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GRASS-WOODY PLANT RELATIONSHIPS

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Bromegrass (*Bromus inermis* Leyss. cult Carlton) was grown alone or with aspen (*Populus tremuloides* Michx.), silverberry (*Elaeagnus commutata* Bernh.), or western snowberry (*Symphoricarpos occidentalis* Hook.) in the greenhouse for 90 days. Competition reduced the yields of grass and woody plants compared with yields obtained when either was grown alone. Bromegrass grown alone or with aspen or snowberry produced similar total yields, but when grown with high density silverberry, the total yields were significantly greater. The yield of oat forage obtained from soil that had grown a previous crop of woody plants was reduced by previous high production of aspen or snowberry, but oat yield increased with previous high production of silverberry. It is known that another species of the genus *Elaeagnus* is a nitrogen-fixer and the silverberry plants used in this study were nodulated. The beneficial effects of silverberry on the grass may have been due to nitrogen fixation.

On a cultivé en serre pendant 90 jours du brome (*Bromus inermis* Leyss. cult Carlton), soit seul, soit avec des peupliers-trembles (*Populus tremuloides* Michx.), des chalefs changeants (*Elaeagnus commutata* Bernh.), ou des symphorines (*Symphoricarpos occidentalis* Hook.). La concurrence a abaissé les rendements de la graminée et des plantes ligneuses, par rapport aux rendements obtenus lorsque chaque plante était cultivée seule. Le brome cultivé seul ou avec des peupliers-trembles ou des symphorines a donné des rendements totaux semblables, mais lorsqu'il était cultivé avec des chalefs changeants à forte densité, les rendements totaux étaient significativement plus grands. Le rendement en avoine fourragère obtenu sur un sol ayant porté précédemment des plantes ligneuses a été abaissé par une forte production antérieure de peupliers-trembles ou de symphorines, mais augmenté par une production antérieure de chalefs. On sait qu'une autre espèce du genre *Elaeagnus* est un fixateur de l'azote, et les chalefs ayant servi à cette étude avaient des racines noduleuses. Les effets bénéfiques du chlef changeant sur la culture du brome peuvent provenir de sa capacité de fixer l'azote.

INTRODUCTION

Many native grasslands in the aspen parkland region of the Canadian prairies have been invaded by trees and shrubs in this century (Maini 1960; Johnston and Smoliak 1968; Wroe 1971). Accompanying the invasion of most woody plants is a sharp decline in density and herbage production of desirable forages. Three of the important invading woody species in the parklands of central Alberta are aspen (*Populus tremuloides* Michx.), silverberry (*Elaeagnus commutata* Bernh.), and western snowberry (*Symphoricarpos occidentalis* Hook.). All three species multiply rapidly from a vigor-

ous root system particularly in the absence of competition. Little is known about their competitive relationships with grasses other than that dense stands of aspen or western snowberry cause a sharp decline in grass production (Friesen et al. 1965; Wroe 1971), whereas silverberry often causes either no change or an increase in grass production (Corns and Schraa 1965; Bailey 1970).

The objectives of the study were to compare in the greenhouse the competitive interactions between each of the three woody species and a grass, and to evaluate the effects of the three woody species on the soil as measured by subsequent growth of another grass.

MATERIALS AND METHODS

Live lateral roots of the three woody plants were collected in the fall of 1969 at the University of Alberta Ranch, Kinsella, Alta., 152.86 km (95 miles) southeast of Edmonton. Initial trials were made to determine if the roots of all three species would sprout. Profuse sprouting occurred on roots of aspen and western snowberry but not on silverberry roots. Consequently, small plants of silverberry were collected for the main experiment. The tops and roots of each silverberry were cut back leaving a 15-cm main root and then stored in a cold-room at 5 C. Fifteen-cm roots of aspen and snowberry were planted in flats containing perlite and placed in the greenhouse at temperatures of 16 C night and 21 C day. One month later, 7 February 1970, roots having vigorous 5–8 cm long sprouts were transplanted into 23-cm plastic pots into soil that had been sterilized. The soil had a 6:4:1 ratio of loam, sand, and peat. At this time young silverberry plants were taken from a cold room and planted into 23-cm plastic pots. Brome-grass (*Bromus inermis* Leyss. cult Carlton) was seeded 7 February 1970 and covered with 1 cm of soil. One month after seeding, the grass was thinned to 15 plants/pot. A 16-h light period with temperatures of 21 C day and 16 C night was maintained throughout the experiment. The two densities were one and two woody roots or plants per pot. The three treatments were: (A) woody species alone; (B) woody species with brome-grass; and (C) brome-grass alone. There were nine pots in each treatment.

