CANADA
DEPARTMENT OF AGRICULTURE
EXPERIMENTAL FARMS SERVICE

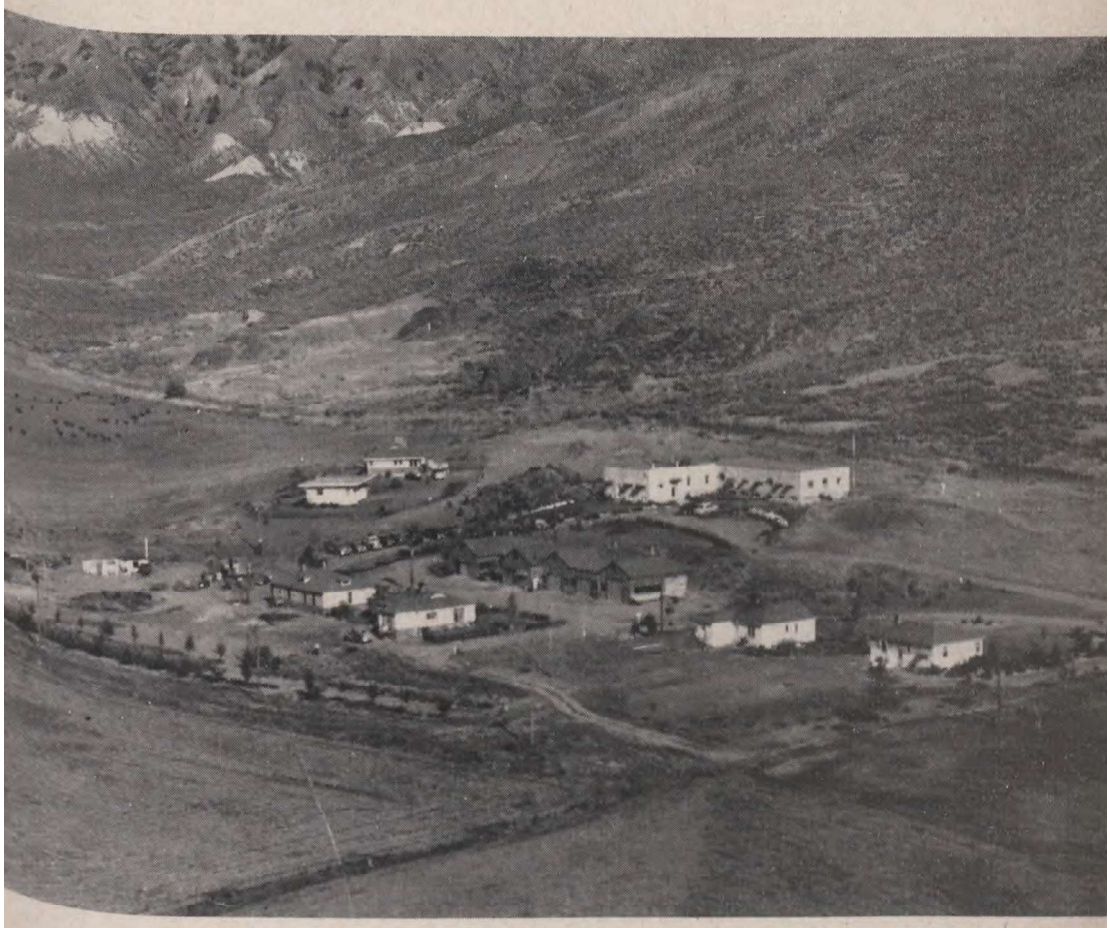
RANGE EXPERIMENT STATION

KAMLOOPS, B.C.

T. G. WILLIS, B.S.A., M.S.A., Superintendent

PROGRESS REPORT

1947 — 1953



AERIAL VIEW OF RANGE EXPERIMENT STATION HEADQUARTERS

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Minister of Agriculture, Ottawa, Canada

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MAP OF BRITISH COLUMBIA SHOWING RANGE AREAS.

(From the Fourth British Columbia Resources Conference.)

INTRODUCTION

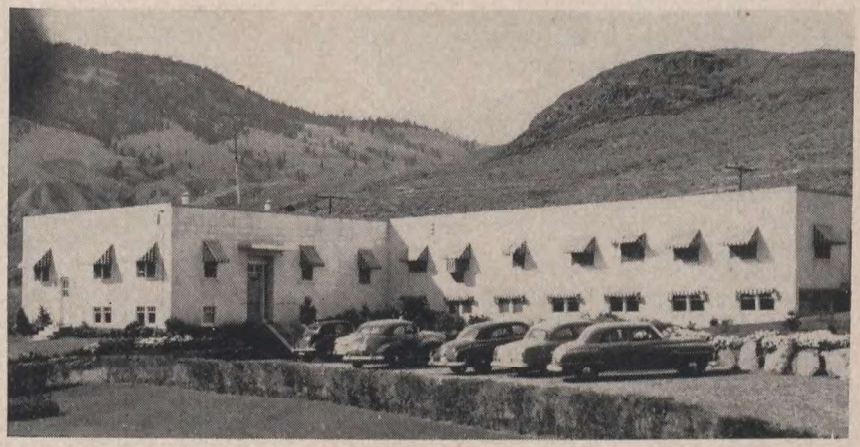


Fig. 1.—Administration Building, Range Experiment Station, Kamloops, B.C.

Personnel

T.G. Willis—B.S.A., M.S.A.,—Superintendent and in charge of Field Husbandry.
Alastair McLean—B.S.A., M.Sc.,—Assistant Superintendent, Agrostologist.
H.H. Nicholson—B.S.A., M.S.A., Animal Husbandman (Succeeding M.A. MacDonald 1951).
W.L. Pringle—B.S.A., M.S.F., Forage Plants.
J.D. Beaton—B.S.A., M.S.A., Field Husbandry.

Land Holdings

The Range Experiment Station was reorganized and re-established in 1947 by Dr. S.E. Clarke. Land was made available by arrangement with the Province of British Columbia including a large tract of summer range which was turned over to the Experimental Farms Service for grazing management investigations, and some arable land was purchased. It was difficult to obtain sufficient land that would be representative of the many grassland zones and types without jeopardizing the rights of certain range users.

The Headquarters of the Range Experiment Station is situated on the river flats near the Kamloops Civic Airport about six miles from the city limits of Kamloops. The flats represent average farm land for the district and the general location and topography of the Station are excellent for the headquarters.

The lower grassland ranges originate in the valley bottom and extend to an altitude of about 2,200 feet above sea level. These grasslands are characteristic of a large amount of the fall, winter, and early spring ranges in British Columbia. The Range Experiment Station has the use of a stretch of lower grassland beginning at the headquarters and extending up towards Pass Lake. Parcels of land representing other grassland types border on the upper reaches of this range. These parcels include all unalienated land in the West half of Township 21, Range 18, West of the 6th Meridian.

By agreement with the British Columbia Forest Service and a stock association, the Experimental Farms Service obtained use of the Tranquille Forest Reserve. At present the Range Station manages a large herd of cattle on this reserve which covers about 100,000 acres lying between 3,500 and 6,000 feet above sea level. The Department of Agriculture owns 1,160 acres of rangeland and an old Forest Ranger Station at Pass Lake at an altitude of 3,100 feet. This site is used as the headquarters for summer range research and is called the Pass Lake Substation.

The holdings under control of the Station are in summary as follows:

1.	Arable bottomland	140 acres	owned
2.	Montane-forest range	1,160 acres	owned
3.	Lower grassland range	160 acres	rented
4.	Open grassland range	6,500 acres	by agreement
5.	Upper grassland and mixed forest range	4,800 acres	by Order-in-Council
6.	Lower and upper montane-forest	106,500 acres	by agreement
	Total	119,260 acres	

Development

As the location of the Range Experiment Station was completely new with the exception of the Pass Lake holdings, most of the activities during the first three years were devoted to construction of plant facilities for research, housing, farming and range management. Consequently, organized research work was not possible until 1950. A considerable amount of preliminary and observational work was done to acquaint the workers with the problems and to map out a satisfactory research program to cope with some of the existing problems.

After some time a general theme for the Station's activity evolved: "Investigation in range management relating to rangelands contiguous to the interior valleys of British Columbia and the Cariboo plateau and investigation of methods of increasing the efficiency of range livestock production consistent with range conservation and revegetation." From this theme the research program became centered around the following:

1. Forage crop investigations on irrigated and dry land.
2. Herbage investigations under different methods of grazing on grassland and forest ranges.
3. Studies of different methods of range management.
4. Study of irrigated pastures on arable lands and how these pastures fit into the ranching industry.
5. Study of various production problems relating to ranching in British Columbia.
6. Study of plants poisonous to livestock and methods of controlling poisoning.
7. Study of the heritability of feed efficiency of beef cattle.
8. Study of irrigation problems as related to hay production.

The Station headquarters consists of a group of buildings and a tract of irrigated land. The buildings provide space for administrative offices, laboratories, divisional warehouses, workshops, stables and corrals, staff houses and implement and oil sheds. The Range Experiment Station attempts to serve the whole range area of the province. The area of range is approximately 20,000,000 acres and this expanse stretches from Soda Creek in the Cariboo to Elko in the East Kootenay District. The widely scattered ranching industry stretches some-

what beyond these limits. By direct highway it is approximately 900 miles from one end of the grazing district to the other.

Pilot work is carried out at the headquarters and applied work at research areas in the many districts. Demonstrations are handled in co-operation with ranchers in all major districts. The Station has three main divisions of activity: Forage Plants, Animal Husbandry, and Field Husbandry. The first two divisions carry out most of the necessary fundamental work and the Field Husbandry Division handles interpretation and application of the fundamental work in the form of management.

WEATHER RECORDS AND CLIMATE

Climate, which is extremely variable for the central interior of British Columbia, is by far the most important single factor affecting the growth of forage crops in this area. In order to study crop reactions to climate, weather stations were established at headquarters and at Pass Lake Subdivision in co-operation with the Meteorological Division, Department of Transport. To date records at Pass Lake have been taken only from May to September each year.

Summary of Weather

The spring of 1949 was warmer and dryer than average, which encouraged early spring growth on the grasslands. High temperatures and low precipitation during July and August reduced vegetative growth and brought about an early seed set. Total precipitation for the year was below average.

The winter of 1949-50 was one of the most severe on record and heavy economic losses were suffered by fruit raisers of the area. Growing conditions were unfavorable because of a cool dry spring followed by a warm, very dry June. Fall was favorable for growth and the native vegetation went into the winter in good condition.

The winter of 1950-51 had above normal precipitation and temperatures were slightly below average. Runoff was rapid and late. Spring was warm and extremely dry. Heavy rains in the fall restored soil moisture which resulted in a good catch from seedings. Rainfall for the year was slightly above normal.

The spring of 1952 was cool with little winter or early spring precipitation but a very wet June stimulated the ranges to peak production. During the last five months of the year rainfall was considerably below average with the total for the year being only 67 per cent of normal.

During the seven-year period at Kamloops the highest temperature reached was 100° F on July 14 and 15, 1949. The lowest temperature was —35° F. on January 18, 1950. Average date for the last spring frost over the five-year period was April 28 and for the first fall frost September 26. On the average, the last killing frost was April 25 and the first killing frost October 20, giving 179 killing-frost-free days, an average of 28 days over the frost-free period. (See Table 4)

Evaporation records are complete for the last two years only and hence are not included in this summary.

Summaries of meteorological readings are presented in Tables 1 and 2. These data indicate the great variability of climate in this area.

TABLE 1.—METEOROLOGICAL SUMMARY, RANGE EXPERIMENT STATION, KAMLOOPS

Month	Temperature ° F. 7 years av.			Precipitation 7 years av.	Bright sun 7 years av.
	Highest	Lowest	Mean	in.	hr.
January	54	−35	18	1·02	56
February	59	−20	27	0·96	91
March	70	−13	37	0·34	144
April	82	17	48	0·68	196
May	94	26	59	0·59	248
June	100	35	64	1·39	240
July	100	38	69	1·17	315
August	97	37	67	0·97	277
September	95	29	61	0·51	203
October	81	18	47	0·71	128
November	60	5	36	0·64	63
December	61	−27	27	1·34	39
Annual	.....	.....	47	10·33	.....
Total	.....	.....	.....	.....	2000

TABLE 2.—MEAN TEMPERATURE. MONTHLY AND ANNUAL MEAN TEMPERATURE FOR YEARS 1947 TO 1953, INCLUSIVE, DEGS. F.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1947	21	30	41	52	61	62	69	67	61	50	35	32	48
1948	29	21	36	41	58	70	67	64	58	46	35	19	45
1949	13	18	38	52	61	63	68	68	61	43	41	21	46
1950	−2	31	37	47	55	68	72	69	63	46	33	33	46
1951	20	22	29	47	58	63	70	67	60	45	35	17	44
1952	16	32	38	50	59	58	68	68	65	50	35	36	48
1953	26	36	43	48	60	63	68	68	61	51	42	32	50
7-Yr. Av.	18	27	37	48	59	64	69	67	61	47	36	27	47
38-Yr. Av.	22	27	39	50	58	64	70	69	60	47	35	28	47

The Water Rights Branch of the British Columbia Department of Lands and Forests co-operated in the location of two snow courses in the Watching Creek watershed. This watershed lies within the holdings of the Range Experiment Station. The above Branch also co-operated in the construction of a stream-measuring weir (Fig. 2) on Watching Creek to facilitate hydrologic studies in the area relative to runoff from timber range.

The snow courses have been measured by the Range Experiment Station for three years. These courses have been located to make representative surveys of the complete watershed of Watching Creek which has been delimited from aerial photographs to be an area of 34.3 square miles or 21,950 acres.

TABLE 3.—MONTHLY AND ANNUAL PRECIPITATION. RANGE EXPERIMENT STATION, KAMLOOPS, B.C. 1947–1953, (7 YEARS) INCHES.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1947	0·84	0·51	0·40	0·30	0·95	3·24	1·00	0·98	0·78	0·71	1·14	0·73	11·58
1948	0·31	0·84	0·02	1·78	0·54	0·62	2·89	3·14	0·83	0·38	1·13	0·76	13·24
1949	0·98	0·75	0·40	0·68	0·39	1·04	0·87	0·15	0·32	0·66	0·08	2·17	8·49
1950	0·92	0·41	0·62	1·15	0·60	0·34	1·41	0·63	0·00	1·09	0·91	1·96	10·04
1951	1·73	2·03	0·41	0·00	0·62	0·43	0·58	0·72	1·11	1·81	0·68	1·84	11·96
1952	1·21	0·96	0·42	0·12	0·12	1·62	1·04	0·44	0·15	0·21	0·11	0·46	6·86
1953	1·18	1·24	0·13	0·72	0·93	2·45	0·41	0·70	0·38	0·10	0·42	1·48	10·14
7-Yr. Av.	1·02	0·96	0·34	0·68	0·59	1·39	1·17	0·97	0·51	0·71	0·64	1·34	10·33
38-Yr. Av.*	0·96	0·68	0·38	0·40	0·95	1·43	0·94	1·04	0·81	0·71	0·88	1·00	10·18

* Kamloops Airport.

