Sheep & Goat Research Journal
Volume 26, 2011 – December

Mixed Grazing Goats With Cattle on Reclaimed Coal Mined Lands in the Appalachian Region: Effects on Forage Standing Biomass, Forage Botanical Composition and Autumn Olive (*Elaeagnus umbellata* Thunb.)

D.M. Webb[1], A.O. Abaye[2], C.D. Teutsch[3], J.-M. Luginbuhl[4], G. Scaglia[5], and C.E. Zipper[2]

[1]*Corresponding author: University of Tennessee Giles County Extension, Pulaski, TN 38478, dwebb15@utk.edu*
[2]*Virginia Polytechnic Institute and State University, Department of Crop and Soil Environmental Sciences, Blacksburg, VA 24061*
[3]*Virginia Polytechnic Institute and State University, Southern Piedmont Agricultural Research and Extension Center, Blackstone, VA 23824*
[4]*North Carolina State University, Crop Science Department, Raleigh, NC, 27695*
[5] *Louisiana State University, Iberia Research Station, Jeanerette, LA 70544*

Acknowledgements

The authors wish to thank Danny Early, Jon Rockett, Jonathan Rotz, Pepper Raines, Libby Yarber, David Meehan, Tom Smith, Clint Steele, and Nick Oates for help with livestock and field work. The authors thank the Virginia Agricultural Council and the Powell River Project for supporting this work.

Summary

Reclaimed coal-mined lands in Appalachia of the United States can be successfully utilized for beef cattle but the proliferation of invasive-plant species, such as autumn olive (*Elaeagnus umbellata* Thunb.) can limit this option. An experiment was conducted in 2006, 2007, and 2008 near Wise, Va. to determine the effects of cattle-alone grazing and mixed grazing of goats with cattle on forage standing biomass, forage botanical composition, and autumn olive. After the first sampling, forage standing biomass remained higher in cattle-alone grazing ($P \leq 0.002$). Weed content was lower at the end of the grazing season in mixed grazing in all years ($P < 0.03$). Total autumn olive branch length was reduced by goat browsing in the mixed grazing treatment by the end of the experiment ($P < 0.02$). Total autumn olive shrub height was not affect by either treatment at the end of the study ($P = 0.33$). Goats grazing with cattle consumed plant species not preferred by cattle. Mixed grazing goats with cattle is a viable option for reclaimed coal-mined lands in Appalachia.

Keywords: Autumn Olive, Browse Species, Cattle, Goat, Grazing, Land Reclamation

Introduction

Mined-land reclamation in the Appalachian coal region of the United States has resulted in successful establishment of pasture for beef-cattle production (Ditsch et al., 2006). However, maintaining desirable pasture species on such sites is difficult due to the low fertility of mine soils and the steep topography (Daniels and Zipper, 2009). As a result, the invasion of undesirable, invasive-plant species is a common occurrence (Wolf et al. 2009).

On reclaimed coal-mined pastures, autumn olive and sericea lespedeza (*Lespedeza cuneata* [Dum.-Cours.] G. Don) are invasive plant species that often reduce pasture production of forage species preferred by cattle. These invasive-plant species are widely adapted with few natural controls, tolerant of poor soil fertility, have physical or chemical deterrents to livestock and wildlife, and compete aggressively with native or more-desirable plant species for nutrients and water (Swearingen et al. 2002; Miller 2003). Sericea lespedeza and autumn olive were commonly used in seed mixtures for coal-mine reclamation (Skousen and Zipper 2009) and may spread in bird droppings (Miller 2003).

Mixed grazing goats with cattle in this region may serve as a viable method of biological control for invasive-plant species. Goats prefer browsing shrub species over grazing grasses and may consume plants with bitter compounds, such as tannins, that are unpalatable by cattle (Luginbuhl et al. 1995). When the two livestock species graze together, competition is minimal, as each species selects their own preferred diet (Walker 1994). In North Carolina, mixed grazing goats with cattle successfully converted brush-infested pasture into desirable, cool-season pasture (Luginbuhl et al. 1999). The objective of this experiment was to investigate the potential effects of mixed grazing goats with cattle versus cattle-alone grazing on forage-standing biomass and forage-botanical composition of pastures infested with invasive-plant species on reclaimed coal-mined lands. The effects of the treatments on autumn olive growth were also investigated.

