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Title: RESPONSE OF CANADA MILKVETCH (ASTRAGALUS CANADENSIS VAR. MORTONII (NUTT.) WATS.) TO RANGE AND FOREST IMPROVEMENT PRACTICES IN NORTHEASTERN OREGON

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Dr. C. E. Poulton

The response of Canada milkvetch (Astragalus canadensis var. mortonii) to range and forest improvement practices was studied on a stand of mixed-coniferous forest which was clear-cut and burned in 1963 and 1964, respectively. The field studies were conducted on the Hall Ranch of the Eastern Oregon Experiment Station during the summers of 1968, 1969, and 1970.

Canada milkvetch, which was virtually absent at the time of treatment, became one of the most important herbaceous species. The cover, frequency, and density of this species rapidly increased from 1965 to 1967; thereafter, these parameters have decreased, even to the levels of 1965 in some cases.

The influence of forest canopy and physical site factors, viz.,

soil moisture, soil temperature, and hydrogen ion concentration of the soil were studied.

Phenology of seedling, root systems, shoot and flower development, seed production and germination were investigated. Studies were also made on the effects of grazing as they influence flowering, plant height, yield and numbers of plants.

The population parameters which were studied included cover, frequency, and density.

The effects of calcium, copper, and cobalt each alone and in all combinations were studied by growing plants in the greenhouse. In addition, nitrogen fixation and the effect of nitrogen upon root nodulation were examined.

The environmental parameters that influence Canada milkvetch are soil moisture and temperature for root nodulation and soil moisture for pod ripening.

Soil from areas dominated by Canada milkvetch has higher pH values than soils in the forest and lower values than soils dominated by introduced grass species. In the experimental area, the amount of organic materials on the soil can be correlated with the intensity of grazing.

Canada milkvetch begins growth shortly after snow melts, flowers in late June and July, and pods ripen in August. Flowering may begin in early June and continue to September, but the ovaries of the flowers produced early or late abort, because pollination occurs only when a medium sized bumble bee (Bombus sp.) is the most active. This is the only species which trips the flowers of Canada milkvetch.

The greatest amount of damage to the reproductive potential of Canada milkvetch is done by a weevil (Apion sp.) which lives within the developing pod. At least 50 percent of the pods were destroyed by this insect during the summers of 1968 and 1969.

Untreated seeds germinate and produce seedlings at the rate of approximately five percent per month. The rate of germination can be greatly increased by moist heat, but the amount of hard seeds remaining decreases and the amount decayed seed increases.

The effects of grazing on this species can be evaluated by plant height, dry weight yield per plant, total yield per unit area, and the number of blossoms per flower stalk. Cattle prefer the inflorescences, but graze the leaves and stems along with the associated species at approximately the same intensity of use. On the other hand, big game preferentially graze this species from the time it begins growth in early spring until the animals leave the area. Canada milkvetch was always more productive under a grazing regime of cattle only than under a regime of domestic plus wild animals.

Because the vegetation of the experimental area is rather low in the successional hierarchy, rapid changes in the values of cover, frequency, and density have occurred. The importance of Canada milkvetch has steadily decreased since 1967 and the relative importance of grasses has increased.

Calcium seems to be required for nutrition and nodulation rather than as an amendment to alter the pH of the soil. Low levels of copper and cobalt also increase growth. Further research is required to adequately define the effects of these elements alone and in combination. Perhaps the successional role of Canada milkvetch can be prolonged by adequate fertility.

This research provides an example demonstrating that range and forestry improvement must be coordinated and management intensified in order to maximize the biological potential of a given area.

Response of Canada Milkvetch (*Astragalus canadensis* var. *mortonii* (Nutt.) Wats.) to Range and Forest Improvement Practices in Northeastern Oregon

by

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INTRODUCTION

Statement of the Problem

The mixed-coniferous forest[1] of eastern Oregon and Washington is presently in a deteriorated condition (Pettit, 1968a). A stand representing this ecologic unit was clear-cut, broadcast-burned, and seeded. On this site the theoretical advantages of vegetation manipulation to the land manager interested in both forage and timber production are being tested. The first objectives of the entire project were to study the early successional trends, maximize forage production, and establish a tree plantation of desirable species, i.e., *Pinus ponderosa*[2] and *Pseudotsuga menziesii*. Subsequent objectives of the project are to test the hypotheses that domestic animals can be used to enhance tree growth via removing competing vegetation and can be used as management tools to maintain browse species in a state most productive for big game.

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[1] The mixed-coniferous forest is a Grand Fir/Douglas-Fir/Larch forest as defined by the Society of American Foresters cover types. Herein it is defined as a specific ecological unit within the *Abies grandis*/*Pachistima* Association of Daubenmire and Daubenmire (1968).

[2] Species list with symbols are given in Appendix I.

The studies of the early successional trends indicated Canada milkvetch (Astragalus canadensis var. mortonii) would be one of the more important species as the general vegetal aspect changed from annual and biennial species to herbaceous perennials (Pettit, 1968a).

Importance and Value of Canada Milkvetch

Canada milkvetch is of special interest because it became so abundant in Exclosure 1 of the experimental area during the summer of 1966 (see Figure 1). This species had very low cover values during 1965 and increased in abundance by nearly 50 percent the following season (Pettit, 1968a). Prior to logging and burning, this species was absent from the experimental area. However, it is a minor component of the mixed-coniferous stand directly adjacent to the experimental area. It is also present in most of the sites in the Wallowa Mountain foothills which have northern-northeastern exposures.

Canada milkvetch is highly palatable--eaten by cattle and wild game. It has a high crude protein content and apparently is capable of fixing nitrogen.

The purpose of this study is to ascertain the salient features of the life history of Canada milkvetch. An ecological life history of this plant can contribute much to an understanding of its local distribution, and aid in solving the general biological problems such as

Figure 1. Abundance of Canada Milkvetch during Summer, 1966 in Exclosure 1.

environmental response and adaptation. Also, an understanding of a particular species is basic to sound range management practices.

THE STUDY AREA

Location of Study Sites

This study was conducted primarily on the clear-cut burned experimental area maintained on the Hall Ranch of Eastern Oregon Experiment Station. The experimental site formerly supported a stand of mixed-coniferous forest and has a northern aspect. The elevation of the study site is approximately 4,000 feet.

The Hall Ranch is located on Catherine Creek about 11 miles southeast of Union, Oregon. This area lies on basalt and basaltic andesite similar in origin to the basalts of the Columbia River Basin (Young, Hedrick, and Keniston, 1967).

The experimental area is composed of three 5-acre exclosures located on a 30-acre tract of land, which was clear-cut and broadcast-burned in 1963 and 1964, respectively. The area was seeded after burning with the following mixture: *Phleum pratense*, *Dactylis glomerata*, *Arrhenatherum elatius*, *Bromus inermis*, and *Trifolium repens* at a seeding rate of 6 pounds per acre. Pure stands of *Elymus glaucus* and *Bromus marginatus* were also planted at the rate of 8 pounds per acre. The exclosures are designated as 1, 2, and 3. Exclosure 1 which is enclosed with a game-proof fence has been grazed by cattle only since 1966, except for 1968. In 1968, nine captive deer were placed in this exclosure from 18 April to 20 June. The cattle grazed Exclosure 1 in 1968 from late June to mid-July. Cattle have grazed Exclosures 2 and 3 in early summer since 1966. These latter exclosures do not have game-proof fences.

Data and observations were also obtained from additional stands of mixed-coniferous forest in the proximity of the experimental area (Table 1). Some data were also collected from the nursery area adjacent to the north side of Exclosure 1. This area is completely protected from all grazing.

Table 1. Location of additional study sites.

Location	Reference Used in Text	Forest Canopy
NW 1/4 Sec 15 T5S R41E	A	Open (0-20% crown cover)
NW 1/4 Sec 15 T5S R41E	B	Dense (41-100% crown cover)
NW 1/4 Sec 15 T5S R41E	C	Intermediate (21-40% crown cover)
Sec 20 T5S R41E	D	Intermediate (selective-cut)
Sec 25 T5S R40E	E	Open (wildfire)
Sec 8 T5N R42E	F	Intermediate (selective-cut)

The cattle grazing occurs in early summer at a stocking rate of one acre per AUM. A more detailed account of the field design and cattle grazing is given by Pettit (1968a). Figure 2 illustrates the field design of the experimental area.

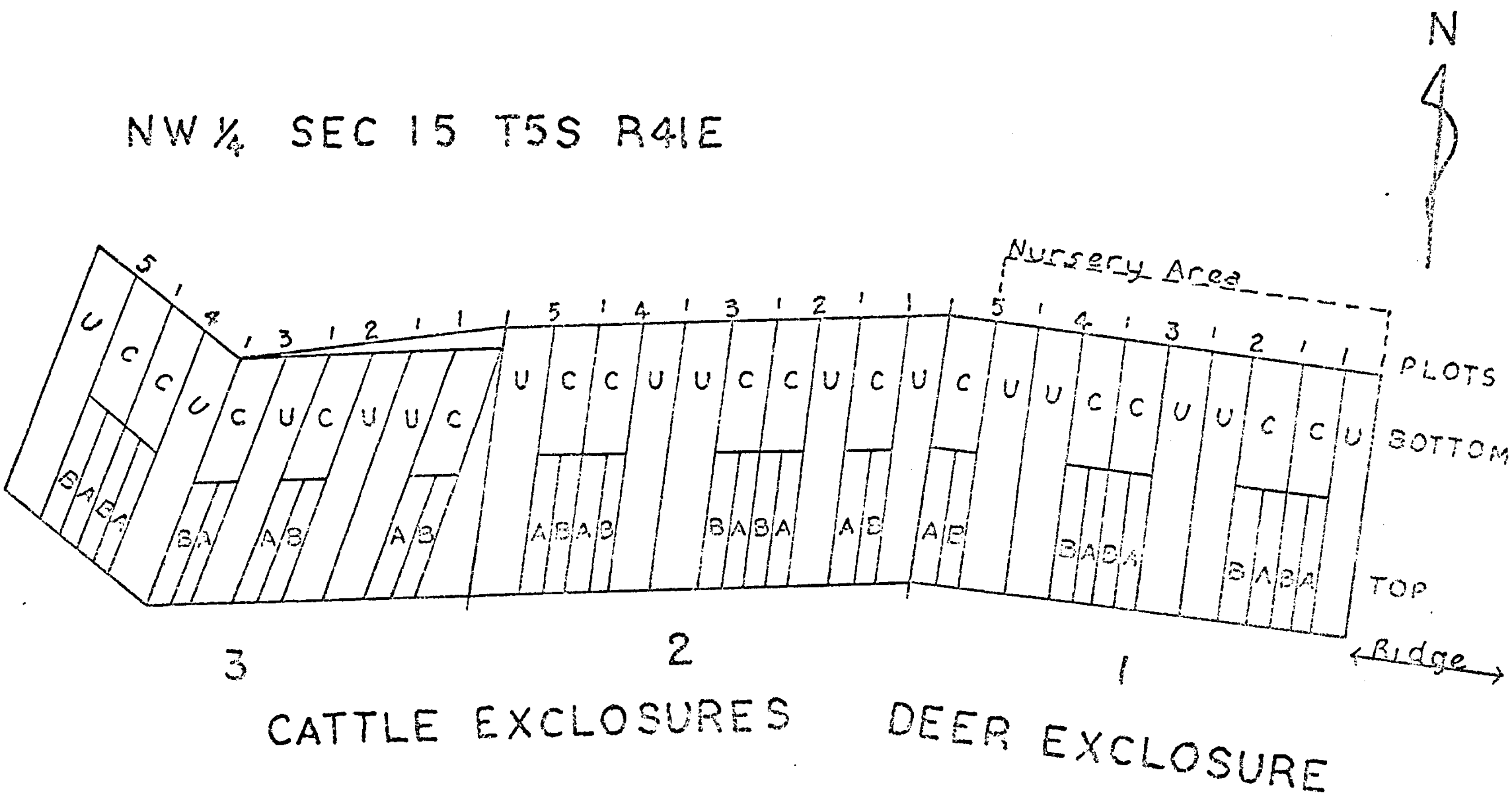


Figure 2. Field design of Experimental Area: Seeding Treatments are A=*Elymus glaucus*; B=*Bromus marginatus*; C=seeded with a mixture of *Dactylis glomerata*, *Arrhenatherum elatius*, *Phleum pratense*, *Bromus inermis*, and *Trifolium repens*; and U=unseeded.

The soils of the mixed-coniferous forest are relatively deep accumulations (up to six feet) of volcanic ash. These soils do not have any appreciable amount of development and typically have A-C horizon sequence. Both horizons characteristically have a silt loam texture, and are loose and friable. Often the ash soil overlies a buried B horizon, which has moderate amounts of clay.

The soil on the study area is Tolo silt loam, a Typic Vitrandept. This series is a well-drained and deep, medium-textured soil, which has been derived from a relatively pure volcanic ash parent material. The ash probably originated from volcanic activity in the Cascade Mountains and was wind-deposited in the lower Wallowa Mountains foothills approximately 7,300 years ago (Strickler, 1965). Underlying the ash mantle is consolidated or fractured basalt. This condition is probably less common than having a buried B horizon.

The volcanic ash is pumicite. Pumicite characteristically has a high water-holding capacity for being predominantly silt-sized. The water-holding capacity is about 40 percent by volume (Strickler, 1965).

Pettit (1968a) and Young, Hedrick and Keniston (1967) have adequately summarized the pertinent information with respect to the geology, physiography, climate and soil of this study area.

Open-grown ponderosa pine occupies much of the fine-textured soils of basaltic origin in the Blue and Wallowa Mountains. Wherever volcanic ash has been deposited to produce great soil depth, there usually is an abrupt change in vegetation to a mixed-coniferous forest. This is one of the best examples of a definite relationship between soils and tree species (Tarrant, 1956a).

Climate

The study area receives the majority of its precipitation as snowfall in the winter period. Rain showers are common during the growing season. However, these summer showers are most commonly isolated thunder showers which provide little moisture to replenish the soil reservoir.

Air temperatures are somewhat cool throughout most of the year. The average yearly temperature for a ponderosa pine-grass site directly adjacent to the experimental area is 78° F. And, the average temperature of the experimental site will certainly be less than this because of its physiographic position on a north-northeast facing slope. In fact, near freezing temperatures can be expected even during the summer months. The precipitation is higher and temperatures are lower in the *Abies grandis* or mixed-coniferous types than in lower forested areas (Franklin and Dyrness, 1969). On the other hand, the mixed-coniferous forest is more mesic and is characterized by warmer temperatures than forest dominated by *Abies lasiocarpa* (Daubenmire, 1956).

Forests dominated by *Abies grandis* are differentiated from those dominated by Pseudotsuga menziesii by being less subject to summer dryness and soil drought (Daubenmire, 1956 and 1968). Soil drought is of minor ecologic significance in grand fir associations (McMinn, 1952).

LITERATURE REVIEW

Abies grandis Zone

The Abies grandis Zone is the largest forest zone of mid-elevations in the Cascade Range of Oregon and adjacent Washington, and in the Blue Mountains of eastern Oregon. This zone occurs at 3,600 to 4,900 feet in the central Oregon Cascades (Franklin and Dyrness, 1969). In the Ochoco and Blue Mountains, it is found at 4,900 to 6,500 feet (Hall, 1967) and 5,610 to 6,200 feet in south-central Oregon (Dyrness and Youngberg, 1966). Daubenmire and Daubenmire (1968) have included this zone in the Tsuga heterophylla series of the northern Rocky Mountains. This zone is similar to the forests within the Grand fir-Douglas-fir type as described by Küchler (1964).

Typically, the Abies grandis Zone is bounded by the Abies lasiocarpa Zone at its upper limits and by the Pseudotsuga menziesii or Pinus ponderosa Zones at its lower limits (Franklin and Dyrness, 1969), or it may even be adjacent to Artemisia steppe without a coniferous forest (Hall, 1967).

Seral Vegetation of Abies grandis Zone

Pinus ponderosa, Pseudotsuga menziesii, Larix occidentalis and Abies grandis are the principal tree species of the Abies grandis

Zone. Any one of these four species may dominate seral stands. In fact, these species may attain maximum growth in the grand fir zone. Daubenmire (1961) reported Pinus ponderosa has better growth on grand fir habitat-type sites than on sites where it may be climax.

The principal understory shrubs following logging are: Amelanchier alnifolia, Berberis repens, Holodiscus discolor, Pachistima myrsinites, Rosa spp., Spiraea betulifolia, Symphoricarpos albus, and Vaccinium membranaceum. Areas that are logged and burned are dominated by Ceanothus sanguineus with various amounts of the species previously mentioned (Pengelly, 1963).

The processes of revegetation on northern slopes by shrub and herbaceous species tends to be slower than on southern exposures. This difference may be because many species typically found on northern aspects are shade tolerant; or, if the area were burned, it may be attributable to the great variation in the intensity of burning always associated with moistness of sites (Pengelly, 1966).

The cycle following a burn is: (1) bull thistle (Circium vulgare) (Figure 3), (2) grasses and forbs (Pettit, 1968a), (3) shrubs, and (4) mixture of conifers proceeding toward climax vegetation dominated by Abies grandis.

Several annual weeds such as Collinsia parviflora, Epilobium paniculatum and Rumex acetosella are associated with the bull thistle stage. In some areas Verbascum thapsis may form rather dense

Figure 3. Bull thistle (Circium vulgare) Stage of Succession Typically Found on Mixed-Coniferous Sites in the Wallowa Mountains and Adjacent Foothills Following a Disturbance, e. g., a Burn.

stands; usually this species is only a minor but significant component of the bull thistle stage. There are also minor amounts of Ceanothus sanguineus, Physocarpus malvaeus, Spiraea betulifolia var. lucida, Canada milkvetch, Frageria spp. and Carex rossii.

The typical shrubby species are Physocarpus malvaceus, Ceanothus sanguineus, C. velutinus var. velutinus, Salix spp. and Holodiscus discolor (Pettit, 1968a). This stage is similar to the one described by Daubenmire and Daubenmire (1968) for eastern Washington and northern Idaho.

Mueggler (1965) reported shrub cover to be the greater on areas broadcast-burned than on areas logged, but not burned. By evaluating succession with respect to type of disturbance and age of stand since disturbance, he found tree canopy and shrub cover to be negatively correlated, and both were positively correlated with time since disturbance. The amount of shrubby vegetation was also related to the amount of soil potassium present. The soil of areas broadcast-burned contains more potassium than soils not burned.

The north and eastern slopes return to conifers more rapidly than the other exposures because they are more moist due to position and depth of soil. Therefore, these are the most productive sites.

