Kentucky bluegrass, ryegrass, and tall fescue (Lin et al., 2001). Kephart and Buxton (1993) reported increased CP in both cool- and warm season species in response to artificial polypropylene fabric shade due to increase numbers of cells in shaded plants. Although cell numbers increased, cell size was reduced, but a constant quantity of nitrogen is contained in each cell (Kephart and Buxton, 1993). In contrast to Lin et al. (2001), Buergler et al. (2006) reported that NDF concentrations were lower in forages grown under medium or high tree densities. These results may be due to decreased temperature, changes in botanical composition, or both (Buergler et al., 2006). Acid detergent fiber was mainly unaffected by shade, with slight increases and no great effect on CP (Buergler et al., 2006). Tree species did affect CP levels, as forages grown under honeylocust trees had greater CP, again likely a compositional response due to greater legumes (Buergler et al., 2006). One potential factor behind these differences may be that the light that penetrates trees – which is mottled and diffuse – varies greatly from the light transmitted through shade cloth. However, Buergler et al. (2006) did observe differences in total non-structural carbohydrate (TNC), which increased three-fold from medium- to high density positions. Acid detergent lignin (ADL) followed a similar pattern, increasing with increasing tree density (Buergler et al., 2006). The Buergler et al. (2006) study supported the results of Kallenbach et al. (2006), who reported an overall increase in forage nutritive value under tree treatments compared to open pastures, which also had increased levels of ADF and NDF (Kallenbach et al., 2006). The authors hypothesized that the increase forage quality (due to mainly higher levels of CP) offset lower forage production (Kallenbach et al., 2006).

Livestock Performance in Silvopastures

Many parameters can be used to evaluate animal performance, but ultimately all represent some measure of animal output or production. Animal performance is most directly affected by intake, which largely is driven by forage nutritive value and availability (Burnett et al., 2012). These are not the only determinants of animal performance, however, comfort and grazing behavior may affect intake and nutrient use efficiency (Safiudo et al., 1998). These may also have consequences for health and subsequent carcass quality (Safiudo et al., 1998).

Benefits of silvopastures for grazing animals may be measured in terms of energy sparing that accompanies both heat and cold/wind chill abatement. McArthur (1991) outlined microclimate variables and their effect upon livestock, noting that trees in silvopastures can protect animals from extreme heat and winds. Roark and McDaniel (1956) found cows and calves had greater gains when provided access to shade in pastures. Animals did not spend more time grazing, but were cooler and spent less time standing and more time lying down, suggesting that the increased productivity was a function of reduced energy demands. Similar benefits of shade for heifers in feedlots were observed by Mitlöhner et al. (2002). The study, conducted during summer in West Texas, USA, showed that animals that had shade avoided standing in direct sun and followed the shade line. Shaded heifers had a 6.1% increase in average daily gain compared to heifers without shade (Mitlöhner et al., 2002). Karki and Goodman (2010) investigated animal behavior in silvopastures systems and reported that distribution evenness index (DEI) was greater in silvopastural systems, with cattle spending 50% to 63% of their time grazing in silvopastural systems compared to 26% to 40% in open pasture systems. Loafing, in this case defined as activities other than grazing or lying, peaked at 26% in silvopastures compared to 54% in open pasture systems (Karki and Goodman, 2010). Activity differences were attributed to reduced solar radiation (14-58%) in the silvopastures compared to the open pastures (Karki and Goodman, 2010).

In silvopasture systems where forage production is decreased, animal performance may not be negatively affected due to the increased animal comfort and/or greater nutritive value of forage. Establishing the energy sparing benefit on animal performance, Kallenbach et al. (2006) found no differences in animal performance of

Angus steers that grazed in open and silvopasture systems with a forage base comprised of cereal rye and ryegrass planted in stands of 6- to 7-year-old pitch pine X loblolly pine hybrids and black walnut trees. This response is notable because the open systems had 20% more forage production and there were 15% fewer grazing days in silvopastures. Teklehoimehit (2002) found no affect on sheep production in terms of carrying capacity and growth rate after 6 years of grazing under young sycamore (*Acer pseudoplatanus* L.)–alder (*Alnus rubra* Bong.) silvopastures. The silvopastures were planted at different densities up to 400 trees ha^{-1} in the United Kingdom (Teklehoimehit, 2002). Such results are common in systems where the trees in the silvopastures are young. As tree canopy closes, however, higher management may be required to continue positive animal performance results. Lehmkuhler (1999) compared grazing management practices in well-established 19-yr-old black walnut silvopastures and found greater average daily gain for steers in rotationally stocked pastures compared to continuously pastures. Though open, traditional pasture systems and their management were not compared, this study establishes the effect that management can have on animal performance (Lehmkuhler, 1999).

Negative animal performance in silvopastures predominantly corresponds with increased tree age (size) and density. Hawke (1991) saw a decrease of 50% of lamb live weight gains from perennial ryegrass and white clover (*Trifolium repens* L.) in 15-yr-old radiata pine (*Pinus radiata* D. Don) plantations. This study compared tree density of 200 stems per ha to open pastures without trees in New Zealand. In a similar study also conducted in New Zealand, pastures of perennial rye-grass and subterranean clover (*Trifolium subterraneum L.*) grown under radiata pine trees had reduced carrying capacities as tree densities increased (Bird et al., 2010). However, the tree age and development is not always the contributing factor to decreased animal performance. Kallenbach et al. (2010) used crossbred Angus steers to strip graze stockpiled tall fescue pastures during winter months in young hardwood silvopastures. Silvopastures contained red oak (*Quercus rubra* L.), black walnut, pecan (*Carya illinoinensis* [Wangenh.] K. Koch), and honeylocust trees. Average daily gain was similar for steers in open and silvopasture systems. However, gain per hectare was lower for silvopastures compared to open pastures because greater area was required in silvopasture systems to supply similar amounts of forage (Kallenbach et al., 2010). Grazing through the winter took away the advantage of heat abatement found in most studies (Kallenbach et al., 2010). Time of year, tree age, tree density, and animal species and class are among the many factors that can affect animal performance in these systems. Greater understanding of the tree-forage-animal interactions in these systems should help increase their implementation and guide management decisions that improve animal performance.

Hair Sheep Potential in Appalachian Silvopastures

Hair sheep offer many advantages over other sheep breeds used in Appalachia. Reduced labor requirements, parasite resistance, and progressive market development have helped expand the hair sheep flock (Wildeus, 1997). Hair sheep production advantages include increased yield with three lambing seasons in two years and multiple births with each ewe (Wildeus, 1997). Therefore, it is not uncommon to have 200+% lamb crop each year (Wildeus, 1997). However, most research on hair sheep breeds has been conducted outside the United States and little information is available on carcass quality and meat characteristics.

Compared to the wool breeds typically raised in the United States, hair sheep have slower growth rates and smaller size at maturity (Wildeus, 1997). Burke and Apple (2005) compared performance and carcass characteristics of ¾ and ⅞ Dorper, purebred Katahdin, purebred St. Croix, and purebred Suffolk that grazed Bermuda grass (*Cynodon dactylon* L.) and annual ryegrass (*Lolium multiflorum* L.) pastures in Oklahoma. Suffolk sheep (a wool breed) had greater average daily gains, and higher weights and carcass weights than the Katahdin and St. Croix (hair sheep) breeds (Burke and Apple, 2005). Although Katahdin sheep had higher yield grade due to greater carcass fat thickness, they had lower carcass quality than the Dorper and Suffolk breeds (Burke and Apple, 2005). Horton and Burgher (1991) found that average daily gains and feed-to-gain ratios were similar between the Dorset (a wool breed) and Katahdin sheep establishing great potential for Katahdin sheep in terms of growth. Some variance in production exists among hair sheep breeds; Burke et al. (2003) found that Katahdin- and St. Croix-sired lambs had lower average daily gain after weaning than Dorper-sired lambs. Lambs sired by Dorper rams had the greatest carcass quality (Burke et al., 2003). Crossbreeding can be a useful means of improving hair sheep productivity. Dorper crosses with Rambouillet (a wool breed) produced heavier, higher quality carcasses than pure-bred Rambouillet and Suffolk-Rambouillet cross lambs (Nell, 1998).

Overall, there are many considerations and opportunities in terms of using hair genetics to increase the profitability of sheep production systems. Limited information is available, however, on use of hair sheep in pasture systems, and their use in silvopastures has not been investigated previously. Determining the utility and value of integrating these two novel production components (trees in pastures and hair sheep) was thus the focus of this study. With further research, recommendations can be developed for the management of hair sheep in silvopasture systems.

Chapter 3: Deciduous Silvopasture Systems for Hair Sheep

Abstract

Silvopastoral management has potential to diversify and increase the output from livestock production systems. Silvopasture production offers solutions to many management issues associated with grazing systems in the Appalachian region. Several tree species have been proposed for silvopastures in humid temperate regions, but little data comparing animal performance from systems with different deciduous tree species are available. Forage and animal performance was compared from open systems (*i.e.*, no trees) with that from silvopastures containing 13-yr-old honeylocust (*Gleditsia triacanthos*) or black walnut (*Juglans nigra*) trees. Cool-season grass-legume pastures were rotationally stocked with hair sheep crosses from mid-June through September. The objectives of this project were to determine forage production, forage nutritive value, and animal gain of crossbred hair sheep grazing honey locust or black walnut silvopastures in comparison with traditional pasture systems.

Forage production varied by year with greater forage production in the 2008 season, but no differences among treatments in 2008. Forage production varied greatly in 2009 season with black walnut having lower production (*P=0.0008*). Only small differences in forage nutritive value were observed. Averaged over the season, silvopastures tended (P<0.1) to have more neutral detergent fiber and hemicellulose, but this was primarily due to greater fibers in forages within black walnut silvopastures. Total gains and average daily gains (ADG) did not differ by treatment in 2008, but during the 2009 season black walnut silvopastures produced half the total gains (P=0.0427**)** and ADG (P=0.0513**)** of open pastures and honeylocust silvopastures. These data suggest

future management is required for black walnut pastures and the potential for honeylocust silvopastures is strong with results similar to open pastures.

Hypothesis

Honey locust and black walnut silvopastures can produce similar forage mass and quality and support similar levels of animal performance as open pasture systems.

Objectives

The objectives of this experiment were to determine:

1) Forage production in honeylocust and black walnut silvopastures compared to that of open pastures.
2) Nutritive value of forages in honeylocust and black walnut silvopastures compared to that of forages grown in open pastures.
3) Average daily gain (ADG) and total gain of lambs that grazed honeylocust and black walnut silvopastures compared to those that grazed open pastures.