Materials and Methods

A grazing experiment was conducted during the 2006, 2007, and 2008 growing seasons at the Powell River Project Research and Education Center in Wise County, Va. (77° 43' 30" west longitude, 38° 57' 30" north latitude, elevation 155.5 m). The experimental design was a randomized complete block, with pastures being the experimental unit. The two treatments included cattle-alone grazing and mixed grazing goats with cattle. Three replicate pastures (1.8 ha each) were used for the treatments. Three crossbred steers (280 kg ± 4.0 kg BW SE) were allocated to each grazing treatment. The stocking rate was based on 0.6 ha steer^{-1}. Glimp (1995) suggested that one to three goats could be added to one cow unit without competing for forage resources. The ratio of goats to cattle was higher than that suggestion in this experiment because control and reduction of invasive-plant species was desired (Table 1). The mixed-grazing treatment included 15 young, intact-male, brush-type goats (20.3 kg ± 2.5 kg BW SE) in 2006 and 2007. In 2008, only five young, intact-male goats were used due to a decrease in browse species from previous years' grazing. Animals were grazed on adjacent pastureland for a week prior to the start of the experiment each year. Animals were rotationally stocked among replicates by grazing one replicate for two weeks and then allowing a 4-week rest. Water and trace minerals were provided free choice at all times. Replicates were sampled and animals weighed three times during the growing season (spring, summer, and fall). All weights were unshrunk weights. In 2007, animals were removed from the study for 20 days because of a shortage of forage-standing biomass resulting from dry environmental conditions (Table 1).

Measurements for forage-standing biomass, forage-botanical composition and autumn olive were taken during spring, mid-summer, and late summer or early fall of each grazing season (Table 1). Late-summer and early-fall measurements are designated as "Fall" in the results that follow. Forage-standing biomass was determined by clipping eight 0.25 m^2 quadrants per treatment to a 2.5 cm height from soil level. Samples were dried in a forced-air oven at 105° C for 48 h. Results are presented on a dry-weight basis. Prior to harvesting the forages within each quadrant, the area was visually evaluated by trained evaluators for estimates of percentage ground cover and percent cover by grass, legume, and weed species, with "weed" as a residual category for all species not classified as pasture grasses or pasture legumes, including sericea lespedeza. Sericea lespedeza was classified as a weed in this experiment, due to its lower palatability by cattle (Wolf et al. 2009).

Autumn olive measurements included shrub height, branch length, and shrub survival. Each year, eight shrubs were randomly identified and tagged with a letter in each replicate in the treatments. On each selected shrub, four branches were randomly tagged and numbered from ground level to 3 m. Autumn olive was measured in spring, summer, and fall during each growing season. Branch length was measured with a tape measure in centimeters from

Table 1. Sampling dates for the three experimental years of cattle-alone grazing or mixed grazing goats with cattle on reclaimed pastures in the Appalachian coal region.

	Vegetation sampling dates	Total grazing days	Cattle alone grazing	Mixed grazing
			AUM/ha	
2006	May 30, July 13, and September 29	122	0.9	2.0
2007[a]	May 30, July 13, and August 30	72	0.9	2.0
2008	May 27, July 8, and September 18	114	0.9	1.0[b]

[a] Due to severe drought, animals were removed from treatment paddocks and grazed on adjacent pastures from 13 July to 2 August.
[b] Due to a decrease in autumn olive, the number of goats was reduced in mixed grazing.

the base of the branch to tip at the beginning and end of each sampling period (Oba and Post 1999). Branch length change for the spring-summer period was estimated as the difference between the branch-length measurement at the summer sampling and the initial branch-length measurement at the spring sampling in each treatment. Likewise, the branch length change for the summer-fall period is the difference between the fall sampling and the summer sampling. Total branch-length change was calculated by summing the period changes of spring-summer and summer-fall sampling periods for each year (Oba and Post 1999). Branches that were broken or dead due to goat browsing were recorded. Shrub height was measured with a clinometer at a distance of 10 meters. Shrub-height changes were calculated the same as branch-length change.

