Agroforestry Systems **44**: 241–252, 1999.

Use of goats as biological agents for the renovation of pastures in the Appalachian region of the United States

J-M. LUGINBUHL[1, 2, *], T. E. HARVEY[3], J. T. GREEN, JR.[2], M. H. POORE[1] and J. P. MUELLER[2]

[1] *Department of Animal Science,* [2] *Department of Crop Science,* [3] *Haywood County Cooperation Extension Service, North Carolina State University, Raleigh, North Carolina, USA (*Author for correspondence: Department of Crop Science, North Carolina State University, Box 7620, Raleigh, NC 27695-7620, USA, E-Mail: Jean-Marie_Luginbuhl@ncsu.edu)*

Key words: browse, cattle, defoliation, pasture reclamation, *Rosa multiflora*

Abstract. Much of hill-land pasture in the Appalachian region of the United States is dominated by herbaceous weeds and brush. Low cost, low input and environmentally acceptable reclamation procedures are needed to maintain the productivity of these pastures. This experiment evaluated the effectiveness of using goats (*Capra hircus hircus*) alone (30 mature, brush does/ha) or cattle (*Bos taurus*) with goats (17 mature, brush does/ha + two to three steers/ha – 225 kg average live weight) to reclaim a pasture from an abandoned, overgrown 5.9 ha orchard left untouched for 15 years. Over four grazing seasons, managed defoliation resulted in a substantial increase in herbaceous vegetative cover in plots grazed by goats alone (65 to 86%) and by goats with cattle (65 to 80%) while vegetative cover decreased from 70 to 22% in the control plot. Similarly, the cover by grass species increased in the grazed plots (goats: 16 to 63%; goats + cattle: 13 to 54%) while averaging 10% in the control plot. Multiflora rose (*Rosa multiflora* Thumb.) bushes were practically eliminated after four grazing seasons as quantified by an average reduction in height from 2.1 m to 0.6 m, and by the number of dead canes (stems) in both the goat (100%) or goat + cattle (92%) treatments. Results indicated that the foraging habits of goats resulted in the elimination of multiflora rose bushes and in a significant increase in desirable forage species.

Introduction

Much of hill-land pasture in the Appalachian region of the United States is dominated by herbaceous weeds, brush and multiflora rose bushes imported from Japan in 1886 as a rootstock for ornamental roses (Mays and Kok, 1988). Multiflora rose plants can be eliminated by herbicides. However, viable seeds may remain in the soil for up to twenty years. New bushes may develop from these seeds and from seeds introduced by birds and other animals. Consequently, an effective management program is needed for years after eliminating the original plants (Kay et al., 1995). Therefore, low cost, low input and environmentally acceptable reclamation procedures are needed to provide owners with ways to renovate and maintain these pastures. The role of goats (*Capra hircus hircus*) as biological control agents is becoming ever more important due to environmental concerns and elevated costs of other control methods such as mechanical cutting and herbicide application

(Magadlela et al., 1995). Concomitantly, goats are becoming increasingly important contributors to the income of many producers in Southeastern United States (Pinkerton et al., 1994).

There is also a need to evaluate the effects of grazing goats with cattle (*Bos taurus*) on pasture botanical composition. It is estimated that most beef cattle farmers would have enough 'excess' or under utilized forage in cattle pastures to feed one to two goats per cow with no additional feed input (Luginbuhl et al., 1995). The complementary effects of grazing cattle and goats on the same farm provide an opportunity to enhance and augment the existing beef cattle industry by improving pasture condition and feed quality.

The objectives of this study were to evaluate the effectiveness of utilizing goats alone or in combination with cattle to renovate hill-land pastures that have become overgrown with invading herbaceous weeds and woody species.

