ID#18-03

RELATIONSHIP BETWEEN CANOPY CLOSURE AND PASTURE PRODUCTION IN DECIDUOUS TREE BASED TEMPERATE SILVOPASTORAL SYSTEMS

N. R. Devkota, A. J. Wall, P. D. Kemp, and J. Hodgson

Institute of Natural Resources, Massey University, Private Bag: 11222

Palmerston North, New Zealand

Abstract

Experiments were carried out in New Zealand with 11 year-old alder (*Alnus chordata*) on lowland pasture, and with 30+ year-old poplar (*Populus spp*) on hill pasture. Alder tree shade decreased ($P<0.001$) tiller density and total herbage harvested, with the highest tiller density at the lowest shade level of 41% canopy closure (DifN 0.59). Net herbage accumulation (NHA) directly under a poplar canopy was 35% of the NHA of open pasture, but NHA in canopy gaps increased with gap size. These results suggested that keeping canopy closure percentage in the 40-50% range for a deciduous tree silvopastoral system, would maintain pasture production and tiller density at approximately two-thirds of that of unshaded pasture.

Keywords: Alder, canopy closure, DifN, poplar, silvopastoral system, shade,

Introduction

Large areas of New Zealand pastoral hill country are susceptible to soil erosion, and the planting of soil conservation trees has become a common land-use practice to counter the negative impact of erosion. (Wall et al., 1997). Broad-leaved deciduous trees are preferred for these silvopastoral systems due to their excellent root development (Guevara–Escobar et al., 1997), and their better understorey pasture production than for evergreen trees (Wall et al., 1997).

Understorey pasture productivity is mainly affected by tree shade, which in turn depends upon the degree of canopy closure and characteristics of the tree canopy. Canopy closure and available light provide measures of the potential shading by trees (Knowles et al., 1997) that are independent of tree stems per hectare and the height to which trees have been pruned. However, the percentage of tree canopy closure required to maintain pastoral enterprises under deciduous trees requires definition.

Materials and Methods

Experiment 1 was on a moist, lowland site at Aokautere, New Zealand (latitude 40.22^0 S, longitude 175.35^0 E). The long term means for annual rainfall and mean annual air temperature are 995 mm and 12.9^0, respectively. The soil is a silt loam, fairly well drained with medium to poor fertility. The trees were 11 year-old Italian grey alder (*Alnus chordata*) evenly spaced at 3m by 4m for a stocking rate of 1197 stems/ha.

There were three main blocks (23 stems per block of $192m^2$), each with four sub-plots, replicated four times. The main blocks were shade treatments created by pruning trees (mean height 10.4m) to 2.5 m (heavy shading), 5.0 m (medium shading), and 7.0 m (light shading) from ground level, and the subplots were mixed species pastures. Canopy closure and diffuse non-intercepted light (DifN) for the trees in both experiments were measured using a LAI 2000 Plant Canopy Analyser (Welles, 1990). From October 1997 to May 1998, the tiller density (2 0×0.01 m^2 quadrats) and herbage dry matter harvested above 50mm defoliation height (1×1 m^2 quadrats) were measured monthly.

Experiment 2 was located on steeply dissected hill (15-35^o slopes) farmland at Kiwitea, New Zealand (40.08^{0}S, 175.50^{0}E). The long term mean annual rainfall is 1062 mm. Soils are medium fertility sandy loams (Suckling, 1975). Mature, unpruned, 30+ year old *Populus spp.* (poplar) growing in typical hill pasture cover the site (Suckling, 1975).

Net herbage accumulation (NHA) was measured for four tree stocking rates (0-89 stems/ha), replicated twice. Exclusion cages were randomly positioned within predetermined zones; Zone 1 (directly under tree crown) and Zone 2 (gap between tree crowns). Monthly measurements of NHA were taken for each leaf (November 1998 to March 1999) and no leaf (June 1999 to October 1999) period. Net herbage accumulation (NHA) was estimated using the trim technique (Guevara–Escobar et al., 1997).

Results

Shade significantly (P<0.001) decreased tiller density (Table 1). Highest tiller density was produced under light shade (canopy closure 41%, DifN 0.59). Tiller densities under heavy and medium shade were 84% and 68% respectively, of the tiller density under light shade (Table 1).

Total herbage harvested during November 1997 to May 1998 was also significantly decreased as shade level increased ($P<0.0001$). Under medium shade (canopy closure 75%, DifN 0.24) the total herbage harvested relative to the herbage harvested under light shade was 84%, and for heavy shade (canopy closure 89%, DifN 0.10) it was 60% (Table 1).