TABLE 4.—FROST RECORDS. RANGE EXPERIMENT STATION, KAMLOOPS, B.C.

	Frost 32° F. or lower.					Killing frost 28 ° F. or lower.				
	Last frost in spring		First frost in fall		Number of frost-free days	Last killing frost in spring		First killing frost in fall		Number of killing-frost-free days
Year	Date	Temp.	Date	Temp.		Date	Temp.	Date	Temp.	
1949	May 5	30	Sept. 12	31	130	May 2	24	Oct. 18	28	169
1950	Apr. 29	32	Sept. 30	28	154	Apr. 18	27	Sept. 30	28	165
1951	Apr. 24	30	Sept. 26	29	155	Apr. 23	28	Oct. 25	19	185
1952	May 7	30	Oct. 14	30	160	May 5	27	Nov. 5	26	184
1953	Apr. 16	30	Sept. 20	30	157	Apr. 14	28	Oct. 22	24	191
5-Yr. Av.	Apr. 28	.....	Sept. 26	.....	151	Apr. 25	.....	Oct. 20	.....	179

TABLE 5.—HOURS OF BRIGHT SUNSHINE BY MONTHS

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total for Year
1947	41	77	161	172	283	206	300	280	203	109	29	26	1887
1948	83	91	153	167	197	267	237	199	175	130	58	41	1798
1949	53	68	160	187	261	213	279	280	213	121	67	36	1938
1950	67	87	122	186	214	292	341	292	257	114	78	45	2095
1951	67	103	133	305	251	305	372	302	203	116	79	46	2282
1952	49	104	143	186	270	209	341	306	196	179	65	48	2096
1953	35	108	139	172	258	188	332	281	176	128	66	30	1913
7-Yr. Av.	56	91	144	196	248	240	315	277	203	128	63	39	2000
43-Yr. Av.*	60	99	168	199	245	256	316	286	211	142	66	46	2094

* Kamloops Airport.

Fig. 2.—The weir constructed on Watching Creek to aid in recording runoff from timber range.

TABLE 6.—SNOW-PACK AND RUNOFF MEASUREMENTS. WATCHING CREEK WATERSHED, RANGE EXPERIMENT STATION, KAMLOOPS, B.C.

Year	Water content (inches)		Runoff ac.-ft. Irrigation season	Runoff depth inches. Irrigation season
	Pass Lake	Tranquille Lake		
1950	4·9	9·1	7750	4·82
1952	6·1	15·0	6280	3·91
1953	2·1	8·8	6660	4·15

The data in Table 6 do not show significant trends or relationships. After several more years the data will be very useful in studies of runoff in relation to vegetative cover of timber range.

FIELD HUSBANDRY

T.G. Willis, J.D. Beaton

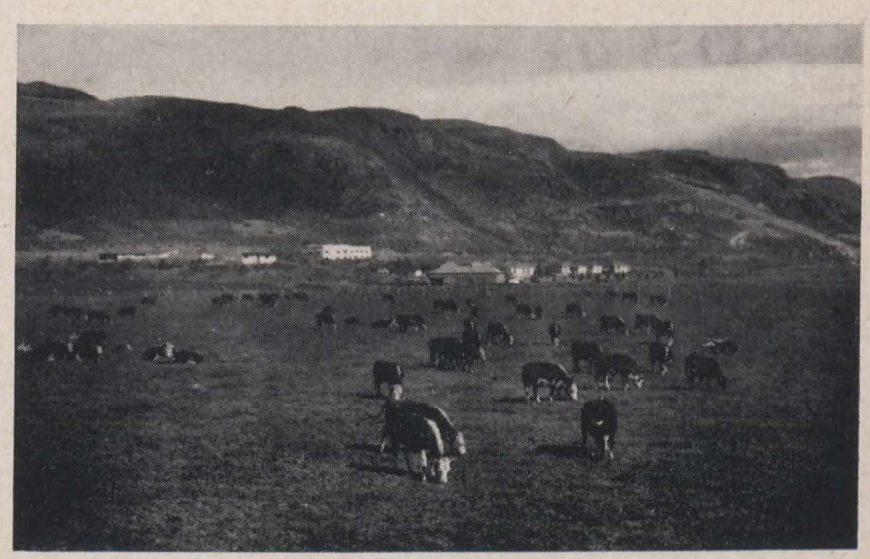


Fig. 3.—Panorama of Range Experiment Station Headquarters—irrigated pasture in foreground.

Range Weed Control

In considering range weed problems it should be borne in mind that rangelands are extensive uncultivated areas. The average assessed value is $2.50 per acre and the average annual production runs under 10 pounds of meat per grazed acre. It is obvious then that at present, no extensive program of weed control can be economically possible through the use of herbicides. Large infested areas can be handled by proper grazing management and new infestations relatively small in area can be checked by chemical or biological methods.

Range weeds can be placed in three groups;

1. Tenacious noxious invaders that may justify expending considerable funds for spot eradication;
   (1) Diffuse knapweed *(Centaurea diffusa)*
   (2) Goatweed *(Hypericum perforatum)*
   (3) Leafy spurge *(Euphorbia esula)*
2. Weeds that have invaded many range areas and under some conditions warrant eradication;
   (1) Big sage *(Artemisia tridentata)*
   (2) Cheat grass *(Bromus tectorum)*
   (3) Dandelion *(Taraxacum officinale)*
   (4) Jack pine *(Pinus contorta)*
   (5) Rabbit brush *(Chrysothamnus nauseosus)*
   (6) Pasture sage *(Artemisia frigida)*

3. Poisonous weeds;
   (1) Localized;
      a. Water hemlock *(Cicuta douglasi)*
      b. Arrowgrass *(Triglochin maritima)*
   (2) Widespread;
      a. Timber milk vetch *(Astragalus serotinus)*
      b. Death camas *(Zygadenus venenosus)*
      c. Larkspur *(Delphinium bicolor)*
      d. Lupine *(Lupinus sericeus)*

The weed control work of the Range Experiment Station has been concerned mainly with those under group one:—diffuse knapweed, goatweed, and leafy spurge. In addition big sage and cheat grass in the second group have received some attention.

Diffuse Knapweed

This weed was first classified as a biennial but recently evidence has been found to indicate that it is at least a short-lived perennial. Plants four years old have been found and there are indications of older plants in the vicinity of Pritchard, B.C. The weed invades abandoned land and over-grazed range very rapidly. It extends along highways and into damaged wildlands.

The hormone-type herbicides were used on plots for several successive years. The application of 2,4-D and 2,4,5-T and mixtures of both did not appear to control the weed effectively. Applications of 2,4-D at the rate of 1½ pounds of acid equivalent per acre did not destroy adult plants but inhibited seed setting. This rate of application will reduce the population of yearling rosettes and seedlings.

Plots were laid down using other types of herbicides. The 1952 and previous years' results indicated that in small patches the application of boron compounds, polyborchlorate and polyborate gave favorable eradication. However, for large areas the cost of boron treatments would be prohibitive. Moreover, soil sterilants produce dangerous conditions that may favor soil erosion.

The best method of control based on the plot studies appears to be a combination of the use of herbicides and reseeding the area to grasses for competition. A large-scale experiment is under way where a field sprayed with 2,4-D was divided up and part was reseeded to a mixture of dryland grasses. The effect of the competition of these grasses on the knapweed seedlings will be studied.

For roadside control of knapweed, preliminary information indicates that sodium TCA may have promise.

Goatweed

This is a very aggressive moderately poisonous perennial weed. It establishes readily on over-grazed range and when it is once well established it forms dense patches and dominates the soil to the exclusion of practically all other vegetation. The area of infestation is, as yet, not large. It was found that concentrated borax would control goatweed on plots if applied at the rate of 800 to 900 pounds per acre. This is expensive and in nearly all cases there was sufficient residual growth when handled on a field scale to reinfest the area.

At present, studies in biological control of this weed are being conducted by entomologists who are using several species of beetles imported from the United States.

Leafy Spurge

Some work is in progress but no results are available. The area of range infested with this weed is small and still at a stage where soil sterilants can be effectively used.

Big Sage

This is a large perennial dryland shrub that has invaded most British Columbia grasslands between the altitudes of 1,100 feet and 1,800 feet and in some places at higher altitudes. It now covers an estimated 750,000 acres.

In 1947 preliminary experiments were conducted at the Range Experiment Station to determine the susceptibility of big sage to 2,4-D. The plot experiments looked promising but when the same rates of 2,4-D were applied on a field scale with field equipment, the killing was much less effective. A mixture of 2,4-D and 2,4,5-T at 1½ pounds acid of each per acre gave effective control on a field scale using both tractor sprayers and aircraft spraying equipment. It

Fig. 4.—Upper: Seeding machine used for grubbing out sagebrush and reseeding to grass. Lower: Strip seeded with above machine, showing good catch of grass and fair elimination of sagebrush.

was found that the most effective period to treat big sage with 2,4-D and 2,4,5-T was in May or June when the growth is rapid. Treatments after mid-July were totally ineffective presumably because the sage goes into summer dormancy. Costs run in excess of $4 per acre. With the effective use of herbicides a dangerous erosion problem is introduced. Unless this type of control is coupled with re-seeding it is not recommended.

The Range Experiment Station has developed an implement that will grub out about 60 per cent of the sagebrush. In the same operation it will partially cultivate the soil, sow and cover the seed. This operation is confined to areas of suitable slope for the operation of field equipment (Fig. 4). Under these conditions the combined tillage and seeding operation can be accomplished for $2.50 per acre.

At the Range Experiment Station a number of trials were undertaken with this machine. The residual sagebrush growth and regrowth now is less than 25 per cent of the original stand and the grass yields are higher. Crested wheat grass was sown at the rate of 4 pounds per acre.

Irrigation

Fig. 5.—Tractor-moved sprinkler irrigation system on Range Experiment Station, Kamloops, B. C.

Forage is the largest acreage irrigated crop in British Columbia. In spite of this, irrigation research has touched only very lightly on problems of ranchers. With the advent of sprinkler irrigation, the Range Experiment Station received many requests for information. At the same time a sprinkler system was being adapted for use on the newly developed lands of the Station.

It could be seen that for the production of low priced forage crops, the cost of labor for the proper handling of a portable sprinkler system made its use appear improvident in many cases. The capital cost of converting from furrow or flood irrigation appeared unjustified. Hence, sprinklers should be used only under special circumstances.

A program was initiated to establish a completely portable system that could be moved at least partially mechanically and that could be installed at a minimum cost per acre.

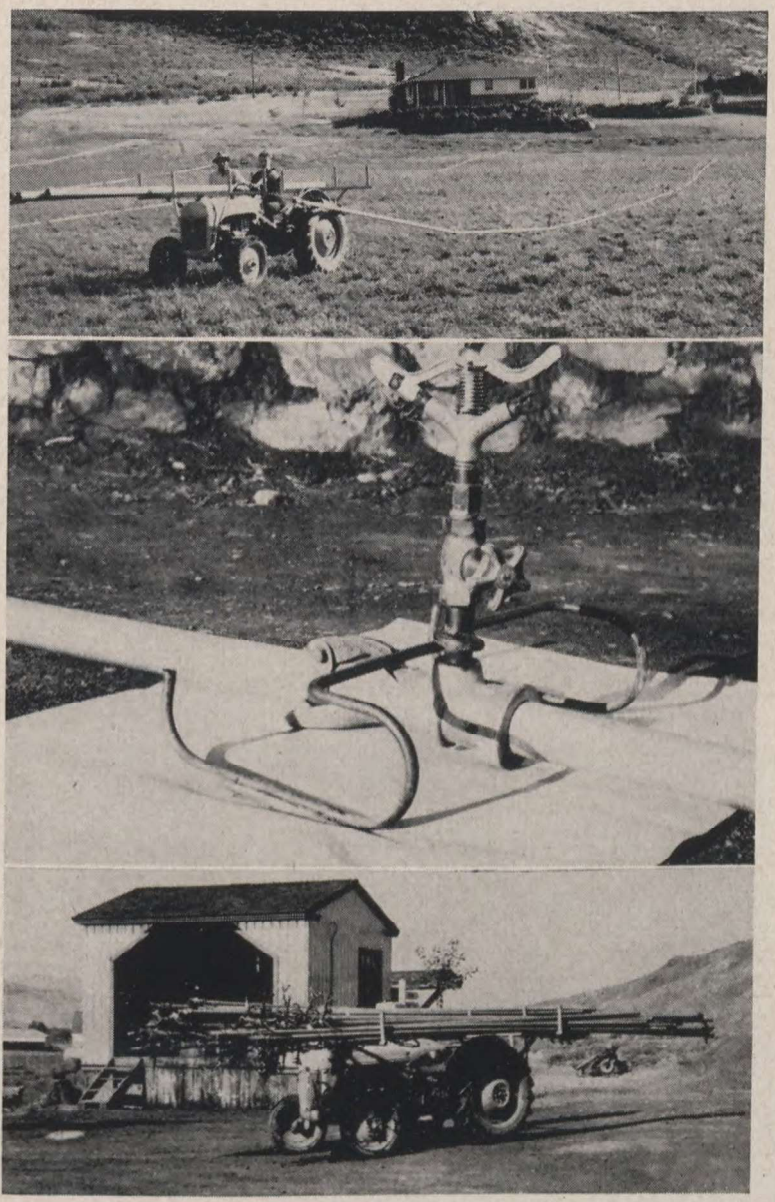


Fig. 6.—Upper: Illustrating end hauling of portable pipe with farm tractor. Center: Skid made to adapt portable coupler for end hauling. Lower: Rack built on tractor to haul pipe out of field.

Since that time a system has evolved that effects a saving of 75 per cent of the labor cost of a hand-moved system. The capital cost per acre is relatively low:

33.20 per acre for pipe

33.60 per acre for pumping equipment, power line, transformers, etc.

$66.80

The system is designed to cover 5 acres per setting. Approximately two man-hours are required to move the system each day. The design provides for a 20-day repeatability of irrigation.

A small skid was developed that could be used on any coupler. Its purpose was to provide stability for each sprinkler and allow the pipes to be towed endwise without damaging either the coupler or the crop (Fig. 6).

TABLE 7—IRRIGATION COSTS, RANGE EXPERIMENT STATION, KAMLOOPS, B.C.