Materials and methods

A field study was conducted at the North Carolina Department of Agriculture Research Station located in Waynesville at approximately 35°50′ N latitude and 83°00′ W longitude. The study site was an abandoned, overgrown 5.9 ha orchard left untouched for 15 years. The orchard, located on a Hayesville Loam soil with slopes of 15 to 60%, was divided into six unequal sections consisting of two control (C) paddocks, two replicated paddocks grazed by goats (G) alone and two replicated paddocks grazed by goats + cattle (G+C). Brush goats were grazed alone (30 mature does/ha) or with cattle (17 mature does/ha with two to three [225 kg initial body weight] growing steers/ha) for four grazing seasons (1991 to 1994). Each paddock was fenced with six strands of electrified high tensile wire. Water was supplied to the animals via water tubs gravity-fed from a tank mounted on a tractor-pulled wagon. Grazing occurred for 45 to 60 days from May to July and for another 24 to 35 days in September and October. The grazing/browsing periods were dependent upon having at least five to 10 cm of available forage to graze within each paddock.

Multiflora rose measurements

In each paddock, multiflora rose bushes were identified and tagged to determine the effects of browsing on plant survival (number of tagged rose bushes were: nine in the C plot; nine and eight in plots grazed by G and 10 and 10 bushes in plots grazed by G+C). Tagged rose bushes were identified as individual plants or as a clump of contiguous plants. Tagged rose bushes were scored for percent dead canes (stems), live cane heights, ground area covered by live canes, and each canopy was scored for percent leaf-out. Height was determined by measuring the average canopy height. Area was determined by measuring the width and length of the canopy for each tagged rose bush or clump of rose bushes. Percent leaf-out was estimated by relating the

whole canopy relative to full leaf expansion. Thickness or impenetrability of tagged rose bushes was estimated by giving them a density rating from one to five. Estimates of dead canes were made by relating the number of live canes relative to existing canes within an individual plant or within a clump.

Herbaceous plant measurements

Numbered wooden pegs (nine in the C plots; 26 and 31 in plots grazed by G and 33 and 33 in plots grazed by G+C) were driven into the ground along transect lines as permanent observation points throughout the length of the study. A 100 × 10 cm rectangle was placed against each wooden peg and oriented with a compass such that the short sides of the rectangle pointed east and west. Plant species located within the 1,000 cm^2 rectangle were identified and recorded. A master list identifying 58 plant species common to the study site was developed prior to the initiation of the trial. If a specific plant species was observed more than once within the rectangle at a particular observation point, it was recorded only one time at that location. Plant frequency was defined as the percentage of observation points within a given paddock that contained at least one plant of that individual plant species. In addition, percent vegetative ground cover and percent vegetative cover as grass were estimated within the rectangular area at each observation point.

Each spring and fall from 1991 to 1994, measurements and visual observations were recorded at the 132 wooden pegs for herbaceous plants, and at the 46 tagged multiflora rose bushes.

The experimental design was a randomized complete block with two replicates and a factorial arrangement of treatments (three defoliation treatments and two observation seasons). Treatment and season effects were tested by the GLM procedure of SAS (1989) using repeated measure variables generated multiplying the original data by linear coefficients for orthogonal comparisons (F. Giesbrecht, personal communication) in four equally spaced treatments (four grazing seasons). Data from year 1, 2, 3, and 4 were multiplied by –3, –1, +1 and +3, respectively (Steel et al., 1997), then summed. The model used was $Y = u$ + replicate + treatment + season + treatment × season + error. Pre-planned orthogonal contrasts (Steel et al., 1997) were used as follows to determine differences among defoliation treatments: (1) control vs goats grazed alone and goats + cattle grazed together and (2) goats grazed alone vs goats + cattle grazed together.

Results and discussion

Herbaceous plants

Twenty-one of the 58 plant species recorded within the 1,000 cm^2 occurred with a frequency of 13% or more during the course of the four grazing seasons.