Ecology of Hall Ranch

The present mixed-coniferous forest stands located on the Hall Ranch are dominated by Pinus ponderosa and Pseudotsuga menziesii with Abies grandis and Larix occidentalis. However, these sites potentially may support a topoedaphic climax vegetation dominated by Abies grandis (Young, 1965). The mixed-coniferous sites on the Hall Ranch are slightly more xeric than the typical mixed-coniferous community (Young, Hedrick, and Keniston, 1967). However, because of (1) their physiographic position on north-facing slopes, and (2) their location on volcanic ash soils of high moisture holding capacity, they are considered to be Abies grandis climax sites.

Physocarpus malvaceus and Holodiscus discolor are the most common tall shrubs. And, the low shrubs most commonly found in these stands are Symphoricarpos albus, Rosa gymnocarpa, and Vaccinium membranaceum. The ground layer is dominated by Calamagrostis rubescens, Carex geyeri, Elymus glaucus, Thalictrum fendleri, Lathyrus nevadensis spp. cusickii, and Lupinus polyphyllus (Young, Hedrick, and Keniston, 1967). Other species such as Spiraea betulifolia var. lucida, Linnaea boreales longiflora, and Hieracium albiflorum are also found in stands of mixed-coniferous forest (Strickler, 1965).

Because of the dearth of information on the species composition of undisturbed stands of mixed-coniferous forest in the Wallowa or Blue Mountains, direct comparisons cannot be made between the work done in Oregon and that done by R. Daubenmire in the northern Rockies. However, the major difference that seems to exist between these areas is the lack of Pachistima myrsinites in the stands occurring in Oregon.

The species list given above seems to represent at least two associations. Again, there is not enough information available to correlate this list with the work of R. Daubenmire.

Management Implications

Most of the stands of mixed-coniferous forests are too dense or lack suitable forage to carry on a successful grazing program. Approximately only 20 percent of the total herbage production reported in Table 2 is usable forage or browse because either the herbaceous layer is sparse or the shrubs are out of reach of the animals.

Selective cutting over the years has removed the best timber, leaving the most defective trees. This has left these sites in rather poor condition as a result of poor stocking and diseases, such as heart rot and mistletoe. Consequently, they are usually considered to have a low economic potential. However, these sites will outproduce the Pinus ponderosa and Pseudotsuga menziesii/Pinus ponderosa sites on a total volume basis and a per-acre volume basis (Keniston, 1957), but the present timber production is only about one-half of the potential.

Table 2. Total herbage production of a mixed-coniferous forest stand on the Hall Ranch of Eastern Oregon Experiment Station (unpublished research data, Project 429, Range Management, Oregon State University)

Overstory Canopy	Grasses	Forbs	Shrub	Total
		lb/Acre		
Open	196	136	164	496
Intermediate	76	90	142	308
Dense	6	76	24	106

Even though the mixed-coniferous forest sites should be managed for timber production, Young, Hedrick, and Keniston (1967) have reported manipulating the overstory cover through good timber management will substantially increase forage and browse production for both wild and domestic animals. But, because released shrub species are capable of growing very fast, the value of some treated areas for forage production is limited to a relatively short time. For example, Salix sp. can put on four to five feet of new growth after one season; Physocarpus malvaceus and Ceanothus spp. can average two to three feet per season (Leege, 1968).

Also, in some areas greater amounts of forage, particularly browse, are lost through successional trends than through overuse

(Pengelly, 1966).

Natural forest regeneration coupled with the practice of establishing tree plantations will greatly shorten the forage production period for both cattle and big game. However, if timber managers maintain proper timber stand densities, shrub stands can be expected to last for 30 years or longer (Pengelly, 1966). The above statement applies to areas dominated by Abies grandis/Pachistima myrsinites and Pseudotsuga menziesii/Physocarpus malvaceus associations as described by Daubenmire (1952).

The research of Hedrick et al. (1968) has demonstrated: (1) disturbed sites should be seeded, (2) slash should be disposed, and (3) logging debris that would block access to an area should be removed (also see Pengelly, 1966) or lie on the ground in an up and down slope direction in order to facilitate animal movement and distribution.

The above research also indicates that drastic improvement measures such as clear-cutting and burning may be required to correct the low timber values of deteriorated and diseased sites typical of most mixed-coniferous stands in northeastern Oregon. Seeding these sites to perennial grass species compatable with forest regeneration produces an additional resource.

Not all of such post-burn vegetation is palatable forage. Neither is all of the desirable forage utilized or available because of season of use, animal preferences, and plant height. In order to achieve the best results through manipulation of existing vegetation by clearing and fire, logging plans and grazing management should be carefully coordinated with each other as well as with other land uses (Hedrick _et al._, 1968).

Past and concurrent research on the Hall Ranch points out that cattle production, wildlife habitat improvement and tree production are all compatible on mixed-coniferous sites if each resource is properly managed (Hedrick _et al._, 1968).

This type of multiple-use management would enable the landowner to obtain additional income from forage resources, while the forest is still young. Thus, he could realize optimum returns from these productive sites.

Effects of Burning

The effects of burning on the organic materials on and in the soil have been extensively studied because of the importance of organic matter with regard to water infiltration, soil aggregation, moisture holding capacity, and nutrient cycling. Litter on the forest floor helps maintain and protect the surface soil porosity and develop crumb structure, which promotes optimum aeration. These materials on the surface also act as filters which prevent clogging of soil interstices by turbid water.

Microbial activity is increased with increased organic matter in the soil. The primary source of several plant nutrients, i.e., phosphorus, potassium, and calcium (Dyrness, 1963) is the mineralization process which accompanies decomposition of organic materials by microorganisms.

Severe slash burning will remove up to 75 percent of the organic matter to a depth of one-half inch (Austin and Baisinger, 1955). Sixty-five percent can be removed to a depth of three inches (Youngberg, 1953).

Most of the changes that occur to the properties of the soil are due to the disposal of organic materials, and not to the effects of temperature. Only in prolonged, severe burns do the effects of temperature become pronounced. The highest temperatures (> 608° F.) are usually recorded about one inch above the forest floor (Ahlgren and Ahlgren, 1960). Research in the longleaf pine region by the above authors showed the upper one-fourth inch of soil reached temperatures of 150-175° F. for only two-four minutes. There were only slight or insignificant temperature changes at one inch deep, and no changes below two inches deep. Most fires are not hot enough to produce a direct effect on soil structure, except where fuel concentrations are heavy enough to produce fires which remove the litter layer. This exposes the mineral soil to the effects of rain drop splash, puddling and baking of the surface. Then erosion can greatly decrease the total amount of nutrients available for plant growth. However, this may be compensated for by increased plant growth and growth of specific kinds of soil microorganisms, which replenish the soil, both physically and chemically; thereby reducing the effect of erosion and run-off.

Severe burning will seriously lower the rate of water movement into the soil. Light burning does not significantly change water movement in the upper three inches of soil, although the bulk density is decreased somewhat (Tarrant, 1956b).

The amount of nitrogen in the soil is associated with the organic matter content. Austin and Baisinger (1955) reported 67 percent decrease of nitrogen following slash burning. Over one-half of the total nitrogen in heather vegetation is volatilized when it is burned (Allen, 1964).

Temperatures of 300 and 700 °C. as maintained under controlled conditions in the laboratory volatilized 149 and 367 pounds per acre of nitrogen (Knight, 1964). Isacc and Hopkins (1937) reported losses of approximately 435 pounds of nitrogen per acre from heavy slash fires. On the other hand, Burns (1952) reported 50 percent increase of available nitrogen due to controlled burning in pine barrens. He found where the soil surface was only lightly burned, the amount of readily available nitrogen to plants is increased, while the total supply of nitrogen may be little affected. However, in areas which are severely burned, the total nitrogen supply is greatly reduced due to the destruction of organic matter.

Other nutrients such as phosphorus, potassium, and calcium are consistently increased by burning. Smith (1968), working in northern Ontario, reported maximum increases of 398, 351, 525 percent for potassium, calcium, and phosphorus, respectively. He also reported the total soluble salts at the soil surface were increased 324 percent. Austin and Baisinger (1955) reported that phosphorus, potassium, calcium, and magnesium were increased 200, 166, 830, and 337 percent, respectively, by burning logging slash. After two years, phosphorus and magnesium were normal, but potassium was still 112 percent and calcium 327 percent higher than on the unburned plots. This large increase creates an imbalanced ratio of cations which may be as detrimental as deficiencies (Tyron, 1948). Conifers are adapted to soils whose productivity is dependent upon gradual mineralization of the fallen litter. Therefore, establishment of conifer seedlings may be decreased.

Often the soil surface will become covered with a dense carpet of mosses and liverworts immediately after a fire. These species are capable of growing in soils having high concentrations of nutrients (Graff, 1935). If this mat is not broken or prohibited from forming, regeneration of tree species can be markedly slowed down. Fast growing perennial grasses compatible with tree regeneration will prevent this mat from becoming too extensive. Hence, the grasses can be used to take advantage of this increased fertility, as well as control erosion and encourage tree growth.

Domestic livestock could be used also to prepare seedbeds for tree establishment. Their trampling activities adequately bare micro-sites conducive to natural seeding (Hedrick, 1963).

The lighter and more completely burned materials contain the highest concentration of nutrients. This light material is very susceptible to wind erosion--35 percent of the ash was removed by wind during the first month following the controlled burning (Smith, 1968). This is critical for light textured soils, because the bulk of available nutrients after burning is contained in the remaining organic and ash materials.

Light to moderate burning increases the pH of the soil. The pH slowly returns to the initial value, but this takes three-four years (Dyrness, 1963). The increase in pH favors fungi which cause damping off disease in coniferous seedlings. This can be a major problem until the pH adjusts back to the normal situation.

Johnson (1919) heated several soils and found practically all soils which were heated to 100-115° C. produce temporary retardation to seed germination. He reported that species of Graminae were resistant to this toxicity and Leguminosae and Solanaceae are susceptible to it. It was postulated this toxicity is associated with NH_4^+ in the soil solution. However, this toxicity evidently is not long lasting, because Greene (1935) reported a large increase of legumes after fire, and these plants made large contributions to the nitrogen economy of the subsequent seral communities.

The physical soil properties are not significantly altered by burning, except in severely burned areas (Dyrness, Youngberg, and Ruth, 1957). This is especially true for light-medium textured soils. Burning slash as soon as it dries, but while the ground is still moist is the best time to burn. This will minimize any effect on the physical properties of the soil and minimize the loss of organic materials. It must be remembered the layer of organic materials on the soil surface are the heart of the forest soil (Youngberg, 1953); the maintenance and preservation of this layer is one of the most important objectives of sound forest management.

Light burning has little effect on tree growth (Tarrant and Wright, 1955) and water storage (Tarrant, 1956b). It has little effect on erosion potential, if the ground is not left exposed. For this reason it is best to seed an area after the burn as soon as possible, consistent with the management objectives for each particular area.

Disposing of the slash on clear-cut logged areas by burning can be classified as light burning. Tarrant (1954) found that only four percent of a clear-cut area would be affected by severe burning. Nearly half of the total area would be lightly burned and unburned.

The effects of severe burning are then confined to a small proportion of a given area that is clear-cut and burned.

Many of the shrubby species associated with the mixed-coniferous forest sprout prolifically from the root crown following burning. This is particularly true if burning is completed early in the growing season so that there is ample opportunity for the plants to grow before winter dormancy (Leege, 1968). This helps to minimize erosion on disturbed areas such as fire lines and skid trails.

Game populations tend to increase following forest fires. This increase has been attributed to better quality forage produced by browse species. New growth of shrub species contains more water, minerals, and crude protein than plants from unburned areas (Reynolds and Sampson, 1943). Lay (1957) reported burning in any season increased the amount of protein and phosphorus in browse. This effect of burning may last at least two years (DeWitt and Derby, 1955).

There usually is an increase in the total food supply on burned areas (Storer, 1932), because greater amounts of herbaceous vegetation are present in addition to the increased amounts of available browse. The increased quality of a burned range is also attributable to differences in species composition. Fire is used to help maintain stands of several native legumes in southeastern United States (Stoddard, 1961; Greene, 1935). However, very little has been reported with regard to changes in species composition of the herbaceous stratum as a result of prescribed burning in the mixed-coniferous forest.

Nitrogen Fixation and Nodulation

It is difficult to make any accurate statement concerning the amount of nitrogen fixed by native legumes. The total amount of nodulated material per plant and the annual variations in the rate of nitrogen fixation have not been well established. Virtually no research of this kind has been reported for native legume species.

Zavitkovski and Newton (1968) reported the upper soil under *Ceanothus velutinus* which was nodulated did not differ in nitrogen content from that under plants of the same species which were not nodulated. They concluded *Ceanothus velutinus* did not add to the soil any significant amount of nitrogen by fixation. However, the growth of coniferous seedlings in greenhouse studies was positively affected by levels of litter found on the ground. This may be the reason why several workers have reported increased growth of species associated with plants capable of fixing elemental nitrogen (Quick, 1944; Allen and Allen, 1965).

Nodulation is usually retarded by nitrogen fertilization or high concentrations of combined nitrogen in the soil (Ludwig and Allison, 1935; Steward and Bond, 1961).

Most of the research on legume nutrition has been done on those species having an atypical demand for fertile soils of high calcium saturation. As a result, very little is known about the nutritional requirements for plant growth and nodulation of native legumes.

Ample phosphorus, potassium, calcium and magnesium are required more for the well being of the host plant (Burton, 1965), whereas, the trace elements molybdenum, iron, copper, and cobalt are required by the microorganisms.

Boron is used primarily by the host plant, but without nitrates in the growth medium, nodulation will be greatly increased by boron if the medium is approximately pH 6 (Hewitt, 1958). Nodulation is most efficient when the concentration of boron in the growth medium is 2.0 ppm. Hewitt (1958) also discovered large, multiple nodules would form on *Trifolium subterraneum* when copper was supplied at the rate of 0.64 ppm. He did not find any particular requirement for iron or cobalt.

Greenwood (1958) reported that *Trifolium subterraneum* was the most productive when phosphorus, copper, and calcium were supplied at the rates of 8.0, 0.064, and 64.0 ppm, respectively.

Ahmed and Evans (1960) demonstrated cobalt is required for nodulation by *Glycine max*. Allen and Allen (1965) reported 0.01 ppm of cobalt was generally required by several non-leguminous plants to become nodulated.

Vincent (1958) stated fertilizers and even trace elements will decrease the viability of Rhizobium spp. to the extent that nodulation will not take place. He did not, however, state the specific levels of each nutrient or combination of nutrients that would cause this.

Nodulation in Astragalus spp. does not seem to be restricted to a specific inoculation group. Twenty-one isolates from several milkvetch species formed nodules in a total of 22 host plants, representing 18 leguminous genera. Some species of Astragalus have been successfully nodulated by at least 24 strains of Rhizobium (Jensen, 1958). This may be the reason why some Astragalus spp., e.g. A. cicer, can be so heavily nodulated.

Colonizing Species

The most successful colonizers of the plant kingdom appear to be species which have genetic systems with high flexibility. These genetic systems appear to be appropriate compromises between the high recombinational potential of out breeders and the stability of inbreeders (Allard, 1965). This is especially true for legumes. These plants are capable of adjustment to diverse and complex habitats. Hence, many species are opportunistic.

The establishment of a population of a species in an ecological space not previously occupied is achieved by effective dispersal, high somatic plasticity, and high interspecific competitive ability.

Colonizers can also be expected to have very little genetic variance in development time, but have relatively large amounts of variance for fecundity (Lewontin, 1965).

The ancestral niche of legumes is essentially tropical (Russell, 1961); hence, their ecological niche was probably on fairly strongly leached soils. The plants found in a mature tropical forest are rarely nodulated, but commonly nodulated when growing on disturbed sites or on the fringes of the forest.

In the north-latitude ecosystems, leguminous flora tend to play an important pioneer or seral role (Allen, Allen, and Klebesadel, 1963).

Germination of Canada Milkvetch

No specific publications were found in the literature relating to germination of *Astragalus* spp.

Schwendiman (1968) indicated Canada milkvetch is a hard seeded species. Robinson (1960) noted germination was low at constant temperatures in ladino white clover which is also a hard seeded species. Alternating temperatures produced the best germination in his studies.

Dormancy of hard seed species, e.g., *Ceanothus* spp. can be broken by scarification and hot water treatment (Grisez and Hardin, 1967).

Fires apparently do not release chemicals that enhance germination, but heat in a saturated environment will increase germination of some species (see Cushwa, 1967).

Mechanical scarification of Canada milkvetch seeds followed by freezing for 24 hours at -5 °F. resulted in 71.5 percent germination, while freezing alone produced 5.7 percent germination. Freezing alone had the same percentage germination as the control. Brooks (1967) also discovered dry heat ranging from 77 to 212 °F. with exposure times of 30, 45, and 60 minutes did not markedly increase germination of Canada milkvetch. These results confirm that Canada milkvetch is relatively hard seeded.

METHODS OF STUDY

Data from the experimental area were taken primarily from permanent 100 foot transects located in Exclosures 1 and 2 as illustrated in Figures 4 and 5.

Several observations and data were obtained from random plots and microsites within the above exclosures. These data usually do not include data from the plots seeded to pure stands of *Bromus marginatus* and *Elymus glaucus* because these plots are rather atypical of the sites characteristic for Canada milkvetch. These plots are on the upper slope and have shallower soils.