	Cost per acre per year
(a) *Water supply*—cost based on engineers calculations for operation, maintenance, replacement and power costs for 100 acres	$ 8.07
(b) *Distribution* (sprinkling) based on 100 acres	
Sinking fund for replacement of system	2.36
Power 15 h.p. @ 5.00 per h.p. per month for five months	3.75
Labor to move system	5.00
Total cost per acre per year	$19.18

Nearly all sprinkler pipe manufacturers have laid down specifications applying to single-harvest crops. In the ranching areas crops that must be harvested three or four times for hay and up to seven times for pastures have

Fig. 7.—Portable electric pump used instead of buried mainline for distribution system.

to be handled differently. Time must be provided in the irrigation interval for hay curing, poor haying weather and to handle several crops. Accordingly, a system designed for a crop such as potatoes may not necessarily be satisfactory for alfalfa. It appears that for forage crops, a sprinkler system should have design capacity to handle a full irrigation in about two-thirds the normal irrigation time-interval for the soil type. This design requirement makes capital costs high but it provides necessary protection by allowing the operator to "catch-up" after unavoidable delays.

Irrigated Pastures

The ranges of British Columbia are in most cases fully stocked. In some areas there is excessive stocking for proper maintenance of climax grass stands. On over-stocked range, the problem of rehabilitation is acute since grass from alternate areas must be provided.

Moreover there is an ever increasing demand by ranchers to place more stock on the range or at least to carry more cattle on their individual operations.

It appeared that intensive pastures might provide a partial answer to both of these problems. Accordingly a program of investigation was initiated in 1951 to determine the place of irrigated pastures in the ranching industry of British Columbia. The program was designed to provide some answers to the following questions:

(1) What is the best pasture mixture to use ?
(2) What is the proper management to obtain maximum yields ?
(3) What gains can be expected in Interior Drybelt soils with optimum management ?
(4) What are the costs of installing, irrigating, and managing a pasture ?
(5) How long will a pasture sustain high yields ?

On the basis of work done to date it has been possible to draw some conclusions on the first four questions above. (See report on gains per acre and livestock management and for seeding rates and forage yields.)

Establishing Pastures

To ensure good stands it was found that seedbed preparation and seeding were very important. The seedbed was carefully prepared by the standard procedures of plowing, disking, and harrowing. These were followed by packing the soil to get firmness of seedbed. Seeding was done with a seed drill by placing the grass seed in the grain box and the inoculated legume seed in the grass-seed box. The conductors were left out of the drill shoes so that the seed was broadcast on the surface of the seedbed. After seeding, a thorough packing was done to complete the operation.

Annual weeds were controlled by repeated mowing until grazing was started.

TABLE 8.—SHOWING COSTS OF PASTURE ESTABLISHMENT, RANGE EXPERIMENT STATION, KAMLOOPS, B.C.

	Cost per acre
Plowing—2 furrow plow	$ 3.81
Disking—2 times with heavy offset disk	2.16
Harrowing	.60
Cultipacking—2 times	1.96
Seeding	1.23
Seed (June 1951 prices)	8.67
Total	$18.43

Fig. 8.—Irrigated pasture with capacity of three head per acre, Range Experiment Station, Kamloops, B.C.

Management of the pasture is a very important feature in maintaining high yields. During the first and second year of operation it was found that uneven grazing and consequent clumping was an important problem. Clumping was partially overcome by mowing after each grazing rotation. After mowing a chain harrow was used to spread droppings. These operations cost $2 per acre after each grazing.

During the third year an English ripper harrow was used instead of the mower and chain harrow. Cost per operation amounted to $0.80 per acre. It was found that much better control of clumping was effected and the operation was simpler and less expensive.

The fertilizing program consisted of applications of superphosphate (0-19-0) at 600 pounds per acre as a base application. This amount of phosphate should last for about three years. Nitrogen in the form of ammonium nitrate was applied at 100 pounds per acre in early July and late August. Summer applications of nitrogen helped to sustain high hot-weather production and assisted in maintaining a desirable proportion of grass to legume production in the mixture.

It was found that recovery of the pasture was impeded if the sward was grazed lower than 3 inches during each rotation. This indicates the advisability of dividing the pasture into a system of four or more fields, which can be grazed in succession. Proper gauging of grazing intensity can then be accomplished and rate of recovery of pasture after grazing can be assessed.

It was found that best results were obtained by following the cattle with irrigation. This was difficult because the cattle remained on the pastures for a shorter time as the rate of growth decreased throughout the summer. Irrigation, on the other hand, is geared to a fixed schedule. Care had to be taken to allow at least three days between irrigation and grazing.

Electric fences were quite satisfactory. To ensure that the animals were secure, two wires were used on the fences and a separate electric fencing unit was attached to each wire.

TABLE 9.—PASTURE MANAGEMENT COSTS, RANGE EXPERIMENT STATION, KAMLOOPS, B.C.

	Cost per acre per year
	$
Fertilizer	
(a) Phosphate—600 lb. per acre every 4 years @ $50 per ton	3.75
Application	.15
(b) Nitrogen—200 lb. ammonium nitrate @ $82 per ton in two applications of 100 lb.	8.20
Application	1.20
Spreading droppings—harrowing seven times	5.60
Moving cattle	1.05
Equipment for moving irrigation pipe	.90
Total cost per acre per year for management	$20.85

Soil Compaction on Irrigated Pastures

High-producing irrigated pastures require intensive grazing. Pastures with carrying capacity of 3 to 4 head per acre are not uncommon. With this high capacity, fields are grazed by 20 head per acre for short periods.

It was noted that throughout the second year of the pasture program the soil appeared to accept irrigation water more slowly as the season progressed. There was the suggestion that compaction might be occurring as a result of the heavy concentration of animals.

Cores were taken at the end of the season and were compared with cores taken from exactly the same locations the following spring. Some of the compaction seemed to be overcome by winter heaving but the experimental results did not show significant trends. In comparing cores on grazed land with cores from adjacent ungrazed land the following definite results were obtained.

(1) Compaction on silt loam soil as indicated by an increase in volume weight of 18 per cent with grazing in the 0 to 3-inch level of soil. Below this there was no apparent effect.

(2) A decrease of 5·3 per cent in porosity in the 0 to 3-inch layer with grazing.

(3) A decrease of 6·28 per cent non-capillary porosity with grazing in the 0 to 3-inch layer. This is considered to be significant in that non-capillary porosity represents large pores in the soil which are responsible for drainage, infiltration, and aeration.

(4) An increase of 5·27 per cent in capillary porosity with grazing in the 0 to 3-inch layer.

Further studies are being made to determine the effects of trampling on other soil types.

Effect of Forest Fires on the Soil

A general description of range burning is presented in the Forage Plants Section of this report. The main objective of the burning project is to obtain fundamental information that may be useful in assessing the value of burning for rehabilitation of lodgepole pine areas for grazing use. The effects of burns on soil would appear to be an important feature. Accordingly an experiment was undertaken to determine to what extent soil characteristics in forest ranges have been altered by fire. Soil samples were taken by horizon from 1943, 1945,

and 1951 burns in the same general area and from relict unburned adjacent sites. These sites were all in the vicinity of Lac le Jeune, B.C.

Results of the determinations are summarized below:

Volume weight of the 0 to 3-inch layer was increased by destruction of the litter and soil compaction by rainfall. Thus the capillary pore space was increased and the non-capillary pore space decreased. Infiltration rate was also reduced. There was a decrease in base exchange capacity and total nitrogen and an increase in total phosphorus in the surface layer. Increases were measured in total and exchangeable calcium, magnesium and potassium, and in percentage base saturation in the surface soil and also in succeeding lower horizons.

FORAGE CROPS

A. McLean, W.L. Pringle

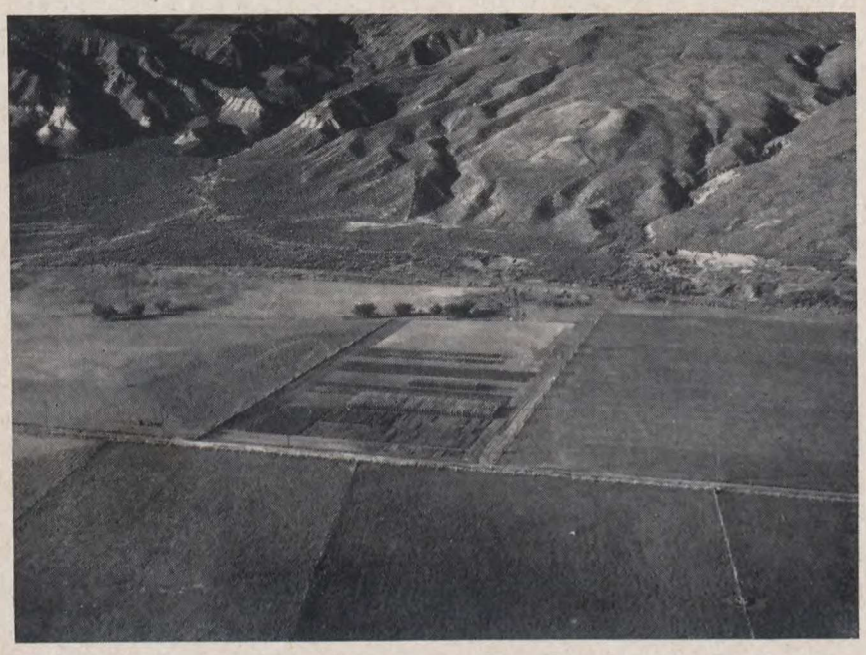


Fig. 9.—Air photograph showing forage plots on Range Experiment Station, Kamloops, B. C. Sagebrush research area shown upper left.

Increased yields and improved quality of forage crops on both cultivated and range lands are rapidly becoming more important as the pressure of townsites, industry, and cash crops reduces the amount of land available for grassland agriculture.

With the reopening of the Range Experiment Station at Kamloops a great deal of preliminary information was available from the experimental results obtained prior to its closure and these data formed the basis for some of the initial research projects. Research in forage crops is divided into two major phases, namely: (1) Studies of native range vegetation or range ecology, which is basic to the solution of all wild-land problems. (2) Studies of cultivated hay

and pasture crops, on both irrigated and dry land. For the most part projects are on a long-term basis and sufficient time has not elapsed to accumulate adequate data from which to draw conclusions or make many recommendations. This report will attempt to show only the set-up of the projects and bring out the more outstanding results as well as point the way for future research.

Plant Introduction Nurseries

Plant introduction nurseries have been established under both dry-land and irrigated conditions for the preliminary testing of new species of forage crops from different parts of the world, and of new varieties and improved strains of more common crops. It is necessary to be constantly on the lookout for more desirable varieties, and plant nurseries afford an opportunity to test the adaptability of new introductions to local conditions. If a species shows promise in the nursery, it is then included in yield tests where further information is obtained before any recommendation is made. The development of drought-tolerant species suitable for range reseeding is one of the main objectives, but species suitable for timber range seeding, high yields of seed and forage, winter hardiness, competitive vigor and longevity are other characteristics that are being sought. To date fifty species have been tested under dry-land conditions and sixty-three species under irrigation. Supplementing these nurseries are a number of demonstration plots put on local ranches in co-operation with the provincial Department of Agriculture.

Dry Land Range Nursery

Some of the introductions in this nursery that show promise and are worthy of further study are:

Elymus junceus (Russian Wild Rye)—A hardy drought-tolerant bunch grass. It begins growth in the spring slightly earlier than crested wheat grass, matures earlier but shows better fall recovery. This species has a low seed yield under British Columbia dry-belt conditions.

Agropyron inerme (Whitmar wheat grass)—A drought-tolerant bunch grass that has been domesticated from the Palouse area of Washington. It has much the same adaptability as crested wheat grass but has a later season of use and is more palatable when mature.

Agropyron intermedium (Intermediate wheat grass)—This species is a mild sod-former that is possibly not so drought-tolerant as crested wheat grass. It has the advantages, however, of a large seed, rapid seedling establishment, and high seedling vigor.

Agropyron desertorum (Desert wheat grass) and *Agropyron sibericum* (Siberian wheat grass) are also doing well but seem to offer little in performance to place them over crested wheat grass.

It is interesting to note that under desert conditions winterfat *(Eurotia lanata)* seems highly adaptable, which points to the desirability of further introductions of palatable half shrubs.

Irrigated Nursery

It is difficult to find species that are sufficiently superior to those now in use, to warrant comment. Different varieties of brome grass and orchard grass, however, show considerable variation in performance, and it is felt that the use of superior named varieties is preferable to the purchase of nondescript seed. The two outstanding varieties of these grasses that bear further investigation

for the Kamloops area, at least, are Manchar brome and Hercules orchard grass. Du Puit shows promise as an early alfalfa variety, however it remains to be seen how winter-hardy it is.

Timber Range Nursery

This nursery is located in the Douglas fir forest region and is non irrigated. The outstanding introduction in this nursery to date is *Poa ampla* (Big blue grass). This bunch grass is a heavy seeder and, although it winterkills in more arid areas, it seems to be doing well on timber range. Big blue grass does well in relatively poor soil and shows rapid seedling establishment. On a grazed site, however, it was observed that cattle had pulled out many of the plants the year after seeding, before the root system had become well established. It appears promising for burned-over areas if given protection for a year or two after seeding.

Corn Hybrids for Ensilage

Corn can be a valuable crop for ensilage where it is desirable to grow an annual crop for this purpose. Above-average yields can be obtained in the Kamloops district with proper cultural practices. In the early maturing group one of the most promising varieties is DeKalb 65, while in the medium group DeKalb 240, and Wisonsin (Canada) 625 are outstanding. The crop must be planted early on fertile soil. At higher altitudes in the district very early maturing varieties such as DeKalb 43 may have to be used.

Soybeans

Soybean variety tests were conducted on the Station for a period of three years. The objective was to obtain a variety that would yield sufficiently to be satisfactory for grain production. The only variety that could be expected to mature consistently was Pagoda and even with this variety early seeding is essential. An even more serious objection to the growing of this crop in the Kamloops district is that, because of the dry atmosphere, the beans shatter as soon as they mature, making it virtually impossible to harvest the crop on a field scale without serious loss.

Perennial Hay Crops

Grass and legume variety tests have been established recently and as yet data are not sufficiently complete to permit recommendations to be made from them. The following recommendations, however, are based on the best present knowledge of crops in the Thompson Valley.

Dry land	*Lb./acre*
(1) crested wheat grass (Fairway)	4 to 6 lb.
alfalfa (Ladak)	2 to 4 lb.
(2) brome grass	6 to 10 lb.
alfalfa (Ladak)	2 to 4 lb.

Casual irrigation
—Use the same mixtures as for dry land except with a slightly higher seeding rate.