These plants were brambles (*Rubus* L. spp.), bluegrass (*Poa pratensis* L.), chickweed (*Stellaria* L. spp.), cinquefoil (*Potentilla* L. spp.), tall fescue (*Festuca arundinacea* L. Schreb.), geranium (*Geranium* L. spp.), goldenrod (*Solidago canadensis* L.), honeysuckle (*Lonicera japonica* Thunberg.), horseweed (*Conyza canadensis* L.), mint (*Mentha* L. spp.), multiflora rose (*Rosa multiflora* Thumb.), nimblewill (*Muhlenbergia schreberi*), oxalis (*Oxalis stricta* L.), plantain (*Plantago lanceolata* L.), poison ivy (*Toxicodendron radicans* [L.] Kuntz), redtop (*Agrostis stolonifera* L.), wild strawberry (*Fragaria virginiana* Duchesne), sweet vernalgrass (*Anthoxanthum* L. spp.), violet (*Viola* L. spp.), white clover (*Trifolium repens* L.) and yarrow (*Achillea millefolium* L.). Of those, the most prevalent plants were three important forage species (bluegrass, tall fescue and white clover) and six undesirable species (brambles, honeysuckle, mint, nimblewill, poison ivy and wild strawberry).

Over the four grazing seasons, the vegetative ground cover increased linearly ($P < 0.01$), from 65% in May 1991 to 86% in October 1994 in the G pasture and from 65 to 80% in the G+C pasture (Figure 1). The increase in vegetative ground cover was similar for both the G and G+C pastures. During

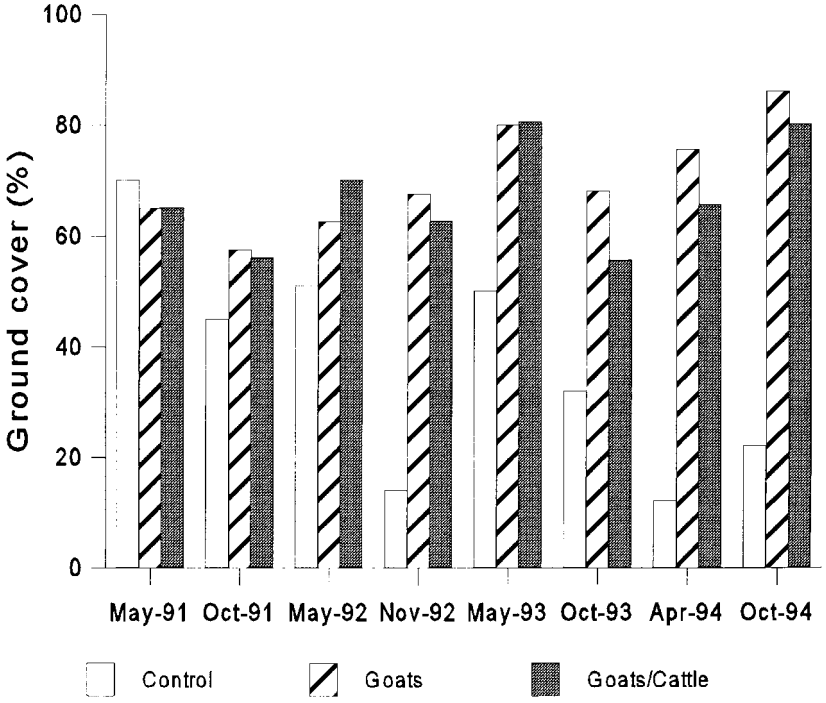

Figure 1. Effect of grazing mountain pastures in the Appalachian region of the United States with goats alone or with goats and cattle on percent vegetative ground cover during four grazing seasons. Orthogonal contrasts: control vs goats and goats + cattle ($P < 0.01$); goats vs goats + cattle ($P < 0.24$); SE = 3.4.

that same period, vegetative ground cover in the C plot declined from 70% in May 1991 to 22% in October 1994 ($P < 0.01$), because overstory of brush, trees and rose bushes shaded out herbaceous vegetation on the ground. In addition, vegetative ground cover declined from spring to fall ($P < 0.01$) due to defoliation in the G and G+C pastures and shading by overstory vegetation leafing out in the C pastures. The cover from herbaceous grass species increased linearly ($P < 0.01$) from 16 to 63% and from 13 to 54% in the G and G+C pastures, respectively (Figure 2), but no difference was observed between the G and G+C pastures. Conversely, cover from herbaceous grass species remained low and ranged from 10 to 27% in the C plot. The shift in botanical composition in the grazed plots was attributed to the preference of goats for the broadleaf species, including tall growing herbaceous and woody species such as multiflora rose bushes and trees, which allowed desired grasses and legumes to be more competitive.

