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Lamb productivity on stockpiled fescue in honeylocust and black walnut silvopastures

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Abstract Trees in silvopastures can provide forage-livestock systems with multiple goods and services, including shade, shelter, and browse, but the provision of browse has received little exploration in temperate systems. Honeylocust trees (*Gleditsia triacanthos*) produce nutritious pods that could serve as supplemental fodder for livestock grazing stockpiled tall fescue (*Schedonorus arundinaceus*). This study compared lamb performance in honeylocust (cv. Millwood) and black walnut (*Juglans nigra*) silvopastures with productivity on open pastures during a six week winter grazing trial. Treatment pastures were rotationally stocked with three (walnut) or six (honeylocust and open) lambs per experimental unit based on forage availability. Lambs were naïve to pods and did not readily consume the fodder until four weeks into the trial. Forage availability did not differ ($P = 0.7580$) between honeylocust silvopastures and open pastures (mean = 5090 $\pm$ 90 kg ha^{-1}) but was greater ($P < 0.0001$) than forage availability in the black walnut silvopastures (3790 $\pm$ 90 kg ha^{-1}). Average daily gains did not differ ($P = 0.3763$) among treatments over the six weeks of study. However, lambs within the honeylocust silvopastures began consuming pods at about week four of the study and had greater ($P = 0.0251$) average daily gains in the final period (0.12 $\pm$ 0.02 kg day^{-1}) than lambs within the open pastures (0 $\pm$ 0.02 kg day^{-1}). These data suggest that honeylocust pods may support greater lamb weight gains, but previous exposure and longer study periods may be necessary to see their nutritional benefit when grazing high quality forages.

Keywords Fodder · Honeylocust · Sheep · Silvopasture · Stockpile · Winter

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Introduction

Along with ecosystem service supporting (e.g., water infiltration, nutrient cycling, and carbon sequestration), trees in silvopastures may provide forage-livestock systems with multiple goods and services, including shade, shelter, and browse (Sharrow et al. 2009). Species such as black walnut (*Juglans nigra*) and honeylocust (*Gleditsia triacanthos*) trees may be particularly well-suited for use in cool-season pasture systems because of their leaf morphology and phenology. Their compound leaf arrangement may allow more sunlight to reach the forage understory than do simple leaf arrangements, and their distinct warm-season growth pattern complements the bimodal spring and fall growth pattern of cool-season forages (Scanlon 1980; Sharrow et al. 2009). Honeylocust trees also produce edible fodder. Leaves produced by the trees are often preferred to clovers (our observation) and its pods are highly nutritious (Foroughbakhch et al. 2006; Johnson et al. 2012, 2013). Honeylocust pods drop in early winter when forage production has otherwise ceased in temperate regions, and thus could provide livestock with a supplementary or alternative feed source on pasture (Scanlon 1980; Wilson 1991; Johnson et al. 2013). Improved varieties of honeylocust trees (e.g., 'Millwood') yield pods of greater size and with greater nonstructural carbohydrate content than those pods produced by unimproved honeylocust trees (Scanlon 1980; Johnson et al. 2013).

Silvopasture practitioners seek to enhance the interactions among system components to increase or optimize services provided by the land. Combining an energy-rich feed, such as honeylocust pods, with a protein-rich feed, such as cool-season forages represents one such beneficial interaction. The associative effect—when the effect of the combination is greater than the sum of the individual effects—of supplementing pasture-fed livestock with corn is well documented (Dixon and Stockdale 1999; Moore et al. 1999). Previous research has demonstrated the nutritional similarity of Millwood honeylocust pods to whole ear corn (Wilson 1991; Johnson et al. 2013), and early studies documented that honeylocust pods could replace oats (*Avena sativa*) in dairy cows rations (Atkins 1942). It was hypothesized that providing honeylocust pods to sheep in combination with cool-season forages would result in greater live weight gains and decreased forage consumption.