The above-mentioned mixtures of alfalfa and grass are most satisfactorily seeded in alternate rows, as described under Range Seeding.

Irrigated	*Lb./acre*
(1) Alfalfa (Ladak)	12 to 20 lb.
(2) brome grass	5 to 7 lb.
alfalfa (Ladak)	10 to 14 lb.
(3) orchard grass	4 to 5 lb.
alfalfa	10 to 14 lb.
(4) timothy	4 lb.
brome	6 lb.
red clover	2 lb.
alsike	2 lb.
Flood land	
(1) reed canary grass	6 to 8 lb.
Annual	
(1) fall rye	120 lb.
(2) oats	100 lb.

Perennial Pastures

Perennial pastures are dealt with fully under the Field Husbandry Division Report. Using a mixture of smooth brome, Alta fescue, and orchard grass at 6 pounds per acre each plus 2 pounds of ladino clover, seeded in June 1951, gave an average clipped yield during the following two years of over 7,000 pounds per acre of oven-dry forage. This was the highest yielding mixture of five tested. Trends in irrigated pasture work include finding a rapidly establishing palatable species of grass that will fill in bare spaces and yield as well as the brome which is never much in evidence until the third or fourth year. Bare spaces allow the ladino clover to spread and dominate the sward which adds to the bloat hazard.

Cultivated pastures offer a means of increasing the grazing capacity of land where maximum production is important, or where the shortage of range or pasture for a certain period of the year is common. The following recommendations are made with such use in mind.

Dry land	*lb./Acre*
(1) crested wheat grass (Fairway)	5 to 8 lb.
(2) crested wheat grass (Fairway)	4 to 7
alfalfa (Ladak)	2 to 4
(3) brome grass	8 to 10
alfalfa (Ladak)	2 to 4
Casual Irrigation	
(1) Crested wheat grass (Fairway)	7
alfalfa (Ladak)	4
(or) white clover	1
(2) brome grass	10
alfalfa (Ladak)	4
Irrigated	
(1) orchard grass	8
Alta fescue	6
brome grass	6
ladino clover	½
Flood land	
(1) reed canary grass	6 to 8
Annual	
(1) fall rye	120
(2) oats	100

As with the hay crops the mixtures of grass and alfalfa may be seeded by the alternate row method as described under Range Seeding.

Range Reseeding

Correct stocking and proper seasonal use are the principal factors in a sound range management program. If grazed in the spring before enough plant food is produced for continuous growth, or if subjected to chronic over-grazing, the productive perennial bunch grasses gradually give way before the competition of the less valuable quick growing, shallow-rooted annual grasses and weeds. In other words, plants of excellent soil binding and building qualities are succeeded by plants of inferior qualities. It is obvious, then, that steps must be taken to preserve or restore the forage species that offer the maximum erosion control and highest yields.

If range is once depleted by over-grazing, two principal methods of restoring it are possible, namely, improved management practices such as reduced livestock numbers, delayed turnouts, improved salting and riding practices, drift fencing, etc., or artificial reseeding.

The restoration of key areas in a region by reseeding is of vital importance to the welfare of the grazing industry and other interests and should play an important part in any conservation program. It is not economically practical to seed all over-grazed range. Ranges should be seeded only under the following conditions: (1) when it is obvious that the area cannot be restored in a reasonable time by means of good management, (2) where the cost of seeding is commensurate with the potential production of the area, (3) where conditions for obtaining a catch of grass are reasonably good, (4) where the value of the forage in a range is augmented by watershed or other land values such as on key grazing areas.

Because of the economic importance of reseeding, the Experiment Station has initiated and co-operated in a number of experiments designed to provide more information on range reseeding in an overall range program for British Columbia.

It has been found that seedbed preparation is the most important factor in obtaining a good seeding. The seed has to be buried or covered and other plants on the area subdued. This requires some form of cultivation. Formerly broadcasting and brush-harrowing were considered adequate but with this method the risk of loss is too high. Now the use of a seed drill or a disk drill (Fig. 4) is advocated for best results. This, of course, is only possible where machinery can be used. On rocky and steep areas it is best to rest the range and allow for natural revegetation.

Grassland Range Seeding

On very dry areas of below 12 inches annual precipitation where sagebrush is usually prevalent, crested wheat grass, or its newer counterpart, Russian wild rye, which comes from the same native range of Asia, is well adapted. These are sown at about 4 pounds per acre in the late fall. It has been observed that crested wheat grass may take three to four years to become established but after that it will set seed and gradually take over most areas. On the moister ranges of the middle and upper grasslands where effective precipitation is higher these two dry-land grasses do well, but a greater yield may be obtained by using intermediate wheat grass or whitmar wheat grass at 6 to 7 pounds per acre.

On very good sites, where soil and moisture conditions warrant it, grasses may be sown in alternate rows with alfalfa. (Fig. 10) This is done by placing the grass seed in the grain box and plugging up every other run of the drill and placing the legume seed in the grass-seed attachment with every alternate run plugged. Using this method, various combinations of row width and alternation may be devised. Where effective precipitation is high row width may be narrow, 6 to 7 inches, and a greater number of rows of alfalfa to grass may be seeded. Where moisture is lower a 12- to 14-inch row space is used with a greater number of grass rows.

Benefits from alternate row seeding are many. The rapidly germinating grass seedlings are far enough away from the young legume seedlings that they do not crowd them out. Each species gets a fair start in life. The legume if inoculated properly provides nitrogen which is used up by the adjacent row of grass. With alfalfa in the mixture the nutritive quality of the pasture is increased. A good seeding rate on dryland is 3 to 4 lb. of grass and 2 lb. of alfalfa per acre. For the interior of British Columbia, Ladak alfalfa, because of its wilt resistance, is recommended. This must be inoculated before seeding, which is best done in late May or early June.

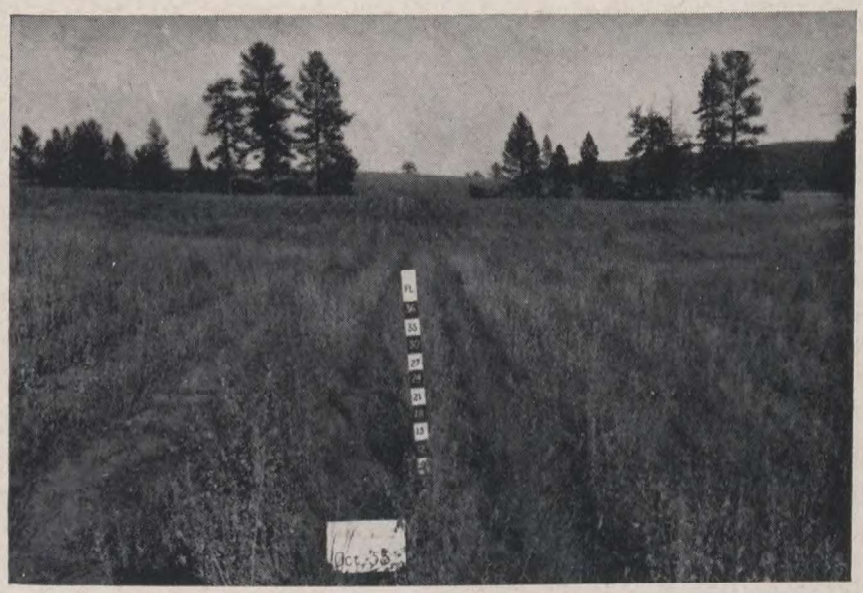


Fig. 10.—An alternate row dry-land seeding of crested wheat grass and Du Puit alfalfa with 14-inch spacing on a good site in the upper grassland. This was seeded in June 1953 and shows a phenomenal seedling catch and excellent growth for so short a time.

On highly alkaline sites where the water table is fairly high, tall wheat grass has shown itself very adaptable. This is a harsh tall-growing grass that is only moderately palatable. It will not tolerate close grazing and must never be grazed or cut lower than 8 inches.

Value of range seedings on dry range may be shown by some initial results of clippings on various treatments adjacent to one another on a uniform site in the sagebrush grass zone. The treatments were carried out in 1949 and the clipping was done four years later. The following results are averages of ten 9·6-square-foot circular plots taken on each treatment.

Treatment	Total oven-dry forage lb. per acre
Disked and seeded to crested wheat grass	426
Disked but no seed	405 (mainly weeds)
Seeded but not disked	63.5
Native sod, untreated	40.5

This shows the rather impressive amount to be gained by killing sagebrush and replanting with a dry-land grass.

Using the same technique on well-established 15-year-old seedings of crested wheat grass an average of three sites showing poor to fair condition returned 748 lb. of oven-dry forage per acre while adjacent native range supported only 348 lb. of oven-dry forage per acre. Two areas in good condition returned an average of 498 lb. of crested wheat grass and unseeded adjacent range gave 381 lb. of oven-dry forage consisting mainly of perennial grasses.

Wild Hay Meadow Seeding

Some investigations were carried out on areas of reseeded wet meadowland. This was done by disking and broadcasting reed canary grass at 5 pounds per acre in the early fall. The stands do not thicken for two or three years but after that the original seeding spreads, chokes out the weeds, and produces a high yield of palatable hay as well as providing considerable aftermath for grazing.

Three distinct types were sampled for comparison at hay cutting time. On an average the native horsetails and grasses produced only 64 per cent of the yield of the canary grass. The lowest producing types, mainly horsetails, yielded only 55 per cent while the highest producing type, mainly couch grass, produced 75 per cent of the yield of reed canary. This is a great difference in yield but the big advantage is in obtaining more palatable and nutritious hay (Table 12).

Timber Range Seeding

Revegetation is also applicable to timber range and experiments have been undertaken on the seeding of skid roads and logged-off areas as well as fire guards and burned-over forest sites. From preliminary work it seems that skid roads or logged-off areas can be successfully broadcast-seeded if the seeding is done shortly after logging operations cease and while the seedbed is still loose. Early fall or early spring seedings are the most likely to be successful. The above principles apply equally well to the seeding of fire guards and to burned-over areas. A good fall catch is most important on a burned-over site because of the extremely high summer temperatures that develop on the blackened soil surface, which causes shriveling of seedlings that are not too well established. Of the common grasses, orchard grass, timothy, and Kentucky blue have done best in seedings to date. If wild white clover is not common to the area it should be included in the seeding. A grass mixture of about 5 pounds per acre should give a good stand. Revegetation of burns is dealt with more fully below.

Range Burning

Of the 19,000,000 acres of grazing land in British Columbia about 15,000,000 acres are classed as timber range. This range is found on the interior plateau at an elevation of about 2,500 to 4,000 feet. In the main its climax state is Douglas fir forest but over large areas it is in a fire climax of lodgepole pine, *Pinus contorta*. This tree grows in very dense stands to the exclusion of almost all other vegetation and is susceptible to insect injury and then wind throw. (See Fig. 11). When this occurs it becomes an impenetrable mass and grazing is impossible. It may also block access to desirable grazing areas.

Fig. 11.—A typical stand of mature lodgepole pine showing the insect-killed fallen trees. Even though the area is productive the heavy windfall prevents its use.

Another phase of timber range management is the encroachment of coniferous species onto the grasslands thus reducing grazing capacities. Many ranchers are of the opinion that open range at higher altitudes in the interior of British Columbia was instigated and maintained by fire, either natural or set by the native Indians. It is estimated that about 75 per cent of British Columbia forest fires at the present time have their source in lightning. In ages past there was no Forest Service to suppress fires and therefore it seems reasonable to suppose that fire has had a great influence on the forest succession over the range area of this province. It is also hard to discredit all tales of burning by the Indian who needed horse range.

Many ranchers, seeing their ranges being reduced through encroachment and windfall areas, have illegally started fires that in some cases have won back range and in others turned rampant and burned up valuable timber resources.

Pass Lake Burn

To date workers have not discovered any way to burn successfully to reduce or eliminate *Pinus contorta*, because it is a "fire" species, establishing and reproducing in conjunction with fire. Range burning is a troublesome problem to the Forest Service, whereas the rancher is convinced it is his only alternative in many cases. Because of these conflicting viewpoints and the fact that little is known about the actual ecological succession after a fire or the effect of fire on the soil, a study of controlled burns was inaugurated in co-operation with the B.C. Forest Service.

The area chosen for study lies two miles northwest of Pass Lake substation in the montane zone on a southwestern exposure between the 3,600 and 4,200 foot levels. The site is a relatively uniform 800 acres surrounded by fire guards and divided into three parts. It was originally planned to have a spring, summer, and fall burn, one on each part. Because of the difficulty of starting a burn and controlling it once it is going this plan had to be modified. From a study of

relict sites the area seems to have been a climax of Douglas fir with yellow pine on the drier slopes. Because of repeated fires it is now in a disclimax state of two sub-types, aspen, and lodgepole pine. The area is well suited to the study because of a variety in age classes, densities, and amount of deadfall.

One 40-acre area was burned rather successfully during September 1949 on area number two when backfires were being set in preparation for burning area number one. The following September about 80 acres of number two were fired. Some of this was in very dense windfall but for the most part the burn was a ground fire. It was found that fires are impossible to start unless the relative humidity is below 35. A great deal of accumulated grass and surface litter is essential to have a fire "run".

Plots were laid out on both burn areas and a vegetative analysis made. From initial observations of the 1949 fire it was apparent that little damage was done to the soil or to deep-rooted perennials such as pine grass, lupine and timber milk vetch. Stoloniferous species like bearberry were the most severely damaged.

Encroachment of Douglas fir onto spring-fall grassland especially in the Cariboo region was studied and experimental burning as a means of control was carried out. A burn in the Williams Lake holding ground was attempted during the middle of May 1949. The area is essentially a forest site which has been held in disclimax through cutting and burning. Another area studied was on the Alkali Lake Ranch where both lodgepole pine and Douglas fir are spreading onto the spring-fall grassland. Here a burn was tried in the spring of 1950. From both these burn tests it was found that fire is successful only where adequate herbaceous cover or carry-over of grass from the previous season is present to carry the fire and provide a hot fuel to ignite the coniferous trees.

Lac le Jeune Burn

During July 1951 a severe burn occurred on Ridge Mountain south and west of Lac le Jeune located twenty miles south of Kamloops. This is an area dominated by lodgepole pine at an altitude of 4,200 to 4,500 feet. Insect injury and wind throw had caused impenetrable tangles in parts and provided a hazardous pile of fuel through which the fire raced almost unchecked. When it was finally brought under control after three weeks, 5,800 acres had been burned over and 23 miles of fire guard had been constructed. In the same vicinity two other burns, one in August 1943 and one in August 1945 had occurred on sites comparable to that of the 1951 burn. This formed an excellent location for an ecological study of different aged burns under varying severity and site condition. The investigation which is under way is designed to determine the place of burning as a tool for increasing grazing on British Columbia timbered ranges.