Bluegrass exhibited linear increases ($P < 0.01$) in frequency from 22.5% in May 1991 to 71% in October 94 in the G pasture and from 12 to 34% in the G and G+C pasture (Figure 3). Frequency patterns were similar for the grazed treatments ($P < 0.09$). With the exception of May 93, however, the

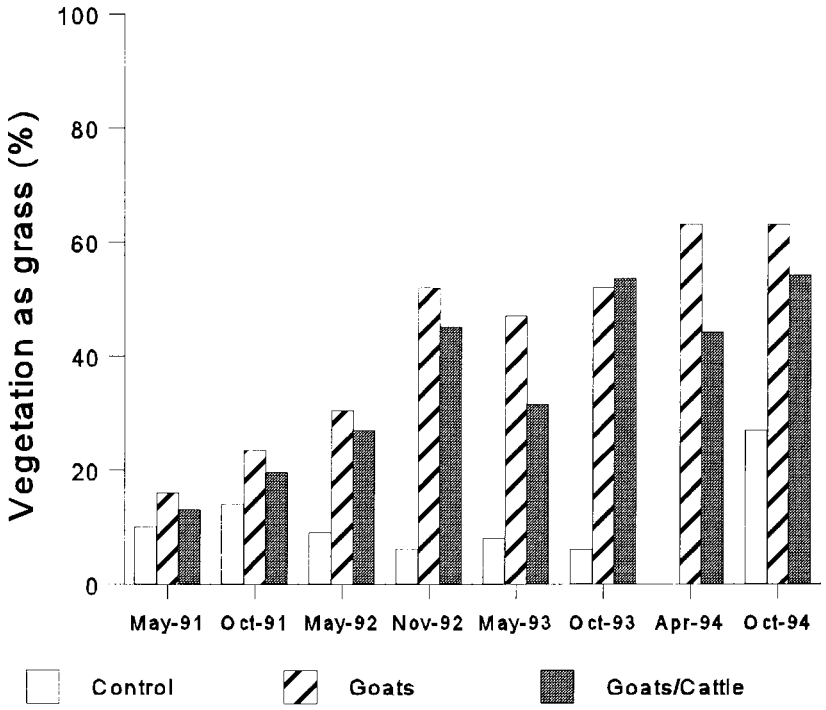

Figure 2. Effect of grazing mountain pastures in the Appalachian region of the United States with goats alone or with goats and cattle on percent vegetation as grass during four grazing seasons. Orthogonal contrasts: control vs goats and goats + cattle ($P < 0.01$); goats vs goats + cattle ($P < 0.19$); SE = 3.4.

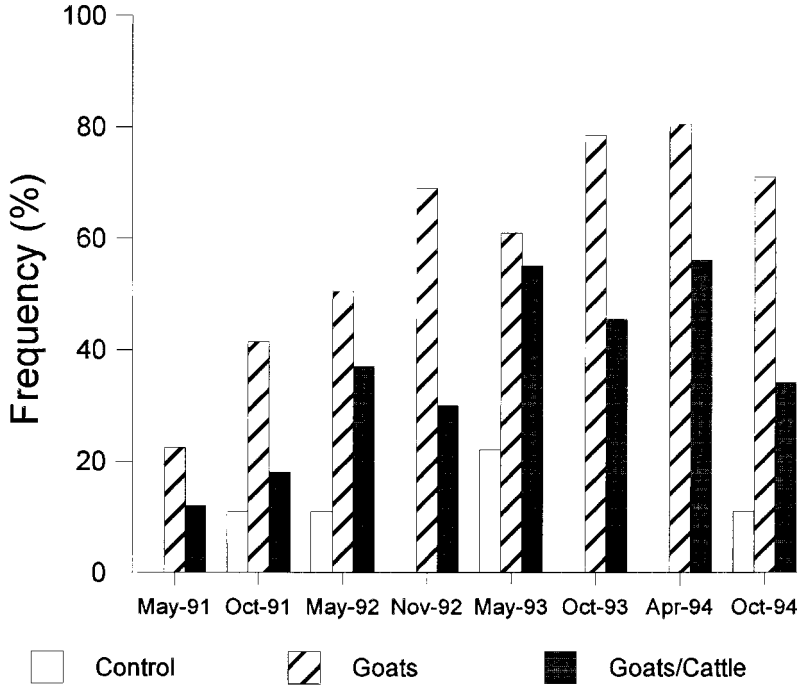

Figure 3. Effect of grazing mountain pastures in the Appalachian region of the United States with goats alone or with goats and cattle on bluegrass frequency (%) during four grazing seasons. Orthogonal contrasts: control vs goats and goats + cattle ($P < 0.01$); goats vs goats + cattle ($P < 0.09$); SE = 2.6.

