EFFECTS OF ROW SPACING AND SEEDING RATES ON SEED YIELD IN RED CLOVER, ALSIKE CLOVER AND BIRDSFOOT TREFOIL

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The effects of various row spacings and seeding rates on seed yield and certain seed yield components, viz, florets per head, seed set, seeds per pod, were studied on single seedings with three successive seed crops of red clover (*Trifolium pratense* L.), alsike clover (*T. hybridum* L.), and birdsfoot trefoil (*Lotus corniculatus* L.). Alsike clover and birdsfoot trefoil produced the highest yields at the narrow 15-cm spacing with successive decreases to the 60-cm spacing. The taller-growing and later-blooming, single-cut red clover was slightly more adaptable to varying spacings with the highest yields at 30- and 45-cm spacings, and slightly lower yields at the 15- and 60-cm spacings. All three crops competed successfully with weeds at the narrow spacings (15 and 30 cm). All three crops were able to compensate within limits in the 2nd and 3rd seed yr for differences in stand caused by different seeding rates. Seeding rates of 2.2 and 4.5 kg/ha were most favorable. Certain components of yield, e.g., florets per inflorescence, percent seed set, and seeds per pod, did not vary within years and are primarily affected by rainfall, soil fertility, pollinator populations and favorable pollinating weather. Differences in seed yields were attributable to total production of flower heads or racemes.

On a étudié l'effet de divers écartements de lignes et taux de semis sur le rendement grainier et certaines de ses composantes (nombre de florules par inflorescence, mise à graine et nombre de graines par gousse) en semis uniques de trois cultures grainières successives de trèfle rouge (*Trifolium pratense* L.), trèfle d'Alsike (*Trifolium hybridum* L.) et lotier corniculé (*Lotus corniculatus* L.). Les deux dernières espèces ont produit leur plus haut rendement à l'écartement de 15 cm, pour ensuite diminuer graduellement jusqu'à l'écartement de 60 cm. Le trèfle rouge à une coupe, de plus grande taille et à floraison plus tardive, s'est montré légèrement plus adaptable à divers interlignes et a produit les rendements les plus élevés à 30 et 45 cm, et des rendements légèrement plus faibles à 15 et 60 cm. Les trois cultures ont réussi à concurrencer les mauvaises herbes aux faibles écartements (15 et 30 cm) et ont pu compenser, dans une certaine mesure, au cours de la seconde et troisième année de production, les différences de densité du peuplement causées par divers taux de semis. Les densités de 2.2 et 4.5 kg/ha ont été les plus productives. Les composantes du rendement grainier n'ont pas varié au cours des années et sont essentiellement fonction de la pluviométrie, de la fertilité du sol, des populations d'insectes pollinisateurs et des conditions météorologiques à l'époque de la pollinisation. On a attribué les différences de rendement grainier à la production totale des inflorescences.

The production of single-cut red clover and alsike clover is an integral part of the economy of Northwestern Canada, while birdsfoot trefoil is a relatively new crop in the area (Production and Marketing Branch, Canada Department of Agriculture 1974). Seed yields of these crops vary from year to year due to climatic conditions, pollinator populations and management.

Row spacings and seeding rates are two management factors that have an effect on seed production of alfalfa, soybeans, buckwheat, crambe and flax. In the U.S.A. row spacings of 1.2–1.5 cm on sandy soils 0.9–1.2 m on medium-textured soils, 0.6–0.9 m on clay or shallow hard pan soils, and spacings as low as 23 cm on heavy clay soils are suggested for alfalfa (Pedersen et al. 1972). In soybeans, optimum row spacings varied from 50 to 60 cm (Lehman and Lambert 1960; Reiss and Sherwood 1965), with wider or narrow spacings yielding less. Spacings of 36 cm for crambe (Massey and Jellum 1973) and 7.5 cm for flax (Alessi and Power 1970) produced highest yields of these crops. Soybeans (Pandey and Torrie 1973) and buckwheat (Ali-Khan 1973) had the ability to compensate by branching for differences in stand caused by different seeding rates. In alfalfa, seeding rates as low as 3.4 kg/ha in solid seedings and 1.1 kg/ha in row plantings were recommended (Pedersen et al. 1972). Information on the legumes, red and alsike clovers and birdsfoot trefoil, is relatively scarce.

The present study was conducted to determine the effects of row spacing and seeding rate on florets per inflorescence, seed set and seed yield of red clover, alsike clover and birdsfoot trefoil.