The pots of all treatments were randomly located on the greenhouse benches using a completely randomized design. Pots were regularly watered and rotated weekly in a regular manner within each bench but no fertilizers were applied.

The pots were harvested 7 May 1970, 3 mo after the experiment began. Length of the longest grass leaf and height of the tallest woody plant were recorded in each pot. The tops and roots of each species were separated, oven-dried, and weighed. Soil of pots having shrubs only were placed back into the same pot and on 10 June 1970 oats (*Avena sativa* L. cult Glenn) were seeded and later thinned to seven seedlings/pot after germination. Adequate watering was maintained throughout the experiment but no fertilizer was applied. The oats were harvested as forage at the milk stage on 27 July 1970.

Statistical tests applied were either the unpaired *t*-test or one-way analysis of variance and Duncan's multiple range test. Linear re-

gression and 19 curvilinear regression equations were fitted to the data. The equation accounting for the greatest amount of variation (r^2 or R^2) was usually presented (Fig. 1 and 2).

RESULTS

Effects of Woody Plants on Brome-grass

The three species of woody plants had little effect upon the height of brome-grass but a detrimental effect on the yield of tops and roots was indicated by the percent yield reduction (Table 1). The yield of brome-grass was also affected by density of woody plants. Two rootstocks per pot consistently yielded less brome than pots having one rootstock. Snowberry caused the least percentage weight reduction and silverberry the greatest percentage weight reduction in tops and roots of brome-grass. It can be demonstrated by regression equations, however, that snowberry and aspen had a greater detrimental influence per weight of woody plant on brome-grass yield than did silverberry (Fig. 1). The effect of snowberry and aspen on brome-grass differed markedly from that of silverberry.

Effects of Brome-grass on Woody Plants

The competition provided by the addition of brome-grass generally resulted in reduced height and yield of the three woody species.

Fig. 1. Effects of snowberry (SYOC), aspen (POTR), and silverberry (ELCO) competition on the production of brome tops and roots. In the regression equations, Y = weight of brome-grass, X = weight of woody plant.

Table 1. Height and yield responses in brome grass and three woody species to inter- and intraspecific competition

Species and no. woody plants/pot	Ht (cm)			Yields (g/pot)			Yield reduction (%)					
	Components in mixture		Shrubs grown alone	Components in mixture		Total grass and shrubs alone	Grass reduction by shrubs		Shrub reduction by grass			
	Grass	Shrubs		Grass	Shrubs		Tops	Roots	Tops	Roots		
Grass alone	88 <i>a</i> *			65 <i>a</i>		65 <i>cde</i>						
Snowberry	1 86 <i>a</i>	41	47	55 <i>ab</i>	10	65 <i>cde</i>	12	22	29	45		
	2 82 <i>a</i>	39	43	46 <i>b</i>	17**	63 <i>cde</i>	27	32	37	31		
Aspen	1 87 <i>a</i>	73***	111	51 <i>b</i>	19***	70 <i>bcd</i>	25	19	49	56		
	2 84 <i>a</i>	88	88	45 <i>b</i>	23***	68 <i>cd</i>	28	35	51	67		
Silverberry	1 92 <i>a</i>	89***	125	48 <i>b</i>	28***	76 <i>bc</i>	23	29	51	44		
	2 78 <i>a</i>	121	139	31 <i>c</i>	69	100 <i>a</i>	50	56	24	29		
Means	1 89	68	94	51	19	70	20	23	43	48		
	2 81	83	90	41	36	77	35	41	37	42		

*Means followed by the same letter in vertical sequence are not significantly different ($P < 0.05$) according to Duncan's multiple range test, outlined columns considered together.

Differs from comparable figure under respective 'shrubs grown alone' columns (= $P < 0.05$; *** = $P < 0.01$).

The treatments most affected by brome-grass were aspen at both rootstock densities and silverberry at one rootstock/pot. These species also reduced the yield of brome-grass the most. Similar reductions in height of shrubs were apparently caused by the competition provided by an additional rootstock in the case of snowberry and aspen cultures. The reduction of aspens showed high statistical significance. On the other hand, the addition of a second silverberry rootstock increased both the yield and height of silverberry, whether grown alone or with brome-grass. The detrimental effects of brome-grass on top and root yield of silverberry were reduced by about 50% in the double density culture, whereas the reduction of brome-grass top and root weight was increased by 100%. The silverberry with two rootstocks/pot and snowberry were least affected by brome-grass. Snowberry, however, had much lower yields than silverberry, and at comparable rootstock densities, its effect on brome-grass yield was about 50% less than that of silverberry (Table 1). In woody plants of similar weight, however, snowberry reduced brome yield more than did silverberry (Fig. 1).