NHA directly under a poplar canopy was 35% of the NHA of open pasture, and was unaffected by tree stocking rate (Zone 1, Table 2). Canopy closure was greater than 86% directly under the trees and DifN averaged 12% of the DifN for open pasture (Table 2). In contrast, the NHA under canopy gaps (Zone 2) was greater the lower the tree stocking rate (Table 2). NHA under canopy gaps was lower than for open pasture, with the NHA for a canopy closure of 47% and DifN of 0.53 still only 76% of the NHA of open pasture (Table 2). NHA was relatively greater under the poplars when their leaves had fallen, but was still lower than the NHA of open pasture (Table 2). DifN and the canopy closure % were less than one for open pasture due to the surrounding hills (Table 2).

Discussion

A disadvantage of using the deciduous trees, poplar and alder, in a silvopastoral system is they decrease pasture production (Wall et al., 1997). The decrease in pasture production under alders and poplars in these two experiments was similar to that measured by Guevara-Escobar et al., (1997) in a mature poplar-pasture system. Guevara-Escobar et al., (1997) found annual pasture production under a canopy closure percentage of 70% was 60% of that of unshaded pasture. As the tree canopy becomes closed, light, followed by the soil moisture content, are the main factors limiting pasture production in the climatic region for this research (Guevara-Escobar et al., 1997).

These results demonstrated that canopy closure is the critical factor to manage if pasture production is to be maintained at an economic level. Either pruning trees or removing trees can decrease canopy closure. Both methods allow the tree leaves to be used as livestock fodder. The percentage canopy closure that allows adequate pasture production should be defined for deciduous tree based silvopastoral systems so that managers have a quantitative criterion to base tree management on that is independent of tree stocking rate, age, pruning regime and site. We suggest the critical threshold is in the 40-50% range. This will maintain pasture production and tiller density at approximately two-thirds that of unshaded pasture (Table 1 and 2, Guevara-Escobar et al., 1997). The prevalence of digital cameras and image analysis software makes the measurement of canopy closure an increasingly routine task (Knowles et al., 1997).

References

Guevara-Escobar, A., Kemp P. D., Hodgson J., Mackay A. D. and Edwards W. R N. (1997). Case study of a mature *Poplus deltoides*-pasture system in a hill environment. *Proceedings of the New Zealand Grassland Association* **59**:179-185.

Knowles R. L., Horvath G. C., Carter M. A. and Hawke M. A. (1997). Developing a canopy closure model to predict overstorey/understorey relationships in Pinus radiata silvopastoral systems. Meeting Proceedings Forest and Farm Plantation Management Co-operative. Pp. 26-34.

Suckling, F.E. (1975). Pasture management trials on unploughable hill country at Te Awa: III Results for 1959 – 69. *New Zealand Journal of Experimental Agriculture* **3**: 51 – 436.

Wall, A. J., Mackay A. D., Kemp P. D., Gillingham A. G. and Edwards W. R. N. (1997). The impact of widely spaced soil conservation trees on hill pastoral systems. *Proceedings of the New Zealand Grassland Association* **59**:171-177.

Welles, J. M. (1990). Some indirect methods of estimating canopy structure. *Remote Sensing Reviews* **5**:31-43.

Table 1 - Experiment 1 - Effects of alder shade on tiller density and total herbage harvested during November 1997 to May 1998.

Treatments/shade levels	DifN	Canopy closure (%)	Tiller density (number/m^2) (Repeated measures, November 1997 to May 1998)	Total herbage harvested (t DM/ha) during November 1997 to May 1998
Mean of heavy shade	0.108	89	2401	3.90
Mean of medium shade	0.247	75	2979	5.52
Mean of light shade	0.594	41	3555	6.54
Analysis of variance				
Shade			P<0.001	P<0.0001
SEM for shade			57.63	0.15

Table 2 - Experiment 2 - Effects of poplar shade on the net herbage accumulated (NHA) during November 1998 – October 1999.

Environment	Stems/ha	DifN		Canopy closure (%)		NHA (t DM/ha)	
		Leaf	No leaf	Leaf	No leaf	Leaf	No leaf
Open	0	0.883	0.933	12	7	6.42	6.28
SEM (n=4)		0.011	0.034	1	3	0.52	0.47
Zone 1	31	0.085	0.570	92	43	2.50	3.86
(under tree)	58	0.092	0.549	91	45	2.16	3.22
	89	0.136	0.547	86	45	2.06	2.77
SEM (n=6)		0.015	0.012	1	1	0.15	0.21
Zone 2	31	0.535	0.866	47	13	4.89	4.25
(in gap)	58	0.276	0.712	72	29	3.07	3.70
	89	0.127	0.568	87	43	2.48	2.18
SEM (n=6)		0.074	0.052	7	5	0.54	0.42