Materials and methods

All procedures were approved by the Virginia Tech Institutional Animal Care and Use Committee (Protocol No. 15-182).

Research site

This six-week winter grazing study took place in 2015 at the Whitethorne Agroforestry Demonstration Center at Virginia Tech's Kentland Farm in Blacksburg, Virginia (37.20 N 80.58 W).

Pasture management

The two silvopasture treatments included either black walnut or honeylocust trees established in 1995 and thinned to an approximate 12.2 m by 12.2 m configuration, with about 90 stems ha^{-1} in 2012. Open and silvopasture treatments were replicated three times across the site in a randomized complete block design. The total area of each experimental unit (EU) was 0.27 ha EU^{-1}, and each EU was subdivided into four subpaddocks for rotational stocking.

Pastures were uniform at tree planting in 1995. Over time, however, tree species affected forage composition, and at the time of the study the open and honeylocust systems were dominated by tall fescue and endophyte infection rates were greater than 75% across all treatments. Walnut systems had abundant fescue but also large amounts of orchardgrass, as well as annual grasses. However, tall fescue was the predominant forage available to lambs grazing in the walnut systems throughout the duration of this study.

Prior to the study, lambs were rotationally stocked on the pastures until the end of August, 2015, and all pastures were stocked according to forage availability. Pastures then were clipped to 13 cm with a rotary mower in preparation for stockpiling. In early September, all black walnut silvopasture systems and the open system in block one were treated with 5 L ha^{-1} of Weedar 64 (2,4-D amine; Nufarm Ltd., Laverton, Australia) to control stickweed (*Verbesina occidentalis*) using a boom sprayer. Any large areas of stickweed present in the other systems were spot-sprayed with the same herbicide mixture using a backpack sprayer. Due to thin stands and presence of undesirable species in the black walnut silvopastures, 1.3 kg of tall fescue (cv. Kentucky 31) and 0.3 kg of orchardgrass (cv. Benchmark +) were broadcast over each black walnut silvopasture EU, then drag harrowed twice. All pastures were fertilized with urea at a rate of 67 kg ha^{-1} to support forage growth for stockpiling.

Sheep and stocking management

Crossbred lambs (n = 50; average weight = 36 kg) for the study were purchased from a local sheep producer. Upon arrival to the research site, lambs received a booster vaccination for *Clostridium perfringens* as well as 8 cc of Cydectin Oral Sheep Drench (Boehringer Ingelheim, Vetmedica, INC., St. Joseph, MO) and 7 cc of Prohibit Levamisole Drench solution (AgriLabs, St. Joseph, MO). Anemia was estimated using the FAMACHA protocol (Kaplan et al. 2004) about two weeks after treating lambs with anthelmintic. Any lamb with a score of 3 or greater received 7 cc of Prohibit Levamisole Drench solution (AgriLabs, St. Joseph, MO) and 10-cc of Panacur Sheep Drench (Intervet Inc., Merck Animal Health, Madison, NJ). Prior to study initiation, the lambs were fed ad libitum hay as a single group on open (non-treatment) pastures adjacent to the research site until study initiation.

Lambs were stratified by sex and body weight (BW) before being randomly assigned to each of the nine EU. Because of lower forage availability, all black walnut silvopastures were stocked with two ewes and one wether while each honeylocust silvopasture and open pasture was stocked with two ewes and four wethers.

Each EU was divided into four paddocks that were rotationally stocked with the assigned lambs on November 22, 2015. Sheep in all EUs were moved concurrently to ungrazed paddocks once average residual forage heights reached approximately 7 cm.

Commercial sheep mineral with Zinpro (Southern States Cooperative, Inc., Richmond, VA) and water was provided ad libitum to all lambs throughout the duration of the study.