During September and October just after the fire was subdued 18 miles of fire guard were seeded, with a cyclone seeder from the back of a jeep, to a mixture of orchard grass, crested wheat, timothy, and brome. One part of the mix also contained Kentucky blue grass and white Dutch clover. In addition to the fire guards about 1,200 acres of the burn were seeded from the air to a mixture of equal parts of timothy, orchard grass and crested wheat at a rate of less than 1 pound per acre. Total cost for this operation including wages for six men came to 46 cents per acre. At the time of seeding both the fire-guard roads and the burn were loose and dusty which provided a penetrable seedbed for broadcast seed. Shortly after seeding heavy rains fell and germination was rapid. One year later it was observed that all road seedings had germinated and were producing well but were being grazed exceptionally heavily. Similar observations were made on the aerial seeding except that it was very sparse in spots.

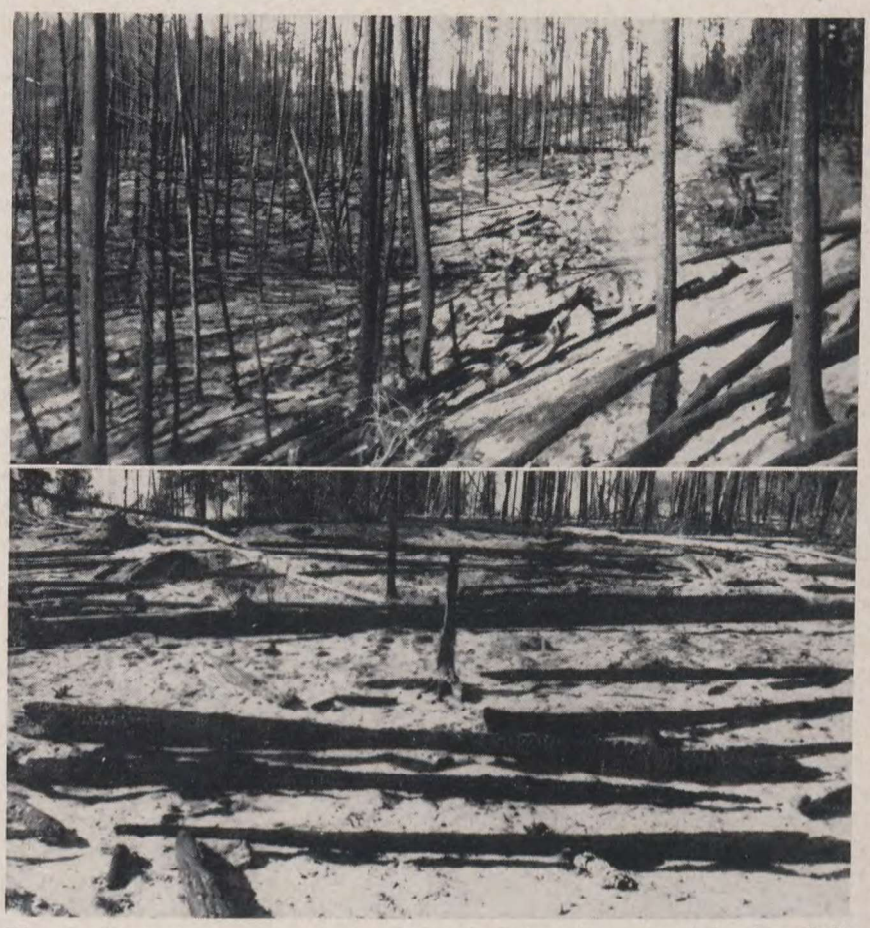


Fig. 12.—Upper: General view of a burn through a lodgepole pine stand showing a bull-dozed fire guard and the effect of a "crown" fire. Note the large amount of standing timber that has been killed and will drop making the area useless for grazing. Lower: An area severely burned with no timber left standing. Note the loose appearance of the completely burned soil. This type of site with its powdery ash mantle is ideal on which to broadcast seed.

It would appear that the flight strips covered a greater width than the originally anticipated 200 feet and therefore the seeding was thinner than planned for. In the future it would be safe to gamble on setting a seeding rate of about 5 pounds per acre. The burn was visited again in 1953 and it was found that production had increased greatly over the previous year so that the cattle had more than adequate grazing. Many plants were untouched and hence increased in vigor and set quantities of seed. (See Fig. 13).

In the first year timothy was the preponderant species while in the second year both orchard grass and crested wheat became more conspicious. Damper areas and swales on the burn seem to have caught more seed and hence have revegetated more fully. Studies are under way to determine if these reseeded species are vigorous enough and in sufficient quantity to suppress pine reproduction. In all, to date, it may be stated that aerial seeding into the ashes of a forest burn is a successful venture.

Fig. 13.—A vigorous stand of grasses, mainly timothy, orchard grass, and crested wheat. This is the result of aerial broadcasting less than one pound of seed per acre into the loose ashes of a forest burn.

Chemical Composition of British Columbia Range Plant Species

The seasonal nature of the grazing ranges of British Columbia makes important the study of variations in nutritive value of forage which result from the growth development of native vegetation. It is important to understand the relative forage value, balance of various chemical constituents, and the importance of deficiencies in the diet of livestock. Chemical analysis, while it does not give complete information with respect to the nutritive value of forage species, is a practical method of estimating their relative feeding value in the native range.

It is important to have a broad picture of the composition of native range species in different stages of maturity before attempting more accurate methods of determining the nutritive value of native species. Many samples were collected on the Tranquille range over a number of years and analyses made. The results obtained showed sufficient consistency and trend to permit a number of generalizations to be made and to form a basis for further studies.

The samples collected were separated on the basis of grassland and forest collections by growth stages. Analyses were conducted for crude protein, crude fiber, total ash, calcium, and phosphorus.

Grasslands

By far the bulk of the forage produced in the grasslands is obtained from grasses. The grazing in these areas occurs principally in the spring until June,

then again from October until winter feeding is started. In the spring, maximum use can be made of the high quality green feed. Fall and winter grazing is a different matter as the feeding value of the grasses is low during this period. The average chemical analyses for the principal forage species are given in Table 10.

The data indicate that the protein content is highest in the leaf stage and drops sharply after flowering. The average protein content of cured forage is less than the 5 per cent level required for an adequate ration. The value of feeding a supplement such as high quality alfalfa hay can readily be seen. The crude fiber content varies in the opposite manner to crude protein, rising sharply after the leaf stage and reaching a maximum in cured forage. Total ash exhibits a general downward trend as growth development progresses but does not show so wide a variation as either crude protein or fiber. The average calcium content showed no particular trend with growth stage but since the average phosphorus content dropped greatly as the plants developed and cured, the calcium-phosphorus ratio increased and proved to be considerably greater than the 2:1 ratio considered optimum for feed value.

It is interesting to note that bluebunch wheat grass dropped to 3 per cent crude protein level by the time seed was shed in August. In addition the calcium-phosphorus ratio rose sharply and was above the desirable 2:1 ratio before the seed became ripe. This grass has been considered one of the more desirable species for winter range but results indicate that animals wintered primarily on this species should receive a supplement. From the above data, sand dropseed is the only species that could be considered to have an adequate winter nutrient level.

TABLE 10.—CHEMICAL COMPOSITION OF PRINCIPAL FORAGE SPECIES OF THE GRASSLAND RANGE

Stage Species and Growth	Chemical Composition in Percentages					
	Crude Protein	Crude Fiber	Total Ash	Ca	P	C/P Ratio
Average of 7 grasses						
Leaf (May)	15·4	24·4	10·1	·4	·7	1·0
Flower (June)	8·7	31·6	8·1	·4	·4	1·1
Seed (July)	6·6	32·1	7·8	·4	·3	1·7
Cured (Oct.-Mar.)	3·6	36·9	7·5	·4	·1	3·8
Common Spear Grass (*Stipa comata*)						
Leaf	12·8	25·8	9·9	·4	·4	1·0
Flower	7·8	33·0	6·6	·2	·2	1·1
Seed	7·6	31·0	9·8	·5	·3	2·6
Cured	5·2	36·1	9·3	·2	·1	2·6
Cured after winter	2·9	33·4	5·6	·5	Trace	.....
Sand Dropseed (*Sporobolus cryptandrus*)						
Leaf	15·6	26·4	8·8	·4	·5	1·0
Flower	10·0	31·4	8·1	·4	·4	1·1
Seed	9·1	29·4	7·2	·4	·3	1·3
Cured	8·0	34·6	7·3	·3	.....	.....
Cured after winter	5·2	35·1	8·5	·4	·2	2·2
Bluebunch Wheat Grass (*Agropyron spicatum*)						
Leaf	14·4	27·7	11·6	·4	·6	·8
Flower	8·8	31·8	8·6	·4	·4	1·2
Seed	6·5	30·3	7·2	·5	·2	2·9
Seed shed (Aug.)	4·6	31·7	9·5	·5	·1	3·3
Cured	3·0	37·5	9·0	·4	·1	4·9
Cured after winter	3·2	38·4	7·9	·4	·1	5·5

Forest Range

Grazing in the forested areas takes place from late June until early October. During June and early July the forage is of maximum nutritive value but declines to a critical point, from the point of view of cattle weight gains, after the middle of August, particularly because of the low value of the pine grass.

Pine grass, which is the most abundant forage species throughout the forest zones as a whole, is relatively low in feed value, being less than 10 per cent protein in the leaf stage and dropping below 5 per cent during the seed stage. Showy aster although not especially high in protein is considerably above average in phosphorus content. Creamy pea-vine is very high in protein throughout the summer and incomplete data for American vetch indicate that the same applies to that species.

Average data indicate that forest zone species provide adequate nutritive levels during the season when they are grazed or at least until late summer. There was, however, greater variation in the data of forest area species and a

TABLE 11.—CHEMICAL COMPOSITION OF THE PRINCIPAL FORAGE SPECIES OF FOREST RANGE

Stage Species and Growth	Chemical Composition in Percentages					
	Crude Protein	Crude Fiber	Total Ash	Ca	P	Ca/P Ratio
Pine grass *(Calamagrostis rubescens)*						
Leaf (June)	9·8	29·3	15·3	·3	·4	·9
Flower (July)	5·9	37·3	7·9	·3	·2	·8
Seed (Aug.)	4·8	34·7	9·3	·4	·2	2·5
Cured (Oct.)	2·6	33·6	17·0	·5	·2	2·6
Showy aster *(Aster conspicuus)*						
Leaf	11·6	20·0	12·8	·9	1·0	1·2
Flower	11·1	24·9	10·3	1·0	1·3	·8
Seed	7·9	24·3	10·4	1·0	1·0	1·8
Cured	4·2	27·3	10·7	1·4	1·1	2·5
Creamy pea-vine *(Lathyrus ochroleucus)*						
Leaf	25·9	23·3	8·7	·6	·4	1·5
Flower	18·0	28·5	7·8	1·5	·6	2·0
Seed	14·7	28·4	6·8	1·4	·4	3·9
Cured	11·7	31·1	6·5	1·8	·2	9·9
Average of 3 grasses						
Leaf	9·8	29·3	15·3	·3	·4	·9
Flower	7·9	35·7	9·8	·3	·4	·8
Seed	4·8	31·3	9·2	·4	·2	2·5
Cured	2·3	33·6	13·5	·5	·2	2·6
Average of 12 forbs						
Leaf	19·3	21·4	9·7	·8	·8	1·5
Flower	13·6	25·7	9·7	1·0	·5	2·2
Seed	9·7	28·5	7·5	1·1	·5	2·6
Cured	7·4	28·5	8·1	1·8	·5	8·1
Average of 11 shrubs						
Leaf	12·0	16·2	6·1	·7	·5	1·8
Flower	12·2	18·1	6·5	·9	·6	1·9
Seed	10·8	16·9	6·5	1·1	·4	3·1
Cured	5·0	31·7	4·8	·9	·3	2·7
Mixed vegetation Pine grass 60%, mixed forbs 40%						
Flower	10·7	27·0	12·9	·5	·3	2·0
Seed	9·9	26·6	17·4	·8	·3	2·7
Cured	4·1	30·7	18·0	·7	·2	4·8

large number of samples would be necessary to detect trends in certain of the constituents such as fiber and ash.

Samples of mixed vegetation were taken from an area of mixed pine grass and forbs and the results compare well with the averages for individual species. This is brought out in Table 11.

Value of Native Meadow Hay for Winter Feed

Because of depth of snow and shortage of winter range, it is often necessary to provide winter feed for a period up to four months. Much of the hay required for this purpose comes from native hay meadows composed mostly of mixed sedges, grasses, and horsetail. It is therefore important to have an estimate of the value of well-cured hay. To obtain such an estimate from a meadow on a river flood plain near Kamloops, samples were taken from a number of stacks of different botanical composition throughout the field. (Table 12.)

TABLE 12.—CHEMICAL COMPOSITION OF NATIVE HAY OF VARYING BOTANICAL COMPOSITION FROM A RIVER FLOOD PLAIN NEAR KAMLOOPS

Composition of Hay %	Crude Protein	Crude Fiber	Total Ash	Ca	P	Ca/P Ratio
Equisetum spp. . . . . 70 Carex, grass. 30	5·5	28·2	15·3	1·2	·1	13·0
Equisetum. . . . . 50 Eleocharis. . . . . 20 Sedge, grass. 30	7·4	27·6	15·7	1·0	·1	9·5
Equisetum spp. . . . . 15 Carex spp. . . . . 80 Grass. 5	8·4	24·9	10·4	·8	·1	9·0
Equisetum. . . . . 10 Carex. . . . . 50 Grass. 40	9·7	24·7	10·9	·7	·1	7·7
Sedge. . . . . 97 Equisetum. 3	11·0	23·3	10·2	·6	·1	5·0

It is interesting to note that the protein content varies inversely with the amount of horsetail (Equisetum) in the hay. The protein content of good quality sedge hay compares favorably with grass-legume hay. The total ash content rises with the proportion of horsetail in the hay, probably because of the high silica content of horsetail. The calcium-phosphorus ratio also increases with the proportion of horsetail and reaches an undesirable ratio with only 10 per cent in the hay.

Witch's Broom in Alfalfa, Kamloops District

The witch's broom disease of alfalfa is a virus infection that occurs in alfalfa fields in the Kootenay, North Okanagan, Thompson, Nicola Valley areas, and lower Cariboo regions. It is transmitted by leaf hoppers and spreads rapidly under certain conditions. It is an important factor in thinning stands and lowering hay yields in areas where it is serious.

Infected plants exhibit chlorosis, shortened internode stem growth, small leaves which are often wrinkled, and proliferation of spindly stems. (Fig. 20).