Materials and Methods

Research Site

Field research was conducted at Virginia Tech's Kentland Farm in Blacksburg, VA (37°11ʻ N latitude, 80°35ʻ W longitude, 545 m elevation above sea level). Soil series on the site include Berks-Lowell-Rayne complex, Unison and Braddock cobbly, and Weaver soils. Soils are primarily fine-textured, mixed mesic, Typic Hapludults and Typic Hapludalfs along with fine loamy mixed mesic Fluvaquentic Eutradepts. The soils generally are well-drained with sloped topography ranging from 10 to 25%, although the soils of the Weaver series (about 20% of the land area) have 0 to 5% slope and are moderately well drained. Soils are characterized by moderate permeability and available water capacity, and generally have low organic matter and inherent fertility.

The plots for this study are part of a larger agroforestry project established in 1995 to research and demonstrate the biological interactions that occur when trees are integrated with agricultural systems. Seedling trees within the silvopasture study site were planted (in 1995) into the existing cool-season forage base in rows parallel with the slope. Trees were planted at a 2.44-m (within row) × 12.2-m (between row) spacing at a density of about 410 stems ha^{-1}. In spring 2008, prior to the grazing study, 40% of the trees were thinned within each silvopasture, leaving an average stand density of about 250 stems ha^{-1}.

Experimental Treatments and Treatment pastures

The three experimental treatments for this study were open pastures, honeylocust silvopastures, or black walnut silvopastures (Figure 3.1). Although visual evaluations at the time of establishment (1995) were not conducted, forages in the pasture systems at the time of tree planting were predominantly tall fescue (*Festuca arundinacea* L., syn. *Lolium arundinaceum* Darbysh., syn. *Schedonorus phonenix* (Scop.) Holub.). Other cool season species such as orchardgrass (*Dactylis glomerata* L.), Kentucky bluegrass (*Poa pretense* L.), and red and white clovers (*Trifolium pretense* L. and *T. repens* L.) were also abundant in these systems. At commencement of the grazing study in 2008, other species such as field clover; (*T. campestre* Schreb.), sweet vernal grass (*Anthoxanthum oderatum* L.) and nimblewill (*Muhlenbergia schreberi* J.F. Gmel.) were also observed. In 2009, prior to the research trial, a visual assessment of relative abundance of forage species was conducted using the DAFOR (dominant, abundant, frequent, observed, rare) scale. DAFOR rankings were converted to a 5-point scale with 5 = dominant and 1 = rare. DAFOR assessments were made on each sub- paddock within each pasture.

Animals, Stocking Rates, and Pasture Management

In 2008, 50 lambs (Katahdin × Dorsett-Finn-Rambouillet) from the Virginia Tech Sheep Center were blocked by weight and then randomly assigned to one of the nine experimental units (3 treatments × 3 replications). Each experimental unit (treatment X rep combination) was 0.27 ha and divided into four sub-paddocks. Fifty-two lambs (Kathadin × Dorsett) from the Center were used for the study in 2009. All three replications were stocked with 6 lambs per experimental unit excluding the black walnut and honeylocust pastures in replication two. These pastures, which had been degraded due to the needs of previous management, were stocked with four lambs in 2008 and five lambs in 2009 due to reduced forage availability. Pastures were rotationally stocked from mid June through late September. In 2009, sub-paddocks were further divided with portable cross fencing to improve forage management. Due to concerns over coyote (*Canis latrans*) predation of sheep, lambs were moved to a central corral for safe housing each evening during the first two weeks of 2009. Two animals were lost from the analysis in 2009 due to coyote predation. Similar sized animals were used as replacements to maintain stocking rates among treatments. A third animal on trial was removed from the analysis due to our inability to successfully treat for internal parasites.

Forage Mass

Each year, pre- and post-graze forage heights were collected with each sub-paddock rotation by taking 30 random measures with a rising plate meter (FILIPS Folding Plate Pasture Meter; JENQUIP, Fielding, NZ). At approximately two-week intervals, eighteen samples of pre-graze and eighteen samples of post-graze forage were measured. The forage underneath the meter plate at resting height was marked by a quadrate and cut with clippers. This material was dried at 55 °C in a forced draft oven for 48 h to determine dry matter (DM). Forage mass was sampled across a range of plate meter height readings and used to build a regression equation of mass relative to plate meter height. The relationship of mass to height was then used to determine pasture DM yield based on the average of plate meter heights within treatment pastures. The equation derived from this relationship, DM = 1.0127x + 4.8821 (r^2 = 0.5064), was used for all pre- and post-graze forage mass calculations.

Forage Nutritive Value

Forage samples were collected every two weeks in the pre-graze pastures to determine nutritive value by treatment. Samples were harvested in the afternoon to limit differences in nutritive value due to diurnal variation. Dried forage samples (55 °C for 48 h) were ground to pass a 1-mm screen with a hammer mill (Christy-Norris, North Lincolnshire, UK). Neutral and acid detergent fiber (NDF and ADF) and acid detergent lignin (ADL) concentrations were determined sequentially using batch procedures of the ANKOM fiber analysis system (ANKOM Technology, Macedon, NY, USA; ANKOM Technology, 2011a, 2011b) following procedures described by Vogel et al. (1999). Crude Protein (CP) was analyzed by the Virginia Tech Soil Fertility Lab using dry combustion procedures with a Vario MAX CNS macro-elemental analyzer (Elementar, Hanau, Germany). All samples were analyzed in duplicate and the analysis was repeated if the coefficient of variation between duplicates exceeded 3%.

Forage *in vitro* true digestibility (IVTD) was determined using ANKOM Daisy batch incubator and fiber analysis system following procedures developed by ANKOM (ANKOM Technology, Macedon, NY, USA; ANKOM Technology, 2005). The rumen fluid collected for the IVTD assays came from a non-lactating Holstein cow in October 2009 and 2010. The cow was housed at the Virginia Tech Dairy Center in accordance with Virginia Tech's Animal Care and Use Protocol (#07-070-CSES). The cow was fed a standard diet of first-cut, mixed, cool-season grass hay ad libitum plus 0.45 kg of cracked corn (*Zea mays* L.) once per day (which constituted less than 5% of daily DMI). The cow was fed each morning at approximately 0700 h and ruminal fluid was sampled at approximately 1300 h. Samples were analyzed in duplicate and the analysis was repeated if the coefficient of variation between duplicates exceeded 4%. Neutral detergent fiber digestibility (NDFD) was calculated from NDF and residual NDF (from IVTD measures) as 100*(1 – residual NDF, g)/NDF, g.

Animal Gain

During weigh days, lambs were moved from pastures in the morning to a central corral. Weigh dates occurred at approximately 32-day intervals during each season. Lambs were weighed on a platform with load cells using a Tru-Test digital scale (Tru-Test, Ltd. Manukau, NZ). Total gain per system was calculated as the sum of all final weights - initial weights within each experimental unit. Lamb ADG (by period and season) was calculated as gain divided by total grazing days within period or season.

Statistical Analysis

Experimental design was a randomized complete block with three replications. Pastures were the experimental units. All data were analyzed using repeated-measures mixed ANOVA with PROC MIXED of SAS, v. 9.2 (SAS Inst., Cary, NC). Compound symmetry covariance structure was used to analyze animal gain and forage nutritive value, while autoregressive covariance structure was used for botanical composition and forage mass data due to better fit statistics. Orthogonal contrasts were used to compare open vs. silvopasture treatments and black walnut vs. honeylocust treatments. Differences were considered significant at $P < 0.05$ and trends are reported, where appropriate, for $P < 0.1$. Data will be presented by year when a year×treatment occurs with $P<0.1$.

Results

Weather

Weather data was divided into 7 day intervals to establish weather pattern throughout the grazing season. Generally, precipitation at the study site is evenly distributed throughout the year, with long-term average precipitation of 1085 mm yr^{-1}. Precipitation at the research site was comparable in each year with dry intervals and raining intervals for each year (Figure 3.2). Insolation (solar radiation reaching the earth's surface) was comparable throughout 2008 and 2009; however, insolation in July and September 2009 was lower than in corresponding months of 2008 (Figure 3.3). Average temperature was comparable for both years following a similar pattern (Figure 3.4).

Botanical Composition

At the start of 2009 grazing season silvopasture treatments were characterized as having abundant tall fescue, but fescue was the dominant forage in open pasture systems (Table 3.1). Black walnut systems had less tall fescue and more Kentucky bluegrass than honeylocust silvopastures; orchardgrass (frequent) and white clover (rare) were fairly uniformly distributed among the three systems. Red clover cover was lower in silvopasture systems, but this was clearly due to sparse red clover populations in black walnut which were rare or not observed – compared with frequently seen red clover in honeylocust pastures. Other low-value pasture species such as sweet vernalgrass, nimblewill, and weedy *Bromus* spp. were predominantly observed in the black walnut systems as well. Although not quantified, nimblewill and warm-season broadleaf weeds increased in visibility later in the grazing season, particularly under black walnuts.

Forage Mass

Pre-graze forage mass did not differ among pasture treatments in 2008, although in the final, late season grazing period open pastures tended (P=0.0699) to have more forage than the silvopasture treatments. Although not significant, mean pre-graze forage mass estimates for the season were about 5.5 and 12.9% lower for honeylocust and black walnut silvopastures than the mean forage mass of open pasture systems (3090 kg ha^{-1}; Table 3.2).

Post-graze forage mass in the black walnut systems was lower (P<0.05) in the late (August-to-September) grazing period and when averaged over the entire grazing season in 2008 when compared to forage mass from open pastures. Although significant, the differences among treatments were not as large in the post-graze measures; forage mass was 10.2 and 1.9% lower for black walnut and honeylocust pastures compared to the mean (2160 kg ha^{-1}) of open pasture systems.