Because lambs were naïve towards the honeylocust pods, several pods were cut into small pieces and mixed with roughly 0.5 kg of whole wheat grain. This mix was fed to each group of lambs within the honeylocust silvopastures. Lambs in the open pastures and black walnut silvopastures received feedings of 0.5 and 0.3 kg of whole wheat grain, respectively. Rations were refreshed when all the grain had been consumed by the sheep (November 23 and December 1, 5, and 9). Due to evidence of coccidiosis, lambs were fed 1.25% Corid pellets (Merial Inc., Duluth, GA) for five days (December 10–14) at a rate of 0.18 kg lamb^{-1} per day.

Lamb weight gains

A livestock crate mounted on load cells (Tru-Test, Ltd., Auckland, NZ) was used for weighing lambs. Lamb BW was determined as the average of two unshrunk BW measurements taken on two consecutive days at days 0 (November 21) and 1, 14 and 15, 28 and 29, and 42 and 43. Each of these two-week intervals was considered a single period.

Average daily gain (ADG) was calculated by dividing the average BW gain per period by 14 days. System gain was calculated as the average within-period BW gain of all healthy lambs in an EU times the total number of lambs in the EU. This approach was taken to correct for depressed gains in visibly sick animals and was used for two lambs at different dates. In one case, the recorded gains of one lamb exceeded reasonable gain and were excluded.

Forage mass

Forage availability and residual mass were estimated by taking 30 random measurements within each of the nine subpaddocks with a rising plate meter (Jenquip, Fielding, NZ) before and after each rotation. Estimates of pre- and post-graze forage mass were calibrated by collecting forage underneath the rising plate meter at three points within each paddock at alternate measurement events (Macoon et al. 2003). Estimates of average daily individual intake were calculated as the difference between pre- and post-graze herbage mass divided by the total number of animals in the EU and the number of days spent in the paddock.

Forage nutritive value

At every other rotation, pure tall fescue samples were collected between 1200 and 1400 h from each subpaddock before entry by lambs. Tall fescue was the primary forage available to and consumed by the lambs throughout this project in all treatments. Samples were cut at a 5 to 8 cm residual height. Samples were dried in a forced air oven at approximately 55 °C for at least four days. Dried samples were ground in a Wiley Mill (Thomas Scientific, Swedesboro, NJ) with a 2-mm screen followed by a Cyclotec Sample Mill (FOSS North America, Eden Prairie, MN) with a 1-mm screen. All samples were scanned with a FOSS 6500 Composite NIR

Spectrometer (FOSS North America, Eden Prairie, MN) using ISIscan software (FOSS North America, Eden Prairie, MN). The Hay and Fresh Forage Master Equation from WinISI software (FOSS North America, Eden Prairie, MN) was used to calculate percentages of CP, NDF and ADF. Concentrations of TDN were calculated as TDN = 1.118 × ADF.

Pod productivity

Any windblown honeylocust pods were removed from surrounding black walnut silvopasture or open pasture experimental units prior to the study. At three randomly-selected locations within each EU, pods were collected from 1-m^2 quadrats placed on the ground prior to entry by the lambs. Pod fresh weights were collected and then returned to the quadrats. Pod yield per hectare was calculated by multiplying the average of these three weights by 10,000. Post-graze pod weights were determined using the same procedure at the same points selected for the pre-graze measures. Pod consumption was calculated as pre-graze minus post-graze measures.

Statistical analysis

The rising plate meter regression was calculated using a linear function of sward height against forage mass of the double-samples with PROC REG in SAS Studio, v. 3.5 (SAS Inst., Cary, NC). All Cook's outliers calculated in the first iteration of the program were removed from the analysis. Pre- and post-graze herbage mass and intake estimates were calculated from the 30 random rising plate meter measurements using this equation.