The disease appears to be most serious in the Nicola, Thompson, and lower Cariboo regions. It is significant that, in these regions, long-term rotations are practised in the alfalfa fields in contrast to the North Okanagan where shorter rotations are more general.

In the Thompson and lower Cariboo areas a number of fields that had been recently plowed and reseeded to alfalfa were observed to contain a scattering of old diseased plants throughout. These would no doubt serve as sources of infection for the new stand. Therefore, field sanitation is important in reducing the infestation of new stands.

Maximum growth height and oven-dry weight is less with diseased plants than with healthy ones and growth development is retarded.

Slower recovery of infected plants after cutting and increased stress due to mowing tends to make them more susceptible to smothering by adjacent healthy ones. Plants so weakened proved susceptible to winterkill.

It is believed that rapid mortality could reduce the stand of alfalfa very quickly to the point where smothering would no longer be a factor. This could also account for the fact that in relatively young stands a greater incidence of the disease is not observed during any one season. In old thin stands, however, diseased plants may remain alive and vigorous for a number of years. Apparent recovery or masking of the disease in a number of plants has also been observed. This effect is not permanent but appears to be a reaction to soil moisture conditions.

Clonal lines of alfalfa in a spaced-planted nursery showed remarkable spread of the witch's broom. Disease-free transplants were set out in June 1949. Witch's broom was first observed in the spring of 1951, when 22 plants out of 304 were diseased and 7 additional ones were suspected. By the fall of 1952 the number of diseased plants had risen to 129. It was interesting to note that 7 of the diseased plants were showing an appreciable degree of recovery from or masking of the disease at this time. Moreover certain clonal lines have shown considerably more resistance to the disease than others.

Preliminary analyses reveal that there is a higher percentage of protein and a lower percentage of fat and crude fiber in diseased plants than in healthy ones at haying time.

Fig. 14.—Plant at left is a healthy one, that on the right is severely affected with witch's broom. Note the great difference in production.

Productiveness of Ranges

As a practical application of the study of productivity of ranges a method of assessing grazing lands through the use of condition classes was devised for the provincial office of the Surveyor of Taxes in Victoria. This valuation pro-

cedure is based on a physical appraisal of the plant species occurring on ranges under varying conditions, which when correlated with other data gives a relative estimate of range carrying capacity. The continued use of the present uniform rate for each acre of grazing land does not ensure an equitable assessment because the value should reflect the existing differences in range carrying capacities throughout the province.

In order that the range condition might be readily discernible, the grazing lands were classified according to their major plant associations. This resulted in the ranges of the province being divided into the lower, middle, and upper grasslands and the timbered areas. The timber areas were not classified according to density of stand but Table 14, given to indicate timber condition, was designed to include this factor.

A major factor in establishing a grazing land valuation technique is the limited time that the assessor can spend on the appraisal of each ranch. The assessor must first master range plant identification, as the method used in estimating the condition of each grazing land class is based on associations and abundance of plant species. It is known that the poorer quality plants increase with over-grazing and gradually replace the better quality species.

Absolute quantities in pounds of forage produced per acre were estimated for each condition class. These are based on research completed at the Range Experiment Station, Kamloops, B.C., and are issued subject to revision following further research studies on forage production.

In making practical application of this grazing land appraisal technique the assessor takes the following steps:

(1) Listing folio numbers and legal descriptions of the land from the assessment rolls and preparing a sketch map of the area on a Grazing Land Appraisal Card. Acreages can best be computed and entered on the card at this time. This work is all completed before going into the field.

(2) Alienation and acreages are checked with the rancher.

(3) A traverse of the ranch is made and species recorded on a tally card. Each area of similar floristic composition is assigned the same compartment number. In each compartment twenty observations are made, at every 100 yards the plant species occurring in a square yard are recorded. From the plant tally the class of range and condition is determined from Tables 13 to 16. This gives the approximate carrying capacity in acres required to support one 1,000-pound cow (or its equivalent) for one month (A.U.M.) for each compartment. When this is divided by the number of acres in the compartment it results in the carrying capacity in animal unit months. Totaling the A.U.M.'s for the compartments results in the capacity of the ranch.

The carrying capacity, in terms of the number of acres required for an animal unit month, is then converted to a dollar value based on the adjusted average net earnings (1938 to 1941) and the long-term average beef price (1935 to 1948). This value works out to $5.50 per animal unit month.

The carrying capacity estimation approach is believed adequate to meet the needs of the assessor in valuations based on the average productive ability of the land. In the absence of sufficient market sales of cattle ranches, this productivity-income approach is considered the best method available for assessment purposes.

TABLE 13.—SHOWING THE NORMAL FLORISTIC COMPOSITION OF LOWER GRASSLANDS AND THE ABUNDANCE OF EACH SPECIES IN ACCORDANCE WITH CONDITIONS

Class	Description	Floristic Composition (Common Name)	Abundance of Species in Following Conditions				Palatability
			Excellent	Good	Fair	Poor	
Lower grassland Altitude— 1,000 to 2,200	Precipitation in inches for growing season—4·2	Bluebunch wheat grass	D	A	C	O	G
		Sandbergs blue grass	C	C	A	D	F
		Spear grass[1]	C	A	D	C	G & M.I.
	P/E ratio—6·5	Sand dropseed[1]	C	C	A	A	F
		June grass	O	C	A	C	F
LEGEND	Av. summer temperature—66°	Indian rice[2]	A	C	C	O	G
(1) Abundance D—Dominant A—Abundant C—Common O—Occasional	Soil—Light brown pedocals	Downy brome	O	O	C	A	F & M.I.
		Russian thistle	O	O	C	A	P
	Approx. grazing date—Spring–Fall, Apr. 15–May 24, Oct. 31–Nov. 30.	Pussytoes (*A. dimorpha*)	O	C	C-A	A	P
(2) Palatability G—Good F—Fair P—Poor PX—Poisonous M.I.—Mechanically injurious		Arrowleaf balsamroot	O	C	C	C	F
	Av. date of first growth—March 18	Big sage	C	C	A-D	D	P
		Rabbit brush[3]	O	O	O	O	P
		Blue bur	O	O	C	A	P
		Cactus	O	O	C	C	P & M.I.
		Erosion	Natural	Natural	Light sheet	Sheet and rill	
	Carrying Capacity Estimation	(1) Estimated pounds of forage per acre	636	500	363	182	
		(2) Pounds of available forage per acre (45% carry-over)	350	275	200	100	
		(3) Pounds of forage required per A.U.M.	660[2]	660	660	660	
		(4) Number of acres required per A.U.M.	1·88	2·40	3·30	6·6	

[1]Dominion Range Experiment Station, Manyberries, Alta. Results of Experiments, 1927–1936 inclusive, Dominion of Canada, Dept. of Agriculture, 1937.
[2]Indian rice grass limited entirely to sandy soils.
[3]Principally on coarse soils.

TABLE 14.—SHOWING THE NORMAL FLORISTIC COMPOSITION OF MIDDLE GRASSLANDS AND THE ABUNDANCE OF EACH SPECIES IN ACCORDANCE WITH CONDITION

Class	Description	Floristic Composition (Common Name)	Abundance of Species in Following Conditions				Palatability
			Excellent	Good	Fair	Poor	
Middle grassland Altitude— 2,200 to 2,700	Precipitation in inches for growing season— 5·5	Bluebunch wheat grass	A-D	A	C	O	G
		Spear grass	A-D	A-D	A	C	G & M.I.
		June grass	C	A	A	C	F
		Sandbergs blue grass	C	C	A	A-D	F
	P/E ratio—10·0	Downy brome	O	O	C-A	A-D	F & M.I.
		Goat's beard	O	C	C	A	P
	Soi—Dark brown pedocals	Pussytoes *A. dimorpha*[1] *A. parvifolia*	C	C	A	A	P
		Yarrow	O	O	C	A	P
	Approx. grazing date— Apr. 15–May 24, Oct. 31–Nov. 30	Dandelion	O	O	C	A	F
		Arrowleaf balsamroot	O	C	A-C	A	F
		Rabbit brush	O	C	C	A	P
		Pasture sage	O	C	A	A	P
		Blue bur	O	O	C	A	P
	Average date of first growth—Mar. 27	Erosion	Natural	Natural	Light sheet	Sheet and rill	
	Carrying Capacity Estimation	(1) Estimated pounds of forage per acre	818	727	545	363	
		(2) Pounds of available forage per acre (45% carry-over)	450	400	300	200	
		(3) Pounds of forage per A.U.M.	660	660	660	660	
		(4) Number of acres required per A.U.M.	1·47	1·65	2·20	3·30	

LEGEND

(1) Abundance
D—Dominant
A—Abundant
C—Common
O—Occasional

(2) Palatability
G—Good
F—Fair
P—Poor
PX—Poisonous
M.I.—Mechanically injurious

[1] ***Antennaria parvifolia*** is the taller species and is found on the moister sites.

TABLE 15.—SHOWING THE NORMAL FLORISTIC COMPOSITION OF UPPER GRASSLANDS AND THE ABUNDANCE OF EACH SPECIES IN ACCORDANCE WITH CONDITION

Class	Description	Floristic Composition (Common Name)	Abundance of Species in Following Conditions				Palatability
			Excellent	Good	Fair	Poor	
Upper grassland Altitude— 2,700 to 3,000 LEGEND (1) Condition D—Dominant A—Abundant C—Common O—Occasional (2) Palatability G—Good F—Fair P—Poor PX—Poisonous M.I.—Mechanically injurious	Precipitation in inches for growing season 7·0 P/E ratio—19.0 Soil—Black earth Approx. grazing date— Spring–Fall June and Oct. May 25–June 28 Sept. 29–Oct. 30 Average date of first growth—Apr. 9	Bluebunch wheat grass[1]	D	A	C	O	G
		Rough fescue[2]	D	D	A-C	O	G
		June grass	C	A	A	C	F
		Columbia needle grass[3]	A	D	A	C	G
		Kentucky blue grass	A	D	D	A	G
		Spear grass	C	C-A	A	C	G & M.I.
		Sandbergs blue grass	O	O	A	D	F
		Downy brome	O	O	A	D	F & M.I.
		Sticky geranium	C	C	O	O	F
		Timber milk vetch	O	C	C	A	P & PX
		Lupine—(*Lupinus sericeus*)	C	C	O	O	G
		Arrowleaf balsamroot	O	C	A	A	F
		Yarrow	C	C	A	A	P
		Pussytoes (*A. parvifolia*)	C	C	A	A	P
		Dandelion	O	C	A	A	F
		Goat's beard	O	C	A	A	P
		Larkspur	O	C	A	A	P & PX
		Death camas	O	C	C	A	P & PX
		Erosion	Natural	Natural	Light sheet	Sheet and rill	
	Carrying Capacity Estimation	(1) Estimated pounds of forage per acre	1200	1090	818	455	
		(2) Pounds of available forage per acre (45% carry-over)	660	660	450	250	
		(3) Pounds of forage required per A.U.M.	660	660	660	660	
		(4) Number of acres required per A.U.M.	1	1·1	1·46	2·64	

[1] Bluebunch wheat grass dominant on the dryer sites.

[2] Location of rough fescue varies greatly with precipitation. This plant favors northern and easterly slopes.

[3] Columbia needle grass will withstand dryer conditions than rough fescue.

TABLE 16.—SHOWING THE NORMAL FLORISTIC COMPOSITION OF TIMBER GRAZING LANDS AND THE ABUNDANCE OF EACH SPECIES IN ACCORDANCE WITH CONDITION

Class	Description	Floristic Composition (Common Name)	Abundance of Species in Following Conditions				Palatability
			Excellent	Good	Fair	Poor	
Timber	Precipitation in inches for growing season—8·0	Douglas fir	O	C	A	D	P
Altitude—		Lodgepole pine	O	C	A	D	P
(1) Lower montane forest 3,000 to 3,700		Yellow pine	O	C	A	D	P
(2) Upper montane forest 3,800 to 4,300	P/E ratio—29·0	Aspen	A-D	A	C	O	F
(3) Sub-alpine forest 4,300 to 5,800	Av. summer temperature—56°	Snowberry	A	A	C	C	G
(4) Upper sub-alpine 5,800 to 6,100		Kinnickinnick	O	O	A	A-D	P
(5) Alpine tundra 6,100 and over	*Soil*	Twinflower	O	C	A	A-D	P
	(1) Montane—Brown-grey forest soils	Blueberry	O	O	A	D	P
LEGEND		Pine grass	A-D	D	A	C	F
(1) Abundance	(2) Sub-alpine—reddish pedalfers	Showy aster	A	C	O	O	G
D—Dominant	(3) Alpine tundra—alpine podsol	Creamy pea-vine	A	A	C	O	G
A—Abundant		American vetch	A	A	C	O	G
C—Common		Lupine (arcticus)	C	A	A	A-D	F
O—Occasional	Approx. grazing date—June 29–Sept. 28	Timber milk vetch	O	C	A	A-D	G & PX
(2) Palatability		Heartleaf arnica	O	C	A	A	P
G—Good	Date of first growth—Apr. 20–May 5	Deadfalls	O	O	C	A	.....
F—Fair		Erosion	Natural	Natural	Light sheet	Sheet and rill	
P—Poor	Carrying Capacity Estimation	(1) Estimated pounds of forage per acre...	545	455	318	182	
PX—Poisonous		(2) Pounds of available forage per acre (45% carry-over)	300	250	175	100	
		(3) Pounds of forage required per A.U.M...	660	660	660	660	
		(4) Number of acres required per A.U.M...	2·2	2·64	3·77	6·6	

ANIMAL HUSBANDRY

H. H. Nicholson

During the first two years of operation much of the work was of a preliminary investigational and developmental nature. This was necessary because the Division had to await the development of adequate research facilities.

The major investigations carried out during this period were as follows:

(1) Cause, incidence, and effect of timber milk vetch *(Astragalus serotinus)* poisoning.

(2) Abortion in beef cows caused by western yellow pine and lodgepole pine.

(3) Nutrition of sheep in relation to cobalt.

(4) Nutrition of sheep in relation to cobalt and urea.

(5) Weight gains of steers on irrigated pastures.

Each of these will be summarized in turn.

Timber Milk Vetch Poisoning

Timber milk vetch *(Astragalus serotinus)* is a perennial legume, which may be found on burned-over land and on open stands of the montane-forest zone and adjacent areas of the upper grassland zone of interior British Columbia. It is poisonous to livestock. Observations indicate that it affects most seriously lactating females but male animals have been known to show signs of poisoning. Annual death losses of 3 to 5 per cent are not uncommon and the economic loss through weight loss, or reduction in rate of gain, is considerable.

Poisoned animals show a variety of symptoms. Emaciation, grinding of the teeth, and faulty ingestion are common. When excited the affected animal may show a continuous nasal discharge and difficult respiration accompanied by coughing, wheezing, and protrusion of the tongue. In addition, when moved, the animals invariably show a partial paralysis of the hind quarters and have difficulty moving around.