Statistical Analysis

Data were analyzed using mixed-model procedures of SAS (SAS Inst. Inc., Cary, N.C.). Forage-standing-biomass and forage-botanical-composition measurements were averaged for each of the sampling seasons (spring, summer, and fall). The model consisted of treatment, season, year, and their interactions. The repeated measure for forage-standing biomass and forage-botanical composition was year x season. Autumn olive data for total branch length and shrub height was averaged to the difference between the spring-summer and summer-fall periods. The model for autumn olive measurements included treatment, period, year and their interactions. The repeated measure for autumn olive measurements was year x period. Significance was declared at $P < 0.05$.

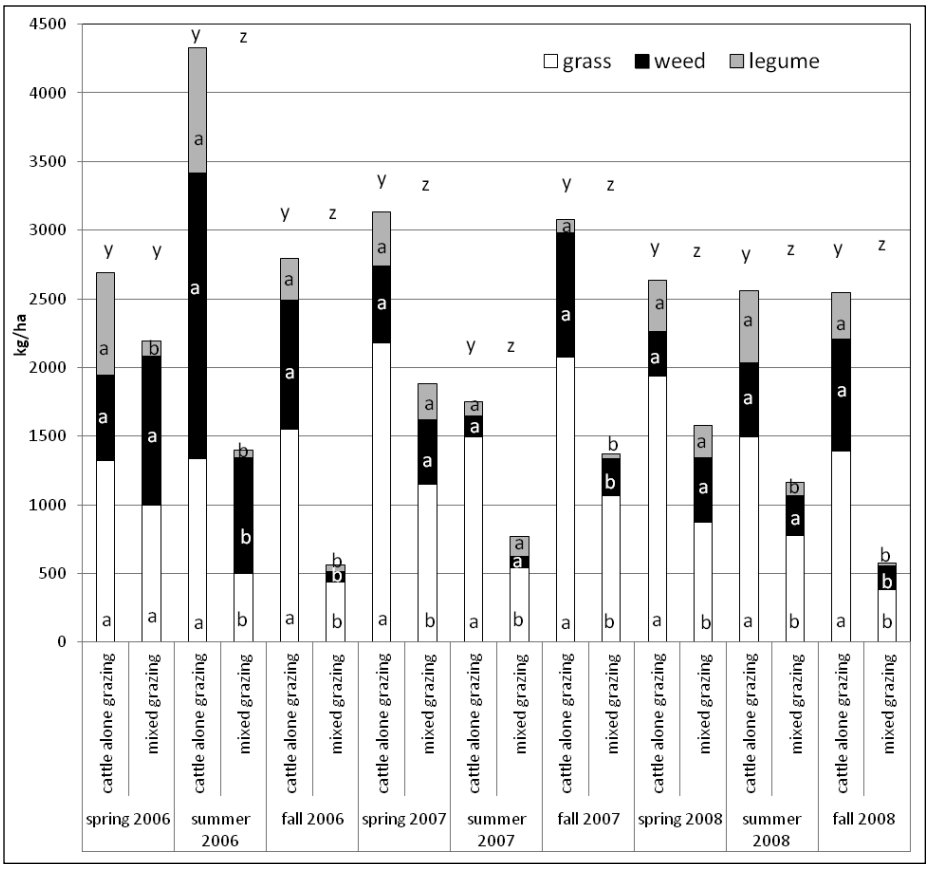
Results and Discussion

Forage Standing Biomass

Forage-standing biomass was influenced by a year x treatment x season interaction ($P < 0.01$). In 2006, forage-standing biomass in the cattle-alone grazing and mixed grazing was similar in spring ($P = 0.06$; Fig. 1). Following the spring of 2006, forage-standing biomass was lower in mixed grazing compared to cattle-alone grazing in all other seasons ($P \leq 0.002$). Goats in mixed grazing readily consumed sericea lespedeza and other weeds. Hart (2001) stated that sericea lespedeza was readily grazed by goats, and invasive stands of sericea lespedeza could be reduced to low levels after three years of grazing. In addition, goats maintained weed species in a vegetative stage of growth that was grazed some by cattle. Sericea lespedeza and other weed species are not tolerant of close and frequent grazing and may be reduced or lost from the stand (Hoveland et al. 1975). Furthermore, most of the weeds, including sericea lespedeza, are tap-rooted species. These species have reduced vigor when grazed late in the growing season due to lower carbohydrate-storage capacity in their roots and may decline from the stand the following year (Hoveland et al. 1975). The combination of goat-diet preferences, greater palatability of re-growth of weed species to cattle, and a slightly higher stocking rate in mixed grazing attributed to lower forage standing biomass in mixed grazing.