A mixed ANOVA of ADG and system gain, pre- and post-graze forage herbage mass and intake estimates, and tall fescue CP, NDF, ADF, and TDN concentrations among treatments was calculated with PROC MIXED in SAS Studio, v. 3.5 (SAS Inst., Cary, NC). Experimental design was a randomized complete block design with three replications. Repeated measures analysis by period was used with a compound symmetry covariance structure for the analysis of ADG. LS-means, standard error, and Tukey's adjusted differences of LS-means were calculated. Differences were considered significant when $P < 0.05$ and as trends when $P < 0.10$.

Results

ADG and system gain

Lamb ADG did not differ among systems for the first two study periods, but lambs in the honeylocust silvopastures outperformed lambs in the open pastures during the third two-week period (treatment × period interaction, $P = 0.0011$; Table 1). Over all periods, lamb ADG did not differ significantly ($P \geq 0.7700$) among treatments. Despite lower stocking rates in the black walnut system, total system gain did not differ significantly ($P = 0.3763$) among treatments. The numerically greater ADG of lambs in the black walnut silvopastures offset the lower stocking rate of these systems. Total system gains in the black walnut silvopastures (0.55 ± 0.22 kg day^{-1}) was no different than system gains in the honeylocust silvopastures (0.89 ± 0.22 kg day^{-1}; $P = 0.4316$) and in the open pastures (0.88 ± 0.22 kg day^{-1}; $P = 0.4562$). There was no difference in system gains between the honeylocust silvopastures and the open pastures ($P = 0.9989$).

Forage mass and intake

The R^2 value of the forage mass prediction model derived from the double samples was 0.6027 (Fig. 1). The prediction model for forage mass (FM) based on sward height (SW) was FM = 267 × SW + 1726.

Forage mass in the honeylocust silvopasture and the open pasture systems did not differ ($P = 0.7580$; Table 2), and both of these systems produced more ($P < 0.0001$) forage than the black walnut silvopasture system. Residual (post-graze) herbage mass values also were lower ($P \leq 0.0041$) in the black walnut silvopastures (Table 2). This occurred despite the goal of keeping these values similar among treatments (by lowering stocking rate in the black walnut systems). However, no differences ($P \geq 0.4407$) among treatments was observed in estimates of individual forage intake (Table 3).

Nutritive value of tall fescue

Tall fescue CP content was greatest in the honeylocust silvopasture samples (Table 3), There was no effect of treatment on NDF ($P = 0.2612$), ADF ($P = 0.1716$), and TDN ($P = 0.1727$) in the tall fescue samples.

Table 1 Mean average daily gains of lambs in silvopastures and open pastures

Period	Treatment			Tukey's adjusted *P* values		
	BW[a] (kg day^{-1} ± SE)	HL[b] (kg day^{-1} ± SE)	OP[c] (kg day^{-1} ± SE)	BW versus HL	BW versus OP	HL versus OP
1	0.29 ± 0.03	0.20 ± 0.02	0.28 ± 0.02	0.4572	1.000	0.2904
2	0.17 ± 0.03	0.13 ± 0.02	0.16 ± 0.02	0.9732	1.000	0.9960
3	0.04 ± 0.03	0.12 ± 0.02	0 ± 0.02	0.6308	0.9924	0.0251
Total	0.17 ± 0.02	0.15 ± 0.01	0.15 ± 0.02	0.8071	0.7700	0.9964

SE standard error

[a]Black walnut silvopasture

[b]Honeylocust silvopasture

[c]Open pasture

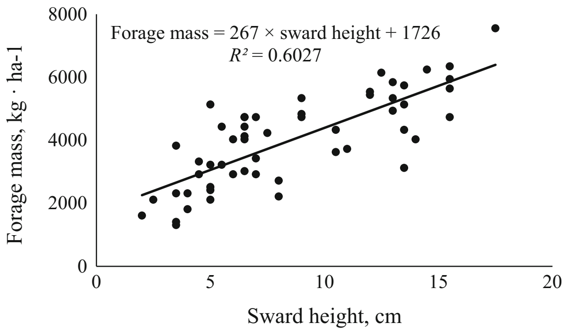

Fig. 1 Regression of forage mass against height of sward

Pod productivity of the honeylocust trees

Mean honeylocust tree pod yields were high, but there was a wide range in values measured (mean ± SD = 4366 ± 2832 kg ha^{-1}). In some cases, post-graze pod measures (mean ± SD = 4166 ± 3405 kg ha^{-1}) were greater than pre-graze pod measures, and as a result, the corresponding disappearance numbers were invalid. Lambs were observed to begin eating pods between the third and fourth weeks of the study (Figs. 2, 3).