MATERIALS AND METHODS

The experiments were conducted at the Research Station, Beaverlodge, Alberta on a dark gray-wooded soil. Soil tests showed a low nitrogen (N = 10 kg/ha) and medium-low phosphorus (P = 25 kg/ha) content, but adequate potassium (K) and sulfur (S). Accordingly, 112 kg/ha of 11–48–0 was incorporated into the soil prior to seeding to improve the fertility of the soil and assist in establishment of the seedling legumes.

Red Clover (*Trifolium pratense* L.)

The plots were arranged in a split-plot, latin-square design with five replicates, five spacings as main plots and six seeding rates as subplots. Spacings were 15, 30, 45, 60 and 90 cm. The seeding rates were based on a 6-m row being 0.1, 0.2, 0.5, 0.8, 1.0 and 2.0 g. The rate per hectare thus ranged from 0.2 kg/ha (0.1 g at 90-cm spacing) to 22.2 kg/ha (2 g at 15-cm spacing). Seed of cv. Altaswede was inoculated and seeded at a depth of 1.5 cm in late May 1969, using eight rows for the 15-cm spacing, five rows in the 30-cm, four rows in the 45-cm, two rows in the 60-cm and one row in the 90-cm spacing. The annual weeds, predominantly stinkweed (*Thlaspi arvense* L.), were mowed in mid-July and again in late August. In 1970, 1971 and 1972, all spacings except 15-cm were shallowly intertilled in early June. Observations were made on weed content in mid-August. Pollination in all 3 yr was provided by an apiary of 25 honey bee colonies located within 300 m of the plots. Bumble bees (*Bombus* spp.) were also present but the population was low. At maturity (September 1–5), five head samples were taken at random from each plot and analyzed for number of florets per head and percent seed set (percent of florets with seed). Samples of 0.9 × 6 m were harvested for seed yield from all plots except those with 60 cm-row spacing where samples of 1.2 × 6 m were taken.

Alsike clover (*Trifolium hybridum* L.) and Birdsfoot Trefoil (*Lotus corniculatus* L.)

The design of the experiment was similar to that for red clover. Row spacings of 15, 30, 45, 60 and 75 cm were used. Seeding rates were 0.6, 1.1, 2.4, 4.5, 6.7 and 9.0 kg/ha. Inoculated seed of Aurora alsike clover and Leo birdsfoot trefoil was planted in late May 1971 at a depth of 1.5 cm. Weeds (predominantly stinkweed, foxtail barley (*Hordeum jubatum* L.)) and oats (*Avena sativa* L.) were mowed in mid-July and late August.

In 1972, 1973 and 1974, all spacings except 15-cm were shallowly cultivated between the rows in early June. Observations on competitive effects of weeds were made in late August. Height of the crops was measured at commencement of bloom. Pollination was provided by 25 colonies of honey bees approximately 250 m distant and by 10,000 cocoons of leaf cutter bees (*Megachile pacifica* (Panzer)) in a shelter adjacent to the plots. Random samples of five heads of alsike clover were taken at maturity from each plot and analyzed for seed set, seeds per pod and florets per head. In birdsfoot trefoil, five racemes were taken at random when 5% of the pods in the field were shattering and analyzed for pods per raceme and seeds per pod.

Table 1. Yields (kg/ha) of red clover at various spacings and rates, and number of florets per head and percent seed set in 1970, 1971 and 1972 from 1969 seeding

	1970	1971	1972	3-yr avg
Spacings (cm)				
15	382 *a*	743 *b*	413 *a*	513 *ab*
30	426 *a*	875 *a*	415 *a*	572 *a*
45	444 *a*	864 *a*	379 *ab*	562 *a*
60	425 *a*	732 *b*	388 *ab*	515 *ab*
90	316 *b*	681 *b*	330 *b*	442 *b*
Rates (g/6-m row)				
0.1	323 *c*	764 *b*	269 *c*	452 *c*
0.2	383 *b*	789 *ab*	367 *b*	512 *b*
0.5	428 *ab*	822 *a*	410 *a*	554 *ab*
0.8	414 *ab*	790 *ab*	413 *a*	539 *ab*
1.0	437 *a*	796 *ab*	437 *a*	557 *a*
2.0	406 *ab*	714 *c*	414 *a*	511 *b*
No. of florets per head	114	119	132	122
% seed set	85	80	74	80

a–c Yields within each column followed by the same letter are not significantly different ($P < 0.05$) based on Duncan's multiple range test.