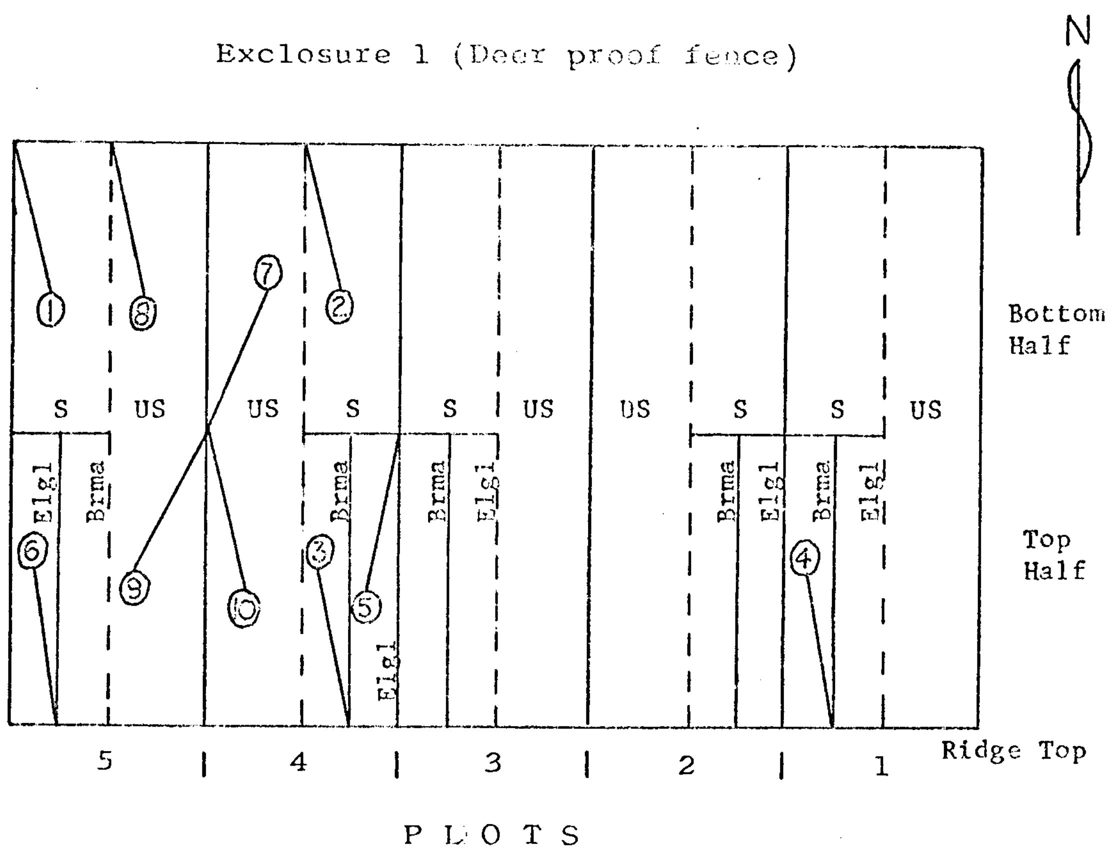
Environmental Measurements

Air Temperature

Air temperatures were measured at four stations--two were located in Exclosure 1 of the experimental area and the other two were located in the adjacent stand of mixed-coniferous forest. At each station maximum-minimum dial thermometers were placed one foot and three feet above the ground surface. These instruments were read at approximately 9:00 a.m. weekly during the summers of 1967 (Pettit, 1968a), 1968, and 1969.

Analyses of these data were made on the temperature differential per Pettit (1968a). This statistic was calculated by subtracting

Exclosure 1 (Deer proof fence)



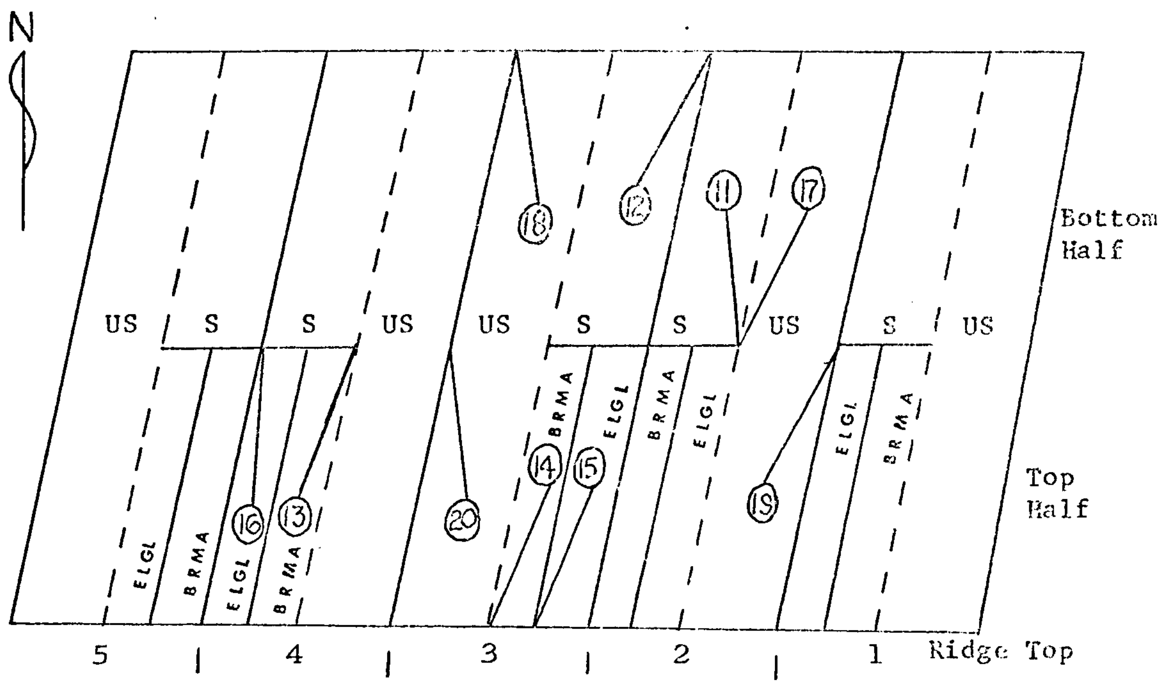
1" = 120'

Transects Sampled in 1968 and 1970

Plot	Treatment	Transect No.
5	Bottom seeded	1
4	Bottom seeded	2
4	Brma	3
1	Brma	4
4	Elgl	5
5	Elgl	6
4	Bottom unseeded	7
5	Bottom unseeded	8
5	Top unseeded	9
4	Top unseeded	10

Figure 4 . Location of Transects Sampled in Exclosure 1.

Exclosure 2 (Cattle Ex)



P L O T S

1" = 120'

Transects Sampled in 1968 and 1970

Plot	Treatment	Transect No.
2	Bottom Seeded	11
3	Bottom Seeded	12
4	Brma	13
3	Brma	14
3	Elgl	15
4	Elgl	16
2	Bottom Unseeded	17
3	Bottom Unseeded	18
2	Top Unseeded	19
3	Top Unseeded	20

Figure 5. Location of Transects Sampled in Exclosure 2.

the temperature recorded at one foot high from that recorded at three feet above the ground. This was done for both the maximum and minimum temperatures. The differential data were treated by an analysis of variance to determine which temperature regime seemed to differentiate the environment of the clear-cut from that of the mature forest.

The number of degrees the temperature environment of the clear-cut deviated from that of the mature forest were also treated statistically by an analysis of variance. The deviations were calculated for both the maximum and minimum temperatures as recorded at three feet and one foot above the ground surface.

Soil Moisture

The correlation of the milliamp readings obtained using gypsum blocks and soil moisture content was determined from 31-1,000 gram soil samples of known moisture content. This moisture content of each sample was determined gravimetrically from duplicate 100 gram subsamples.

Sixteen soil samples were saturated with water to determine what would be the maximum reading that could be obtained that would be consistent with readings at the low end of the scale. That is, the reading of oven-dry soil (considered to be zero percent moisture) was chosen to be the zero point on the milliamp scale.

During 1968, soil moisture data were also obtained using Coleman fiberglas soil-moisture units. This was done to test their accuracy because these devices are more resistant to decay and deterioration than gypsum blocks. The gypsum blocks are also subject to damage by rodents.

Soil moisture data were obtained gravimetrically in 1966 (Pettit, 1968a). In 1967 (Pettit, 1968a), 1968, and 1969, these data were obtained using gypsum resistance blocks. Several stations were located in the clear-cut and adjacent forested areas to represent sites dominated by introduced grasses, native grasses, browse species, and mixed-coniferous forest. Each of these stations also represented sites where Canada milkvetch typically grows, except for the forested stations. In the latter case, Canada milkvetch was only occasionally present.

The gypsum blocks were placed at 6, 12, 24, 36, and 48 inches deep, wherever the soil was not too rocky or too shallow.

Soil pH

The pH of the soil was determined using a Beckman Zeromatic pH meter. A 1:1 soil-water paste was used to make these determinations. The soil samples were collected from 0 to 7 and from 8 to 16 inches deep. Duplicate samples were collected in 1968 and compared to samples collected in early summer of 1965.

In 1965 the samples were collected from mixed seeded plots of Exclosure 1 and those from the forested site were collected beneath an understory of Physocarpus malveceus. Six samples were collected from both areas for this analysis.

The soil samples collected in 1968 from Exclosure 1 represented microsites of plots dominated by Elymus glaucus, Bromus marginatus, Physocarpus malveceus, Ceanothus sanguineus, Rumex acetosella, Canada milkvetch, and Circium vulgare.

Soil Temperature

Soil temperatures were recorded in 1966 and 1967 (Pettit, 1968a) at two inches depth with soil thermometers. The thermometers were randomly placed in the mature mixed-coniferous forest and mixed seeded area of Exclosure 1. In addition, thermometers were placed in microsites dominated by Canada milkvetch and Ceanothus sanguineus. Temperatures were also recorded at a station located on a skid trail, representing bare ground conditions. Duplicate observations were made at each of the above locations.

An analysis of variance of the deviations in soil temperature of the sites in the clear-cut area, except the bare ground site, from the temperatures of the forest was calculated for these data. This was done to discover if this kind of analysis could be used to explain any differences in soil temperature that might exist between the forested and clear-cut area, even though data had been recorded only two years.

Soil temperatures were also recorded by placing soil thermometers at 6, 12, and 18 inches deep. The data were obtained weekly during the summers of 1968 and 1969. These stations were chosen randomly and were maintained under wire cages on plots of Exclosure 1 seeded to introduced grass species.

Taxonomy and Phenology

Taxonomy

The taxonomy and pertinent information on the habitat and range of Canada milkvetch were summarized from the major taxonomic works for the Pacific Northwest. The original descriptions of the type species and the variety under investigation were compared with mounted and living specimens.

Plant Development and Growth

Phenological observations were made weekly on the experimental area and adjacent stands of mixed-coniferous forest. Notes were taken on dates of vegetative growth, flowering, pollination, pod formation, seed ripening, and nodulation throughout the summers of 1968 and 1969.

Roots and Nodulation

The characteristics of the root system of Canada milkvetch were determined in soil pits from which the roots systems were carefully removed.

The amounts of roots and nodules produced under greenhouse conditions were determined by growing ten plants for 12 weeks in Tolo silt loam soil. The environment of the greenhouse was a 16 hour, 80° F. day and 8 hour, 50° F. night with natural light during the day. The plants were randomly repositioned on the bench every week to minimize any differences in exposure to light that may have occurred. The roots systems were harvested by carefully washing the soil away. The amounts of roots and nodules produced were determined separately and were reported as the number of nodules per length of new root growth.

In the field the period of nodulation was determined by digging up at least ten plants each week throughout the summer. This was done during the summers of 1968 and 1969.

Soil temperature was recorded weekly at three depths, viz., 6, 12, and 18 inches, to discover if nodulation could be related to a specific temperature regime. These data were obtained using soil thermometers in the same manner and locations as described above.

The effect of nitrogen on nodulation was studied by growing plants in perlite and Tolo silt loam, with and without nitrogen added as NH_4NO_3. The amount of nitrogen added was equivalent to 20 pounds per acre. These four treatments had ten plants per treatment. The plants were placed randomly on the greenhouse benches.

After the plants had adjusted to transplanting, they were grown for 12 weeks with a 16 hour, 80° F. day and 8 hour, 50° F. night. The light regime was continuous, artificial light. The pots were inoculated with an inoculum made from fresh, pink nodules. This inoculum was applied weekly for four weeks.

At the beginning of the 12 week period, the plants were clipped to begin the study with uniform plant height and to control powdery mildew.

Flowers and Seed Production

Weekly observations were made during the summers of 1968 and 1969 with respect to the details of flowering, pod formation, and seed ripening when applicable.

The reproductive potential of Canada milkvetch was determined by counting the total number of blossoms per inflorescence on 50 plants in each of three areas. These areas are from Exclosures 1 and 2 representing grazing by cattle only, cattle plus game, respectively, and complete protection.

The statistical significance of these data was evaluated by an analysis of variance.

Insects, Disease, and Rodents

Observations were also recorded with regard to rodent damage, insects and diseases. The important insects were identified only to genus.

The effect of insects on the fecundity of this species was determined from the number of seed produced per pod. These counts were made on 100 normal and 100 abnormal pods, selected at random. The abnormal pods were ones that showed some degree of insect damage.

The significance of the difference between the two means was determined with an F test.

Seed Germination and Seedling Development

Seeds were collected in 1968 and 1969 from several locations in the foothills of the Wallowa Mountains. Because Canada milkvetch is preferentially grazed by domestic and wild animals, seeds are hard to find and had to be collected from protected or ungrazed sites.

The seeds were stored in a dry, cool environment until used. Because this species has a rather leathern pod and because it only partially opens at maturity, it was necessary to thrash the seed. A legume thrasher equipped with heavy rubber rubbing bars was used. The seed pods were put through the thrasher three times before the pods were broken down enough to give up the seeds. Then the seed and debris were separated by passing the materials through the thrasher three more times. The seeds were cleaned using a forced air blower which separated the seeds and debris on the basis of weight.

Seeds collected in August, 1967 by R. D. Pettit were planted one-half inch deep in five flats containing perlite medium. Each flat contained 300 select seeds, chosen using three characteristics, i.e., kidney shape, large size, and green color. These flats were placed in a greenhouse with a 16 hour, 80° F. day and 8 hour, 50° F. night. These seeds were kept moist by watering daily with distilled water. This trial began 20 December 1968, and had to be terminated 19 January 1969 because a thick crust of bluegreen and green algae formed on top of the perlite, which prohibited seedling development.

Two other lots consisting of 400 of select seeds each were treated with 1N H_2SO_4 for ten minutes and germinated in perlite under greenhouse conditions. The environment of the greenhouse was 65-72° F. during the day and 48° F. during the night with continuous light. This trial lasted four months, until a crust of green algae prevented further germination.

Samples of seed collected in August, 1969 were sent to the Seed Laboratory of Oregon State University to be examined with X-ray to determine the amount of seed having normal development. Two lots of 400 seeds each were examined; one lot was selected seeds and the other one was seeds representing a normal collection from the field. A subsample from the first lot was also subjected to a tetrazolium viability test developed by this laboratory for Ceanothus spp.

The effect of moist heat was investigated by treating seed with a hot water soak for 12 hours, and by subjecting seed to 100, 200, 400, 600, and 800 °F. in a small muffle furnace. The exposure period for the range of 100-400 °F. was ten minutes and five minutes for 600 and 800 °F. Ten minutes at the higher temperatures charred the seed.

Small containers of saturated soil were heated in the furnace until the temperature of the internal thermocouple remained at the desired temperature. Then seeds enclosed in small envelopes made of filter paper were quickly placed on the soil for the specified time interval.

Quadruple samples each containing 100 treated seeds were then subjected to germination. The seeds were placed in sterile, disposable petri dishes and germinated on paper blotters.

Two temperature regimes were used in the germination trials, i.e., 86 °F. for 16 hours and 68 °F. for 8 hours, and 68 °F. for 16 hours and 38 °F. for 8 hours. The light regime was continuous for both groups. Included in each group were untreated seeds as a control. The germination period was 30 days. Observations were made daily when the seeds were watered.

The details with respect to seedling development were gathered from observations made in the greenhouse and in the field.

Nutrient Effects

The levels of calcium, copper, and cobalt used in this study were as follows:

Level	ppm	Level	lbs. /acre
Cu 1	0.064	Ca 1	120
2	0.640	2	600
		3	1200
Co 1	0.010		
2	0.100		

The treatments consisted of each nutrient alone and all possible combinations, making a total of 36 treatments with four observations per treatment, except for the control which had 16. The nutrients for each treatment were thoroughly mixed in Tolo silt loam soil from the experimental site. The control for this investigation was soil without any nutrients added.

Similar sized plants (ca. four inches tall) were collected from the field during August, 1969 and transplanted into plastic pots containing 1,000 grams of soil (oven-dry weight equivalent). On the first of September, these plants were placed in the greenhouse at Corvallis. The environment of the greenhouse because of other research on forage crops was 72° F., 16 hour day and 38° F., 8 hour night. The light regime was natural until mid-September; then it was continuous.

The plants were inoculated with a commercially prepared Astragalus inoculum.

The plants were clipped in mid-September to begin with a uniform height. Powdery mildew became a problem early in October; spray treatments controlled this pathogen until the shoots were harvested in January, 1970. However, spray treatments during the period from February through May did not successfully control this disease.

Insects and mites were controlled by the routine fumigations conducted by the greenhouse personnel of Oregon State University.

The shoots were clipped 28 January 1970 and composite samples of each treatment were analyzed for crude protein, calcium, phosphorus and yield. These chemical analyses were done by the Animal Nutrition Laboratory of Oregon State University.

The plants were allowed to regrow for another 4.5 months. On 13 June, the roots and shoots as well were harvested. Samples of both the roots and shoots were analyzed for calcium and phosphorus.

Nitrogen Fixation

Nitrogen fixation of intact root nodules of Canada milkvetch was investigated using the methods described by Koch and Evans (1966) and Hardy et al. (1968).

Because the plants were grown in soil, they had to be soaked in water for one-three hours to effectively remove the soil without damaging the nodules. The washed roots were placed in 124 ml flasks, obtaining the greatest proportion of nodules as possible.

The method used capitalizes on the fact that the enzyme nitrogenase will reduce acetylene to ethylene. The production of ethylene from acetylene was measured by use of a Beckman GC-2A gas chromatograph equipped with a hydrogen flame detector, recorder and integrator. The attenuation of the instrument was set at 160.

The samples were analyzed for reduction of acetylene to ethylene immediately after harvest and after a 30 minute incubation period (also 30 minutes after harvest) in an atmosphere of acetylene. Thereafter, the interval after harvest was lengthened 15 minutes before the 30 minute incubation period was begun.

An incubation period of one hour which was begun shortly after harvesting the root nodules, was also investigated to compare the amounts of ethylene produced to that produced after 30 minutes of incubation.

Plants used for this experiment were taken from the control plants of the nutrition experiment discussed above.

Succession Studies

Residual Seed

Soil samples were taken from five locations to determine the number and kind of seed residual in the soil. These samples represent sites having an open forest canopy, moderate canopy (a selective-cut), and no canopy (clear-cut experimental area). The locations (Table 1 and Figure 2) from which the soils were collected represented:

(1) Site A

(2) Site F

(3) Nursery area adjacent to Exclosure 1.

(4) Seeded plots of Exclosure 1.

(5) Unseeded plots of Exclosure 1.

The soil samples were collected early in the summer of 1968 to minimize the amount of perennial seeds obtained from that growing season. It is thought that most of the seeds from annual, spring species found in these samples were produced that year because they were still shiny and did not appear to be weathered.

Three samples (1' x 1' x 1 1/2") were taken at each location.

These samples are designated (a) the duff layer, (b) interface between duff and mineral soil, and (c) mineral soil. Each sample was separated into four arbitrary size fractions using Tyler screens:

No. 1 - Greater than 1.981 mm.

No. 2 - Greater than 1.0 mm and less than 1.981 mm.

No. 3 - Greater than 0.5 mm and less than 1.0 mm.

No. 4 - Less than 0.5 mm.

For convenience, this study was divided into two investigations. The first investigation was used to discover what kind of seed, i.e., grasses, forbs, or shrubs, might be expected to germinate from soils of the mixed coniferous forest.