In 2009, differences among pasture treatments and grazing periods for pre and post-graze measurements were significant (Table 3.2). During the early grazing period, open pastures contained more (P=0.0281) forage than silvopasture treatments (4510 vs. mean of 3810 kg ha^{-1}). Honeylocust silvopastures tended (P=0.0541) to contain more forage in pre-graze measurements than black walnut pastures. These patterns were repeated in the mid-season grazing period; silvopasture treatments had lower (*P=0.0043*) forage mass (mean = kg ha^{-1}) than open pastures (3600 kg ha^{-1}) and black walnut pastures had less (*P*=0.0279) forage (2770 kg ha^{-1}) compared to honeylocust pastures (3111 kg ha^{-1}). Similar patterns were observed in the late-season grazing period; silvopasture treatments had less (*P*=0.0009) forage than open pastures $^{-}$(2670 kg ha^{-1}) and pre-graze herbage mass was lower (*P*=0.0006) in black walnut (2160 kg ha^{-1}) than in honeylocust pastures (2290 kg ha^{-1}). Averaged over the entire season, pre-graze forage mass in open pastures (3590 kg ha^{-1}) was about 20% and 13% greater (*P*=0.0001) than in black walnut and honeylocust pastures

The 2009 post-graze forage mass measurements followed a similar pattern to pre-graze mass estimates except during the mid-season grazing period, when forage mass estimates did not differ among treatments. Over the entire season, average post-graze forage mass in open pastures (2450 kg ha^{-1}) was about 18 and 12% greater (*P*=0.0002) than in black walnut and honeylocust pastures (2000 and 2150 kg ha^{-1}) respectively).

Forage Nutritive Value

Forage nutritive value concentrations did not differ greatly among pasture treatments or grazing periods (Table 3.3). Data presented are the two year averages by as no year×treatment interactions ($P>0.1$) were observed. Data is presented by period due to treatment×period interactions ($P<0.1$) were observed.

Neutral detergent fiber was about 60 g kg^{-1} greater (*P*=0.031) in forages from black walnut silvopastures than those in honeylocust silvopastures in the early grazing period (549 vs. 491 g kg^{-1}). Similar patterns occurred in the mid- season grazing period.

Forages from open pasture treatments had less (*P*=0.0240) fiber than those from silvopasture treatments (474 vs. 517 g kg^{-1}), driven primarily by greater NDF levels in black walnut (529 g kg^{-1}) pastures. Seasonal averages for the two-year study reflected these differences with forages from open pastures tending (*P*=0.0777) to have lower NDF concentrations than silvopasture treatments (504 vs. 531 g kg^{-1}) and black walnut pastures tending (*P*=0.0661) to contain greater NDF concentrations than forages from honeylocust pastures.

Seasonal averages for acid detergent fiber (ADF) did not differ (*P>0.1*) among treatments. Overall season two year averages of open pastures (263 g kg^{-1}), black walnut (277 g kg^{-1}), and honeylocust pastures (268 g kg^{-1}) were very similar. During the mid-season grazing period open pasture systems tended (*P*=0.0604) to have lower ADF concentrations than forages from silvopasture treatments. In the late season grazing period, ADF concentrations tended (*P*=0.0549) to be lower in forages from honeylocust than black walnut silvopastures.

Hemicellulose concentrations (measured as the difference of NDF and ADF) exhibited similar patterns to changes in NDF. This was largely a function of the small changes in ADF among treatments. Hemicellulose concentrations in forages from black walnut pastures (267 g kg^{-1}) were significantly higher (*P=0.0049*) than those in forages from honeylocust pastures (225 g kg^{-1}; for the early grazing period). In the mid-season grazing period, forages from open pasture systems had lower (*P*=0.0288) hemicellose concentrations than forages from silvopasture systems. This response was driven by a trend (*P*=0.0551) of greater hemicellulose in black walnut silvopastures (26 g kg^{-1}) than honeylocust silvopastures (2354 g kg^{-1}). Averaged over the two seasons, open pastures tended (*P*=0.096) to have less hemicellulose than forages from silvopasture systems and this was largely driven by a tendency (*P*=0.0607) of greater hemicellulose in forages from black walnut silvopastures compared to honeylocust silvopastures.

Acid detergent lignin concentrations did not differ throughout the seasons. However, within the late grazing season open pastures tended (*P*=0.0715) to be lower in ADL than compared to silvopasture treatments (29.8 vs. 33.3 g kg^{-1}).

Crude protein and in vitro true digestibility measures did not differ (*P*>0.1) throughout the seasons or grazing periods. In-vitro true digestibility followed the same pattern with no significant differences among the treatments or periods (*P>0.1*).

Neutral detergent fiber digestibility (NDFD) did not differ (*P*>0.1) among treatments for the two-year seasonal average. However, in the early grazing period NDFD from honeylocust silvopastures was lower (*P*=0.0294) than from black walnut silvopastures (225 vs. 304 g kg^{-1}). In the mid-season grazing period, NDFD values for open pastures were lower (*P*=0.0261) than for silvopasture treatments (223 vs. 271 g kg-$^{-1}$, respectively).

Animal Gain

Animal gain responses varied greatly by year and period (*P*<0.001) and data were marked by significant (*P* < 0.1) year × treatment interaction, thus ADG and total gain data are presented by year (Table 3.4). ADG data was analyzed and presented by period within years (P<0.1). Weigh dates took place every 32 days within each grazing season except when a problem with the scale in one period in 2008 delayed weighing by three days. Two animals were lost from the analysis in 2009 due to coyote predation. Similar sized animals were used as replacements to maintain stocking rates among treatments. A third animal on trial was removed from the analysis due to our inability to successfully treat for internal parasites.

Lamb ADG was similar for all treatments both within individual weighing periods and over the grazing season in 2008. However, lamb ADG decreased ($P < 0.0001$) by period over the season. These decreases correspond with reductions in available forage later in the season. Total gain per pasture did not differ by treatment (mean = 48.6 kg pasture^{-1}) in 2008 (Table 3.4), although weight gains on black walnut pastures were numerically lower than gains from open and honeylocust pastures. However, these data reflect lower stocking rates for both black walnut and honeylocust silvopastures.

Over the grazing season in 2009, ADG of lambs grazing in the black walnut silvopastures (0.05 kg d^{-1}) was almost one-third ($P < 0.01$) that of lambs grazing open pastures (0.07 kg d^{-1}) or honeylocust silvopastures (0.08 kg d^{-1}). Gains in the first period were quite low, likely because lambs were corralled each night for the first two weeks of the study. However, ADG on black walnut silvopastures was consistently lower ($P < 0.001$) throughout the season compared to the other treatments. These ADG are reflected in the low total gain (Table 3.4) per pasture in black walnut systems (24.2 kg), which was about half (P=0.0427) the gain on honeylocust and open pasture systems (40.1 and 41.6 kg pasture^{-1}, respectively).

Discussion

Forage Mass

Forage production estimated by pre-graze measurements varied greatly by year. Forage production in 2008 did not differ statistically among treatments, but did decrease throughout the grazing period. Overall open pastures had the greatest production with honeylocust producing 5.6% less and black walnut pastures producing 13.0% less than open pastures systems. Forage production was greater in 2009 than compared to 2008. Forage production in 2009 varied greatly among treatments. Overall forage production exhibited the same pattern as 2008 with open pastures producing the greatest amount of forage. Black walnut and honeylocust herbage mass estimates were 20.3% and 13.3% than estimates from open pastures. Greater forage mass estimates likely reflect a combination of greater rainfall and initial samplings at toe slope positions in the 2009 season.

Forage disappearance, a function of intake and trampling, estimated by post-grazed measurements varied greatly by treatment throughout the grazing season. Open pastures, in addition to greater forage production, had greater disappearance with black walnut pastures having 10.3% less disappearance and honeylocust pastures having 1.6% less disappearance for the 2008 season. 2009 saw even greater variation between treatments with black walnut having 18.1% less disappearance and honeylocust having 12.2% less disappearance.

Forage production in silvopastures is affected by multiple factors such as tree species, age of trees, tree spacing, forage species and variety, and climate. Kallenbach et al. (2006) reported similar decreases in forage production, with cumulative forage yields of annual rye and cereal ryegrass in open pastures 21% greater than that in pine-black walnut silvopasture treatments. These data contrast with those of Buergler et al. (2005)

who found yields were about 20% greater under 7- to 8-year-old emulated black walnut and honeylocust silvopasture than in open sites. In addition, forage yields were about 22% higher under black walnut trees than honeylocust trees (Buergler et al., 2005), which may reflect a positive response to greater levels of shade under black walnuts. Differences between these studies likely reflects the greater age (and thus size and shading) from trees in our study, along with changes in forage botanical composition Lin et al. (1999) reported that tall fescue is one of the more productive cool-season grasses under shade, and the loss of tall fescue, along with red clover, in the walnut systems likely was a significant contributor to the forage production decline. Although not measured in this study, the greater shade from walnut canopies, coupled with lower insolation in much of the 2009 growing season likely profound effects on overall forage production in these systems.

Forage Nutritive Value

Forage nutritive value differences among treatments and grazing period during the study largely were limited to measures of NDF, hemicellulose and NDFD. Forage NDF tended to be greater in silvopasture systems, largely due to higher NDF in forages growing under black walnut treatments compared to honeylocust treatments and open pastures. Kephart and Buxton (1993) reported that shade can decrease NDF due to temperature modifications, and Kallenbach et al. (2006) found equal greater NDF and ADF in open pasture than in pine-black walnut silvopastures. In our study, temperatures in both silvopasture systems were not measured but were noticeably lower under trees. Thus, the higher NDF concentrations in forages from black walnut systems more likely reflect differences in botanical composition among treatments. Greater amounts of warm-season grasses and lower levels of red clover would likely have contributed to the observed tendency of increased forage NDF concentrations in black walnut silvopastures.

Over the grazing seasons, forage ADF concentrations did not differ among pasture treatments, although a tendency of greater ADF concentrations was observed in forages from silvopastures in midseason,. Our results are similar to those of Lin et al. (2001), who found that ADF levels were unaffected by increased shade. In contrast, Kallenbach et al. (2006) reported equal or greater ADF in forages from open pastures compared forage from pine-black walnut silvopastures.

Because hemicellulose concentrations are calculated as NDF – ADF, and because ADF varied little among treatments, differences in hemicellulose naturally followed similar patterns as NDF in response to treatment.

Treatment effects on forage ADL were limited, tending to be greater in silvopastures in late season. Greater ADL concentrations would be expected because ADL typically rises in low light environments due to increases in intermodal tissues which contain higher levels of lignin (Allard et al., 1991). However, ADL concentrations were generally low and the variability associated with the third stage of a sequential analysis may have limited the sensitivity of this assay.