In addition, the 2007 and 2008 growing seasons were affected by extreme weather conditions. In 2007, a late frost slowed the emergence of warm-season plant species and a dry summer hindered overall forage-standing biomass. Forage-standing biomass in the treatments was greater in spring and fall, reflecting greater cool-season grass growth in those seasons and the lack of moisture during the summer period (Fig. 1). Summer forage-standing biomass was 42 percent and 61 percent of spring levels in the cattle-alone and mixed-grazing treatments, respectively (Fig, 1). In 2008, another dry year, the average forage-standing biomass from pastures grazed by cattle-alone grazing remained

Figure 1. Seasonal variations in herbaceous biomass (kg/ha) and biomass components for cattle-alone grazing and mixed grazing goats with cattle during three growing seasons on reclaimed pastures in the Appalachian coal region. Letters (y, z) above bars illustrate differences in herbaceous biomass within a season ($P < 0.05$). Differences (a, b) for biomass components compared between treatments are noted within bars for that particular season and year ($P < 0.05$).



fairly constant from spring to fall. However, forage-standing biomass in mixed grazing declined from spring to fall ($P < 0.05$). Drought conditions can be especially stressful to pastures on reclaimed coal-mined lands, as the mine soils typically have low moisture-holding ability (Ditsch et al. 2006). Due to drought conditions in the last two years, animals were removed from paddocks much earlier than the first year (Table 1).

Forage Botanical Composition

The botanical composition of forage-standing biomass was generally impacted by treatment (Fig. 1). In spring 2006, grass ($P = 0.18$) and weed ($P = 0.06$) content of the two treatments were not different but legume content was lower in the mixed-grazing treatment ($P = 0.02$). In summer and fall, grass ($P < 0.001$), weed ($P \leq 0.03$) and legume ($P < 0.001$) content was lower in mixed grazing compared to cattle-alone grazing. Sericea lespedeza and other warm-season weeds made up the large portion of biomass during the summer and fall months. The productive season for these warm-season species is from late May to October (Ball et al. 2007). Goats were observed to consume sericea lespedeza and other weed species readily and helped to reduced forage-standing biomass of these components (Fig. 1) Sericea lespedeza regrowth was multi-branched and leafy, which increased its acceptance by both cattle and goats. Cattle in cattle-alone grazing were observed to only eat the tips of sericea lespedeza and allowed it to become mature and unpalatable.

In 2007, warm-season weeds, such as sericea lespedeza and other species, were not as evident as in the previous year due to a late-spring frost that slowed the growth of these species. Grasses made up the largest fraction of the forage standing biomass for all treatments in spring and summer (Fig. 1). The grass component was lower in mixed grazing compared to cattle-alone grazing in all seasons ($P < 0.001$). Dry conditions during the summer slowed the growth of many species. The tap-rooted, drought-tolerant forbs, such as sericea lespedeza and other warm-season weeds did not make much of an impact on forage-standing biomass until fall. Weed biomass was no different between the treatments in summer ($P = 0.16$). Weed biomass was greater in cattle-alone grazing in the fall compared to mixed grazing ($P = 0.024$). The presence of legumes in forage-standing biomass was similar between treatments in spring ($P = 0.27$) and summer ($P = 0.55$) but lower in mixed grazing in the fall ($P = 0.017$).

In 2008, grass made up a larger portion of forage-standing biomass in cattle-alone grazing compared to mixed grazing during all seasons ($P \leq 0.007$). Similar to 2007, weed content was lower statistically in mixed grazing only during fall compared to cattle-alone grazing ($P = 0.015$). Legumes were similar between the treatments in spring ($P = 0.43$) but lower in mixed grazing in summer ($P = 0.024$) and fall ($P = 0.001$). Legumes were always at a low level during each season as a component of biomass. The drought, acid conditions of reclaimed soils are not favorable for growth of legumes, such as red and white clover (Daniels and Zipper 2009).