increase was more dramatic for G, possibly due to a lack of preference for bluegrass by goats. Similarly, tall fescue (Figure 4) increased linearly ($P < 0.01$) in frequency from 11% in May 91 to 48% in October 94 in both G and G+C pastures, with no difference between the grazed treatments. White clover increased linearly ($P < 0.05$) over the years in the grazed plots (Figure 5). However, frequency was similar in both G and G+C pastures, averaging four and 53% in May 91 and October 94, respectively. Bluegrass, white clover and fescue remained a minor component in the control plots throughout the study, most probably due to a lack of sunlight at the ground level resulting from the natural successional reforestation process of maple, oaks, dogwood and other saplings and the absence of defoliation by livestock.

Undesirable plant species are shown in Table 1. Poison ivy decreased steadily over the four grazing seasons in both the G and G+C pastures ($P < 0.05$). Goats seemed to exhibit a preference for poison ivy and were able to control its growth and survival over the length of the study period. Brambles were well controlled and grazed to a similar extent in both G and G+C pastures. Research in West Virginia has shown that brambles were reduced from 39 to 9% by grazing hill land pastures with cattle, sheep and goats (Mills

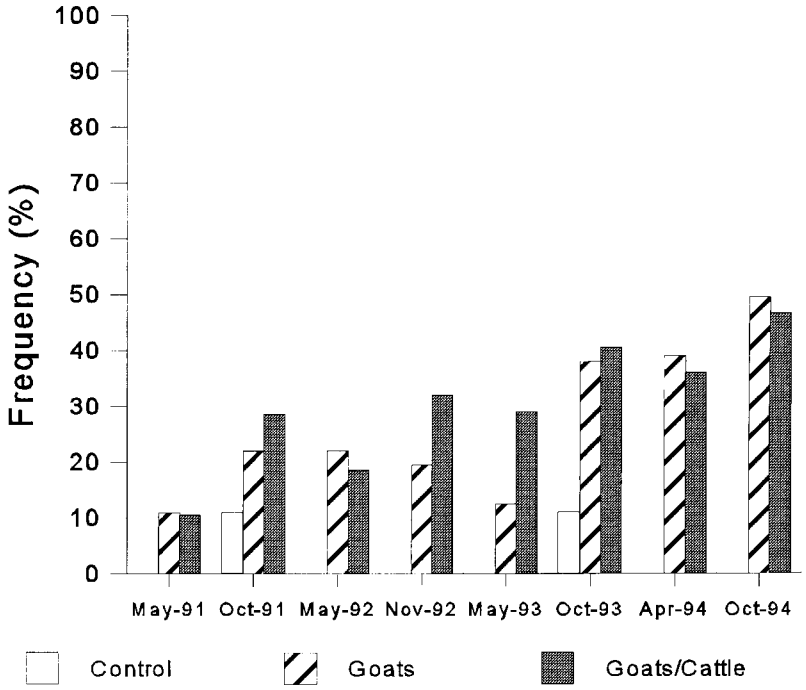

Figure 4. Effect of grazing mountain pastures in the Appalachian region of the United States with goats alone or with goats and cattle on tall fescue frequency (%) during four grazing seasons. Orthogonal contrasts: control vs goats and goats + cattle ($P < 0.02$); goats vs goats + cattle ($P < 0.7$); SE = 4.9.

and Bryan, 1983). In that study, goats and sheep defoliated brambles 100% the first year and controlled the number and height of regrowth shoots adequately the second year. The same authors also reported poor defoliation and control of brambles regrowth by cattle.