Approximately 500 ml of sample "a" from Site A and 100 gram subsamples of each of the four size fractions of sample "a" representing the unseeded plots of Exclosure 1 were spread evenly over the surface of a flat containing perlite medium. This layer of soil was approximately one-fourth inch deep.

The flats were placed in a greenhouse having 80° F. - 16 hour days and 50° F. - 8 hour nights. The germination period for this investigation was 118 days in the case of Site A and 136 days for the unseeded area. Observations were made daily at the time the flats were watered.

Subsamples each weighing 100 grams, from size fraction No. 4 of all three samples were also included in this investigation. These flats were kept in the greenhouse 118 days.

It was intended to carry on these investigations for six months. However, they had to be terminated much earlier than this because of the abundance of algae, mosses, and liverworts, which "carpeted" the surface of the flats.

Positive identification of each plant that grew was made from the seed, seedling, or mature plant, whichever was applicable.

In the second investigation the number and kind of seed were determined in each sample by examining four gram subsamples under a binocular scope. The organic matter and seeds were sorted with teasing needles until every particle was critically examined and the seeds counted. All the seeds were identified by comparison to a seed collection made throughout the summer of 1969 and/or by germination.

The above subsamples were then placed in a growth chamber for 30 days. Only the total number of grasses and forbs were tallied, because the time period was too short to make positive identification of each species. In addition, samples from Site B representing an undisturbed, moderately dense canopy were included in the germination phase of this investigation.

The environment of the growth chamber was 80° F., 16 hour day and 55° F., 8 hour night.

Community Analyses

The data for community analyses were obtained from five pairs of permanent, 1' x 100' belt transects located in Exclosures 1 and 2 of the experimental area (Figures 4 and 5).

Cover data were obtained by using cover class estimates in a manner similar to the procedures described by Daubenmire (1959). These data were estimated on 20, 5-square foot plots along each transect.

The cover classes used were:

Cover class	Percentage cover
1	0.0 - 5.0
2	6.0 - 12.0
3	13.0 - 25.0
4	26.0 - 50.0
5	51.0 - 75.0
6	76.0 - 95.0
7	96.0 - 100.0

Average percentage cover, relative dominance, frequency and relative frequency were calculated by species for each pair of transects.

The maturity index of Pichi-Sermalli (1948) was calculated from the frequency data. This statistic is based on the notion that the higher the frequency percentage of each species and the smaller the number of sporadic species, the more mature the plant community will be. It was designed to be of use in investigations of the development of vegetation.

Cover and frequency data with regard to Canada milkvetch were also taken from the above transects using 1' x 1' plots; therefore, 100 contiguous plots were examined per transect. This was done to compare the data collected in 1965 and 1966 by Pettit (1968a) to that collected in 1968 and 1970. In addition, density data were obtained in 1968, 1969, and 1970.

Density data were also obtained from Sites A - F as a means of comparing the effect of the overstory canopy on numbers of Canada milkvetch plants per unit area. These data were gathered in the same manner as described in the above paragraph.

Forage Value and Effect of Grazing

Nutrient Analyses

Chemical analyses of Canada milkvetch with regard to crude protein, calcium, and phosphorus were conducted by the Animal Nutrition Laboratory at Oregon State University.

Plant Vigor

The influence of grazing on plant height was determined by measuring the height of the plant to the top of the inflorescence. These data were obtained from the nursery area and Exclosures 1 and 2 for 1968, 1969, and 1970. Measurements were made on 100 plants at each location. Plants were selected using the random pairs method as discussed by Lemon (1962).

The number of plants less than two inches tall was determined from plant counts per 100 square feet. The data were obtained from four 100 foot random transects in Exclosures 1 and 2, and two 100 foot random transects in the nursery area adjacent to Exclosure 1.

Plant vigor was also determined by the average dry weight yield per plant. These data were gathered by clipping and weighing the plants from each plot and calculating the average yield of dry matter per plant. Data were collected in 1968 and 1969 in Exclosure 1 and in the nursery adjacent to it. Thirty, 9.6 square foot plots were taken in each area representing equally the seeded and unseeded stands.

The effect of grazing upon the reproductive potential of this milkvetch was determined from a statistical analysis of the differences in numbers of blossoms produced per inflorescence. Fifty inflorescences were selected at random in each of three locations, i.e., nursery area and Exclosures 1 and 2.

Yields

Forage yields of Canada milkvetch were determined by clipping 20 random, 9.6 square foot plots in each of the seeded and unseeded stands of Exclosures 1 and 2. In addition, density data were obtained to make direct comparisons of yield data with the number of plants present.

RESULTS AND DISCUSSION

Environmental Measurements

Air Temperature

The minimum temperatures at three feet above the ground tend to be somewhat warmer in the clear-cut than in the forest and those recorded at one foot high were definitely cooler in the clear-cut (See Appendix III).

The environment nearer the ground is cooler in the clear-cut because the abundant herbaceous vegetation confines a layer of air next to the ground. During the cooling processes, the vegetation prevents eddy diffusion from occurring, which would mix the lower layer with the layer above it. However, during the warming processes, the steep temperature gradients of the incoming radiation cause enough eddy diffusion to take place, which eliminates any differences between the two layers under consideration (Geiger, 1957).

The variance ratios for the temperature differentials (Table 3) indicate the minimum temperatures seem to be the temperatures which differentiate the environments of the clear-cut and the mature forest. Even though the number of observations is small, this differentiation was statistically significant for each summer the observations were recorded. The variation among dates of observation did not contribute significantly to the total variation, except in the case of the maximum temperatures in 1968.

The statistical analyses of the temperature deviations of the environment of the clear-cut from that of the mature forest (Table 4) did not indicate there are major differences between them. Apparently, this method is not as sensitive to the differences that exist as the previous method because of the great amount of variation among years. Because the variance ratio indicating a significant relationship between plant cover and maximum temperatures recorded three feet above the ground has a small value, more data are required to accurately evaluate this relationship.

Soil Moisture

There is a good correlation between the milliamp readings obtained using the moisture blocks made of gypsum and the moisture content of the soil. The range tested was from 40 percent down to zero percent (oven-dry soil). The regressions of y on x = 0.2014 x +0.0748; y is the percentage soil moisture on oven-dry weight basis and x is the milliamp reading. This relationship is illustrated in Figure 6.

Tolo silt loam is capable of holding up to 60 percent moisture at saturation (oven-dry basis). The range was 47 to 60 percent. The maximum milliamp reading possible at saturation was 200, if zero

Table 3. Variance ratios calculated from analyses of variance of air temperature differentials as determined per Pettit (1968).

Source of Variance	TEMPERATURE[1] 1967 max.	1967 min.	1968 max.	1968 min.	1969 max.	1969 min.
Plant cover (undisturbed forest vs. clear-cut)	3.201	65.869**	0.021	14.755**	1.155	10.083**
Dates	0.752	1.436	14.652**	0.864	2.255	0.690

[1] Data in Appendix IV.

**Significant at p = 0.01.

Table 4. Variance ratios calculated for temperature deviations of the environment of the clear-cut from that of the undisturbed forest.

Source of Variance	TEMPERATURE[1] 3 ft. above ground max.	3 ft. above ground min.	1 ft. above ground max.	1 ft. above ground min.
Plant cover	4.590*	0.329	1.423	1.915
Date	2.985	1.425	1.592	1.241

[1] Data in Appendix V.

*Significant at p = 0.05.

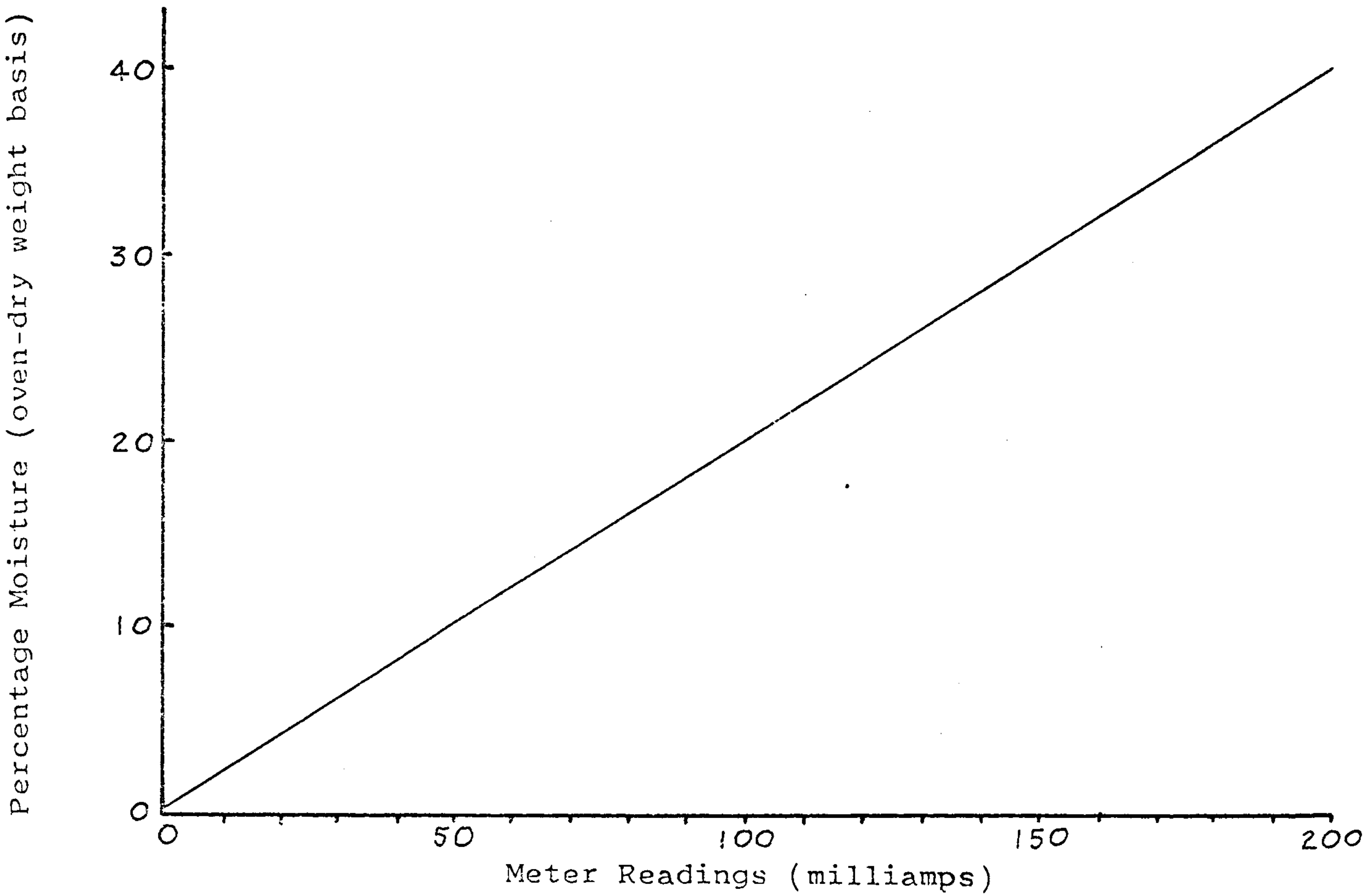


Figure 6. Relationship Between Percentage Soil Moisture (oven-dry weight basis) and Gypsum Moisture Block Readings.

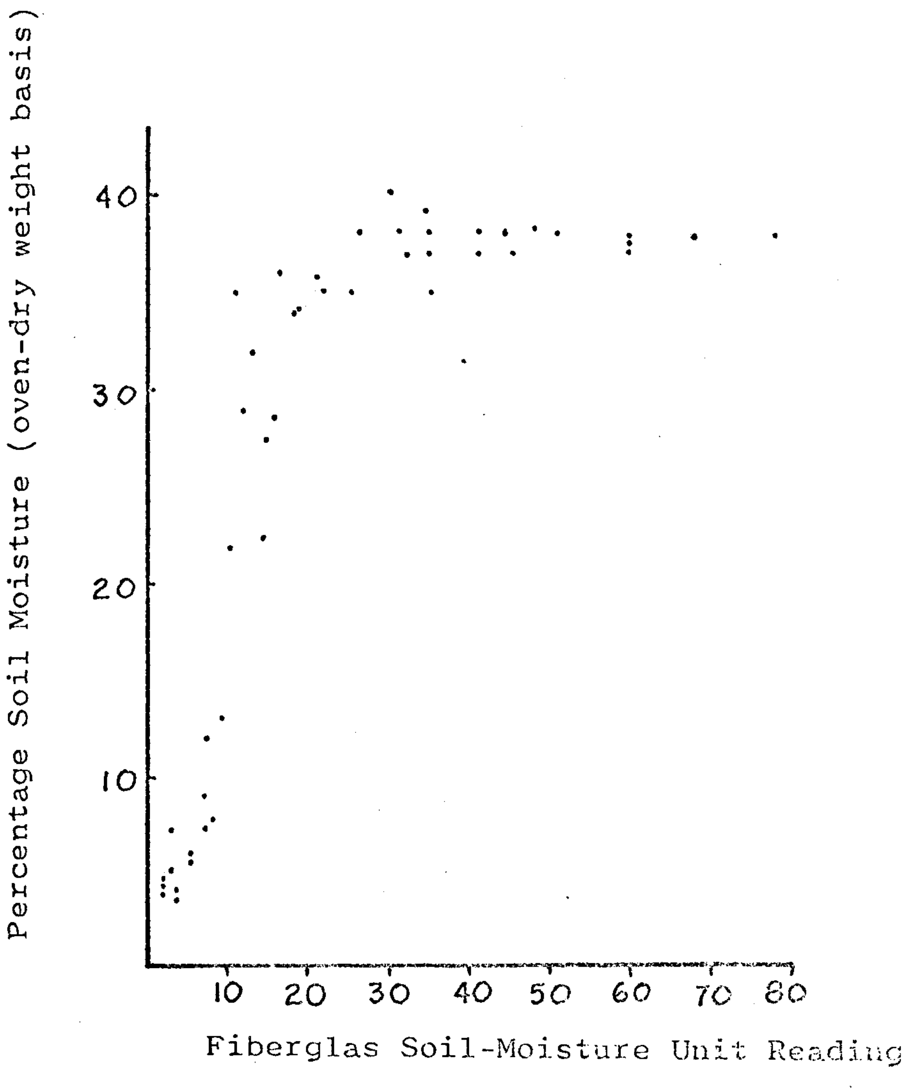
percent moisture (oven-dry soil) was chosen as the zero point on the milliamp scale. On this basis, it was found maximum readings were always obtained when the soil moisture content was equal to or greater than 40 percent.

The relationship between percentage soil moisture and the readings obtained using fiberglas soil-moisture units is not as useful as the above. Nevertheless, the data presented in Figure 7 indicate these devices could be used to determine the amount of soil moisture present, but the ends of the curve will not be reliable. The metal resistors would not be recommended to obtain soil moisture data, except where conditions of the soil would cause rapid decay or malfunction of the gypsum blocks.

The reason why the Coleman soil-moisture units are less accurate than the gypsum blocks is apparently the water films in the disk are discontinuous. This would cause a hysteresis effect which would not be overcome until sufficient water had entered the disk to close all the pore spaces.

Gypsum blocks have been removed from the soil after remaining in the soil two, three, and four years. Only after the third year were there any signs of deterioration. The most obvious cause of deterioration is rodents. They will gnaw on the blocks at the shallower depths. And, they also damage the wire leads. Moth balls placed on top of the ground near the leads effectively discouraged the rodents

Figure 7 . Relationship Between Percentage Soil Moisture and Fiberglas Soil-Moisture Unit Readings.



from damaging the blocks or leads, except for the occasional deep burrowing individual.

The soil moisture trends on the study area and the adjacent stand of mixed-coniferous forest are illustrated in Figure 8. These trends clearly show grasses and forbs use less soil moisture throughout the summer season than tree or browse species.

The mature forest is more efficient than seral, herbaceous and shrubby vegetation in removing moisture from the soil.

Observations recorded in late summer, 1969 and in the summer of 1970 indicates sites dominated by Ceanothus sanguineus retain deep (24-48 inches) moisture longer than sites dominated by ninebark. However, the soil under both kinds of vegetation had approximately the same soil moisture content at the end of the growing season in September.

The forest canopy did not markedly affect the amount of moisture stored in the soil after the winter season, except during the driest year (Table 5). The amount of precipitation received during the precipitation year beginning in September, 1965 through August, 1966 was only 16.8 inches as compared to more than 27 inches received in the other years of record. The station within the stand of mixed-coniferous forest had less than 50 percent of the soil moisture possible in mid-June, 1965; whereas, the sites in the clear-cut had considerably more moisture, even in the lower root zone.

Figure 8. Soil Moisture Trends on Experimental Area and Adjacent Stand of Mixed-Coniferous Forest (from 1966-1970 data; wilting percentage is approximately 15% moisture on oven-dry weight basis).

Season	Depth (inches)	D O M I N A N T V E G E T A T I O N: Seeded Grasses	Native Grasses & Forbs	Cesa & Grasses	Forest w/ Hodi Understory	Forest w/ Phma Understory
Mid-June	0- 6	Above WP	Above WP	Above WP	Above WP	Above WP
	6-12	Above WP	Above WP	Above WP	Above WP	Above WP
	12-24	Above WP	Above WP	Above WP	Above WP	Above WP
	24-36	Above WP	Above WP	Above WP	Above WP	Above WP
	36-48	Above WP	Above WP	Above WP	Above WP	Above WP
Mid-July	0- 6	1	1	Above WP	Above WP	Above WP
	6-12	1	Above WP	Above WP	Above WP	1
	12-24	Above WP	Above WP	Above WP	Above WP	Above WP
	24-36	Above WP	Above WP	Above WP	Above WP	Above WP
	36-48	Above WP	Above WP	Above WP	Above WP	Above WP
Mid-August	0- 6	Below WP	Below WP	Below WP	Below WP	Below WP
	6-12	Below WP	1	Below WP	Below WP	Below WP
	12-24	1	Above WP	Below WP	Below WP	Below WP
	24-36	Above WP	Above WP	Above WP	Below WP	Below WP
	36-48	Above WP	Above WP	Above WP	Below WP	Below WP
Mid-September	0- 6[2]					
	6-12	Below WP	Below WP	Below WP	Below WP	Below WP
	12-24	Below WP	Above WP	Below WP	Below WP	Below WP
	24-36	Above WP	Above WP	Below WP	Below WP	Below WP
	36-48	Above WP	Above WP	Below WP	Below WP	Below WP

1/ One-half the years of record above WP and one-half the years of record below WP.
2/ Moisture content of top 6 inches is dependent upon fall showers. The surface is very dry (≤ 5% moisture on oven-dry weight basis) unless fall rains moisten it.

[/ / / / /] Above wilting percentage [• • • •] Below wilting percentage

Table 5. Precipitation as recorded on Ponderosa pine-grass site adjacent to experimental area.