The grass components of the pastures were increased at best or maintained in the grazing treatments. The persistence of grasses in the mixed-grazing treatment can in part be attributed to the grazing behavior of goats, which is to graze a sward from top to bottom and thus reduce the shading of grasses and allow tillering (McCall and Lambert 1987). Luginbuhl et al. (2000) showed in North Carolina that grass frequency increased and broadleaf weeds decreased under mixed grazing of goats with cattle. Our experiment showed that grass became a major component of forage-standing biomass in both treatments; however, grass content was lower in mixed grazing compared to cattle-alone grazing after the spring of 2006.

The legume component of the pastures, mainly red and white clover, was not affected by the grazing treatments (Fig. 1). Generally, legumes made of the lowest proportion of forage-standing biomass compared to grass and weed. The only times that legume content was similar between treatments was in the spring and summer of 2007 and in the spring of 2008. In the cattle-alone grazing paddocks, clover was more or less stable during the first growing season but declined by the end of the second grazing season. Cattle tend to select clover over grass when grazing (Ball et al. 2007). Furthermore, the same authors indicated that the reduction in clover content of the cattle pastures can be attributed to shading by grasses and weeds that resulted from spot grazing by cattle (Ball et al. 2007). In the mixed-grazing paddocks, legume content did not make a considerable component of forage-standing biomass.

Autumn Olive

Autumn olive branch length showed treatment x period x year interactions ($P < 0.001$). For 2006, autumn olive branch length was negatively impacted by goat browsing in mixed grazing during the spring-summer period

Table 2. Changes in autumn olive branch length (cm) during three growing seasons on reclaimed pastures in the Appalachian coal region. Columns within season with a different letter differ ($P < 0.05$).

	2006			2007			2008		
Autumn olive	spr-sum	sum-fall	total	spr-sum	sum-fall	total	spr-sum	sum-fall	total
Cattle alone	20.37	1.01[a]	21.38[a]	4.92	5.05	9.98	13.79	9.08	22.86[a]
Mixed	9.47	-5.58*[b]	3.89[b]	0.53	3.76	4.29	9.02	4.05	13.07[b]
SE	3.50	1.30	3.63	1.77	2.90	3.08	2.57	2.18	2.86
P-value	0.03	<0.001	<0.001	0.08	0.75	0.19	0.19	0.10	0.02

* Negative number indicates branch length decreased, with the branch unable to grow back during specified season.

Table 3. Changes in autumn olive shrub height (m) during three growing seasons on reclaimed pastures in the Appalachian coal region. Columns within season with a different letter differ ($P < 0.05$).

	2006			2007			2008		
Autumn olive	spr-sum	sum-fall	Total	spr-sum	sum-fall	total	spr-sum	sum-fall	total
Cattle alone	-0.04*	0.23[a]	0.19	0.12	0.28	0.40	0.13	0.14[a]	0.27
Mixed	0.22	-0.14*[b]	0.08	-0.07*	0.47	0.39	0.15	-0.12*[b]	0.03
SE	0.19	0.09	0.19	0.09	0.17	0.13	0.11	0.08	0.11
P-value	0.34	0.005	0.69	0.13	0.44	0.95	0.94	0.02	0.12

* Negative number indicates shrub height decreased, with the shrub unable to regain height during specified season.