Crude protein did not vary among treatments or by period. Contrasting these findings, Kephart and Buxton (1993) reported CP frequently is greater in shaded plants. Kallenbach et al. (2006) also reported equal or greater CP in shaded forages in silvopastures. Buergler et al., (2006) reported greater levels of CP in forages grown under honeylocust silvopastures than in forages from black walnut silvopastures and open pastures. The higher levels were attributed to higher levels of clover in honeylocust silvopastures. Based on Buergler et al. (2006) results, and given the lower level of legumes in walnut pastures (Table 3.1), it is surprising that differences in CP were not observed in this study.

In vitro true digestibility did not vary among pasture treatments. In contrast, NDFD, which is calculated from NDF and IVTD, followed a pattern similar to NDF. Greater early season NDFD in forage from black walnut silvopastures and from both silvopastures in the mid-season period appears to have compensated for the higher absolute NDF concentrations. That NDFD did not differ with treatment over the grazing season likely reflects the lack of differences in NDFD in the late-season grazing period, when forage yields were more limiting.

Animal Gain

The differences in total gain and average daily gain (ADG) between 2008 and 2009 seasons could be attributed to several factors including differences in forage production and nutritive value. Coyote strikes early in 2009 season forced us to corral all animals during the night for two weeks at the beginning of the season and likely limited early-season gains. Gains were similar among treatments by the end of the mid-season grazing period; the decline in animal gains on black walnut silvopastures in the late season may reflect greater weed abundance – particularly nimblewill and stickweed (*Verbesina occidentalis*) –species which generally are not preferred by lambs and whose presence could have contributed to lower gain and ADG in animals grazing in those pastures.

Towards the end of both growing seasons some honeylocust pods dropped with some sheep consuming the pods (Figure 3.3). Honeylocust has good potential as a fodder crop, Johnson et al. (2012) and may be useful as a supplement for small ruminants. However, most pods dropped well after the end of our study periods; thus pods likely contributed little to animal gains in this study.

For the two years honeylocust silvopastures supported similar total gain and ADG as open pastures, and these systems show great promise for livestock production. Similar to this study, Kallenbach (2006) found no differences in ADG between open pastures and silvopastures grazed by crossbred beef heifers. That ADG was similar for all treatments in 2008 suggests that black walnut-based silvopasture systems can be as productive as open systems. However, using these trees likely will require greater management in order to maintain levels of light and legumes capable of supporting suitable botanical composition and forage production

Conclusions

Honeylocust silvopastures supported animal output similar to open pastures, and these systems show great promise for temperate hardwood silvopastures in the Appalachian region. Forage production and nutritive value were similar to open pastures allowing for similar animal output. Future research should focus on the potential of fodder crop as concentrate supplemental feed.

Black walnut silvopasture systems performed well in 2008 with similar animal production despite somewhat lower forage yields. Black walnut silvopastures performed poorly in 2009; forage production was lower and ADG was accordingly compromised.

Changes in forage species contained in black walnut silvopastures was likely a contributing factor. Further research on tree management and suitable forage species for black walnut silvopastures may be required to produce similar production as honeylocust silvopastures and open pasture systems.

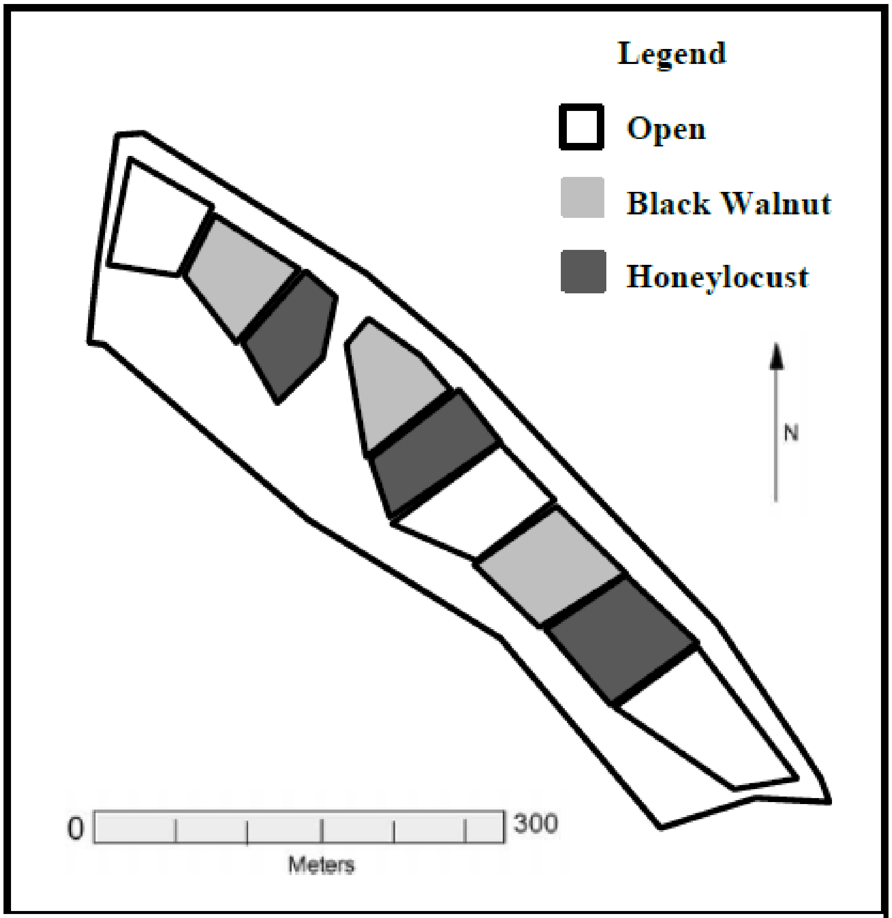

Figure 3.1. Schematic of the silvopasture research plots at Virginia Tech's Kentland Farm.

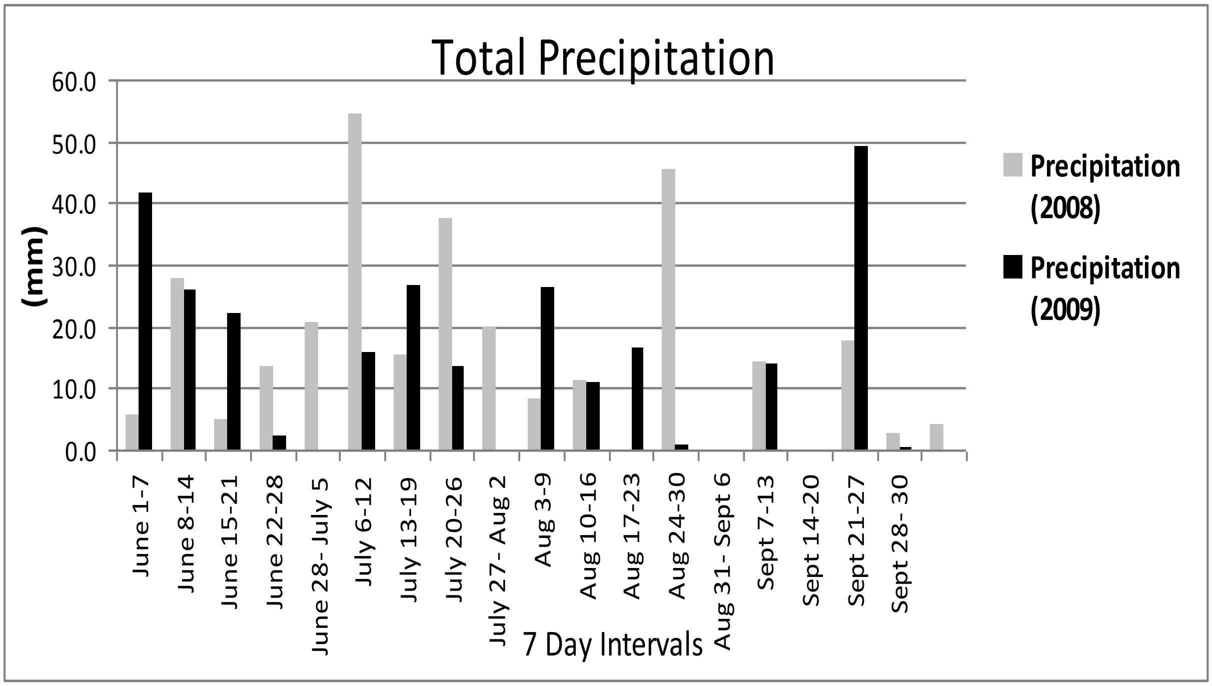

Figure 3.2. Total precipitation (mm) at Kentland Farms during 2008 and 2009 grazing seasons.

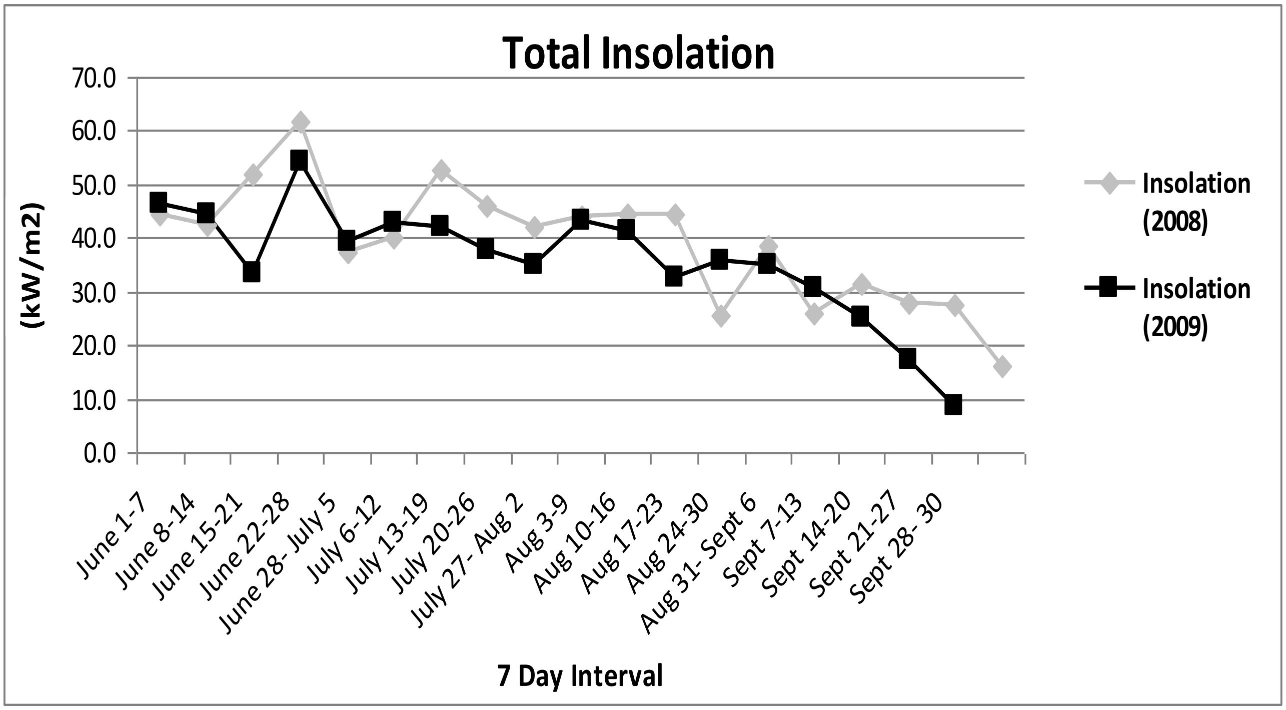

Figure 3.3. Total insolation (kw/m^2) at Kentland Farms during 2008 and 2009 grazing seasons.