	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70	Avg.	%
Sept.	0.6	1.4	0.9	1.4	2.7	1.1		
Oct.	0.9	0.0	1.9	2.2	1.8	2.2		
Nov.	2.3	2.2	3.3	1.9	4.7	0.8		
Dec.	7.6	0.5	4.9	5.0	4.3	4.5		
Jan.	6.8	2.5	4.2	2.5	4.0	6.2		
Fall and Winter	18.2	6.6	15.2	13.0	17.5	14.8	14.2	53
Feb.	2.3	3.0	1.4	2.9	1.5	1.9		
Mar.	0.5	2.7	3.3	2.8	1.5	3.2		
Apr.	2.0	1.0	3.6	1.2	3.7	1.9		
May	1.9	1.1	2.2	2.5	2.0	2.1		
Spring	6.7	7.8	10.5	9.4	8.7	9.1	8.7	33
Sept. through May	24.9	14.4	25.7	22.4	26.2	23.9	22.9	86
June	1.7	1.8	0.9	1.8	3.7	3.2		
July	0.9	0.3	0.6	0.5	0.3	1.7		
Aug.	2.0	0.3	0.0	2.2	0.0	0.0		
Summer	4.6	2.4	1.5	4.5	4.0	4.9	3.6	14
Yearly	29.5	16.8	27.2	26.9	30.0	28.8	26.5	100

The plots on the clear-cut study area dominated by introduced grasses had more moisture in the soil at the end of the growing season than sites dominated by browse species. The grass plots are readily grazed by cattle, but the browse plots are only partially utilized by cattle in the summer period. This indicates grazing does reduce soil moisture losses via transpiration. Those plots dominated by native species tend to have the highest soil moisture content at the end of the summer. This is the result of two factors. These plots are dominated principally by Ross sedge and tufted hairgrass which are deep rooted and shallow rooted, respectively. The sedge is preferentially grazed which greatly reduces its transpiration potential. And, tufted hairgrass is summer dormant which also reduces the amount of soil moisture lost via transpiration.

The soil moisture data expressed as a percentage on oven-dry weight basis are presented in Appendix VI.

Soil pH

As expected, no change was detected in the soil pH under the forest canopy. However, there were several changes in soil pH from 1965 to 1968 in the clear-cut. The pH values reported in Table 6 for the clear-cut in 1965 are good averages for the entire area. The entire area had been dominated by Circium vulgare in 1964 and the grass plots were just becoming established in 1965.

Table 6. pH of selected sites from the study area and adjacent forest.

Depth (inches	0-7	8-16
Clear-cut 1965		
Introduced Grasses	6.42	6.35
Forest 1968[1]	6.28	6.50
Clear-cut 1968		
Dominant Vegetation		
Holodiscus discolor	6.10	6.45
Physocarpus malvaceus	6.10	6.45
Introduced Grasses	6.10	5.95
Astragalus canadensis var. *mortonii*	6.25	6.60
Native Grasses	6.35	6.70
Ceanothus sanguineus	6.60	6.68
Elymus glaucus	6.88	6.92
Rumex acetosella	6.80	6.45
Bromus marginatus	7.00	6.82

[1] Similar pH values were obtained in 1965 from soil collected in a mature stand of mixed-coniferous forest.

The surface soils under introduced grasses, Holodiscus discolor and Physocarpus malvaceus may be leached more than the soil in the forest. These species apparently do not contribute much to the cation chemistry of the soil. In fact the pH under these species is less than that under the forest.

The soils under introduced grasses may be leached more because they are bunchgrasses and because the grazing intensity has been such that appreciable amounts of organic materials have not accumulated in the interspaces among the plants. This would allow snow and rainfall to reach the soil without having to penetrate through a vegetal canopy. There is sufficient organic matter in the soil and plant cover on these plots that the precipitation enters the soil with little or no run-off.

The situation involving Holodiscus discolor and Physocarpus malvaceus is similar to that above. Grazing does remove some of the organic materials, but these plants, which resprouted from rootstocks after burning, have not developed dense canopies, as yet.

The area dominated by Canada milkvetch had been protected from grazing for three years. As a result, moderate amounts of organic materials have added to the soil each year because the entire aerial shoot of this species is deciduous. However, the plant materials are not coarse like those of the grasses; therefore, less dry matter would be added to the soil as compared to that added in the cases discussed below.

The plots dominated by native grasses, Ceanothus sanguineus, Elymus glaucus, Rumex acetosella, and Bromus marginatus have received less grazing pressure than any of the plots mentioned above. The order given herein is the approximate order of descending use. The organic materials which have accumulated on these plots are rather coarse and substantial amounts have filled the interspaces among the plants. Consequently, more precipitation is intercepted and more is lost via evaporation. The result is probably less water moves into the soil than is the case on the more heavily grazed plots. The coarser materials would also contain a higher content of cations on a dry weight basis, which would help to maintain a higher pH in the soil.

Soil Temperature

Sufficient soil temperature data were not recorded to specifically characterize the effects of the different kinds of vegetal cover on this parameter. Nevertheless, the soil temperature at two inches deep under the mixed-coniferous forest canopy was two-four degrees (° C.) cooler than under the herbaceous canopies of the experimental area. However, in 1967 the temperatures at this depth under canopies of mature forest and Canada milkvetch were similar; those recorded under introduced grasses were slightly higher than in the forest area;

and those recorded under the shrub-forb canopy were considerably higher than those in the forest.

The graphs of Figure 9 indicate the canopies of introduced species and the forest affect soil temperature similarly. Also, the canopy of Canada milkvetch affected soil temperature in a manner similar to that of the forest canopy in 1967, but not in 1966. This may be due to the fact that in 1966 Canada milkvetch did not produce as abundant foliage as it did in 1967. The foliage in 1967, therefore, produced a more stable microenvironment which simulated that of the forest in spite of lower stature of Canada milkvetch.

Perhaps other data, e.g. temperatures recorded at four inches deep and at the ground surface, would add the additional information required to specifically characterize the influence of each kind of vegetal cover on soil temperature.

There are not sufficient data to evaluate the influence of the overstory canopy on soil temperature by analysis of soil temperature deviations from temperatures recorded at two inches deep in the mature forest. These data only indicate that the two years in which the data were recorded were different. These analyses are presented in Table 7.

Even though soil temperatures were recorded at 6, 12, and 18 inches deep for only two seasons, the results indicate (Figure 9) temperatures at these depths would not be markedly affected by

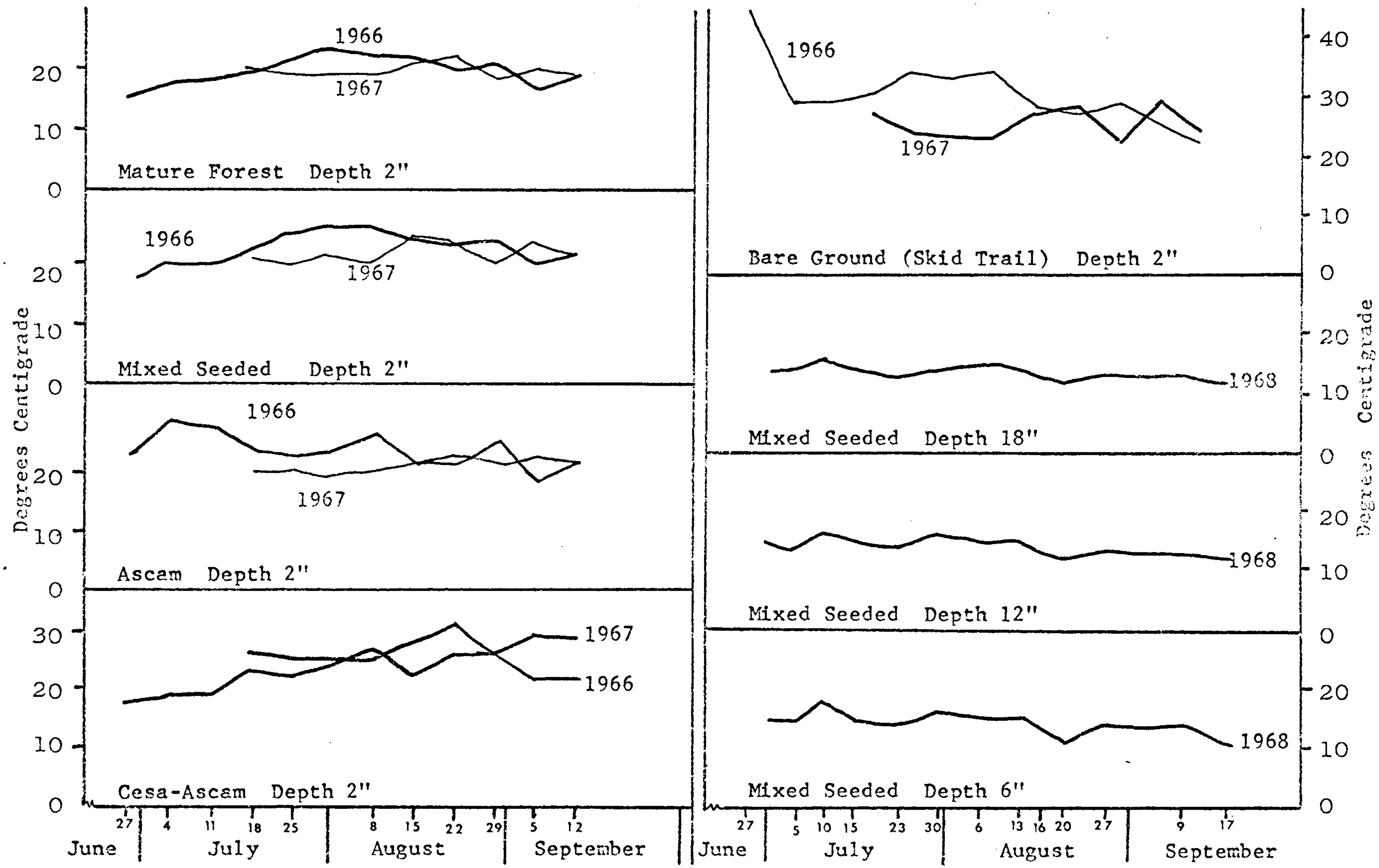


Figure 9. Soil Temperatures Recorded on the Study Area.

vegetal cover. Nor, do these temperatures seem to be correlated with moisture content or moisture depletion, because the ranges of change throughout the entire summer season did not exceed 7° C. Likewise, the ranges of change recorded within a 24-hour period were only 1-3° C.

Table 7. Analyses of soil temperature deviations from temperatures of the undisturbed forest recorded at two inches deep.

Source of Variance	Sums of Squares	Degrees of Freedom	Mean Squares
1966			
Sites	3.50	2	1.750
Dates	46.05	11	4.186
Residual	137.20	22	6.236
Total	186.75	35	
1967			
Sites	212.519	2	106.260*
Dates	23.819	8	2.977
Residual	16.186	16	1.011

*Significant at 0.01 level

Taxonomy and Range

Canada milkvetch is the western form of the species *Astragalus canadensis*. The banner of *A. canadensis* is rather fleshy, whereas that of the subspecies under study is not. The pods are deeply sulcate and arched as compared to the type species. Some northern forms have pods very similar to those of *A. terminalis* (Jones, 1923).

The following description and synony for the type species and

Canada milkvetch are according to Hitchcock et al. (1961):

Astragalus canadensis L. Sp. Pl. 757. 1753. ("Habitat in Virginia, Canada")

Tragacantha mortoni Kuntze, Rev. Gen. 2:946. 1891.

Phaca mortoni Piper, Contr. U. S. Nat. Herb. 11:372. 1906 ("Sources of the Missouri in Montana")

A. spicatus Nutt. in T. and G. Fl. N. Am. 1:336. 1838, not of Pallas in 1753.

A. pachystachys Rydb. N. Am. F. 247:448. 1929, not of Bunge in 1869.

A. mortoni f. brevidens Gandg. Bull. Soc. Bot. Fr. 48:16. 1902

A. canadensis var. brevidens Barneby, leafl. West. Bot. 4: 238. 1946. (Nelson, Evanston, Wyo.)

Plant 3-8 dm. tall, glabrate and greenish to grayish-strigillose with dolabriform hairs; stipules lanceolate-accuminate, 6-15 mm. long, some of them more or less connate or all free; leaves mostly 10-20 cm. long; leaflets 13-29, ovate-lanceolate to oblong, 1.5-4 cm. long, (3) 5-18 mm. broad, truncate to retuse, usually glabrous on the upper surface; peduncles 5-20 cm. long; racemes spikelike, 5-15 cm. long, closely 30- to 150 flowered; pedicels stout, 1-2 mm. long, with 2 tiny linear bracteoles at the top just below the calyx; flowers ochroleucous to white, spreading-drooping, 12-18 mm. long; calyx 6-9 mm. long, finely strigillose, the base asymmetrical, the tube about twice the length of the linear-lanceolate teeth; wing petals very narrow, about equal to the banner, 1-2 mm. longer than the blunt, usually purplish-tipped keel at maturity; pod erect, sessile, 8-20 mm. long, 4-5 mm. broad, cartilaginous-woody, cordate-terete in section, completely 2-celled by the intrusion of the lower suture, abruptly sharp pointed, rather generally strigillose; seeds kidney-shaped, green to light brown in color.

A. canadensis var. mortonii (Nutt.) Wats. Bot. King Exp. 68. 1871.

A. mortoni Nutt. Journ. Acad. Phila. 7:19. 1834.

A. tristis Nutt. in T. and G, Fl. N. Am. 1:336. 1838.

Calyx pubescent with both white and black hairs, the teeth subequal, 1.5-3 mm. long; plant greenish, not silvery-pubescent; chiefly in ponderosa pine and lower montane forest, less commonly along water-N=8.

Abrams (1944) recognizes A. canadensis var. mortonii as a synonym for the species A. mortonii. However, most authors have not given this variety specific rank.

Canada milkvetch grows principally on disturbed sites of north and northeastern exposures associated with stands of mixed-coniferous forest (see Figure 10). This species is also found in ponderosa

Figure 10. Habitat of Canada Milkvetch.

pine and lower montane forests, and less commonly along watercourses in the sagebrush zone. The approximate geographical range of Canada milkvetch is shown in Figure 11.

Autecology of Canada Milkvetch

Plant Development and Growth

Canada milkvetch is an early growing species. Growth begins shortly after the snow has melted. The plants reach the two-leaf stage rapidly but remain in this stage until the days become warmer. Flower buds form even before less than half of the vegetative growth has been produced. The inflorescence remains small and its stalk elongates only shortly before flowering occurs. Full vegetation growth is usually completed by early July. At this time plants that have grown in full sunlight will average 12-18 inches high, while those grown in shaded sites will be only five-six inches high, bearing only one-three leaves. These latter plants usually do not form flower buds.

Plants found in selectively cut areas are rather tall, but lodge easily. These plants will average 18-24 inches tall with the inflorescence adding at least another 12 inches to the total height.

The chronology of plant development is presented in Table 8. Vegetation and reproductive growth do not seem to be a function of

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AND ADJACENT CANADA

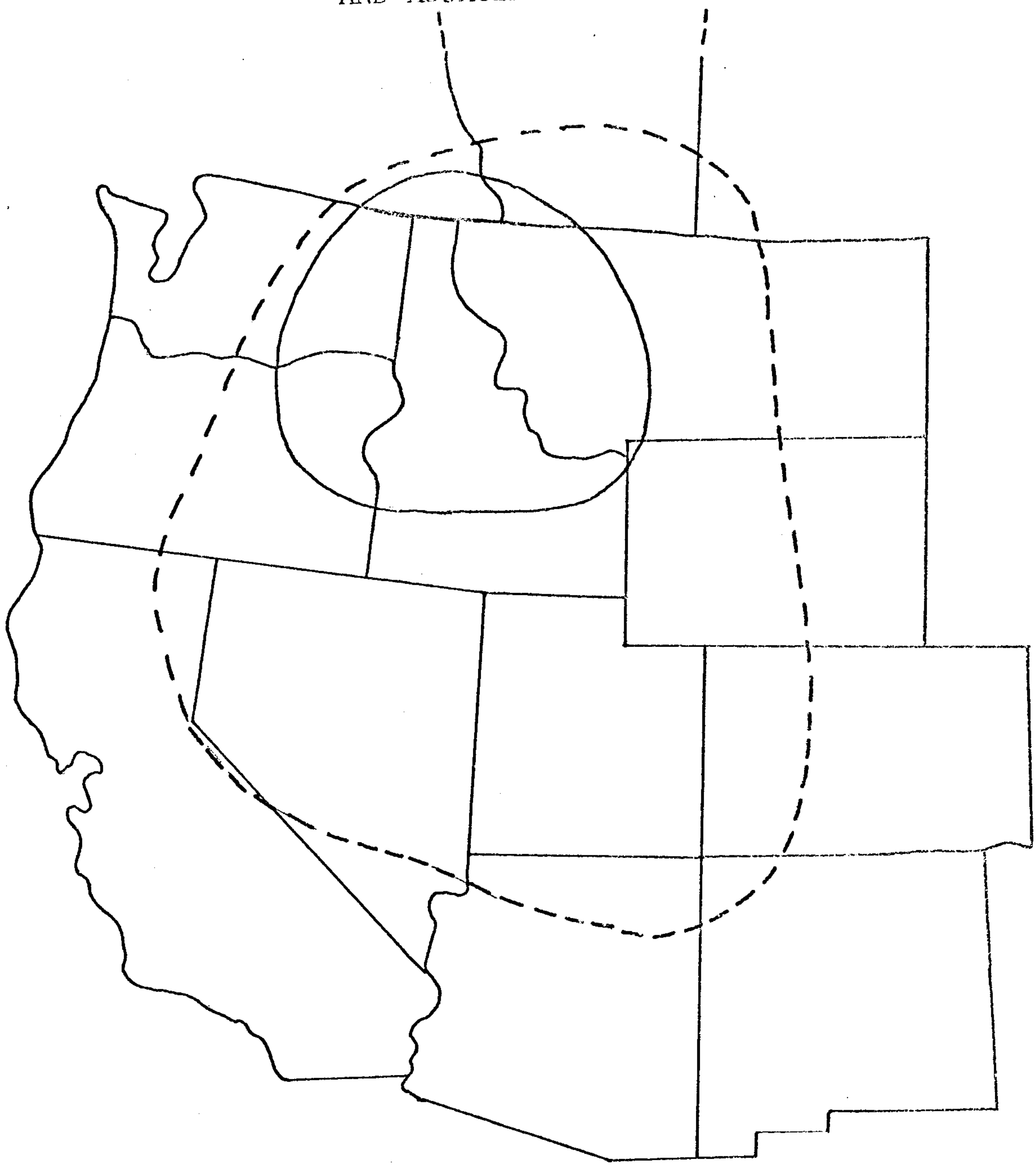


Figure 11. Geographical Range of Canada Milkvetch (Adapted from Hitchcock *et al*. 1961, and Jones, 1923).