Honeysucke was controlled to a similar extent in both the G and G+C pastures, although a numerical difference was observed. Goats selected honeysuckle and the response was most probably a stocking rate effect (G: 30; G+C: 17 goats). Honeysuckle in the C plot remained high throughout the study because it tolerates shade, resulting in an overall across treatments seasonal increase from 39% in spring to 44% in fall ($P < 0.01$).

Nimblewill, wild strawberry and mint showed unusual frequency patterns. Nimblewill is not considered a preferred grass by either goats or cattle. Nimblewill was absent from the C plot throughout the study, but was always observed in the fall, at increasing frequencies in the grazed plots, resulting in an overall linear increase ($P < 0.05$). Wild strawberry remained fairly stable in the G+C pasture throughout the study, but showed an increased frequency in both C and G pastures that resulted in an overall linear increase ($P < 0.01$). Mint was not affected by the defoliation treatments but appeared to increase

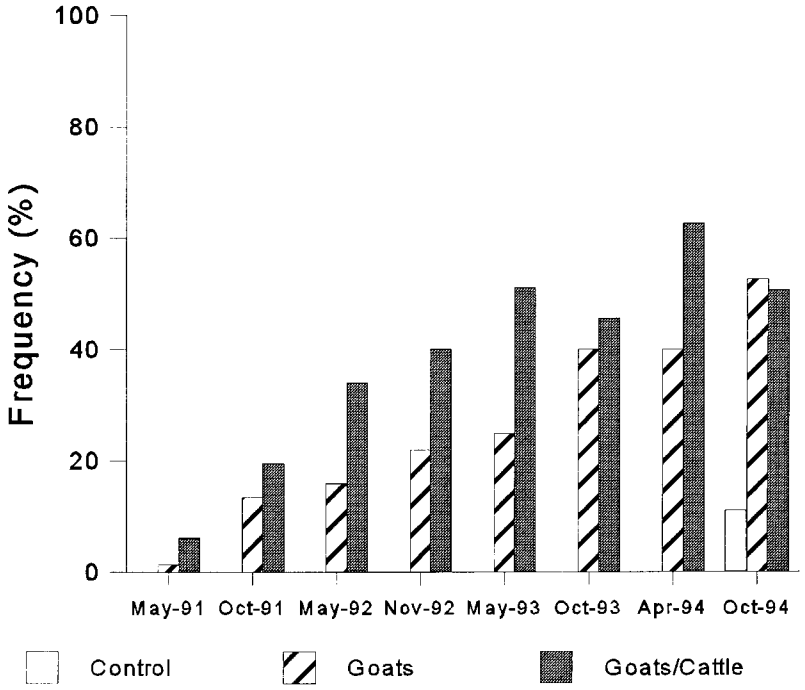

Figure 5. Effect of grazing mountain pastures in the Appalachian region of the United States with goats alone or with goats and cattle on white clover frequency (%) during four grazing seasons. Orthogonal contrasts: control vs goats and goats + cattle ($P < 0.02$); goats vs goats + cattle ($P < 0.75$); SE = 6.0.

in frequency only in the G pasture. The difference observed for wild strawberry and mint may be related to grazing behavior. Cattle graze closer to the ground than goats and have a wider mouth that gives them less opportunity to selectively graze. Therefore, cattle may have ingested both mint and wild strawberry along with other preferred plants. Trampling by cattle may also have played a role.

Reports on botanical species changes over time due to grazing by goats and cattle are limited. Increase in grasses and native white clover populations have been reported when brush-infested pastures were grazed by different ratios of goats and sheep (Clark et al., 1982; Yerex, 1986).

Multiflora roses

Goats and goats + cattle were also very effective in controlling multiflora rose bushes (Table 2). The linear reduction in height ($P < 0.03$) and density ($P < 0.01$) of the bushes after four growing seasons indicated that their condition was severely affected. In the G pasture, height and density index of multiflora roses decreased, respectively, from 2.1 m and 2.1 in May 1991 to 0.4 m and

Table 1. Effects of grazing mountain pastures in the Appalachian region of the United States with goats alone or with goats and cattle on six unproductive weed species frequency (%) during four grazing seasons (data from 1992 and 1993 grazing seasons not shown).