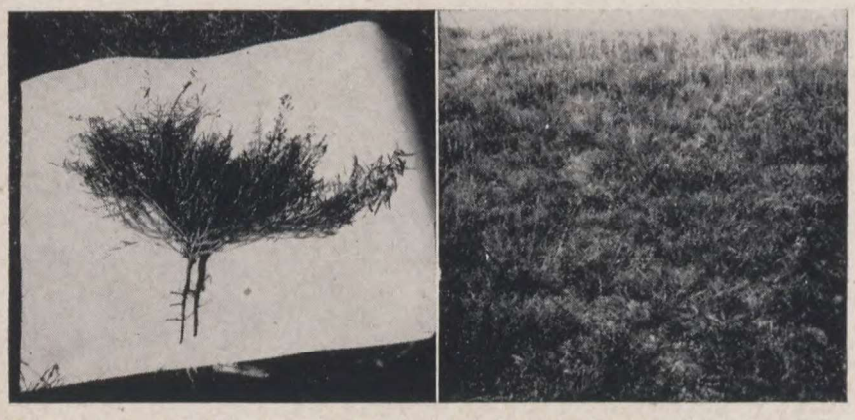


Fig. 15.—Timber milk vetch. Left—A typical plant (background 18 inches high). Right—A badly infested range area.

Experimental Work with Cattle

In an experiment performed during 1949, 450 pounds of the green plant material was found to be sufficient to bring about signs of the poisoning in lactating beef cows weighing 1,000 pounds.

Removal of affected cattle to an area that will provide good feed and water is the only treatment known at present. In the event that animals are too weak to be moved, good quality feed and water should be provided until they gain enough strength to be moved. Prevention of astragalus poisoning would appear to be the best treatment. This can be brought about only by thoroughly practising the principles of good range management whereby potentially poisonous ranges are grazed by properly distributed herds of correct size.

Because dry females are not so susceptible to poisoning as lactating cows, less risk is involved when they are allowed to graze in areas infested with timber milk vetch provided over-grazing is not permitted. Since lactating cows and ewes are susceptible they should be kept off infested areas until the timber milk vetch has dried up. There is evidence that the plant is not poisonous after it has completely cured in the stand.

Small Animal Work with Timber Milk Vetch

In 1950 work was started in an attempt to determine, by feeding timber milk vetch, if it was possible to develop the symptoms and effects of poisoning in: (a) Rabbits and (b) Guinea pigs.

Some of the important advantages of using laboratory animals are: (1) small cost, (2) short life cycle, and (3) slaughter and histological examination are easier and more economical to perform.

Four groups of lactating female rabbits were placed on rations containing different amounts of astragalus. The rations fed are given in Table 17.

TABLE 17.—RATIONS FED TO RABBITS ON ASTRAGALUS

Group I	Group II	Group III	Group IV
Control Group			
100 grams commercial rabbit pellets, 50 grams field carrots per head per day.	118 grams commercial rabbit pellets, 37 grams astragalus per head per day.	75 grams commercial rabbit pellets, 75 grams astragalus per head per day.	150 grams astragalus per head per day.

Rabbits are apparently not suitable laboratory animals for astragalus work. No sign of poisoning was apparent in any of the groups. The control group and Group II maintained normal body weight throughout the 8-week period of the trial. The animals in Group III and Group IV lost considerable weight but appeared normal in all other respects. All groups raised normal young.

TABLE 18.—RATIONS FED TO GUINEA PIGS ON ASTRAGALUS TEST

Group I Control	Group II	Group III	Group IV
Commercial pellets ad libitum.	80 grams astragalus. 40 grams commercial pellets per group per day.	120 grams of astragalus per group per day.	40 grams of astragalus, 80 grams commercial pellets per group per day.

Four groups of lactating female guinea pigs were placed on rations containing different amounts of timber milk vetch. The rations fed are given in Table 18.

The astragalus did not appear to be very palatable. The average daily consumption by groups was as follows:

Group I — 0 grams astragalus, average daily consumption
Group II — 12 grams " " " "
Group III — 12 grams " " " "
Group IV — 10 grams " " " "

The guinea pigs in Groups I, II and IV suckled their young and gained weight during the 10-week experimental period. The animals in Group III were fed astragalus as their sole ration. These animals suckled their young but lost weight, and were all dead by the end of the fourth week. Deaths began early in the third week on test. Autopsy findings did not indicate any abnormalities of the main organs but showed signs that death may have been caused by starvation. Average starting and finishing weights of the guinea pigs are given in Table 19.

TABLE 19.—AVERAGE STARTING AND FINISHING WEIGHT OF GUINEA PIGS FED ASTRAGALUS

Group I Control	Group II	Group III	Group IV
Start 246 grams	212 grams	219 grams	214 grams
Finish 686 grams	411 grams	196 grams	498 grams

Chemical analysis of timber milk vetch would indicate that while it may not be an ideal feed, its nutrient content is such that it should maintain life. The average chemical analysis is given in Table 20.

TABLE 20.—PROXIMATE CHEMICAL ANALYSIS OF *ASTRAGALUS SEROTINUS*, 1949

	Protein N x 6·25	Ether Extract	Crude Fiber	Total Ash	Calcium	Phosphorus
Average	12·37	2·65	30·80	5·48	0·86	0·36
Maximum	18·93	3·24	37·70	7·68	1·20	0·48
Minimum	9·95	1·51	25·73	4·26	0·70	0·27

None of the guinea pigs that died showed the classical symptoms of poisoning common to cattle or sheep. Work is in progress to determine the causative agent of poisoning.

Abortion in Beef Cows Caused by Western Yellow and Lodgepole Pine Needles

For a number of years ranchers in range areas of British Columbia, Washington, Idaho, and Oregon have claimed that pine needles and pine buds were causing nutritional or mechanical abortion in beef cattle. In British Columbia most of

these claims centered in savannah-like range areas where the dominant pine is western yellow pine *(Pinus ponderosa)* and in the Cariboo area where many of the cattle are wintered on native meadows that are surrounded by dense stands of lodgepole pine *(Pinus contorta)*. Such claims of pine needle abortion have been generally discounted since brucellosis and deficiencies of phosphorus and vitamin A, each a possible cause of abortion, are not unknown in these areas. In 1950 the British Columbia Beef Growers Association requested that the Range Experiment Station at Kamloops undertake a study or series of studies to determine whether pine needles do or do not cause abortion in range beef cattle.

Experimental Work with Cattle

During the winter of 1950-51 an experiment was undertaken with 18 pregnant, brucellosis-free cows. These animals were divided into three equal groups and fed the ration shown in Table 21.

The calving record of the control group was 5 normal calves. One animal was removed from this group because of unthriftiness. The 12 animals that received pine needles produced 3 normal calves, 4 dead calves, 5 calves born alive but died shortly after birth, and 1 weak calf that lived. One cow in Group I produced twins. These results are given in tabular form in Table 22.

From these results it was assumed that yellow pine needles were a causative agent of abortion when consumed by pregnant beef animals.

During the winter of 1952-53 a further test was carried out using lodgepole pine needles *(Pinus contorta)*. The rations fed the animals in this experiment are presented in Table 23.

TABLE 21.—NUTRIENTS FED PER HEAD PER DAY ON YELLOW PINE EXPERIMENT

Feed stuff	Amount of feed in lb.	Pounds of Nutrients Consumed				
		Crude* protein	Ether extract	Crude fiber	N.F.E.	T.D.N.†
Group I—Pine Needles (Limited)						
Pine needles	6·4	0·4	0·5	1·5	1·4	2·1
Crested wheat grass hay	10·5	0·6	0·2	3·5	4·6	4·5
Alfalfa hay	3·1	0·4	0·1	1·2	0·9	1·3
Oilcake meal	0·5	0·2	0·0	0·0	0·2	0·2
Total	20·5	1·6	0·8	6·2	7·1	8·1
Group II—Pine Needles (Free access)						
Pine needles	4·9	0·3	0·4	1·1	1·2	1·7
Crested wheat grass hay	16·8	1·0	0·4	5·5	7·1	7·3
Alfalfa hay	3·1	0·4	0·1	1·2	0·9	1·3
Oilcake meal	0·5	0·2	0·0	0·0	0·2	0·2
Total	25·3	1·9	0·9	7·8	9·4	10·5
Group III—Control (No pine needles)						
Crested wheat grass hay	16·8	1·0	0·4	5·5	7·1	7·3
Alfalfa hay	3·1	0·4	0·1	1·2	0·9	1·3
Oilcake meal	0·5	0·2	0·0	0·0	0·2	0·2
Total	20·4	1·6	0·5	6·7	8·2	8·8

*Crude Protein = Nitrogen x 6·25.
†T.D.N. = computed assuming 50% digestibility.

TABLE 22.—CALVING RECORD OF ANIMALS ON YELLOW PINE NEEDLE EXPERIMENT

Dates	Group			Comment
	I—Pine needles	II—Free access	III—Control	
Feb. 6	Bull			Born premature and dead.
8		Heifer		Born premature and dead.
Mar. 1	Twins, bull and heifer			Born premature and dead.
2		Bull		Born premature and alive, dead Mar. 4.
6		Heifer		Born premature and alive, dead Mar. 7.
12	Bull			Born alive, died shortly after birth.
17		Heifer		Born alive, weak, died in 36 hours.
21			Heifer	Born alive, normal, weight 70 lb.
27			Heifer	Born alive, normal, weight 70 lb.
27	Heifer			Born alive, normal, weight 65 lb.
28		Heifer		Born alive, appeared normal, died in 18 hours.
Apr. 7			Bull	Born alive, normal, weight 75 lb.
24	Heifer			Born alive, weak, weight 45 lb.
25		Bull		Born alive, normal, weight 60 lb.
27			Bull	Born alive, normal, weight 78 lb.
28			Bull	Born alive, normal, weight 70 lb.
May 7				Cattle turned out.
17	Heifer			Born alive, normal, —after turn-out.

In this test the 12 animals that received pine needles produced normal calves, as did the four pregnant animals in the control group. The results of this test are presented in Table 24.

These results indicate that lodgepole pine needles were not a causative agent in abortion of beef cows.

During the winter of 1953-54 a test was conducted to verify the results of the first test with yellow pine needles. The procedure used was the same as in the two previous experiments. The animals went on test November 1. The first calf was born February 28, the last calf April 11.

One cow in the control group aborted after the test had been under way for four weeks. Another cow in the control group was found to be not pregnant.

One cow in the group that had free access to pine needles produced a mummified foetus three months after the test commenced.

One cow in the controlled-consumption group aborted four weeks after the commencement of the test.

The remainder of the cows produced normal healthy calves.

TABLE 23.—NUTRIENTS FED PER HEAD PER DAY ON LODGEPOLE PINE EXPERIMENT

Feed stuff	Amount of feed in lb.	Pounds of Nutrients Consumed				
		Crude* protein	Ether extract	Crude fiber	N.F.E.	T.D.N.†
Group I—Control						
Alfalfa hay	20·00	2·4	0·4	5·6	5·2	9·2
Oilcake meal	0·50	0·2	0·0	0·0	0·2	0·2
Pine needles	0·00	0·0	0·0	0·0	0·0	0·0
Total	20·5	2·6	0·4	5·6	5·4	9·4
Group II—Free Access						
Alfalfa hay	20·0	2·4	0·4	5·6	5·3	9·2
Oilcake meal	0·5	0·2	0·03	0·05	0·2	0·2
Pine needles	5·4	0·3	0·2	0·9	2·2	1·9
Total	25·9	2·9	0·7	6·6	7·7	11·3
Group III—Controlled Consumption						
Alfalfa hay	15·0	1·8	0·3	5·58	3·9	6·9
Oilcake meal	0·5	0·2	0·03	0·05	0·2	0·3
Pine needles	5·3	0·3	0·26	0·96	2·1	1·8
Total	20·8	2·3	0·59	6·59	6·2	9·0

*Crude protein = nitrogen x 6·25.
†T.D.N. = computed assuming 50% digestibility.

TABLE 24.—CALVING RECORD OF ANIMALS ON LODGEPOLE PINE NEEDLE EXPERIMENT

Date	Group			Comment
	I—Control*	II—Free access	III—Controlled consumption	
Feb. 7			Bull	Normal, weight 72 lb.
Mar. 21		Heifer		Normal, weight 68 lb.
24		Bull		Normal, weight 88 lb.
24			Bull	Normal, weight 61 lb.
31			Heifer	Normal, weight 66 lb.
Apr. 1	Bull			Normal, weight 65 lb.
4		Heifer		Normal, weight 65 lb.
5			Bull	Normal, weight 74 lb.
6			Bull	Normal, weight 75 lb.
7			Heifer	Normal, weight 63 lb.
19	Bull			Normal, weight 72 lb.
21		Bull		Appeared normal, died after 36 hr., weight 52 lb.
27		Heifer		Normal, weight 71 lb.
May 8	Heifer			Normal, weight 56 lb.
13		Heifer		Normal, weight 80 lb.
16	Heifer			Normal but small, difficulty in suckling, weight 43 lb.

*Two animals in the control group were found to be not pregnant.

Consumption of pine needles by the controlled-consumption group averaged 8.5 pounds per head per day. The free-access group consumed an average of 6.0 pounds of needles per head per day.

Why the results of this test were at variance with those of the test run in 1950-51 has not been determined. Work is being carried out to verify these findings.

Small Animal Work with Pine Needles

The work with small animals was an attempt to find an experimental animal that would reduce the cost of experimentation and still provide results applicable to larger animals with a certain degree of accuracy.

The first test was conducted by M.A. MacDonald, former Station Animal Husbandman, using guinea pigs and yellow pine needles. In an unpublished report he indicated that the results were negative in nature and that all the guinea pigs on the test produced normal young.

The second test conducted in 1952, was performed with pregnant guinea pigs and lodgepole pine needles. Fifteen guinea pigs were divided into 3 groups of 5 animals each. The following feeding schedule was used:

Group I (Control group)—30 grams of commercial pellets per head per day plus free access to alfalfa hay.

Group II—20 grams of commercial pellets plus 10 grams of pine needles per head per day.

Group III—30 grams of commercial pellets per head per day plus free access to pine needles.

A weigh back was taken on all feed each morning. To prevent a Vitamin C deficiency a solution of Vitamin C was fed orally to the guinea pigs twice weekly. The test was started on January 16, 1952 and continued until February 28, at which time all farrowing had been completed. Average consumption of pine needles in Group II was 10 grams per head per day. Average consumption in Group III was 15 grams per head per day. The results of the litterings were as follows:

Group I —(Control group)
3 sows farrowed a total of 7 young, all of which were normal; 2 sows were not pregnant.