--- *Astragalus canadensis* (type species)

—— *A. canadensis* var. *mortonii*

Table 8. Plant development of Canada milkvetch.

	mid-May	early June	mid-June	early July	mid-July	early Aug.	mid Aug.	early Sept.	mid-late Sept.
Vegetative growth	2"[1]	4-6"	5-12"	12-18"					
Nodulation			+2"[3]	X					
Flower bud formation		X				X			
Flowering			X[2]	X[3]	X		X	X	
Pollination by bumble bees			X	X					
Seeds ripe (pod split open)					X[4]	X			
New shoot formation			X		X	X		X	
Shoots decidious									X

[1] Growth began: 1968 in last week of April; 1969 in first week of May.

[2] A few plants bloomed as early as 4 June in 1968; plants in forest stands with open canopy usually begin blooming one week later than plants on clear-cut.

[3] Locations approximately 1000 feet higher than study area or in forested areas having moderate to dense canopies.

[4] At lower elevations, e.g., $\leq$4000 feet.

soil moisture and temperature. However, nodulation (discussed below) and pod formation seem to correlate with soil moisture.

The formation of seed pods coincided with a decrease of soil moisture in the top 12 inches of soil. This is the zone where the majority of the root system of this species grows.

After the pods are ripe, much of the plant's energy is expended to produce next year's aerial shoots. Most of these shoots remain underground, but many grow to a height of two-three inches before freezing weather and snows occur.

Canada milkvetch is an erect to decumbent plant (Figure 12) that usually grows in clones. The leaves are pinnately divided, having six-eight pairs of leaflets. The leaves are 1-1.5 dm. long and the leaflets are one-three cm. long.

The aerial shoots are annual, being deciduous at the end of the growing season. They arise from well-developed rhizomes (Figure 13) which are found primarily in the top six-eight inches of soil.

Vegetative reproduction is the most consistent form of propagation. One hundred plants less than one inch were examined and only one was a true seedling. The rest were new shoots from horizontal rhizomes which grew on the average of four inches below the soil surface. These plants typically had only few secondary branches, some of which penetrated as deep as two-three feet deep. These deep adventitious roots prevent the plants from wilting and

Figure 12. Growth habit of Canada milkvetch.

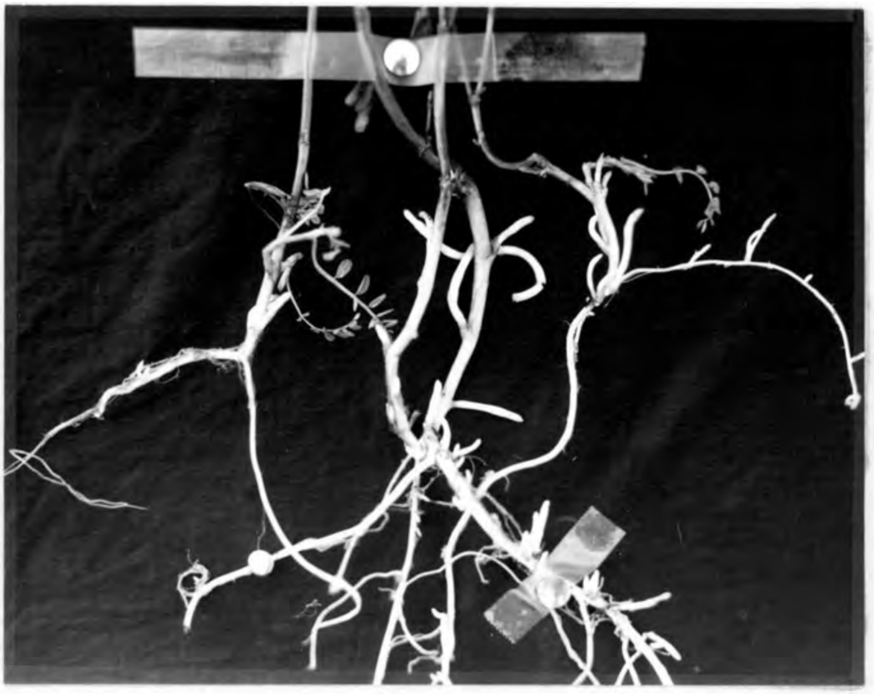


Figure 13. Rhizomes of Canada Milkvetch.

consequently dying, when the surface soil becomes dry in mid-summer.

Roots and Nodulation

The root system of the young plants is initially a strong tap root with little rhizome development (Figure 14). As the plants mature, the tap root is replaced by strong development of horizontal rhizomes. It is not unusual to observe mature clones of Canada milkvetch which have only one-two taproots penetrating to 20-30 inches deep and several horizontal rhizomes four-five feet long. These clones are usually three-four feet in diameter.

The period of root development was not determined under natural conditions because the formation and growth of new aerial shoots seems to occur whenever vegetative growth is not interrupted by formation of flowers. During the growing season, any root development is masked by development of aerial shoots.

According to Abrams (1944) this species has woody rootstocks. However, woody rootstocks were never found during the course of this study.

Under greenhouse conditions, Canada milkvetch produced extensive, fibrous-like root systems. In 12 weeks the root system more than doubled in total length. The plants also became nodulated during this period of time. The least vigorous plants produced one

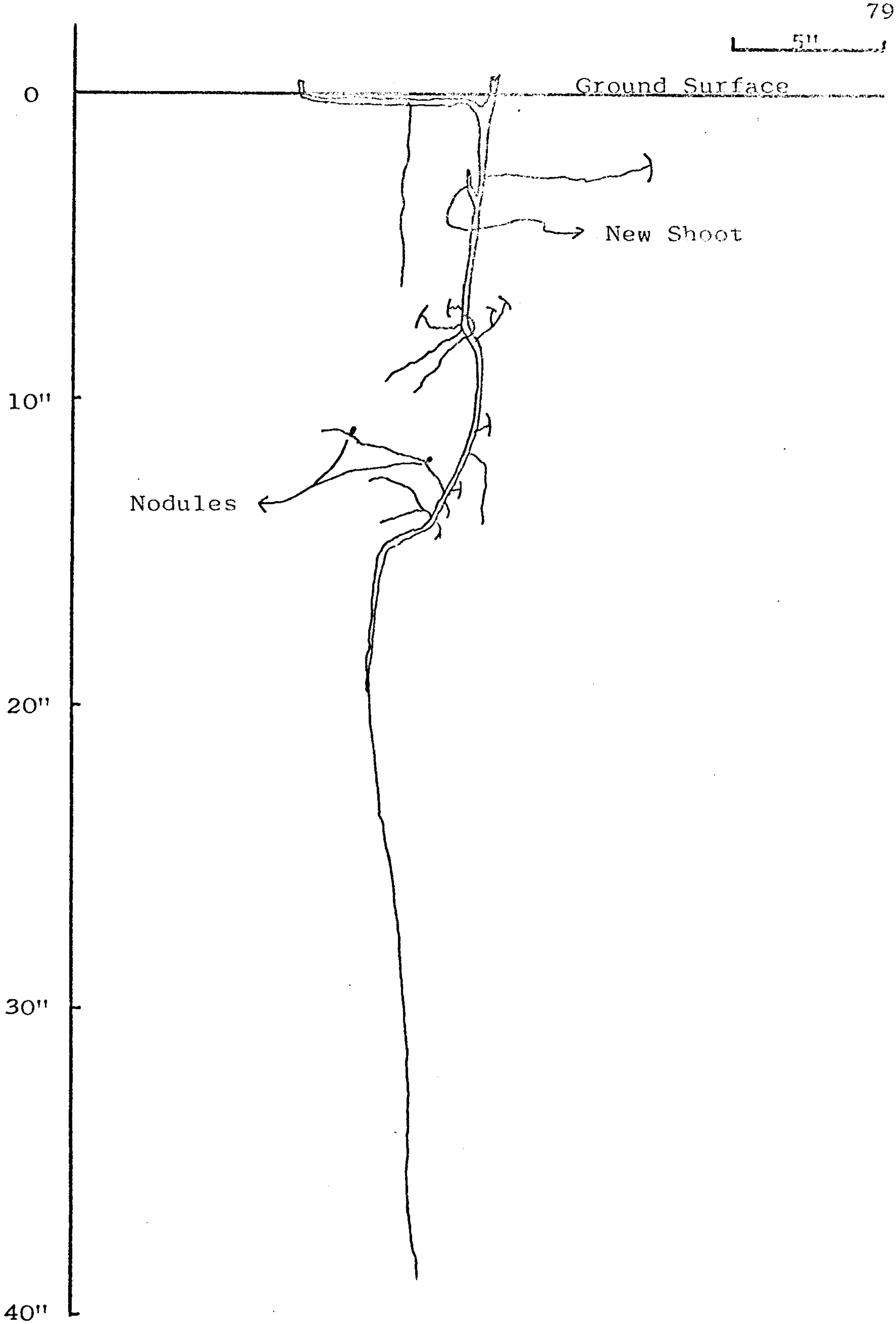


Figure 14. Root System of a Young Canada Milkvetch Plant.

nodule per 4 3/16 inches of new root growth, while the most vigorous produced one nodule per 1 3/8 inches of new root growth.

Wherever there was abundant growth of cellulolytic fungi, plant growth was less vigorous, and consequently nodulation was minimized. This was observed in the field and in the greenhouse.

In the field, nodulation occurred during the first two weeks of July in 1968 and 1969. The moisture content of the soil was approximately 50-70 percent of the water holding capacity. This moisture range has been demonstrated to be the range in which microbial activity is the greatest (Alexander, 1965).

Nodulation coincided with the short period after vegetative growth and before the plants flowered. This period is also the time when soil temperatures at 6, 12, and 18 inches deep were maximum for the growing seasons of 1968 and 1969 (see Table 9).

Table 9. Maximum soil temperatures (^{o}F) for 1968 and 1969 growing seasons (data from plot No. 4 of Fxclosure 1).

Depth (inches)	Date	*Elymus glaucus* stand	Mixed Seeded stand
6	7-10	63	63
12	7-10	61	62
18	7-10	60	59

During and after flowering the nodules decayed. Nodule development is dependent largely upon carbohydrate-nitrogen relationships (Ludwig and Allison, 1935). If for any reason, the carbohydrate supply is limited, i.e., during flowering, nodulation ceases and the bacteria become parasitic (Russell, 1961).

Nodulation may not always take place even though growth of the root system is adequate and there are sufficient contacts between root hairs and nodule bacteria. The plants grown in soil with nitrogen added equivalent to 20 pounds per acre produced very few nodules. The results of the other treatments of this experiment are tabulated below:

Perlite Medium	+N	-N
Nodule Color	white	salmon pink
Avg. N. nodules/plant	5 (single nodules)	4.4 clusters of nodules
Nodule size	< 1 mm. long	1.0-1.5 cm. diameter

Tolo Silt Loam	+N	-N
Nodule Color	white	salmon pink
Avg. No. nodules/plant	2.3 (single nodules)	4.0 clusters of nodules
Nodule size	< 1 mm. long	1.0-1.5 cm. diameter

Table 10 reports milligrams of nodule produced per gram of root or shoot produced for this experiment. Other studies conducted by the author at the same time as this one indicated that ten pounds of nitrogen per acre enhanced root nodulation and plant growth. However, the total amount of nodulation was not greater.

Table 10. Milligrams of nodule (dry weight basis) produced per gram of root or shoot (dry weight basis).

	w/nitrogen		w/o nitrogen	
Growth Medium	Root	Shoot	Root	Shoot
Perlite	14.0	14.0	37.2	42.1
Tolo Silt Loam	1.5	2.4	25.1	58.6

The plants grown in perlite without nitrogen had larger root systems than those grown in the soil; those grown in soil without nitrogen had more shoot growth than those grown in perlite. Consequently, the amount of nodulation was greatest on those plants grown in perlite medium. Hence, nodulation is related to the physiological conditions of the root environment, as well as the amount of nitrogen in the soil.

Nodulation was also affected by temperature. Plants kept at 65-72° F. during the day produced more and larger nodules than those grown at 80° F. As temperature increased, the nodules changed from pink color to white. It is possible that higher greenhouse temperatures interfere with leghaemoglobin formation.

In the field as in the greenhouse, plants which have flowered, have few nodules. Nodulation is most abundant in the vegetative stages of growth. Field observations indicate light grazing tends to keep Canada milkvetch in the vegetative state, and tends to encourage nodule formation. However, Canada milkvetch is seldom lightly grazed by cattle or game, especially by game.

Flowers and Seed Production

The general flowering period is from mid-June to mid-July, but flowering does occur in early June and continued as late as 20 September in 1968 (Table 8).

Plants growing at higher elevations, e.g., > 5,000 feet, bloom approximately three-four weeks later than those on the clear-cut study area.

Blossoms produced early in the season usually do not produce seed. Possibly the cool weather of early summer does not allow development of the insects needed to pollinate this species. The most common insect to visit Canada milkvetch is a medium sized bumble bee (*Bombus* sp.). Flies, wasps, and honey bees do not open or trip the flowers of this species.

Bumble bees are most common from mid-June to mid-July and these are the only insects observed which preferentially seek out flowers of Canada milkvetch. In late summer, the blossoms seldom produce seed, but abort. Therefore, it is assumed that cross-pollination is required for seed production.

Some plants produce up to three sets of flower stalks during the growing season. This means that plants will have pods ripening while new floral buds are forming. The ovaries developed early and late in the season aborted, and only those developed in mid-season produced ripe pods. Almost continuous flowering is restricted to the most vigorous clones which have been protected from grazing and which are free of disease.

Ovary abortion seems to be characteristic to Canada milkvetch. This phenomenon was not observed on introduced legumes such as _Lotus corniculatus_ or _Vicia americana_; nor was it observed in native _Lathyrus_ sp. or _Lupinus_ sp.

Canada milkvetch has a high reproductive potential. In 1968, a typical clone occupying 12 square feet produced nearly 150 flower stalks by mid-July. This year the number of seeds produced per pod was 6. In 1967, Pettit (1968b) said this species produced 22 seeds per pod. He also said the plants had an average of three flower stalks per plant each bearing 40 flowers. This was a potential of 2,640 seeds per plant.

The reproductive potential of the plants in Exclosures 1 and 2 and the nursery area was 45, 30, and 47 blossoms per inflorescence. The differences between the nursery area and Exclosure 1 and Exclosure 2 are significant at the 1 percent level. This indicates there is heavier grazing pressure on Canada milkvetch in Exclosure 2 than in Exclosure 1. This heavier grazing is attributed to big game.

The differences in seed production between 1967 and 1968 were probably due to the influences of insect damage. Also, the effects of grazing and the successional characteristics of this species decrease plant vigor. These aspects will be discussed below.

Insects, Disease and Rodents

Developing pods are attacked by a weevil species. The species was not positively identified but probably belongs to the genus *Apion* (Chu, 1949). The adult insect lays the egg in the ovary and the young larva lives in an ovule; later to emerge and eat other ovules. When it matures, it eats its way out of the pod. If the pod is still green and succulent, the larva may consume nearly half of the pod before leaving. This event causes the flower stalk to die prematurely. If the pod is dry, the insect emerges through a small hole bored, usually near the calyx end, in the ovary wall.

During 1967, this insect apparently was not abundant, but in 1968 and 1969 it was. It was estimated at least 50 percent of the pods were destroyed in 1968 and 1969, before the ripening period. Of the pods remaining, insect damage reduced the number of seeds produced per pod from six to five. This change, although slight, was significant at the 5 percent level (Table 11).

Table 11. Number of seeds produced per pod during 1968 growing season.

	$\overline{X}$	n	s^2	s	Range	σd
Normal pods	6.0	100	15.1919	3.898	1-17	0.4858
Pod with some insect damage	5.0	100	8.404	2.899	1-12	

Canada milkvetch is also attacked by a red spider mite (Tetranychus sp.) and an unidentified aphid. The damage caused by these organisms is slight in comparison to that caused by the weevil.

A powdery mildew is common on Canada milkvetch throughout the Wallowa Mountains and adjoining foothills. This disease appeared after flowering and just before the pods were ripe. It weakens the plants, but generally does not kill them. Seeds from infected plants did not seem to be affected because of lowered vigor.

This disease was especially common on the plants grown in the greenhouse. In the field there seemed to be a differential vulnerability among clones and locations, but in the greenhouse all plants were equally susceptible, regardless from where they were collected.

Rodents, particularly chipmunks (Eutamias sp.) decrease the reproductive potential by removing the blossoms. They removed about 15 percent (Table 12) of the blossoms during the first part of the summer. There was a marked decrease in the amount of grazing after mid-July, probably because rodents prefer blossoms producing nectar. The rodents did not graze the green or mature pods.

The difference in grazing by rodents on seeded and unseeded plots is related to the kind of other species present, such as bull thistle. The chipmunks utilize the blossoms of bull thistle to a larger extent than Canada milkvetch because new blossoms are abundantly available throughout the summer.

Table 12. Percentage of inflorescences grazed by rodents (10 July 1968).

	Seeded %	Unseeded %
w/o Inflorescence	17.0	21.1
w/ Infertile blossoms	5.6	11.2
w/ Inflorescence	60.5	56.0
Grazed by Rodents	16.9	11.7
	100.0	100.0

Seed Germination and Seedling Development

The first germination trial lasted about 3.5 months. During this time a total of 15.9 percent of the seeds germinated and produced seedlings. Only 1.5 percent of the seeds produced seedlings during the first 30 days; whereas, 11.1 percent and 3.3 percent were produced during the next 30 days and 41 days, respectively. Because these seeds were not pre-treated, it took considerable time for water to penetrate the hard seed coat.

In addition to the above germination, approximately two percent per month broke dormancy and produced either a radical or cotyledons, but not both.

Very few seeds rotted even though they were kept moist for over three months. At the end of the 3.5 month period, those seeds which had not broke dormancy were still very hard. The characteristic of a hard seed coat and slow germination have great ecological significance. This means if conditions are favorable, germination will continue for a prolonged period of time. Thus, some plants will surely become established. Also, if conditions become adverse, there still will be a reservoir of hard seed left in the soil. In this investigation, germination began six days after the seeds were watered and up to the day the trial was terminated.

The acid treatment used to break the seed coats was effective in speeding up germination. The time required for the first seeds to germinate was reduced to two days. These plants also produced their first leaves ten days earlier than the seeds in the first trial.

During the first 17 days, 11.2 percent of the seeds germinated. Thereafter, an average of 2.5 percent germinated per month for about three more months. At the end of four months germination had ceased.

After the first two weeks, seeds began to rot. The acid scarification caused many seeds to swell rapidly and the seeds burst open, exposing the contents. As a result, fungi developed rapidly on the seeds; thus, many seeds were destroyed before germination had actually begun.