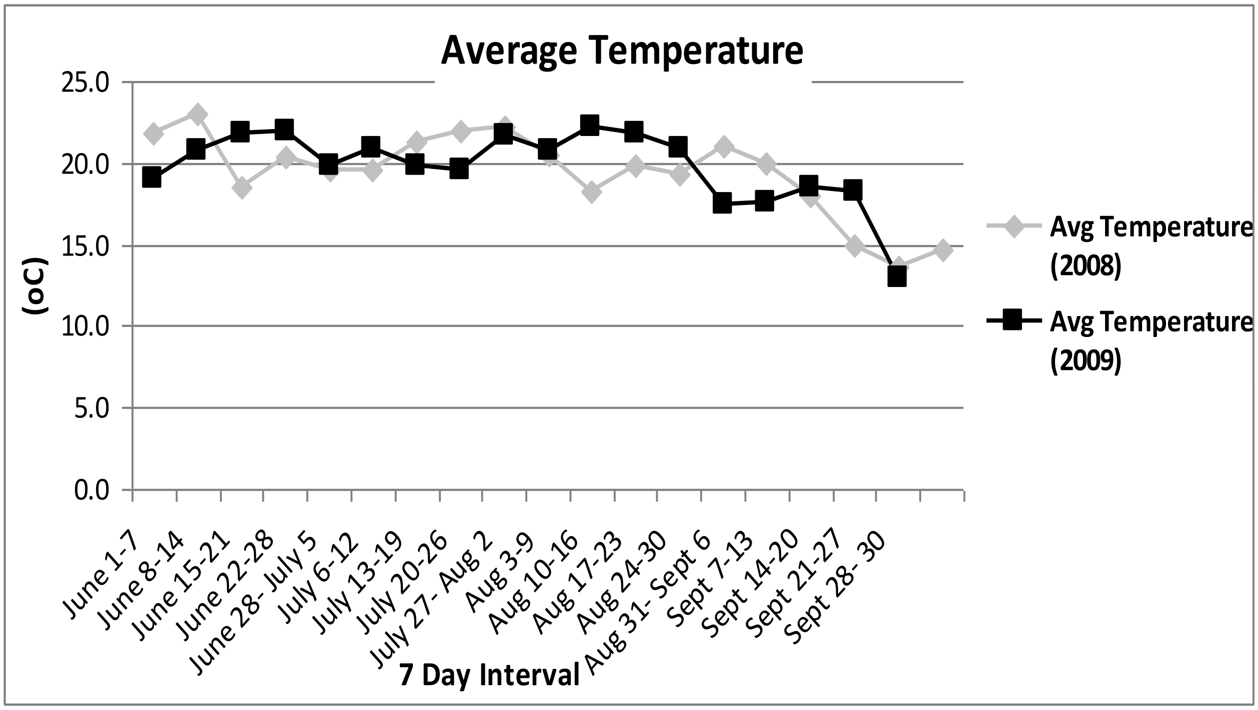

Figure 3.4. Average Temperature (^{0}C) at Kentland Farms during 2008 and 2009 grazing seasons.

Table 3.1. Mean botanical composition scores of species cover† within pasture systems collected in May 2009.

Species	Open‡	BW	HL	SE	Contrast *P* value	
					Open vs. silvo	**BW vs. HL**
Tall fescue	5.00	4.00	4.51	0.17	0.9527	0.0055
Kentucky bluegrass	2.91	4.10	2.79	0.36	0.1532	0.0486
Orchardgrass	2.93	2.72	2.87	0.28	0.8943	0.6036
White clover	0.75	1.50	0.73	0.34	0.3587	0.1345
Red clover	2.22	0.86	3.39	0.31	0.0009	0.0124
Field clover	0.17	0.91	0.36	0.20	0.5057	0.0255
Broadleaf weed	0.27	1.17	0.28	0.47	0.4787	0.2269
Sweet vernalgrass	0	0.44	0	0.07	0.0280	0.0006
Nimblewill	0	0.44	0	0.10	0.1134	0.0130
Bromus spp.	0	0.50	0.26	0.19	0.2850	0.0721

†Species cover was defined as: Dominant – > 50% of species cover; Abundant – 30 to 50% cover; Frequent – ; Observed – ; Rare – a few scattered plants.. This "DAFOR" (Dominant, Abundant, Frequent, Observed, and Rare) scoring system and quantified by enumerating on a 5-point (5 = dominant, 1 = rare) scale. (Averages are weighted by 0 values when a given species was not observed.)

‡Open pastures, black walnut (BW) and honeylocust (HL) silvopasture (silvo) treatments.

Table 3.2. Pre- and post-graze forage mass (kg ha^{-1}) of open pastures and black walnut (BW) and honeylocust (HL) silvopasture (silvo) treatments in 2008 and 2009.

Period†		Open‡	BW	HL	SE	Contrast P-values: Open vs. Tree	Contrast P-values: BW vs. HL
		— g kg^{-1} of dry matter—					
2008							
Pre	Early	3510	3180	3410	226	0.3313	0.7556
	Mid	3270	2840	3270	249	0.3546	0.5275
	Late	2590	2110	2360	149	0.0699	0.3280
	Season	3090	2690	2920	139	0.0957	0.3966
Post	Early	2410	2200	2340	111	0.2418	0.6427
	Mid	2110	1960	2170	105	0.1970	0.6971
	Late	1960	1650	1860	73	0.0156	0.3539
	Season	2160	1940	2120	61	0.0114	0.6921
2009							
Pre	Early	4510	3660	3950	187	0.0281	0.0541
	Mid	3600	2770	3110	140	0.0043	0.0279
	Late	2670	2160	2290	55	0.0009	0.0006
	Season	3590	2860	3120	92	0.0001	0.0008
Post	Early	2780	2410	2530	65	0.0056	0.0135
	Mid	2290	1900	2090	128	0.0998	0.2939
	Late	2330	1740	1850	41	<0.0001	<0.0001
	Season	2450	2000	2150	59	0.0002	0.0009

†Grazing trials were divided into early, mid- and late season periods which were from approximately mid-June to mid-July, mid-July to mid-August, and mid-August to mid-September.

‡Open pastures, black walnut (BW) and honeylocust (HL) silvopasture (silvo) treatments.

Table 3.3. Average nutritive value concentrations of forages grown in open pastures and black walnut (BW) and honeylocust (HL) silvopasture (silvo) treatments grazed by sheep in 2008 and 2009.

						Contrast P-values	
Item†	**Period‡**	**Open**	**BW**	**HL**	**SE**	**Open vs. Silvo**	**BW vs. HL**
		— g kg^{-1} of dry matter—					
NDF	Early	498	549	491	11.5	0.1466	0.0031
	Mid	474	529	505	11.8	0.0240	0.1870
	Late	538	560	547	9.7	0.2429	0.3658
	Seasonal	504	547	514	10.3	0.0777	0.0661
ADF	Early	263	282	266	7.0	0.2406	0.1486
	Mid	252	268	269	5.9	0.0604	0.9327
	Late	274	281	268	4.1	0.8960	0.0549
	Seasonal	263	277	268	5.0	0.1694	0.2284
Hemi	Early	235	267	225	9.2	0.3500	0.0049
	Mid	222	261	235	7.6	0.0288	0.0551
	Late	279	265	279	6.7	0.1311	0.9831
	Seasonal	241	270	247	7.1	0.0960	0.0607
ADL	Early	34.8	36.7	33.0	2.30	0.9739	0.2851
	Mid	29.6	31.6	31.9	1.00	0.1281	0.8009
	Late	29.8	34.7	31.9	1.30	0.0715	0.1911
	Seasonal	31.2	34.2	32.2	0.84	0.1003	0.1394
CP	Early	121	127	122	4.8	0.5215	0.5305
	Mid	131	127	130	4.8	0.6968	0.6975
	Late	129	127	127	3.2	0.6601	0.9022
	Seasonal	127	127	126	3.0	0.9784	0.8936
IVTD	Early	740	745	727	12.4	0.7971	0.3126
	Mid	739	743	745	13.2	0.7769	0.8965
	Late	728	696	722	10.7	0.1935	0.1291
	Seasonal	736	732	727	9.1	0.6109	0.7544
NDFD	Early	249	304	225	19.9	0.5408	0.0294
	Mid	223	281	260	13.1	0.0261	0.2854
	Late	276	265	278	13.7	0.7823	0.5125
	Seasonal	249	283	255	12.4	0.2326	0.1653

† NDF = neutral detergent fiber; ADF = acid detergent fiber; Hemi = hemicellulose; ADL = acid detergent lignin; CP = crude protein; IVTD = in-vitro true digestibility; NDFD = neutral detergent fiber digestibility.

‡ Grazing trials were divided into early, mid- and late season periods which were from approximately mid-June to mid-July, mid-July to mid-August, and mid-August to mid-September.

Table 3.4. Average daily gain of crossbred hair sheep lambs grazing in open pastures and black walnut (BW) and honeylocust (HL) silvopasture (silvo) treatments in 2008 and 2009.