The plots were harvested immediately after. Sizes of harvested samples were 0.9 × 6 m for the 15-, 30- and 45-cm spacings, 1.2 × 6 m for the 60-cm spacing and 1.5 × 6 m for the 75-cm spacing.

RESULTS AND DISCUSSION

Red Clover

Spacings of 30 and 45 cm gave maximum seed yields (Table 1). Yields were significantly lower in the 90-cm spacings in all 3 yr, the 15- and 60-cm spacings being significantly lower in 1971. Only in the very low rates (less than 0.5 kg/ha) and in rates above 8 kg/ha were yields significantly lower, which resulted in a significant interaction between spacings and rates in 1971. Red clover was able to compensate for the range of seeding rates between 1 and 5 kg/ha and spacings between 15 and 60 cm for the varying plant populations within the rows.

No differences were evident within years between the various rates and spacings in either number of florets per head or seed set, so that higher seed yields were attributable to greater head production. Precipitation in June and July affected the growth of the crop which was excellent in 1971 but less favorable in 1970 and 1972 (Table 2). Lower temperatures accompanied by cloudy weather and intermittent

Table 2. Temperature (C) and precipitation (mm) at Beaverlodge, Alta. for May, June, July, August 1970-1974 compared to 59-yr mean (1916-1974)

	May		June		July		August	
Year	Prec.	Temp.	Prec.	Temp.	Prec.	Temp.	Prec.	Temp.
1970	25	8.8	36	14.8	23	15.6	41	15.4
1971	2	11.3	176	13.4	66	15.6	39	15.9
1972	1	11.1	54	13.8	58	13.6	46	15.1
1973	10	10.6	56	12.2	16	14.8	101	12.1
1974	52	7.5	13	13.1	69	13.3	59	13.4
59-yr mean	38	9.6	58	13.2	61	15.4	53	14.3

rain during late July and early August 1972 when the red clover was in full bloom affected the efficiency of the pollinators, and thus reduced the percent seed set.

Weeds, particularly dandelion (*Taraxacum officinale* L.), were abundant in the 90- and 60-cm spacings, particularly at the lower rates of seeding, but less evident in the 15-, 30- and 45-cm spacings. They may have had some effect on seed production.

Row spacings of 30–45 cm and seeding rates of 2–4 kg/ha can be recommended to produce high seed yields and offer competition with weeds.

Alsike Clover

In the 1st seed yr, narrow row spacings (15 cm) gave the highest yields (Table 3), with a significant decrease in yields with each increase in spacing up to 60 cm. Differences in subsequent years were not significant with the exception of the 75-cm spacings, suggesting a compensatory effect by the crop.

The intermediate seeding rates (2.2–4.5 kg/ha) were the most efficient, with both higher and lower seeding rates producing less seed. There was no interaction between seeding rates and spacings, suggesting a compensatory effect for varying plant populations.

As in red clover, no differences occurred within years in the number of florets per head, percent seed set, or seeds per pod which were governed by fertility, climate and pollination efficiency. Differences in seed yields were primarily a factor of seed head production. It is also evident that a reduction of seed yield occurs with increased age of stand, particularly in the 3rd seed crop yr when winterkilling (up to 25%) occurred.

There were some variations in height of stand in the 1st seed yr. At 5% bloom, plant height of the 15-cm spacing was 19 cm compared to 15 cm for the 60- and 75-cm spacing. No differences in height were apparent in the 2nd and 3rd seed yr.

Another advantage of narrow spacing was the competitive effect over weeds. Common groundsel (*Senecio vulgaris* L.), dandelion, foxtail barley, and oats were present at harvesting between the rows in the 60- and 75-cm spacings despite spring cultivation, and may have had some effect on reduction in seed yield. Fewer weeds

Table 3. Seed yields (kg/ha) of alsike clover at various row spacings and seeding rates, and florets per head, seed set (%) and seeds per floret in 1972, 1973 and 1974 from 1971 seeding