($P = 0.03$) and the summer-fall period ($P < 0.001$) (Table 2). Goats were observed to chew the tips of branches if branch tips were slender and tender (Webb 2008). At season's end, the branch-length growth in the mixed grazing treatment was very low compared to cattle-alone grazing ($P < 0.001$). Branch length growth was reduced by 82 percent in mixed-grazing treatment. In 2007, there were no significant differences among treatments at any point during the season ($P = 0.19$). One possible reason for the lack of difference could be that this growing season was drier and autumn olive may go into dormancy during dry periods. However, little research has been conducted on autumn olive to demonstrate this physiological response. In 2008, there was significant difference in total autumn olive branch length ($P = 0.016$) by the end of the grazing season. Any reduction in the growth of autumn olive shrubs by goats can be attributed to the browsing pattern of the goats. When browsing, goats will stand on their hind legs and hold down branches with their weight for easy access to leaves and twigs. When a goat bends down a branch, other goats in the herd may also gather around to browse the branch, thus allowing it to be completely defoliated within a short period. As a result of this browsing behavior, a browse line may develop on shrubs. In our study, we observed an average browse height of 205 cm. This was higher than the 150 cm reported for free-ranging goats browsing *Acacia tortilis* in Kenya (Oba and Post 1999). Browsing height is likely influenced by the size of the goat. Branches were broken and killed at times, as branches became brittle from excessive browsing. As forage became limiting at the end of the growing season, goats began to strip bark from shrubs. Bark stripping can girdle and kill shrubs. This is similar to findings from New Zealand, where goats were observed to strip bark from gorse (*Ulex europaeus*) and eventually eliminate this leguminous shrub in four years of heavy browsing (Field and Daly 1990). Another cause for autumn olive loss may be that browsing the shrubs late in the growing season can cause a reduction in energy storage in the roots needed for winter survival. Loescher et al. (1990) stated that late summer and autumn pruning of fruit or timber tree species resulted in decreased carbohydrate storage in the roots and lower production the following year.

Autumn olive shrub height showed a weak treatment x period x year effect ($P = 0.057$). In 2006, there were no differences during the spring-summer period among treatments (Table 3) but during the summer-fall period, the mixed-grazing-height change was significantly lower ($P = 0.005$). In 2007, autumn olive height was not significantly affected by any treatment ($P = 0.95$). In 2008, spring-summer period was not affected by goat browsing but summer-fall period was affected ($P = 0.02$). Generally, mixed grazing did not have influence on autumn olive height compared to cattle-along grazing by end of the grazing season of each of the experimental years ($P = 0.33$). This is in agreement with the findings of Oba and Post (1999) of browsing of *Acacia tortilis* by goats in Kenya.

Despite persistent browsing by goats in the mixed-grazing treatment, autumn olive illustrated a degree of resiliency. After hard browsing and branch death, the shrub would occasionally produce numerous suckers from the base of the plant. This lush growth lacked thorns or physical deterrents. This growth was highly preferred and accessible to goats. Cattle would occasionally browse this growth if it was accessible. Luginbuhl et al. (2000) observed that cattle would browse black locust (*Robina pseudoacacia*) and that when given opportunity cattle would browse and become opportunistic browsers. Another observation of the resiliency of autumn olive was that when allowed a rest period of four to six weeks, due to rotational grazing pattern, leaves would regrow to the size prior to browsing. In a long-term study, Carmel and Kadmon (1999) found that the grazing of goats and cattle slowed the establishment and growth of woody vegetation but did not halt the succession of rough topography pasturelands to woody vegetation in the Mediterranean region in Israel. If not an exotic invasive species of high concern, the high protein and feed value (data not shown) of autumn olive would warrant it to be managed as a possible continual forage source for goats (Webb 2008). Additionally, with autumn olive being a non-leguminous, nitrogen fixer, it could possibly improve nitrogen cycling on reclaimed coal-mined areas. A similar suggestion (maintenance of invasive-browse species in pastures) was presented for gorse- (another nitrogen fixing shrub) infested pastures in New Zealand but has not met wide-spread acceptance with producers (Field and Daly 1990).

Conclusions

Goats can complement cattle on botanically diverse pastures on reclaimed coal-mined lands in the Appalachian region. Research has indicated that one to three goats can be added per cow unit without competing for forage resources. In this experiment, the goal was to reduce invasive-plant species quickly,

and this can be accomplished with an increased ratio of goats to cattle. The presence of weeds was reduced in mixed grazing compared to cattle-alone grazing. The change in forage-botanical composition due to grazing can be attributed to the grazing pattern and diet preference of the grazing animals. Goats and cattle differ in their grazing behaviors and diet preferences. Goats showed a clear preference for browse species and warm-season weeds. Goat browsing had a negative impact on autumn olive branch length. Reducing autumn olive as a pasture component can benefit cattle by allowing other desirable pasture species an opportunity to compete for sunlight and nutrients. Mixed grazing goats with cattle is a viable practice on reclaimed coal-mined lands, where there is a diversity of plant species found in pasture.