Period†	Open‡	BW	HL	SE	Contrast P value	
2008 ADG		kg/ day			Open vs. Silvo	BW vs. HL
Early	0.11	0.13	0.13	0.02	0.7488	0.4374
Mid	0.11	0.11	0.11	0.01	0.8330	0.6702
Late	0.02	0.03	0.04	0.007	0.0588	0.3329
Season	0.08	0.09	0.09	0.009	0.5234	0.5739
2009 ADG						
Early	0.02	0.03	0.05	0.02	0.2220	0.5339
Mid	0.13	0.11	0.11	0.01	0.7797	0.3848
Late	0.08	0.01	0.07	0.01	0.1540	0.0078
Season	0.07	0.05	0.08	0.007	0.0768	0.0513
Total Gain		kg				
2008	49.8	46.8	49.3	3.25	0.8030	0.5455
2009	41.6	24.2	40.1	4.80	0.0705	0.0068

†Grazing trials were divided into early, mid- and late season periods which were from approximately mid-June to mid-July, mid-July to mid-August, and mid-August to mid-September.

‡Open pastures, black walnut (BW) and honeylocust (HL) silvopasture (silvo) treatments.

Figure 3.3. Lamb consuming pods that have dropped from honeylocust trees.

Chapter 4: Carcass Characteristics and Meat Quality of Hair Sheep Grazing in an Appalachian, Deciduous Silvopasture

Abstract

Silvopastoral management has potential to diversify and increase the output from livestock production systems. Silvopasture production offers solutions to many management issues associated with grazing systems in the Appalachian region. Several tree species have been proposed for silvopastures in humid temperate regions, but little data comparing animal performance from systems with different deciduous tree species are available. Forage and animal performance was compared from open systems (*i.e.*, no trees) with that from silvopastures containing 13-yr-old honeylocust (*Gleditsia triacanthos*) or black walnut (*Juglans nigra*) trees. Cool-season grass-legume pastures were rotationally stocked with hair sheep crosses from mid-June through September. The objective of this project was to determine carcass characteristics and meat quality of hair sheep crosses grazing honey locust or black walnut silvopastures in comparison with traditional pasture systems.

Carcass characteristics evaluated did not vary among treatments except hot carcass weight with black walnut had lower hot carcass weight ($P=.0045$). All treatments received similar quality grades of good. Meat quality characteristics did not vary among treatments. Shear force and fat content showed great differences and varied by year. Overall, carcass and meat quality was similar for all treatments showing great promise for silvopastures.

Hypothesis

Honeylocust and black walnut silvopastures can support similar carcass quality and meat quality as traditional open pasture systems when grazed by hair sheep.

Objectives

The objectives of this experiment were to compare:

1) Carcass quality of hair sheep lambs that grazed honeylocust and black walnut silvopastures with those that grazed open pastures.
2) Meat quality of lambs that grazed honeylocust and black walnut silvopastures with those that grazed open pastures.

Methods and Materials

Animal Handling and Carcass Evaluation

Lambs were handled according to Virginia Tech's IACUC protocols following committee approval (07-070-CSES). The lambs were weighed about every 32 days during each season and ADG was calculated as seasonal gain divided by total seasonal grazing days. After the final weighing, the mean weight of all lambs within an experimental unit (i.e., pasture) was calculated. Two animals were lost from the analysis in 2009 due to coyote predation. Similar sized animals were used as replacements to maintain stocking rates among treatments. A third animal on trial was removed from the analysis due to our inability to successfully treat for internal parasites. Two additional animals were missed during ultra-sound analysis.

Longissimus muscle area (LMA) and backfat thickness (BF) were measured at the completion of each grazing trial using ultra-sound. The same technician scanned all lambs in the study. Scans were performed on the right side of the lambs between the 12th and 13th ribs using an Aloka 500 ultrasound machine (Corometrics Medical Systems, Wallingford, CT) set at 2× magnification and equipped with an 11-cm, 3.5-mHz transducer. The transducer was fitted with a Superflab standoff guide (Mick Radio-Nuclear Instruments Inc., Mt. Vernon, NY) to ensure proper contact with the animals and minimize tissue distortion in the images. Lambs were held in a relaxed position by an assistant, wool was shorn from the scan site, and vegetable oil was applied as a couplant to obtain adequate acoustic contact. An image deemed suitable by the technician was captured and recorded to a laptop computer. Images were interpreted by the scan technician using Rib-O-Matic Version 2.0 software (Critical Visions Inc., Atlanta, GA). The perimeter of the LM was traced to determine LMA, and BF was measured at the midpoint of the LM. Two independent interpretations were made for each image, and resulting values were averaged before analysis.

After the final weighing, the mean weight of all lambs within an experimental unit (i.e., pasture) was calculated. The two sheep whose weights were closest to the group mean for each experimental unit were selected from each pasture for harvest at the Virginia Tech Meats Lab. Lambs were rendered unconscious and insensitive to pain by captive-bolt. After stunning, lambs were harvested according to industry-accepted procedures. Carcass quality grade data were then collected by an experienced evaluator in accordance with grading standards for young lambs (USDA, 1992).

Following evaluation, carcasses were ribbed between the twelfth and thirteenth thoracic vertebrae and yield grade data were collected. Bodywall thickness was measured 7.5 cm distal to the ventral end of the longissimus thoracic (LT) muscle. Back fat thickness was measured on 12^{th} rib and backfat thickness assessed at three sites on the rib by metal ruler, and longissimus muscle area was measured with a plastic grid. A leg score for each lamb (defined as Prime, Choice, and Good) was determined by graders based upon muscling and coded by a number ranging with 15=Prime+ to 7=Good-. Quality grades were assigned to each carcass based upon characteristics of the lean muscle and carcass conformation and defined as Prime, Choice, Good and Utility. Quality grade was coded by number for statistic analysis with 10=Choice -, 9= High Good, and 8=Low Good.

Meat Evaluation

Subsamples of the loin and rib were collected, vacuumed packed, and frozen. These subsamples were sent to the USDA-ARS Meat Science Research Laboratory (Beltsville, MD, USA) for further analysis. The frozen loin primal cuts were sectioned into 2.5-cm-thick loin chops. Two non-adjacent chops per loin were designated for proximate analysis and 4 to 6 chops per loin were utilized for texture analysis. All chops were vacuum-packaged and stored at -20°C until analyzed.

The chops utilized for proximate analysis were tempered, the longissimus muscle was separated from the chop, and the subcutaneous fat and epimysial tissue were removed from the muscle sample. The muscle sample was then finely minced while slightly frozen. Moisture and fat contents were determined using the oven drying method (AOAC procedures 960.39 and 945.16A) using petroleum ether in a Soxhlet apparatus. Assuming 1% ash content in the muscle, the protein percent was calculated as: protein (%)= 99 – (moisture + fat). Proximate analyses assays were performed in triplicate.

Chops utilized for texture analysis were thawed overnight at 4 ºC and the longissimus muscle was removed and trimmed free of fat. Samples were grilled on a covered electric grill (GRR50, 1600W, Salton Maxim Housewares, Inc., Mt. Prospect, Ill., U. S. A.) using the maximum heat setting (270 ± 5 ºC). Samples were turned once when the internal temperature reached 39 ºC and grilling was continued to a 71 ºC endpoint. Temperature was continuously monitored throughout grilling using a micro-processor thermometer (HH21, Omega Engineering, Stamford, Conn., U. S. A.) with a Type-J thermocouple inserted into the geometric center of the sample. Cooked samples were cooled to room temperature before determining tenderness instrumentally by shear force. Cores for Warner-Bratzler shear force (WBSF) were removed parallel to muscle fiber direction using a coring tool (1.27 cm inside diameter) and sheared one time using a texture measurement system (TMS-90, Food Technology Corp., Chantilly, VA, USA). Due to the small size of the chops, only 2 or 3 cores could be obtained. WBSF was measured at room temperature using a Warner-Bratzler meat shear cell with an inverted-V cutout blade, 1.18 mm thick, at crosshead speed of 3.8 mm/s. Shear force was recorded in kg and reported as the average shear force for the 4 to 6 chops from each loin.

Statistics Analysis

The model was randomized complete block design with three replications. Experimental units included open pastures, black walnut pastures, and honeylocust pastures. Data were analyzed using a mixed model ANOVA with PROC MIXED of SAS, v. 9.2 (SAS Inst. Inc., Cary, NC) to test effects of treatments on carcass and meat quality parameters. Orthogonal contrasts were used to compare open vs. silvopasture treatments and black walnut vs. honeylocust treatments. Treatments were considered different at $P < 0.05$ and trends are reported, where appropriate, for $P < 0.1$. Data will be presented by year when a year×treatment occurs with $P<0.1$.

Results

Carcass Evaluation

Backfat thickness and longissimus muscle area was measured by ultrasound for all animals on trial excluding those mentioned above. Carcass evaluation measurements included live weight, hot carcass weight, backfat thickness, longissimus muscle area, body wall thickness, leg confirmation grade, and quality grade for the selected animals. Carcass data presented (Table 4.1) are two-year means as no year×treatment interactions were observed.

Ultrasound analysis of backfat thickness and longissimus muscle area did not differ among treatments ($P>0.1$). Backfat thickness, bodywall thickness, longissimus muscle area, leg score, and quality grade of all treatments from carcass evaluation did not differ among treatments ($P>0.1$). Although differences in live weight for each experimental unit were observed (Fannon, Chapter 3), lambs selected for carcass evaluation were chosen for being near the mean group weight. Thus, live weights of lambs selected for carcass evaluation did not differ ($P>0.1$). However, hot carcass weight was lower ($P=0.0045$) for lambs from black walnut silvopastures. Over the two years of study, hot carcass weights were about 1.5 kg lower for animals that had grazed black walnut silvopastures compared with those that grazed open or honeylocust silvopastures.

Meat Quality

Meat quality analyses included cooking yield percent, percent protein, percent moisture, and shear force (Table 4.2). Cooking yield, moisture, and protein data are presented as two year averages because year×treatment interactions were not observed.

Cooking yield, moisture, and protein did not differ among treatments (*P*>0.1). Fat and shear force data differed by year (*P*<0.001) and it could not be determined if the lab conducted tests on loins or ribs in both years. Thus, although treatments had no effects fat or shear force; data are presented by year given the large year-to-year differences.

Discussion

Carcass Evaluation

Lamb live weights did not different among treatments. However, the lower hot carcass weights for animals that grazed black walnut silvopastures suggest that these animals had greater fill. Such an interpretation and would agree with previous findings of Fannon (Chapter 3) in which forages from black walnut silvopastures generally had elevated NDF concentrations.

All carcasses attributes (leg score, body wall, backfat thickness, and longissimus muscle area) which help make up the quality grade were similar among treatments including those found from ultrasound. Quality grade reflects the eating satisfaction or palatability expected and takes into account carcass characteristics (USDA, 1992). Quality grades include the ratings 'prime', 'choice', 'good' and 'utility', which are in order of best to least quality (USDA, 1992). Lamb carcasses from all treatments averaged good, indicating that silvopastures can support productivity and quality similar to open (traditional) treatments.