The results of examining the seeds with X-rays are presented in Table 13. The large proportion of seeds from the field collection which had abnormal development explains why many seeds break dormancy, but yet do not produce seedlings.

The tetrazolium viability test confirmed that Canada milkvetch is a hard seeded species, and that approximately five percent of the seed would germinate in a standard germination trial. These results are in agreement with the results previously stated herein.

Moist heat does encourage germination of Canada milkvetch seeds. However, a good proportion of the seeds decay. The average number of seeds which decayed is approximately the same for both temperature regimes investigated (Table 14). However, the higher temperature regime tended to produce more decayed seeds. In contrast, there were more hard seed present at the end of the germination period under the lower temperature regime.

Under both temperature regimes, temperature treatments of 200° F. produced the best germination. Data from the experimental burn indicate that the most common temperature at the soil surface was more than 100° F. and less than 400° F. Therefore, it is concluded that broadcast burning either in the spring or summer should

Table 13. X-ray examination of Canada milkvetch seeds.

	Lot 1 (Field collection)	Lot 2 (Select seeds)
	(Percent)	
Normal development	19	88
Questionable development	9	4
Abnormal development	36	6
Damaged by insects	17	1
Broken seeds	7	1
Empty seeds	12	0
	100	100

Table 14. Average germination of Canada milkvetch.

Temperature Regimes													
86°F - 16 hour day; 68°F - 8 hour night.							68°F - 16 hour day; 38°F - 8 hour night.						
Seed Treatments Before Germination[1]													
a	b	c	d	e	f	g	a	b	c	d	e	f	g
Germinated Seeds/100 Seeds													
45	74	54	68	59	60	47	40	56	40	71	59	63	53
Hard Seeds/100 Seeds													
38	8	33	8	3	3	1	52	1	43	18	14	11	14
Decayed Seeds/100 Seeds													
17	18	13	24	38	37	52	8	43	17	11	27	26	43

[1] a. untreated seeds as control
b. hot water soak for 12 hours
c. 100°F for 10 minutes
d. 200°F for 10 minutes
e. 400°F for 10 minutes
f. 600°F for 5 minutes
g. 800°F for 5 minutes

have a significant effect in enhancing germination of hard seeded species, such as Canada milkvetch.

Seedling development from the cotyledon stage to the trifoliate leaf stage is a rather long time period. In the greenhouse as well as in the field, Canada milkvetch seedlings remained in the cotyledon stage an average of two weeks. Then growth was fairly rapid. Generally two to three trifoliate leaves would be produced in the third week. Thereafter, growth was dependent on extent of nodulation, soil moisture, and depth of rooting. Seedlings that did not become nodulated became chlorotic and died.

During the first growing season Canada milkvetch plants remain small and spindly. Most of the growth occurs in the root system, which generally grows deep enough to have adequate soil moisture throughout the season. Because the young plants produce only a minimum of leaf growth, they are seldom or are only lightly grazed while the seedling becomes established.

If growing conditions occur in the fall, seedlings of the current year will produce abundant leafy growth. These plants are very cold hardy, for no deaths due to frost were observed before the snows came. And of course, the snows provide a protective blanket against freezing throughout the winter. When the snows melt, these plants were some of the first on the experimental area to be grazed by wild game.

Nutrient Effects

Some of the nutrient treatments were toxic to Canada milkvetch. This was particularly true for the higher levels of copper and cobalt. The effects of these nutrients upon vegetative growth are described in Table 15. None of the plants in these treatments produced new shoots. In fact, most of them lost their leaves or developed discolored leaves, which were either chlorotic or very dark green. Often the intervenal tissue became a color contrasting to the color of the veins.

The yields of the treatments which did not inhibit growth are given in Figure 15. Included in this figure are two treatments, viz., Ca 1 + Co 2 and Ca 1 + Cu 1 + Co 1, which did not produce any measureable growth during the first period, but did so during the second. Apparently the abundant growth of cryptogams and leaching reduced the amounts of the added nutrients to levels that could be tolerated by Canada milkvetch. It is also interesting to note that treatment Ca 3 + Cu 1 + Co 2 did not produce any measureable growth during the second growth period. Perhaps calcium masked the effect of the micronutrients during the first period of growth. Then, because of leaching, sufficient calcium did not remain in the soil to be effective in doing this during the second growth period.

The treatments which produced the highest yields are tabulated

Table 15. Effect of calcium, copper, and cobalt on vegetative growth of Canada milkvetch.

Treatment (4 observations/tmt)			1 November 1969		11 November 1969		6 March 1970		10 June 1970
			Vigor[1]	No. Dead	Vigor	No. Dead	Vigor	No. Dead	
Cu2			Low	-	Low-toxic	-	Low	2	
Co 2			Low-chlorotic	1	Low-toxic	2	Mod.	2	No charge
Cu 1 + Co 2			Low-chlorotic	2	Low-toxic	-	-	4	
Cu 2 + Co 1			Low-chlorotic	-	Low-toxic	-	Poor	2	since
Cu 2 + Co 2			Low-chlorotic	1	Low-toxic	2	Poor	2	
Ca 1 + Cu 2			Low-chlorotic	-	Low-toxic	-	Poor	2	6 March
Ca 1 + Co 2			Low-chlorotic	3	Low-toxic	3	Poor	3	
Ca 2 + Cu 2			Low-dark green	-	Low-toxic	-	Low	2	
Ca 2 + Co 2			Low- chlorotic	3	Low-toxic	3	Poor	3	
Ca 3 + Cu 2			Low-chlorotic	-	Low-toxic	-	Low	2	
Ca 3 + Co 2			Low-chlorotic	1	Low-toxic	1	Poor	2	
Ca	Cu	Co							
1	2	2	Low-chlorotic	-	Low-toxic	-	Poor	1	
1	2	1	Low-chlorotic	1	Low-toxic	1	Low	2	
1	2	2	Low-chlorotic	2	Low-toxic	3	-	4	
2	1	2	Low-chlorotic	-	Low-chlorotic	-	Low	2	
2	2	1	Low-chlorotic	-	Low-chlorotic	-	Low	2	
2	2	2	Low-chlorotic	1	Low-toxic	1	Poor	2	
3	2	1	Low-chlorotic	-	Low-chlorotic	-	Poor	2	
3	2	2	Low-chlorotic	-	Low-toxic	2	Mod.	2	

[1] Vigor scale:

- High - abundant growth; plants $\geq$ 12 inches high
- Moderate - good growth; plants $<$ 12 inches high
- Low - some new growth, but very slow
- Poor - no new growth; plant with very small leaves

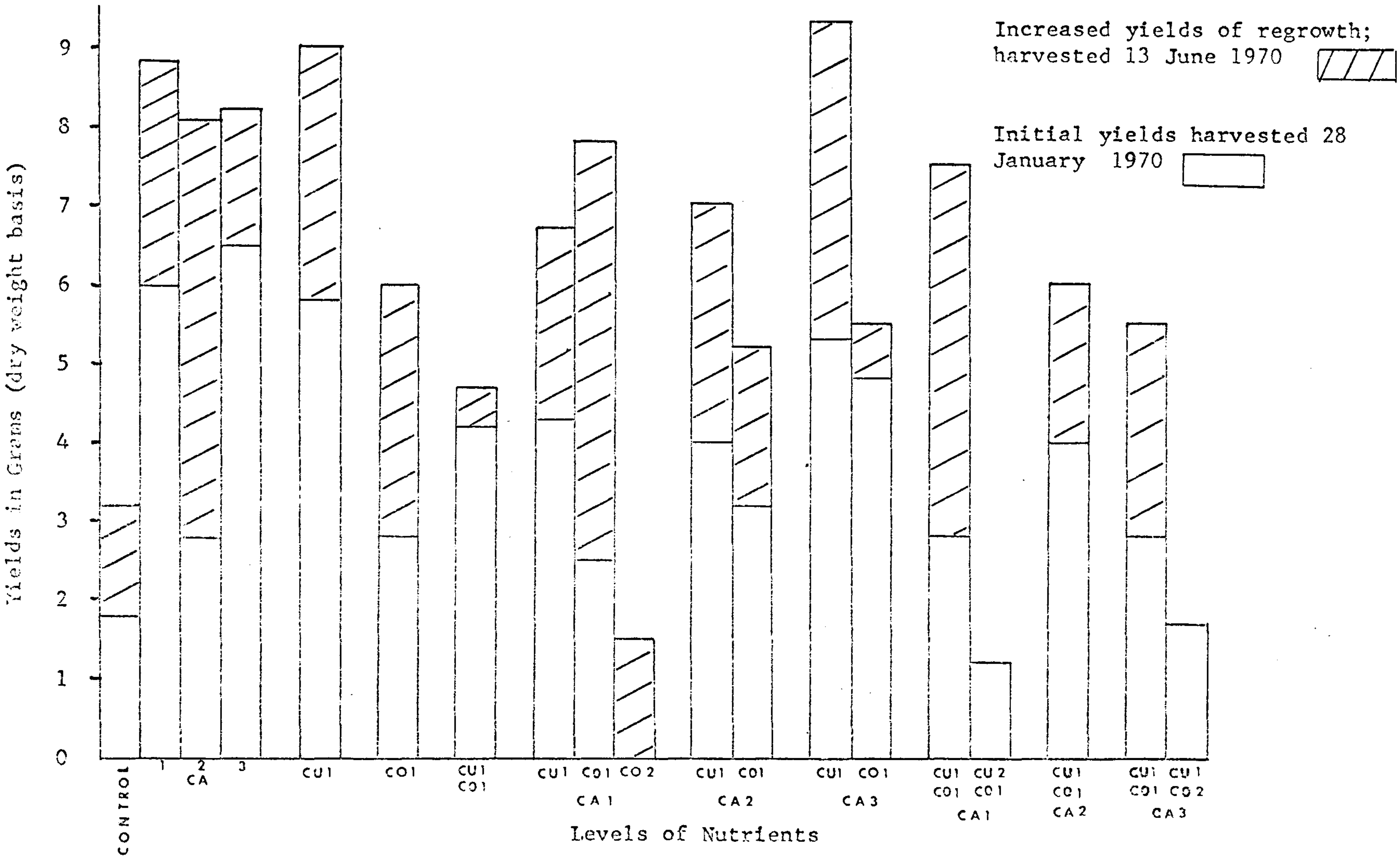


Figure 15. Yields of Canada Milkvetch as Affected by Calcium (CA), Copper (CU), and Cobalt (CO).

below:

Treatment	Growth Period 1	2
	(g - dry weight)	
Ca 1	6.0	8.8
Ca 3	6.5	8.2
Cu 1	5.8	8.2
Ca 3 + Cu 1	5.3	9.3

Even though the rates of calcium are widely different, i.e., 120, 600, and 1200 pounds per acre, there is no great difference in final yields. This suggests calcium is required for nutrition rather than for altering the pH of the soil.

The plants which received calcium produced the largest and most abundant nodules.

The lower levels of copper and cobalt alone and in combination with each other had marked effects on the appearance of the plants. Likewise, this was true for combinations including calcium. However, more data are required to evaluate the effects and interactions of these nutrients.

It was intended to investigate the effect of these treatments on the rate of nitrogen fixation. But, the temperatures of the greenhouse unexpectedly became too high shortly before the roots were harvested, and the nodules were discolored or decayed at the time of harvest.

The treatments which produced the best yields were the ones which had the most favorable effects on the amounts of phosphorus, calcium, and crude protein in the forages. But because the data had considerable variation, more research is required to establish the true relationships between these nutrients and the analyses.

All of the pots had a carpet of mosses and liverworts growing on the surface. This layer was one-half to two inches thick. This layer was best developed on the pots in which the plants did not grow or died. Whenever roots of Canada milkvetch grew into this layer, at least a few, large clusters of nodules were produced. This was true even if the plant had low vigor or minimum root development. In fact, those plants with the least root development produced new roots only in this layer.

Apparently the mosses and liverworts, which are able to thrive in environments having high levels of nutrients, utilized the nutrients in such a way that optimum levels of nutrients for enhancing nodulation remained. The mosses not only reduced the level of micronutrients to that desirable, but also, probably created a nitrogen deficient environment. This combination of events is sure to encourage root nodulation.

Other nutrients, such as iron and sulfur, which were investigated only on an exploratory basis, did increase yields of Canada milkvetch. But, these yields were less than the yields reported above. However, low levels of these nutrients did have marked effects on root growth, which may indicate the competitiveness of this species may be enhanced by applications of an iron chelate or sulfur at the rates of ten and five pounds to the acre, respectively.

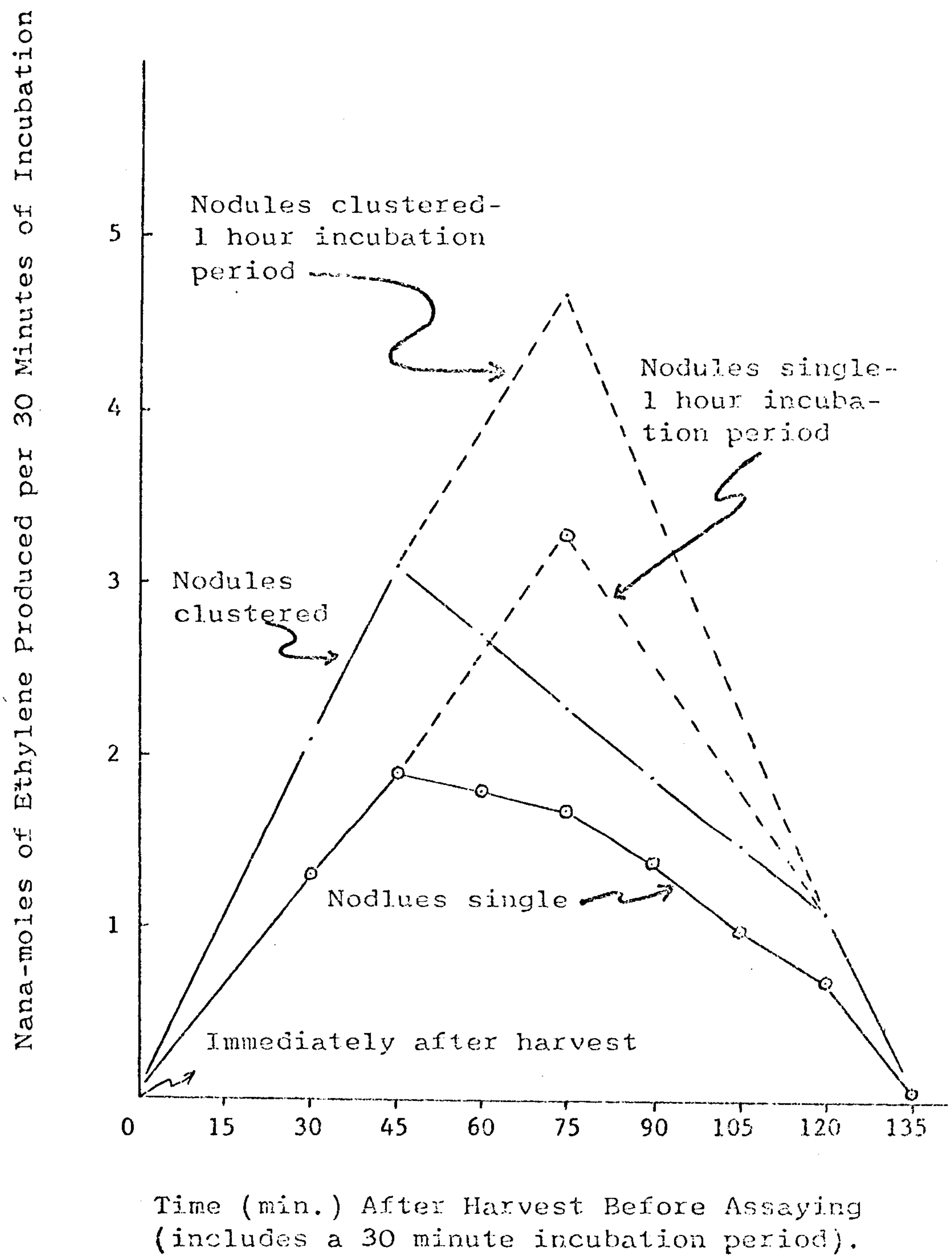
Nitrogen Fixation

Ethylene production proceeded almost linearly for approximately an hour if the nodules were placed in an atmosphere of acetylene immediately after harvest. The time course of the production of ethylene is illustrated in Figure 16. Each datum point on the graphs is an average of four samples.

The ratio of moles of acetylene reduced to moles of nitrogen fixed is approximately 3:1 (Hardy et al., 1968). The data reported herein would indicate that the rates of reduction are rather low (Schwinghamer et al., 1970). The plants had to be soaked one-three hours in order to remove the soil from the roots. This may have limited oxygen to the roots for too long a period. Oxygen has been recently reported to be required for optimum activity of nodules (Sprent, 1969).

This investigation has shown that nodules of Canada milkvetch do reduce acetylene to ethylene. These results then demonstrate that this method can be used to evaluate nitrogen fixation of intact nodules of Canada milkvetch. The nodules should be incubated

Figure 16. Time Course of Nitrogen Fixation.



immediately after harvesting. And, an incubation period of one hour seems best for obtaining maximum fixation. Thereafter, the reaction falls off rapidly probably due to inactivity of the nitrogenase enzyme.

Succession

Residual Seed

The principal grass species which germinated from seed residual in the soil were Calamagrostis rubescens, Deschampsia elongata, Arrhenatherum elatius, and Bromus marginatus with traces of Elymus glaucus, Festuca occidentalis, and Bromus tectorum; these species are listed in descending order of importance. The principal forb species in descending order of importance were Circium vulgare, Collinsia parviflora, Frageria spp., and Epilobium paniculatum. Shrub species were not important from any of the soil samples. Physocarpus malvaceus and Holodiscus discolor were the only woody species represented.

No species germinated from size fraction No. 4 in any of the samples. The 0.5 mm. screen was apparently small enough to retain seeds in size fraction No. 3.

The results presented in Tables 16 and 17 were obtained within the first 82 days. No seedlings were observed in the remaining days of the germination periods. Forbs were the first to germinate and

Table 16. Seed residual in the duff layer of undisturbed forest soil.

Site A[1]

Species	No. Seedlings	Percent
Viola adunca adunca	4	4.3
Circium vulgare	34	36.6[2]
Epilobium paniculatum	6	6.4
Collinsia parviflora	20	21.5[2]
Montia perfoliata	3	3.2
Gnaphalium palustre	4	4.3
Frageria spp.	1	1.7
Stellaria sp.	2	2.1
Verbascum thapsis	1	1.7
Forbs	75	80.8
Poa pratensis	5	5.4
Bromus marginatus	2	2.1
Calamagrostis rubescens	7	7.5
Grasses	14	15.0
Physocarpus malvaceus	2	2.1
Holodiscus discolor	2	2.1
Shrubs	4	4.2
Totals	93	100.0

[1] Soil sample was not separated into size fractions.