Group II —10 grams of pine needles per animal daily.
5 sows farrowed a total of 12 young; 4 of these sows produced normal young. The fifth sow produced 2 dead young and one alive.

Group III—Free Access to pine needles.
4 sows farrowed a total of 5 young; one sow was not pregnant. All pigs produced were normal.

The above results would not indicate that lodgepole pine needles had any marked toxic effect on reproduction since all the pregnant pigs but one produced normal offspring.

Nutrition of Sheep in Relation to Cobalt

The work done on nutritional requirements of sheep was part of a co-operative project in which several western Experiment Stations and Universities co-operated. The work performed at Kamloops was set up to determine whether

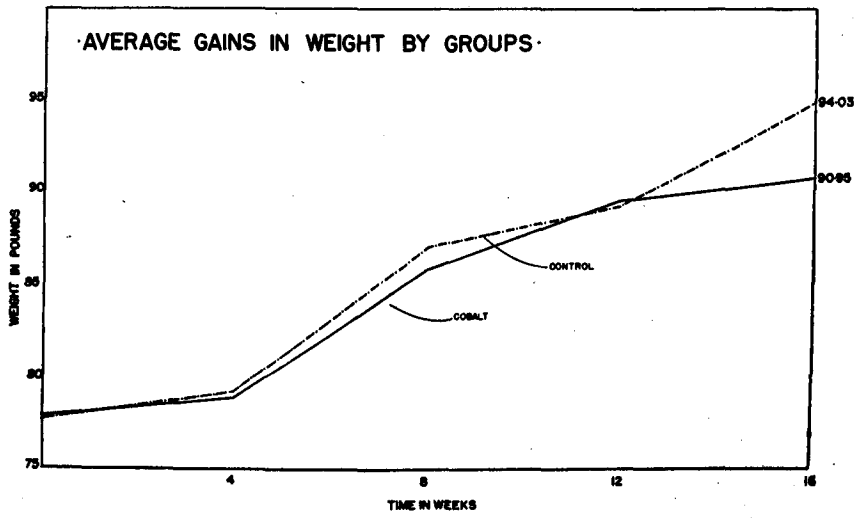
a slight or moderate cobalt deficiency existed in the area. Forty-eight lambs of Rambouillet breeding were divided into two groups and fed on locally grown hay, barley, and oats. In addition one of the groups received, free choice, a mineral supplement containing cobalt while the other group received the same mineral supplement minus the cobalt. The cobalt contents of the feeds were as listed in Table 25.

TABLE 25

Feed Stuff	Non-legume Hay	Whole Oats	Whole Barley
Cobalt content (PPM).....	0·20	0·05	0·09

There was no significant difference in the weight gain between the group receiving cobalt supplement and the group not receiving the supplement. This is illustrated by Graph 1.

Throughout the trial the cobalt-supplemented group received cobalt at the rate of 37 p.p.m. of the dry matter while the unsupplemented group received cobalt at the rate of 9.1 p.p.m. of the dry matter. On the basis of these results it would appear that a ration containing cobalt at the level of 9 p.p.m. of the dry matter will meet the cobalt requirements of feeder lambs in the Kamloops area.



Nutrition of Sheep in Relation to Cobalt and Urea

Work in this phase of sheep nutrition was undertaken to investigate two things: (1) the possibility of borderline cases of cobalt deficiency; and (2) the utilization of urea as a source of nitrogen for conversion to protein.

In this test 4 groups of Rambouillet lambs of 25 animals each were used. All groups were fed locally-grown non-legume hay, oats, and barley. In addition Group I and II received a supplement of linseed oilmeal and Group III and IV received a supplement of urea. Groups II and IV also received a mineral mix which contained cobalt. The linseed meal and urea were fed at a level that would give a ration containing 10 per cent protein. The rations fed to each group are presented in Table 26.

TABLE 26.—RATIONS FED TO SHEEP IN THE COBALT AND UREA TRIAL

Linseed meal		Urea	
Group I No cobalt	Group II Cobalt	Group III No cobalt	Group IV Cobalt
Non-legume hay. Oats and barley. Linseed meal.	Non-legume hay. Oats and barley. Linseed meal. Cobalt.	Non-legume hay. Oats and barley. Urea.	Non-legume hay. Oats and barley. Urea. Cobalt.

The hay ration was limited to 1 pound per head daily at the beginning of the trial and was increased to 1.5 pounds as the size of the animals increased. The oats and barley were increased in quantity and in proportion of barley to oats as the size of the animals increased.

The results obtained in the two years that this trial was run would indicate that the feeds grown in the Kamloops area contain adequate cobalt since no significant increase in rate of gain was obtained in groups fed cobalt supplement.

In both years, groups fed linseed meal made greater gains than those fed urea. No difficulty was experienced in feeding urea when it was mixed with enough molasses to mask its taste. A summary of the results obtained in the last year of the trial is given in Table 27.

TABLE 27.—RESULTS OF COBALT FEEDING TO LAMBS

	Linseed Meal		Urea	
	Group 1 No cobalt	Group 2 Cobalt	Group 3 No cobalt	Group 4 Cobalt
Number of lambs	25	25	25	25
Length of trial—days	112	112	112	112
Av. initial wt.—lb.	96·5	95·2	96·7	96·6
Av. final wt.—lb.	123·0	120·4	120·1	121·1
Av. gain—lb.	26·5	25·2	23·4	24·5
Av. daily gain	0·236	0·225	0·210	0·219
Feed required per 100 lb.	1,283	1,364	1,466	1,405

Weight Gains of Steers on Irrigated Pastures

Irrigated lands have provided forage for beef cattle in British Columbia since the time of the earliest ranch settlements. The forage has normally been harvested as hay and used for winter feeding. Some aftermath grazing is practised on these irrigated lands during the fall months. A recent innovation has been the use of intensively managed irrigated lands for summer grazing and fattening of beef animals. That they have a place in the ranch economy of the province is appreciated when it is realized that the natural range resources are being used to very nearly their fullest extent at present. Irrigated pastures provide a means of intensifying production and permit increased beef output from the limited land areas available in the province.

The irrigated pasture studies were undertaken to study the value of irrigation as a means of increasing animal production, and to study the management factors necessary for the most provident use of such pastures. While the research project is still in its initial stages, it is already possible to indicate certain basic conclusions from these early data.

The 18 acres of irrigated pastures at Kamloops were seeded in June 1951 and grazing commenced in August of that year. The results of the 1952 grazing season are given in Table 28.

During the 1953 season the pastures were grazed by yearling beef heifers. There were too many animals for the original 18 acres of pastures and consequently it was necessary to use approximately 7 acres of hayland after the first crop was harvested as hay and silage.

Table 28 indicates the weight gain made by the animals on the irrigated pasture.

TABLE 28.—PASTURE LIVESTOCK PRODUCTION ON IRRIGATED PASTURES

	1952	1953
Number of acres in pasture	18	25
Number of pasture days	148	145
Average number of animals carried during season	44·6	96
Total pounds of beef gain produced	12,911	21,504
Pounds of beef produced per acre	717	827
Average daily gain per head in pounds	2·6	1·56

The animals used to graze the pastures during 1952 were two-year-old steers. These animals finished on grass to a degree that would make them acceptable to the packers. Observations made on carcasses after slaughter would indicate that there was no objectionable yellowing of the fat. The carcasses from the grass-fed animals were compared with those from animals that had been on dry-lot feed of hay and grain for three months.

The management of beef animals on irrigated pasture is much more intensive than the management of range beef cattle. They require closer attention and daily observation. The conditions that prevail on irrigated pasture, ie. relative crowding, dampness of pastures, and confined areas used continuously, appear to be conducive to the development of foot rot. Unless prompt treatment of affected animals is undertaken, the disease may spread quickly. Animals suffering from foot rot lose weight and, if untreated, will become lame and require a long time to recover. Prompt treatment, using any of the commercial sulfa drugs available, appears to give good control.

The incidence of bloat on irrigated pastures can create a serious problem. Immediate treatment is necessary as soon as an animal shows signs of bloat. There are several recommended treatments but none is completely satisfactory since it is difficult to catch and treat beef animals because of their temperament. All treatments appear to reduce bloat if used early enough. Drenching of the animals with a pint of mineral oil, or a cup of coal oil in a cup of milk appears to relieve bloat in many cases. The use of a trocar and canula is a positive means of relieving bloat, but care must be taken that the instrument is clean and that it is inserted in the right area.

The following practices appear to have some merit in preventing bloat:

(1) Keep the legumes in the pasture forage below 50 per cent by weight.

(2) Feed dry hay, preferably non-legume, before turning animals to pasture.

(3) Keep the animals on pasture all the time so that they do not become overly hungry.

With animals on irrigated pasture it is necessary to feed dry hay during periods when the grass is wet. If dry hay is not fed the animals become very

loose and will lose condition rapidly. It appears that this loose condition in the cattle is caused by the "washy" nature of the grass. This condition could also be controlled by the feeding of any dry concentrate feed.

Timber Range Livestock Management

In addition to the aforementioned work a great deal of preliminary investigation has been carried out on the management of cattle on timber range. Timber range in British Columbia makes up over 85 per cent of the grazing potential. Therefore, it is readily apparent that the proper use of this grazing resource is important.

The management of cattle on timber range is complicated by the rough terrain, dead-fall timber, and climatic conditions. Each of these factors makes the proper handling of cattle difficult but they can be overcome to a certain extent by following good range management practices. Good range management practices on the timber range are dependent largely upon the range rider. A rider who will disperse the cattle both by riding and the proper use of salt will do much toward making the maximum use of range. The number of breeding females to each bull has arbitrarily been set at 20 animals on most of the timber range in British Columbia. This ratio of bulls to females appears to be adequate, provided diligent riding is done during the breeding season to keep the bulls dispersed. It is doubtful if an increase in the ratio of bulls to females will economically improve the calf crop return if adequate range riding is not practised.

The proper use of timber range is closely related to times of turn-out and time of removal of animals. In general, growth is never far enough advanced on timber range to permit turn-out before June 15. If animals are turned out before this time both animals and forage will suffer. Observations also tend to indicate that animals lose condition rapidly after the end of September if kept

Fig. 16.—Timber range showing inaccessibility to cattle because of fallen timber.

on timber range. Therefore, for economical use of timber range forage and economical production of cattle it appears to be desirable to use timber range only during the months of June, July, August, and September.

Range livestock management has a number of objectives but the two primary ones are: (1) the production of meat animals that are suitable to market demands; and (2) the production of these animals in such a way that the best economic use is made of the range resource. To accomplish these two objectives, care must be exercised in many phases of cattle management.

Table 29 gives the various grazing zones of British Columbia rangeland.

TABLE 29.—GRAZING ZONES OF BRITISH COLUMBIA RANGELANDS

Zone	Altitude in feet	Soil type	Approx. grazing date	Av. date of first growth
Lower grassland	1,000–2,200	Light brown pedocals	Spring—fall Mid-Apr.--June	March 18
Middle grassland	2,200–2,700	Dark brown pedocals	Nov.—mid-Nov.	March 27
Upper grassland	2,700–3,000	Black soils	Spring—fall June and Oct.	April 9
Montane forest	3,000–4,000	Brown-grey forest soils	Summer, July, Aug. and Sept.	April 20 May 5
Sub-alpine forest	4,000–5,800	Reddish pedalfers	Of little grazing value	.....
Alpine tundra	5,800–6,100	Alpine podsol	Generally grazed only by sheep	.....

The grazing dates as listed in Table 29 will vary from year to year according to climatic conditions but use of these grazing zones during the seasons indicated will generally result in better utilization of the range forage and the production of better livestock.

The greatest danger to range lies in too early turn-out. Range grasses are easily injured during their first weeks of growth in the spring and too early turn-out invariably results in a depleted range. Grasses should be allowed a month to six weeks' growth before animals graze them in the spring.

The control of animals while grazing a range is all-important. This can be accomplished by herding, fencing, and salting. The use of fencing is in most cases considered too expensive but the utilization of natural barriers and short drift fences often will lower the cost and accomplish the required division.

Salting is probably the easiest way in which to control the grazing habits of animals. Salt should be used in adequate amounts and in well-selected locations. The salt should be placed away from watering facilities so that the animals will be drawn away from the watering places and thus prevent over-grazing. The amount of salt required by animals varies according to climate, type of forage, season of the year, and class of livestock. Beef cattle on the Range Experiment Station consume an average of 3 pounds of salt per month. Consumption is usually higher during the spring and summer months than during the winter months. Sheep in general consume 0·5 pounds of salt per month and in the case of sheep it is advisable to use salt of a fairly course grind such as one half or three-quarter grind. Iodized salt is used in all cases but the use of most so-called medicated salts generally has no advantage.

Fig. 17.—Aspen, lodgepole pine area. Note open area between trees which provides excellent grazing conditions.

Economical beef or sheep production cannot be attained unless healthy vigorous stock are used. The health of livestock is not only affected by disease but also by the feeding practices throughout the year. Animals that are allowed to become too thin during the winter are susceptible to disease with a resulting loss of life or lowering of production. The vigor of animals can be maintained by using the best quality males and selecting replacements from among the best offspring. This practice can change a nondescript herd to good quality stock in a very few generations.

Good range livestock management can be attained by following these practices:

(1) Stocking the range at the correct rate and season. (2) Controlling the animals on the range by herding, fencing, and salting. (3) Maintaining a healthy vigorous herd by controlling disease; providing for adequate nutrition, during both summer and winter; and using top quality sires with selection of replacements from the best offspring.

ACTIVE PROJECTS

Range Experiment Station
Kamloops, B.C.

Field Husbandry

Weather records.

Improvement of native vegetation by cultivation, fertilization, and eradication of weeds.

Range burning techniques and costs.

A study of control and eradication of diffuse knapweed and big sage.

Farm and garden tractor operating costs and utility.

Forage Crops

Plant introductions and testing of new species on irrigated, dry land, forest, and district nurseries.

A study of the growth, development and characteristics of principal native species, including taxonomic studies.

Variety tests of alfalfa, corn and soybeans.

Tests of perennial and biennial grasses and legumes for hay and for pastures.

The revegetation of special areas such as over-grazed range, burned-over areas, and weed-control sites.

The productiveness and carrying capacity of range pastures.

Herbarium, collection, preservation, and classification of plant specimens.

Animal Husbandry

Studies to confirm the toxicity and incidence of timber milk vetch (*Astragalus serotinus*).

A study of the cause, symptoms, and effects of pine needle poisoning.

To determine the effect of cobalt and molasses on urea utilization in feeder lambs or replacement ewe lambs.

A cold-tolerance test for beef cattle.

Beef bull research project on selection.

Irrigated pasture experiments.

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