Quality grades were lower than commonly desired for retail meat markets but were typical for pasture-fed lambs without supplements, particularly hair sheep. Other studies in which supplements or concentrate diets have been fed have found better carcass quality for Katahdin lambs. Burke et al. (2003) reported higher quality grades for Katahdin lambs fed high protein diets than compared to this study. However, high protein diets require more input costs. This establishes the merits for the use honeylocust pods in grazing situations and further study of their effect on carcass characteristics.

Meat Quality

The lack of meat quality differences among experimental treatments indicates that silvopasture production systems can effectively support meat production as well as can traditional, open pasture systems. Meat quality measures conducted by the USDA's Meat Science Research Laboratory to evaluate fat content and shear force were apparently conducted on two different cuts of meat. Thus, comparisons of fat percent and shear force over years were not conducted. Meat quality data from our study were similar to other data in the literature. For example, Burke and Apple (2007) reported that Katahdin lambs that grazed pasture and were fed protein supplements had meat cooking yield of 70.4% and Warner-Bratzler shear force values of 4 kg. Organoleptic characteristics of lamb meats were not studied with this research; whether browsing tree species and products affected meat flavors remains to be explored.

Conclusions

Animals from all pasture treatments were lean. Lambs that grazed in black walnut silvopastures had lower hot carcass weights compared to lambs that grazed honeylocust and open pasture treatments, but no measures of carcass quality or meat quality were different by pasture treatment. These data and those of Fannon (Chapter 3) suggest that black walnut silvopastures may require more management (e.g., lower tree density, greater tree trimming, alternative forage species and greater fertility inputs among others) in order to maintain levels of performance similar to that of open pasture systems. Honeylocust silvopastures supported production of hot carcass weights and meat characteristics similar to open treatments. These data establish honeylocust as a strong candidate tree for future silvopasture systems research and development. Overall, both silvopasture treatments produced similar results in carcass and meat quality compared to open (traditional) pasture treatments. Hence, livestock production in terms of meat and carcass quality will not be hindered upon adopting silvopasture grazing systems. Further economic research is needed to compare the value of these systems based on labor inputs and economic outputs (timber, nuts, and pods) associated with these tree species.

Table 4.1. Carcass characteristics of lambs grazing open pastures (Open) and black walnut (BW) and honeylocust (HL) silvopasture (silvo) treatments in 2008 and 2009.

					Contrast P-values	
Measurement	Open‡	BW	HL	SE	Open vs. Silvo	BW vs. HL
Ultrasound						
Backfat, mm	2.21	2.15	2.34	0.12	0.8450	0.2666
Longissimus Area, cm^2	8.94	8.58	9.22	0.34	0.9308	0.1973
Carcass Evaluation						
Live Weight, kg	33.1	32.0	33.5	0.6	0.6658	0.1050
Hot Carcass, kg	16.2	14.8	16.4	0.4	0.2229	0.0045
Backfat, mm	1.55	1.63	1.21	0.22	0.5974	0.1482
Bodywall, mm	8.83	7.98	8.40	0.47	0.2954	0.5498
Longissimus Area , cm^2	10.18	9.45	9.50	0.47	0.3945	0.2573
Leg Score	9.67	9.45	9.5	0.21	0.4643	0.8803
Quality Grade	9.25	8.73	9.08	0.22	0.2244	0.2827

‡Open pastures, black walnut (BW) and honeylocust (HL) silvopasture (silvo) treatments.

Table 4.2. Meat characteristics of hair sheep grazing in open pastures and black walnut (BW) and honeylocust (HL) silvopasture (silvo) treatments in 2008 and 2009.

	Open‡	BW	HL	SE	Contrast P-values	
					Open vs. Tree	BW vs. HL
2-Year Avg						
Cooking Yield,%	75.15	75.08	75.83	0.88	0.7804	0.5571
Moisture,%	75.41	75.98	75.06	0.41	0.8346	0.1232
Protein,%	20.68	20.30	21.03	0.31	0.9621	0.1035
2008						
Fat,%	1.91	1.61	1.99	0.24	0.7259	0.3004
Shear Force, kg	7.58	7.28	8.37	0.88	0.8236	0.4035
2009						
Fat,%	3.89	4.07	3.67	0.48	0.9650	0.5413
Shear Force, kg	2.59	2.67	2.34	0.26	0.7999	0.3616

‡Open pastures, black walnut (BW) and honeylocust (HL) silvopasture (silvo) treatments.

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Appendices: Kentland Farm Silvopasture PAR Late Summer 2008

These plots are for data taken between August 8 and 19 for toe slopes and between August 19 and 29 for shoulder slope positions. Photosynthetically active radiation (PAR) was measured using LI-COR LI-191-SB line quantum sensors (LI-COR inc., Lincoln, NE) with values measured every 10 s and plotted as hourly averages. Data were collected using 21X data loggers (Campbell Scientific, Logan UT). There were 16 sensors used during each measurement period: 8 within black walnut and 8 within honey locust plots. Two replicate sensors (4 m apart) were installed at 4 locations within each plot, (east side 3 m from north-south tree row, within tree row, west side 3 m from tree row, and mid-alley, which was 6 m from tree rows).

Data from the Kentland Farm weather station were analyzed to find the highest hourly average solar radiation and matched to corresponding PAR values for those measurement periods. The respective highest hourly values were used to plot a composite sunniest day for each tree-landscape position site. All PAR sensors were calibrated and raw data normalized for sensor differences.

Total daily PAR (mol m^{-2} d^{-1}) in the open was estimated from weather data solar radiation values by totaling the constructed sunny day hourly values and multiplying by 1000 X 2 X 3600 / 1000000 (which is times 7.2)

These data provide a preliminary description of differences among treatments during sunny weather. Additional analyses of the raw data – e.g., testing differences under low light conditions – may also be useful.

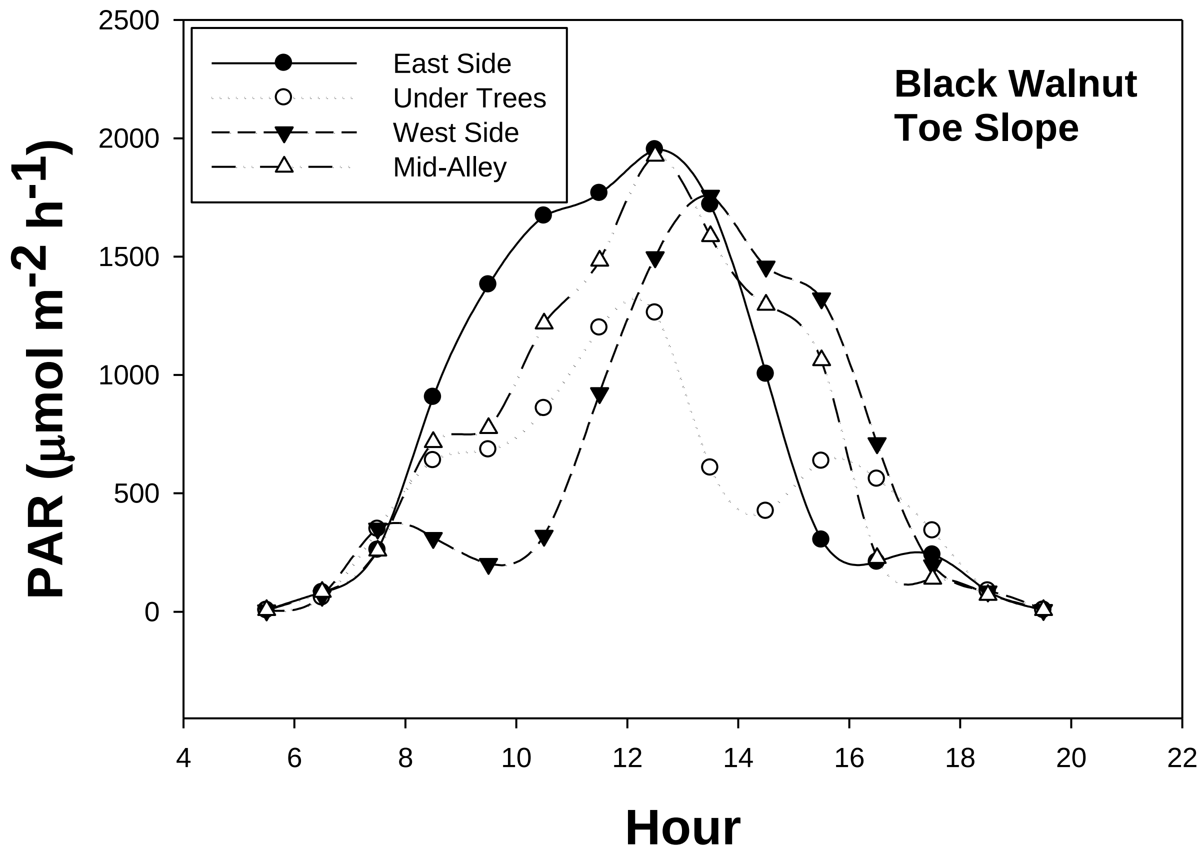

Figure A.1. Photosynthetically active radiation (PAR) of black walnut silvopasture at the toe slope position in 2008.

Table A.1. Total daily photosynthetically active radiation (PAR) and % PAR compared to open for black walnut silvopasture at the toe slope position in 2008.