Discussion

ADG and system gain

The live weight gains of the lambs decreased over the course of the study, likely a consequence of switching from feeding a low quality hay prior to the start of the study to providing a high quality forage at the initiation of the study. The lambs likely consumed high amounts of fresh forage during the first period, resulting in the highest ADG values, followed by compensatory gain and more moderate levels of intake in the second period. Gut fill and muscle development were likely lowest in the third period, which resulted in lower levels of gain for lambs in the black walnut

Table 2 Forage productivity, residual forage, and calculated forage intake per lamb in silvopastures and open pastures

Variable	Treatment			SE	Tukey's adjusted *P* values		
	BW[a]	HL[b]	OP[c]		BW versus HL	BW versus OP	HL versus OP
Forage availability (kg ha^{-1})	3790	5140	5050	80	< 0.0001	< 0.0001	0.7580
Residual forage (kg ha^{-1})	2880	3500	3340	90	0.0002	0.0041	0.3793
Individual forage intake (kg day^{-1})	1.52	1.57	1.66	0.08	0.8827	0.4407	0.7245

SE standard error

[a]Black walnut silvopasture

[b]Honeylocust silvopasture

[c]Open pasture

Table 3 Nutritive value of tall fescue (*Schedonorus arundianceus*) in silvopastures and open pastures

Variable	Treatment			SE	Tukey's adjusted *P* values		
	BW[a]	HL[b]	OP[c]		BW versus HL	BW versus OP	HL versus OP
Protein (%)	17.1	18.5	16.8	0.4	0.0321	0.8789	0.0116
Neutral detergent fiber (%)	43.7	43.8	43.3	0.9	0.2611	0.9257	0.4404
Acid detergent fiber (%)	22.5	21.1	22.2	0.6	0.1798	0.9341	0.3119
Total digestible nutrients (%)	75.2	76.8	75.5	0.6	0.1808	0.9341	0.3136

SE standard error

[a]Black walnut silvopasture

[b]Honeylocust silvopasture

[c]Open pasture

Fig. 2 Lambs foraging on a pile of honeylocust pods on December 14

silvopasture and open pasture systems. It could be that the consumption of honeylocust pods by the lambs in the honeylocust silvopastures maintained the gains of lambs in these systems.

Although there were no differences in ADG for lambs in all systems for the first two periods, lambs in the honeylocust silvopasture outperformed lambs in the open pastures during the third period. Coincidently, lambs were observed to begin eating pods right before the conclusion of the second period.

Fig. 3 Lamb manure containing seeds from digested honeylocust pods

The significant increase in live weight gains for the lambs in the honeylocust silvopastures coincided with the point in time when the lambs finally began to consume the pods. Taken alone, this data seems to indicate that the consumption of pods by the lambs had a positive effect on their live weight gains. This effect, however, may be augmented by the sheltering effects of the trees, as demonstrated by the similar ADG of lambs in the black walnut silvopastures compared to the ADG of lambs in the honeylocust silvopastures during the third period. More work should be done to elucidate the benefits of animal comfort in the silvopastures during the early winter months compared to the benefits of pod intake alone.

Forage mass and intake

Similar work during the summer months in black walnut based silvopasture systems also has indicated depressed forage availability in these systems, while honeylocust trees appear to have little to no effect on forage productivity (Kallenbach et al. 2006; Fannon et al. 2017). The results from this study also confirm that, in terms of plant biomass, anything produced by honeylocust trees (pods, leaf litter, timber, and belowground biomass) represents the net productivity of these systems over open pasture systems.