Frequency, %	May 1991			Oct 1991			Apr 1994			Oct 1994				C vs G & G+C[a]	G vs G+C[b]
	C	G	G+C	C	G	G+C	C	G	G+C	C	G	G+C	SE[c]	*P* <	*P* <
Poison ivy	78	51	30	67	33	26	0	0	0	0	10	14	6.4	0.02	0.36
Brambles	67	32	29	11	25	17	22	10	12	22	5	17	6.7	0.67	0.39
Honeysuckle	22	12	35	67	30	52	67	9	39	56	13	37	4.5	0.04	0.57
Nimblewill	0	0	0	11	17	30	0	2	10	0	33	63	3.3	0.03	0.17
Strawberry	11	35	15	22	49	33	67	65	18	33	46	31	3.2	0.01	0.07
Mint	22	28	5	33	39	24	0	5	23	11	51	6	8.5	0.24	0.97

[a] Orthogonal contrast: Control vs goats and goats + cattle.
[b] Orthogonal contrast: Goats vs goats + cattle.
[c] Standard error derived from the statistical model.

Table 2. Effects of grazing mountain pastures in the Appalachian region of the United States with goats alone or with goats and cattle on multiflora rose bushes during four grazing seasons (data from 1992 and 1993 grazing seasons not shown; data from 1991 and 1992 [dead canes] and May 1991 [leaf out] not collected).

Multiflora rose	May 1991			Oct 1991			Apr 1994			Oct 1994				C vs G & G+C[a]	G vs G+C[b]
	C	G	G+C	C	G	G+C	C	G	G+C	C	G	G+C	SE[c]	*P* <	*P* <
Height, m	2.7	2.1	2.1	2.5	2.0	2.1	2.1	0.44	0.96	2.0	0.42	0.71	6.2	0.02	0.17
Density[d]	3.9	2.1	4.0	3.3	1.9	3.2	4.8	1.3	2.9	5.0	1.1	1.2	0.3	0.01	0.63
Area, m^2	14.8	6.2	16.8	51.2	7.3	13.8	17.3	0.32	4.7	16.0	0.33	4.7	2.6	0.15	0.54
Leaf out, %				17.5	5.7	6.8	77.5	32.1	53.8	100	42.5	48.9	5.0	0.02	0.02
Dead canes, %							6.3	95.6	79.5	0	100	91.9	4.7	0.01	0.2

[a] Orthogonal contrast: Control vs goats and goats + cattle.
[b] Orthogonal contrast: Goats vs goats + cattle.
[c] Standard error derived from the statistical model.
[d] Density index = 1 (least dense) to 5 (most dense).

1.1 in October 1994. Respective decreases in height and density for the G+C pasture were from 2.1 m and 4.0 in May 1991, to 0.7 m and 1.2 in October 1994. Multiflora rose area declined steadily in the grazed pastures compared to C. However, overall trends were not significant due to the large numerical values of multiflora rose areas of C. Percent leaf out of multiflora rose bushes exhibited a linear decrease overtime ($P < 0.01$) as well as a seasonal effect (spring: 62%; fall: 33%; $P < 0.01$) and a treatment by season interaction ($P < 0.02$). In addition, percent leaf out was greater in the G (36% than the G+C (28%) pastures ($P < 0.02$). This difference may not be biologically significant but nonetheless surprising because 30 goats were stocked per acre in the G pasture compared to 17 in the G+C pasture. Furthermore, cattle were not observed defoliating multiflora rose bushes. Multiflora rose dead canes increased linearly overtime ($P < 0.01$), but no difference was observed between the G and G+C pastures. By October 1994, 100 and 92% of the multiflora rose canes were dead in the G and G+C pastures, respectively. The greater number of goats stocked on the G pasture may have resulted in a more effective control of multiflora rose bushes compared to the G+C pasture. Recent observations, however, indicated that new shoots have sprouted on the pasture following two years of rest. The size of the emerging shoots and the presence or absence of multiple basal shoots could indicate that some roots had survived, and that smaller, slender shoots appeared to have originated from new seedlings.