Brome significantly reduced the weight of aspen at both rootstock densities. Aspen height growth, however, was more variable. A significant reduction was caused by brome-grass when there was one rootstock/pot but there was no difference ($P < 0.05$) in aspen height amongst one aspen rootstock with brome and two aspen rootstocks with or without brome. Apparently competition from either grass or another rootstock yielded the same result for aspen height growth.

Total yield comparisons among the shrub and shrub-grass cultures showed that woody plants grown alone produced less than grass and woody plants grown together. Snowberry at both densities and aspen at one rootstock/pot produced significantly less than brome-grass. All combined grass and woody plant yields were greater than for the woody plants grown at their respective densities, and for snowberry, aspen, and one rootstock/pot of silverberry, the yields were significantly higher. However, for silverberry at two rootstocks/pot, whether grown alone or in combination with grass, yields were significantly higher than brome-grass grown alone. Furthermore, at this density, silverberry and grass produced significantly more than any other species or combination.

Effects of Woody Plants on Yield of a Subsequent Crop

The yields of oat forage grown on soil that had previously supported the three woody species differed markedly (Table 2). Major differences can be attributed to woody species, rootstock density, and shrub yield. For snowberry and aspen, as the yield of tops and roots of woody plants increased, yield of the subsequent crop of oat forage declined (Fig. 2). For silverberry, however, as the yield of woody tops and roots increased, so did the yield of oat forage.

DISCUSSION

All three woody plant species reduced brome-grass yields compared with the yield of grass grown alone. There was a competition for the limited resources available. However, brome-grass usually caused a substantially greater reduction in the yield of

Table 2. Effects of three woody species on oat forage subsequently grown in the same soil

Species	Woody plants/pot	Plant wt, g/pot	Oat forage, g/pot
Snowberry	1	14 <i>e</i> *	7.8 <i>b</i>
Snowberry	2	25 <i>de</i>	7.6 <i>bc</i>
Aspen	1	36 <i>cd</i>	7.5 <i>bc</i>
Aspen	2	51 <i>bc</i>	7.0 <i>c</i>
Silverberry	1	55 <i>b</i>	7.8 <i>b</i>
Silverberry	2	85 <i>a</i>	8.5 <i>a</i>

*Means followed by the same letter in vertical sequence are not significantly different ($P < 0.05$) according to Duncan's multiple range test.

Fig. 2. Effects of snowberry (SYOC), aspen (POTR), and silverberry (ELCO) on the production of oat forage subsequently grown in the same soil.

woody plants than vice versa. This is in general agreement with the results of a field study by Bailey (*unpublished data*, 1972), which revealed that seeded grasses effectively reduced the density and height of regenerating suckers of aspen and snowberry. Of the forage grasses planted, brome-grass was the most competitive with woody suckers.

Snowberry and aspen both had a detrimental influence on the subsequent crop of oats and this relationship was strongly negatively correlated. Apparently snowberry and aspen used up nutrients to the extent that they became limiting to the growth of the subsequent crop. Aspen is known to transform the soil under some native stands (Dormaer and Lutwick 1966) but the soil changes are assumed to take years rather than months.

Silverberry produced greater yields at comparable densities than did aspen or snowberry. At the high density, silverberry and brome-grass together yielded significantly more than any other treatment. This occurred in spite of the 53% yield reduction in brome-grass. It would appear that silverberry has some special characteristic that makes it more competitive with brome-

grass. One might expect that the subsequent crop of oats would be lower yielding than for either snowberry or aspen. This was not the case. There was a positive relationship between silverberry yield and yield of the subsequent crop of oat forage.

Silverberry is a member of the genus *Elaeagnus*, one of the nonleguminous, nodule-bearing genera of woody plants (Bond 1963). Gardner (1958) has demonstrated that Russian olive (*Elaeagnus angustifolia* L.) fixes nitrogen. Moore (1964) observed nodules on silverberry roots and indicated that it was a nitrogen-fixer; he provided no evidence to support the observation. Nodules were observed on the silverberry plants used in the present study. The soil had been sterilized but the rootstocks planted were not. The positive correlation ($r = 0.86$) between silverberry weight and yield of the subsequent crop of oat forage may be due to the nitrogen-fixing capabilities of silverberry. Similar responses have been found for other nonleguminous, woody nitrogen-fixers (i.e., Wollum and Youngberg 1964).

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