Literature Cited

Ball, D.M., C.S. Hoveland, and G.D. Lacefield. 2007. Southern Forages. 4th edn. International Plant Nutrition Inst., Lawrenceville, Ga.

Carmel, Y. and R. Kadmon. 1999. Effects of grazing and topography on long-term vegetation changes in a Mediterranean ecosystem in Israel. Plant Ecology 145:243-254.

Daniels, W. L., and C. E. Zipper. 2009. Creation and Management of Productive Mine Soils. VCE Publ 460-121.

Ditsch, D.C., C.D. Teutsch, M. Collins, W.D. Whittier, J. Rockett, C. Zipper, and J.T. Johns. 2006. Managing livestock forage for beef cattle production on reclaimed surface-mined land. University of Kentucky Cooperative Ext Publ ID-157.

Field, R.J. and G.T. Daly. 1990. Weed biology and management. In: Langer RHM (ed). Pastures: their ecology and management, Oxford University Press, Auckland, pp 407-449.

Glimp, H.A. 1995. Meat Goat Production and Marketing. J Anim Sci 73:291-295.

Hart, S.P. 2001. Recent perspectives in using goats for vegetation management in the USA. J Dairy Sci 84:E170-E176.

Hoveland, C.S., R.F. McCormick, Jr, W.B. Anthony, and F.T. Glaze. 1975. Management of Serala sericea for forage and seed. Auburn University Agric Exp Stn Circ 222.

Loescher, W.H., T. McCamant, and J.D. Keller. 1990. Carbohydrate reserves, translocation, and storage in wood plant roots. Hortscience 25:274-281.

Luginbuhl, J.M., J.T. Green, J.P. Mueller, and M.H. Poore. 1995. Forage needs for meat goats and sheep. In: Chamblee DS and Green JT. Production and utilization of pastures and forages in North Carolina. North Carolina Agric Res Service. North Carolina State University Tech Bull 305, pp 105-111.

Luginbuhl, J.M., T.E. Harvey, J.T. Green, Jr, M.H. Poore, and J.P. Mueller. 1999. Use of goats as biological agents for the renovation of pastures in the Appalachian region of the United States. Agrofor Syst 44:241-252.

Luginbuhl, J.M., J.T. Green, Jr., M.H. Poore, and A.P. Conrad. 2000. Use of goats to manage vegetation in cattle pastures in the Appalachian region of North Carolina. Sheep & Goat Res. J. 16:124-135.

McCall, D.G. and M.G. Lambert. 1987. Pasture feeding of goats. In; Nicol AM (edn) Livestock feeding on pasture. New Zealand Soc. of Animal Production. Occasional Publ. No. 10, NZ, pp 105-109.

Miller, J.H. 2003. Nonnative plants of southern forests: a field guide for identification and control. Gen. Tech. Rep. SRS-62, USDA, Forest Service, Southern Res. Stn, Asheville, N.C., pp 93.

Oba, G. and Post, E. 1999. Browse production and offtake by free-ranging goats in an arid zone, Kenya. J of Arid Environ 43:183-195.

SAS. 2002-2003. SAS/STAT User's Guide (Release 9.1). SAS Inst. Inc., Cary, N.C.

Skousen, J. and C.E. Zipper. 2009. Revegetation species and practices. VCE Publ 460-122.

Swearingen, J., K. Reshetiloff, B. Slattery, and S. Zwicker. 2002. Plant invaders of mid-Atlantic natural areas. National Park Service and US Fish and Wildlife Service, Washington, DC.

Walker, J.W. 1994. Multispecies grazing: The ecological advantage. Sheep Res J: Special Issue.

Webb, D.M. 2008. Assessing the potential of mixed grazing goats with beef cattle to improve animal performance and increase the utilization of marginal pasturelands in Appalachian coal region. Master's thesis. Virginia Polytechnic and State University.

Wolf, D., J. Fike, and C. Zipper. 2009. Conversion of Sericea lespedeza-dominant vegetation to quality forages for livestock use. VCE Publ 460-119.