Defoliating multiflora rose bushes at four and eight weeks intervals starting in May resulted in 21% mortality by the beginning of the second year, 78% by the third year and 94% by the beginning of the fourth season (WB Bryan, pers. comm., 1993). In addition, spring and summer proved to be critical grazing times whereas grazing after August 1 was of negligible value (WB Bryan, pers. comm., 1996). Grazing on a powerline right of way, goats reduced brush cover from 45 to 15% in one year, and to 2% after five years of grazing (Magadlela et al., 1995).

Goats choose the most nutritious parts and portions of plants (Norton, 1984) and select approximately 60% browse and 40% grass in mixed plant populations (Pinkerton et al., 1991). In addition, selective feeding and a strong preference for browse allow goats to reduce dietary energy and protein variations caused by environmental conditions or management (Fedele et al., 1991). Therefore, due to their versatile grazing/browsing behavior, goats are able to sucessfully control encroaching vegetation while at the same time selecting a diet that meet their nutritional requirements in situations where other domestic ruminant species would be at a disadvantage.

Conclusions

The results of this experiment demonstrated that goats grazing alone or grazing with cattle were effective in shifting botanical composition toward desirable

forage species in overgrown mountain pastures. In addition, goats were very effective in controlling encroaching multiflora rose bushes. Multiflora rose bushes, however, may be difficult to eradicate permanently and the integration of goats into mountain grazing systems may prove to be a very useful management tool to keep these pastures in production. Finally, a strong preference for browse seems to indicate that some woody plant species may prove to be an important component of goats forage systems.

Acknowledgements

The authors wish to thank F. G. Giesbrecht, Department of Statistics, North Carolina State University, for statistical recommendations. The authors also express their thanks to Scott Goodman for his invaluable help in identifying plant species and the other personnel of the North Carolina Department of Agriculture Mountain Research Station for help with the field work.

References

Clark DA, Lambert MG, Rolston MP and Dymock N (1982) Diet selection by goats and sheep on hill country. Proc New Zealand Soc Anim Production 42: 155–157

Fedele V, Pizzillo M, Claps S, Morand-Fehr P and Rubino R (1993) Grazing behavior and diet selection of goats on native pasture in Southern Italy. Small Rumin Res 11: 305–322

Kay SH, Lewis WM and Langel and KA (1995) Integrated management of multiflora rose in North Carolina, 17 pp. North Carolina Cooperative Extension Service Publication No. AG-536

Luginbuhl J-M, Green Jr JT, Mueller JP and Poore MH (1995) Grazing habits and forage needs for meat goats and sheep – Chapter 20. In: Chamblee DS (ed) Production and Utilization of Pastures and Forages in North Carolina, pp 105–111. North Carolina Agricultural Research Service Technical Bulletin No. 305

Magadlela AM, Dabaan ME, Bryan WB, Prigge EC, Skousen JG, D'Souza GE, Arbogast BL and Flores G (1995) Brush clearing on hill land pasture with sheep and goats. J Agron & Crop Sci 174: 1–8

Mays WJ and Kok LP (1988) Seed wasp on multiflora rose, Rosa multiflora in Virginia. Weed Technol: 265–268

Mills TA and Bryan WB (1983) Improving hill pastures with grazing animals. Proc Symp Foothills for Food and Forest, pp 341–344. Corvallis, OR

Norton BW (1984) Nutrition of the Goat: A Review. Proc Goat Nutrition and Research in the Tropics, pp 75–81. Brisbane, Australia

Pinkerton F, Escobar N, Harwell L and Drinkwater W (1994) A Survey of Prevalent Production and Marketing Practices in Meat Goats of Southern Origin. SRDC Publication No. 182, 47 pp. Southern Rural Dev Center, Mississippi State, MS

Steel RGD, Torrie JH and Dickey DA (1997) Principles and Procedures of Statistics. 3rd Ed. McGraw-Hill Company, New York, NY

Yerex D (1986) The Farming of Goats, Fibre and Meat Production in New Zealand. Ampersand Publishing Assoc Ltd, Careterton, New Zealand