	Total Daily PAR	% of open
East Side	41.7	74.4
Under Tree	27.8	49.4
West Side	33.2	59.2
Mid-Alley	39.1	69.7

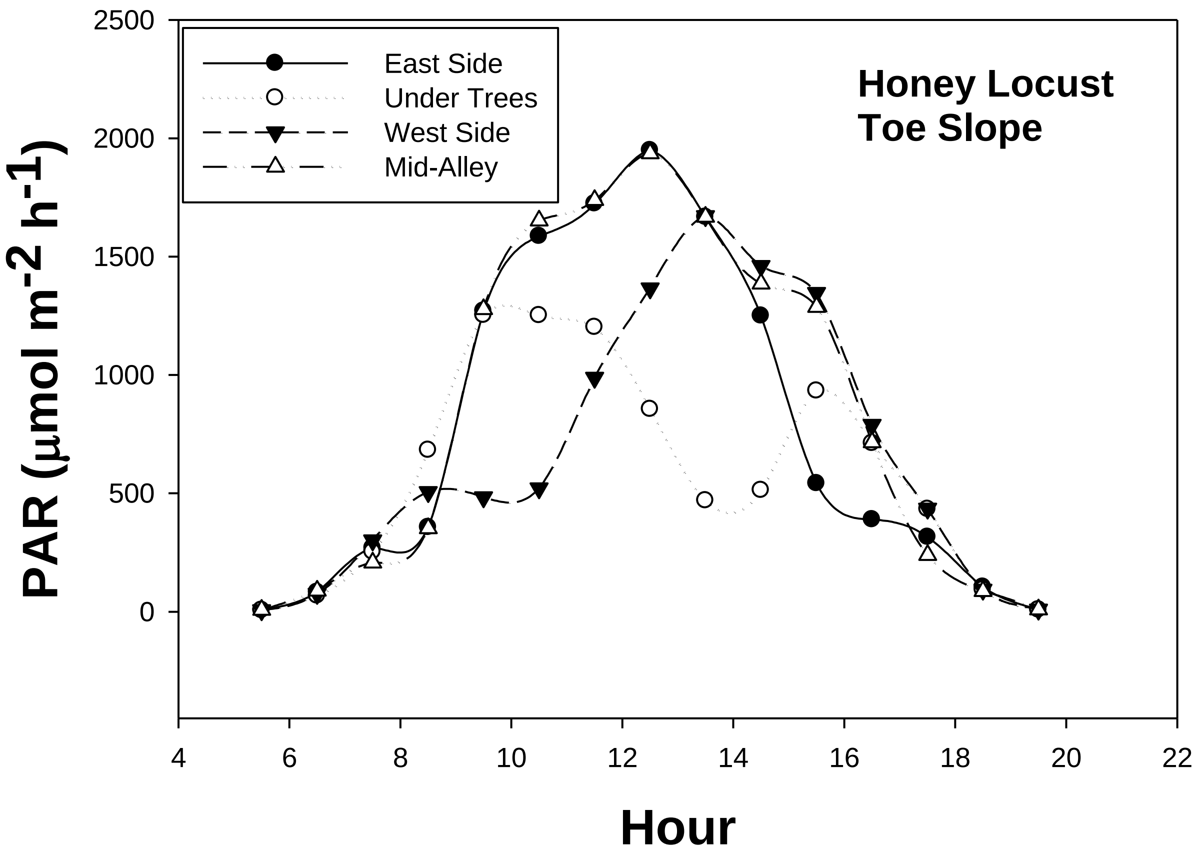

Figure A.2. Photosynthetically active radiation (PAR) of honeylocust silvopasture at the toe slope position in 2008.

Table A.2. Total daily photosynthetically active radiation (PAR) and % PAR compared to open for honeylocust silvopasture at the toe slope position in 2008.

	Total Daily PAR	% of open
East Side	41.5	73.9
Under Tree	31.4	56.0
West Side	36.2	64.5
Mid-Alley	45.5	81.2

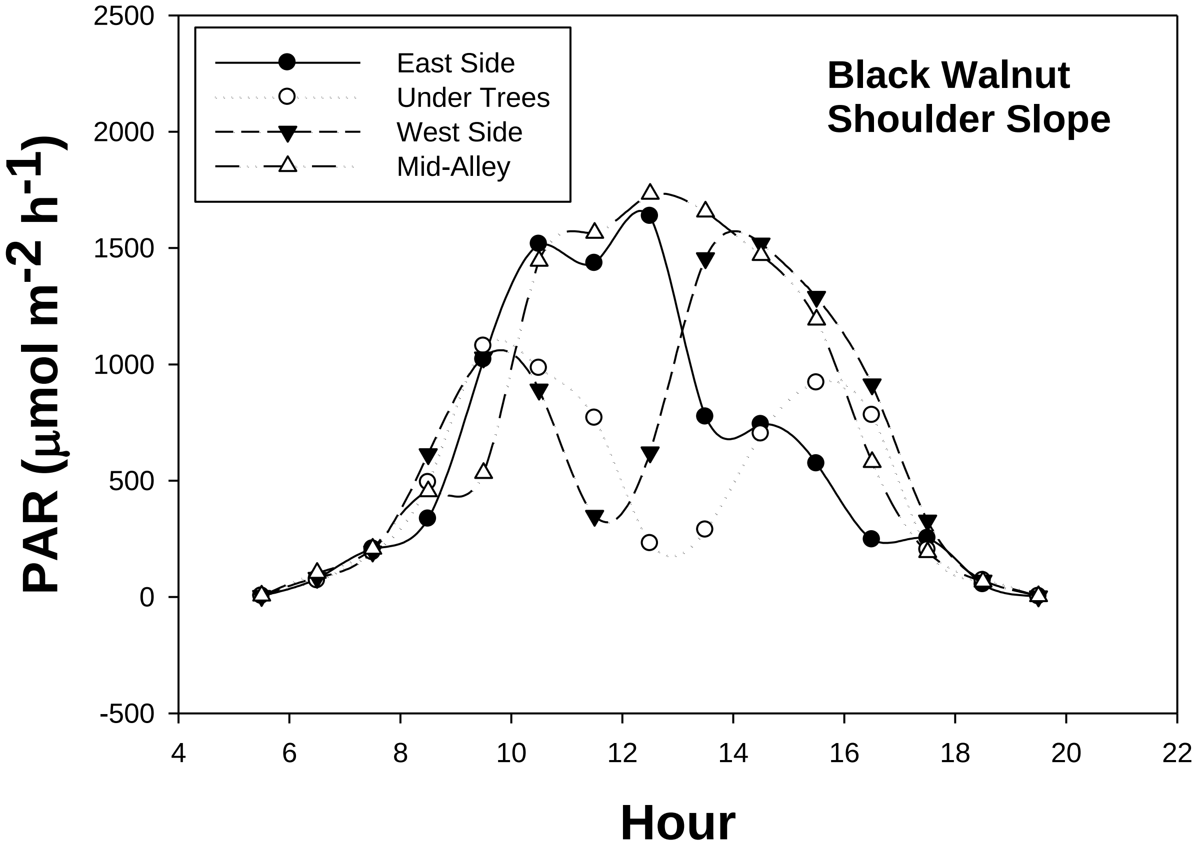

Figure A.3. Photosynthetically active radiation (PAR) of black walnut silvopasture at the shoulder slope position in 2008.

Table A.3. Total daily photosynthetically active radiation (PAR) and % PAR compared to open for black walnut silvopasture at the shoulder slope position in 2008.

	Total Daily PAR	% of open
East Side	31.9	59.4
Under Tree	24.4	45.4
West Side	33.7	62.7
Mid-Alley	40.3	74.9

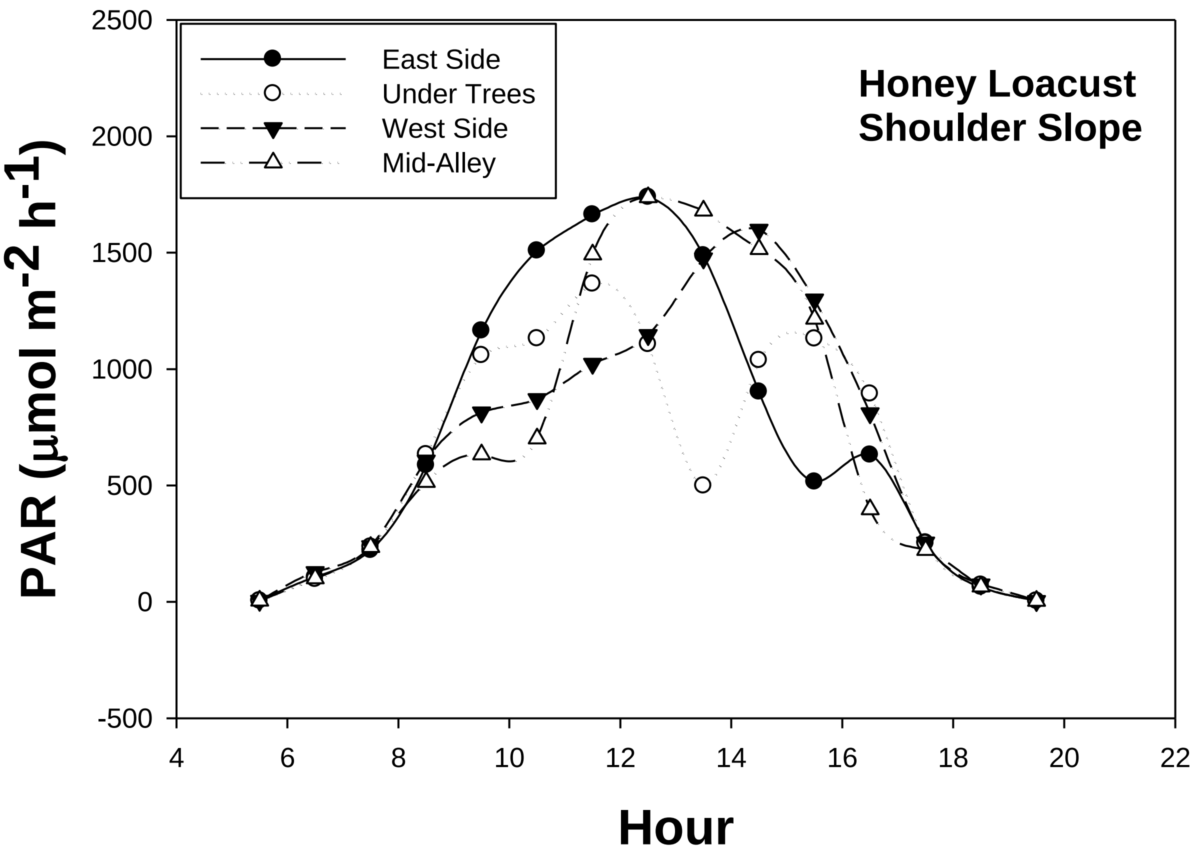

Figure A.4. Photosynthetically active radiation (PAR) of honeylocust silvopasture at the shoulder slope position in 2008.

Table A.4. Total daily photosynthetically active radiation (PAR) and % PAR compared to open for honeylocust silvopasture at the shoulder slope position in 2008.

	Total Daily PAR	% of open
East Side	39.1	72.6
Under Tree	34.3	63.7
West Side	37.3	69.2
Mid-Alley	37.9	70.4