	1972	1973	1974	3-yr avg
Spacings (cm)				
15	1,114 *a*	546 *a*	295 *a*	652 *a*
30	936 *b*	498 *ab*	290 *a*	575 *ab*
45	689 *c*	515 *ab*	252 *ab*	485 *ab*
60	439 *d*	461 *ab*	200 *ab*	367 *b*
75	393 *d*	410 *b*	162 *d*	322 *b*
Seeding rates (kg/ha)				
0.6	626 *c*	465 *b*	207 *c*	433 *d*
1.1	695 *b*	513 *a*	233 *bc*	480 *bc*
2.2	758 *a*	492 *ab*	262 *a*	504 *ab*
4.5	760 *a*	509 *a*	263 *a*	511 *a*
6.7	752 *a*	458 *b*	233 *bc*	481 *bc*
9.0	694 *b*	475 *ab*	244 *ab*	471 *c*
Avg florets/head	64	72	59	65
Avg % seed set	83	77	73	78
Avg seeds/pod	2.2	1.7	1.6	1.8

a–d Yields within each column followed by same letter are not statistically different ($P < 0.05$) based on Duncan's multiple range test.

were observed in the 45-cm spacing. The 30-cm spacing was weed-free except at the 0.6 and 1.1 kg/ha rate of seeding. The 15-cm spacing was practically free of weeds. Thus, for high seed yields, and for competiton with weeds, narrow spacings (15 cm and seeding rates of 2–5 kg/ha are recommended for alsike clover seed production in the Peace River region.

Birdsfoot Trefoil

As in alsike clover, the narrow spacing (15 cm) gave the highest seed yield in the 1st seed yr, with significant reduction with each increase in spacing up to 60 cm (Table 4). Despite some compensatory effects in subsequent years, the superiority of the narrower spacings persisted. Unlike alsike, trefoil at the higher rates of seeding (4.5–9 kg/ha) produced more seed the 1st yr. In subsequent years, only in the lowest rate (0.6 kg/ha) were the yields significantly lower. There was a highly significant interaction in the 1st seed yr between spacings and rates of seeding, showing the beneficial effect of increased seeding rates up to 8.8 kg/ha. These results illustrate the low compensatory nature of this legume in the year of establishment and the 1st seed yr. In the 2nd and 3rd seed yr, no interaction was observed, indicating that the crop had compensated for the varying plant populations and spacings. The number of pods per raceme and seeds per pod were similar within each year and between years, suggesting that these two yield components are dependent on the pollinator populations which were stable throughout the period of the test. Competition with weeds followed a pattern similar to that of alsike clover, with the space between the rows of the 60- and 75-cm spacings very weedy by August despite spring cultivation. The weeds also interfered with harvesting. The 15- and 30-cm spacings were practically weed-free at the higher rates of seeding, but weeds were present within the rows in the two lowest rates (0.6 and 1.1 kg/ha) denoting the poor competitive nature of this crop.

The results of these experiments indicate that narrow row spacings (15 and 30 cm) are more advantageous to the short-growing and less competitive crops, birdsfoot trefoil and alsike clover. At narrow spacings they produce more bloom and compete better with weeds. The taller-growing and later-blooming, single-cut red clover Altaswede competes more strongly with weeds and

Table 4. Seed yields (kg/ha) of birdsfoot trefoil at various row spacings and seeding rates, and florets per raceme and seeds per pod in 1972, 1973, 1974 from 1971 seeding

	1972	1973	1974	3-yr avg
Row spacings (cm)				
15	742 *a*	479 *a*	389 *a*	537 *a*
30	655 *b*	437 *a*	335 *b*	476 *ab*
45	467 *c*	446 *a*	296 *b*	403 *ab*
60	317 *d*	378 *b*	287 *bc*	327 *b*
75	305 *d*	371 *b*	247 *c*	308 *b*
Seeding rates (kg/ha)				
0.6	223 *d*	350 *b*	264 *b*	279 *b*
1.1	428 *c*	441 *a*	308 *a*	392 *a*
2.2	536 *b*	455 *a*	339 *a*	443 *a*
4.5	584 *a*	433 *a*	313 *a*	443 *a*
6.7	593 *a*	413 *a*	336 *a*	447 *a*
9.0	621 *a*	444 *a*	304 *a*	456 *a*
Pods/raceme	4.8	4.6	4.7	4.7
Seeds/pod	17.0	15.0	16.8	16.3

a–d Yields within each column followed by same letter are not statistically different ($P < 0.05$) based on Duncan's multiple range test.

adapts to the slightly wider spacings and seeding rates, but such compensation is usually evident only in the 2nd and 3rd seed crop years. The yield component, florets per head, was associated primarily with climatic factors and seed set was dependent on the pollinator populations available and the weather conditions affecting their performance.

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