Although the goal was to keep post-graze herbage mass values constant across all treatments, they were lowest for the black walnut silvopastures. This may have been a result of the less mature and thereby less rigid pre-graze sward of the black walnut silvopasture, which would deflate forage mass predictions for the post-graze sward using the overall forage mass regression equation.

It was hypothesized that pod consumption by the lambs would depress their forage intake. However, along with the delay in pod consumption, the methodology for forage measurement may have not been sensitive enough to pick up any differences in true individual animal intake. Future work should investigate the forage intake rates of sheep supplemented with honeylocust pods compared to sheep without any supplementation as they may be depressed (Loy et al. 2007) or unaffected (Brokaw et al. 2001).

Nutritive value of tall fescue

Greater CP in tall fescue in the honeylocust system likely reflects greater available soil N due to high levels of red clover (*Trifolium pratense*) observed in these systems during the summer growing season (Fannon et al. 2017). Honeylocust are non-nodulating and do not provide N to the system (Gold and Hanover 1993). Although previous reports have indicated that shade can lead to elevated CP in forage (Stritzke et al. 1976; Lin et al. 2001; Neel and Belesky 2017), shading likely would not have been a significant factor in this study. Leaf shed occurred in October for both species and shade from the bare trees, which was minimal, would have been similar in the two silvopasture treatments. Greater CP in the tall fescue within the honeylocust silvopastures would not be expected to affect differences in animal weight gains across these systems as forage CP was adequate for growing lambs (National Research Council 2007) in all treatments. The weight gains of these lambs may have been improved with greater TDN intake as the TDN from the tall fescue was limiting animal performance.

Pod productivity of the honeylocust trees

The methods used to estimate pod consumption were not sensitive enough to detect pod intake by the lambs and did not account for windblown or stray pods, hence the occasional negative values of pod intake. Nevertheless, the amount of pods available in these systems was significant. Because the forage productivity of the honeylocust silvopastures was equal to that of the treeless pastures, this pod yield represents the harvestable net biomass these systems produced over the conventional open pasture systems during the year of this study (Sharrow et al. 2009). In addition, these pods are available to grazing livestock during the winter months when forages have largely ceased growing. Unfortunately, in this case the value of this net primary productivity was not realized in animal performance given the initially low voluntary intake of pods by the lambs.

Prior observation has indicated that lambs grazing honeylocust silvopastures during the growing season will preferentially browse honeylocust leaves (over available herbage). However, this sometimes takes about a week for the animals to sample the plant material and learn of its acceptability. In addition, lambs in these systems will eat pods that drop prior to maturation and we have observed naïve goats eating pods without a "learning delay." Dairy cattle (Atkins 1942) and calves (Scanlon 1980) also have been reported to consume the pods readily. Based on these experiences we did not anticipate the effect that lamb naiveté would have on pod consumption. Eventually the lambs did begin to consume the honeylocust pods, and high (0.12 kg day^{-1}) ADG in the final two-week period suggest the potential of honeylocust pods as a feed supplement. As this study demonstrated, however, naïve lambs must acquire a taste for the pods before they will voluntarily consume them.

Conclusion

The net biomass production of the honeylocust silvopastures, in terms of forage and pods, exceeded the biomass production of the open pastures during this study. Naïve lambs in this study did not consume pods until late in the study. The high weight gains that occurred once lambs began consuming pods indicates that honeylocust pods can be a useful supplement for lambs in a cool-season forage-livestock system. The potential for associative effects in these systems remains to be determined. Nevertheless, this study has documented the overyielding potential of honeylocust-based silvopastures towards net primary productivity, and these data suggest that lamb live weight gains may be increased when honeylocust pods are consumed in combination with cool-season forages.

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