[2] Circium vulgare and Collinsia parviflora were the most abundant species on the unseeded areas of the clear-cut study area in 1968.

Table 17. Seed residual in the duff layer of soil from an unseeded plot of clear-cut study area.

Size Fraction	Species	No. Seedlings	Percent
1	Bromus marginatus	7	70.0
	Deschampsia elongata	2	20.0
	Calamagrostis rubescens	1	10.0
		10	100.0
2	Unidentified Forb	4	3.9
	Arnica cordifolia	1	1.0
	Calamagrostis rubescens	90	87.4
	Elymus glaucus	2	1.9
	Arrhenatherum elatius	2	1.9
	Other grasses	4	3.9
		103	100.0
3	Unidentified Forb	2	1.4
	Circium vulgare	1	0.7
	Arnica cordifolia	2	1.4
	Poa pratensis	4	2.8
	Calamagrostis rubescens	118	83.7
	Elymus glaucus	1	0.7
	Arrhenatherum elatius	5	3.5
	Phleum pratense	1	0.7
	Other grasses	7	5.0
		141	100.0
4	No seed germinated		

did not germinate after the first 30 days. Grasses began to germinate within six days and continued to germinate up to the 82nd day. One of the reasons why germination ceased was the dense growth of cryptogams on the surface of the soils.

Observations were made on these soils for three months after the germination trial was terminated. No seedlings emerged through the moss layer during the fifth and sixth months. However, during the seventh month Carex sp. seedlings grew up through the moss layer.

No Carex seeds were seen in any of the soil samples examined. These seeds are quite small and apparently are not easily distinguished from soil particles.

This investigation was repeated using size fraction No. 1 of each sample and some selected fractions of sample "c." There were no significant changes in the kind of species observed. The only new species observed was Arnica cordifolia. Two plants of this species grew from pieces of rhizomes in sample "a" of Site A. This was the only species that reproduced vegetatively.

The correlation between the number of seeds counted in the soil samples (Table 18) and the number of seedlings produced (Table 19) is not always good. This is because the seeds of some species were not counted apparently due to their small size and/or likeness to soil particles. And, often when the germination tallies were less than the

Table 18. Number of intact seeds residual in the soil as determined by actual count (seeds per four grams of soil).

		a_2[1]	a_3	b_2	b_3	c_2	c_3
Site A--Undisturbed mixed-coniferous forest with open canopy	Brte[2]	1			No Seed		No Seed
	Popr		1				
	Podo	1	1	1			
	Copa					1	
	Forb		1			1	
	Total	2	3	1	-	2	-
Site F: Selective-cut in mixed-coniferous forest		No Seed	No Seed	No Seed	No Seed		No Seed
	Ascam					1	
	Total	-	-	-	-	1	-
Nursery area adjacent to Exclosure 1	Deel	1					1
	Feoc	7		5			
	Arel	8		1			
	Phpr	9		3			
	Brome	6	1	2	1		
	Grass spp.	17					
	Ascam	42		29		8	
	Forb	9		3	3		1
	Cevev					1	
	Conifer			5			
	Total	99	1	48	4	9	2
Exclosure 1--Seeded	Deel	60	76		10		
	Trca		1				
	Popr	4	1				
	Feoc	1	2				
	Arel	2					
	Phpr	1					
	Caru	2		3		2	1
	Grass spp.	3	7				
	Ascam	4					
	Eppa	11	2				
	Podo	1					
	Composite	1					
	Forb	2					
	Conifer	1					
	Total	93	89	3	10	2	1
Exclosure 1--Unseeded	Deel	--[3]	--	3	No Seed	No Seed	No Seed
	Total	--	--	3			

[1] Letter refers to soil sample; number refers to size fraction.

[2] Symbols defined in Appendix I.

[3] Seeds in sample "a" were not counted.

Table 19. Residual seed in four gram soil samples as determined by germination in a growth chamber.

Soil Sample	Size Fraction	Grasses (Percent)	Forbs	Number of Seedlings
Site A: Undisturbed mixed coniferous forest with open canopy				
a	No. 1	50.0	50.0	2
a	No. 2	100	--[1]	1
a	No. 3	31.2	68.8	16
b	No. 1	--	--	--
b	No. 2	--	--	--
b	No. 3	--	100.0	2
c	No. 1	--	--	--
c	No. 2	--	--	--
c	No. 3	--	100.0	4
Site B: Undisturbed mixed coniferous forest with dense canopy				
a	No. 1	100.0	--	1
a	No. 2	100.0	--	4
a	No. 3	31.6	68.4	19
b	No. 1	--	--	--
b	No. 2	--	--	--
b	No. 3	14.3	85.7	7
c	No. 1	--	100.0	1
c	No. 2	66.7	33.3	3
c	No. 3	--	--	--
Site F. Selective-cut in mixed-coniferous forest				
a	No. 1	--	100.0	1
a	No. 2	--	100.0	3
a	No. 3	--	--	--
b	No. 1	--	100.0	1
b	No. 2	--	--	--
b	No. 3	--	--	--
c	No. 1	--	--	--
c	No. 2	--	--	--
c	No. 3	--	--	--

Table 19. Continued.

Soil Sample	Size Fraction	Grasses (Percent)	Forbs	Number of Seedlings
Nursery area adjacent to Exclosure 1				
a	No. 1	100.0	--	7
a	No. 2	77.2	22.8	44
a	No. 3	75.0	25.0	40
b	No. 1	100.0	--	1
b	No. 2	50.0	50.0	22
b	No. 3	33.3	66.7	9
c	No. 1	--	--	--
c	No. 2	100.0	--	2
c	No. 3	--	--	--
Exclosure 1--Seeded				
a	No. 1	100.0	--	3
a	No. 2	94.5	5.5	110
a	No. 3	86.2	13.8	87
b	No. 1	--	--	--
b	No. 2	86.7	13.3	15
b	No. 3	92.0	8.0	25
c	No. 1	--	--	--
c	No. 2	100.0	--	14
c	No. 3	80.0	20.0	10
Exclosure 1--Unseeded				
a	No. 1	—[2]	—	—
a	No. 2	--	--	--
a	No. 3	--	--	--
b	No. 1	--	--	--
b	No. 2	87.5	12.5	8
b	No. 3	--	--	--
c	No. 1	--	--	--
c	No. 2	85.7	14.3	7
c	No. 3	100.0	--	9

[1]No seedlings observed.

[2]No data available; soil was used in first investigation.

actual count, hard-seeded species like Canada milkvetch were involved. No seedlings of hard-species like Ceanothus sp. or Canada milkvetch were obtained; however, only decayed seeds of Ceanothus sp. were seen in the soil samples examined microscopically. Likewise, no sound coniferous seeds were seen in any of the samples even though they were one of the most abundant seeds present in the soil.

In addition to the above investigations, several other observations were made both in the uncut forest and clear-cut area to determine if seeds of Canada milkvetch are present in the duff layer. Seeds of this species were found only under and near active clones. The seeds apparently are not dispersed by wind or any other agent. The pods merely fall to the ground where they decay and release their seeds. This explains why seeds of Canada milkvetch are commonly found in patches.

The number of Canada milkvetch seeds per square foot ranged from less than ten seeds to more than 300, depending upon the size and vigor of the clone.

Community Analyses

The data presented in Table 20 cannot be compared to any other data previously collected. This is because the data obtained by Pettit (1968a) was based on observations from 1' x 1' plots, whereas the

Table 20. Frequency and percentage composition by species on experimental area. (June, 1968; cover data in Appendix IX)

	Ex 1					Ex 2				
	Bottom Seeded	Brma	Elgl	Bottom Unseeded	Top Unseeded	Bottom Seeded	Brma	Elgl	Bottom Unseeded	Top Unseeded
	F/C	F/C	F/C	F/C	F/C	F/C	F/C	F/C	F/C	F/C
<u>Grasses and Carexes</u>										
Brte[1]	20/4	25/4	2/T[2]	48/17	90/21	28/7	50/1	32/3	55/15	62/13
Fepa			2/T		2/T		2/T		2/T	
Brbr							5/T		5/T	
Caro	65/11	48/3	40/3	52/12	60/6	8/20	40/18	50/10	62/10	75/16
Caco	30/1	8/T	20/T	12/T	48/2	18/1	40/3	25/5	28/2	38/3
Cage	18/T	20/1		5/T			8/T	8/T	5/T	5/1
Caru	5/T	5/1		2/T		28/18			5/T	5/T
Feoc	5/T			8/T	28/1		8/T	18/3	12/T	20/1
Trca				2/T						2/T
Mebu										8/T
Stcon				5/T	2/T					
Hoju				5/T						
Deel	5/T		2/T	18/T	28/T		20/T		38/13	10/1
Popr	5/T		5/T		10/1	2/T	2/T		12/4	8/T
Dagl	90/23		2/T	50/19	5/T	85/26			15/2	2/T
Phpr	82/14			32/4	2/T	45/4	8/T	8/T	5/T	2/T
Arel	72/10		5/T	12/3	5/T	35/9		5/2	10/T	8/T
Brin	48/4			12/2		10/1			2/T	
Elgl		12/1	98/59	10/T	15/T			92/38		12/T
Brma		100/59			35/2	5/T	85/23	2/T	2/T	30/T

Table 20. Continued.

	Ex 1 Bottom Seeded	Ex 1 Brma	Ex 1 Elgl	Ex 1 Bottom Unseeded	Ex 1 Top Unseeded	Ex 2 Bottom Seeded	Ex 2 Brma	Ex 2 Elgl	Ex 2 Bottom Unseeded	Ex 2 Top Unseeded
	F/C	F/C	F/C	F/C	F/C	F/C	F/C	F/C	F/C	F/C
<u>Forbs</u>										
Ascam	80/9	22/2	70/10	75/11	88/9	60/8	40/6	60/5	50/9	78/10
Gnmi					18/2	5/T			5/T	5/T
Fraga	40/4	15/1	10/1	45/7	28/3	10/1	22/2	50/3	18/4	32/4
Acmil	2/T	35/4	10/1	2/T	18/2		28/3	25/1	8/T	8/T
Arco	8/T	38/5	18/3	8/T	20/2		20/T	20/T	8/T	12/T
Lumuc2		2/T								
Trdu				2/T						
Pogl	2/T									
Libu		8/T	2/T							
Lupob		2/T								
Gebi					8/T					
Polem		8/T								
Caco2		5/T								
Anlu									4/T	
Civu	62/7	52/6	90/14	70/10	98/10	75/12	50/16	88/12	88/24	98/27
Eppa	62/3	72/9	65/10	55/7	68/7	15/T	52/8	30/1	62/2	60/4
Ruac	20/2		5/T	10/1	12/T	2/T	15/4	50/4	10/T	18/2
Copa	38/4	50/6	28/4	28/3	62/7	12/T	25/1	20/1	35/3	52/3
Epan										10/T
Cogr2		10/T					2/T	10/T		
Veth			2/T		20/2		10/T		8/T	10/T
Phhe	5/T	8/T	5/T	10/T	8/T	2/T	2/T		8/2	10/T
Bor.							2/T			
Craf					2/T		8/T		20/1	
Cru.		2/T			2/T					
Descu		2/T			5/T					

Table 20. Continued.

	Ex 1					Ex 2				
	Bottom Seeded F/C	Brma F/C	Elgl F/C	Bottom Unseeded F/C	Top Unseeded F/C	Bottom Seeded F/C	Brma F/C	Elgl F/C	Bottom Unseeded F/C	Top Unseeded F/C
Forbs										
Lase		5/T	5/T	2/T	20/T					
Viada	40/4	12/1	10/1	10/1	18/1	2/T	18/T	18/T	12/T	20/T
Anor	12/1	20/2	15/2	10/1	18/2		2/T	15/T		2/T
Thfe	5/T		2/T	8/T	2/T			15/T		
Gatr		10/1								
Mope	8/T	30/3	50/7	12/1	60/6		5/T	5/T	5/T	
Taof	20/T	2/T					2/T	5/T		
Lathy						5/T	5/T	2/T		
Arma3		18/2	8/3				5/T		10/T	
Frpu		18/2	2/T							
Trifo	2/T									
Shrubs										
Cesa	10/1	62/8	35/5	2/T	10/1	10/T	35/7	12/2		38/6
Phma	8/T	70/9	22/3	5/T	38/4		10/T	20/2	5/T	10/T
Spbel	38/4	18/2	25/3	18/3	22/2		2/T	18/2	12/T	28/1
Cevev	10/1	2/T	8/1	15/2	8/T	2/T		10/1		
Salix	8/T		2/T	2/T	5/T	2/T	2/T	2/T		5/T
Hodi			2/T						2/T	
Syal	12/1	8/T		5/T				5/T		
Rivi	8/T			5/T		2/T			8/T	8/T
Ricec		2/T							2/T	
Amal								2/T		
Sace					2/T					
Rogy	2/T	8/T	5/T		5/T		2/T	2/T	2/T	
Bere	2/T			2/T						
Vame	2/T									

1 Symbols defined in Appendix I. 2 T = <1%.

data herein are based on 1' x 5' plots. The plot size was changed to reduce the amount of time required to gather these data. However, these data show that the trends of plant succession are the same as Pettit (1968a) reported. That is, the seeded plots are dominated by the introduced grass species and the most important perennial forb is Canada milkvetch. Circium vulgare and other forbs associated with disturbance have become minor species. In fact, competition from the seeded species was strong enough that Circium vulgare and other forbs associated with disturbance have become minor species. In fact, competition from the seeded species was strong enough that Circium vulgare did not develop beyond the three to five leaf stage of the rosette phase of its life cycle during the summers of 1968-1970.

Bromus tectorum, Carex rossii, Circium vulgare, and Canada milkvetch are the dominant species on the unseeded plots.

The differences between the two exclosures can be accounted for largely by the inherent variability of the two locations. However, differences do exist because of grazing. Exclosure 2 was grazed earlier in the season for the first two years than Exclosure 1. Because Exclosure 1 was grazed in 1966 and 1967 about the time of seed maturity of the introduced species, orchardgrass became well established in the unseeded and seeded plots as well. The trampling activities of the animals prepared an excellent seedbed for this species. This was also true for the coniferous species.

The frequency data (Table 20) indicate the distribution of the introduced species has not enlarged from the original plots. However, the distribution of Circium vulgare has decreased on the seeded plots, being restricted to the areas which have disturbed soil surfaces. This disturbance is due to rodents and/or trampling. Erosion seems to be minimal in this area, even on the skid trails.

The comparisons that can be made in Table 20 indicate that seeding disturbed sites is advantageous because increased production is possible. In other words, range improvement practices can coincide with standard forestry practices to improve production.

The maturity indices reported in Table 21 for the clear-cut area point out that the study area is rather low in the successional hierarchy. Therefore, rapid changes in plant densities and dominance are expected to occur.

Canada milkvetch was not recorded as being present on the study area prior to logging and burning which occurred in 1963 and 1964, respectively. In 1965 its frequency was approximately 11 percent in Exclosures 1 and 2 (Table 22). From 1965 to 1966 this frequency increased nearly 2.5 times in Exclosure 1 and 75 percent in Exclosure 2. This rapid increase continued until 1967 and 1968. Then from 1968 to 1970 the frequency of Canada milkvetch greatly decreased, approaching the frequency of 1965 in some cases. The latter trend has also documented with respect to cover (Table 23)

Table 21. Maturity indices of clear-cut study area and mature mixed-coniferous forest.

Site	Total Number Species Present	Maturity Index[1]	Date of Sampling
Clear-cut Study Area			
Bottom Seeded			
Ex 1	32	28.7	1968
Ex 2	17	28.3	1968
Brma			
Ex 1	31	27.0	1968
Ex 2	26	23.8	1968
Elgl			
Ex 1	25	27.2	1968
Ex 2	26	27.8	1968
Bottom Unseeded			
Ex 1	28	23.9	1968
Ex 2	28	23.9	1968
Top Unseeded			
Ex 1	33	29.9	1968
Ex 2	27	28.8	1968
East Side of Hall Ranch (Uncut Mixed-Coniferous Forest)			
	13	55.1	1967
West Side of Hall Ranch (Selective cut in 1960; Mixed-Coniferous Forest)			
Intermed. canopy (21-40% crown cover)	19	53.6	1967
Open canopy (0-20% crown cover)	39	21.3	1969

[1] Maturity index = $\frac{\text{total frequency percentages of all species}}{\text{number of species found at a given locatin, plot or sample}}$.

Table 22. Frequency of Canada milkvetch on clear-cut study area (based on 1' x 1' plots).

	Unseeded			Seeded	
	Bottom	Top	Bottom	Brma	Elgl
			Ex 1		
1965	12	10	11	11	11
1966	34	23	39	24	39
1967	66	33	56	32	50
1968	60	--[1]	37	--	--
1970	18	30	28	10	25
			Ex 2		
1965	8	10	17	8	10
1966	12	21	24	12	23
1967	24	33	32	26	30
1968	49	--	29	--	--
1970	14	11	19	15	28

[1] No data available.

Table 23. Percentage cover of Canada milkvetch on clear-cut study area.

	Unseeded		Seeded		
	Bottom	Top	Bottom	Brma	Flgl
			Ex 1		
1966	15.9	14.2	24.1	9.2	17.4
1968	4.8	7.8	7.9	2.4	6.0
1970	1.1	2.0	1.9	0.7	1.1
			Ex 2		
1966	2.3	5.9	7.6	4.0	7.5
1968	4.9	2.5	1.3	1.8	1.2
1970	0.8	0.5	1.2	0.6	1.2
			Percentage Change		
			Ex 1		
1966-68	-69.8	-45.1	-67.2	-73.9	-65.5
1966-70	-93.1	-89.5	-92.1	-92.4	-93.7
			Ex 2		
1966-68	+113.0	-57.6	-69.7	-55.0	-84.0
1966-70	-65.2	-91.5	-84.2	-85.0	-84.0

and density (Tables 24 and 25).

An increase in the amount of Canada milkvetch is a function of the overstory canopy and the amount of soil disturbance. This species is rarely found in a dense forest. It is found at the edge of the forest, in logged areas, and in clear-cut areas. Invariably, this species grows on soils which have been highly disturbed, i.e., skid roads, log landings, and road banks.

The data given in Table 26 indicate that burning is not necessary for establishment of Canada milkvetch. However, none of the sites reported in Table 26 have had the high densities and production of this species which existed on the clear-cut study area.

Forage Value of Canada Milkvetch

The levels of crude protein and phosphorus are high in each stage of plant development (Table 27). This species greatly increases the value of the total forage produced on the experimental site. Analyses of other forages, i.e., Dactylis glomerata and Carex geyeri harvested in late July contained 3.65 and 6.08 percent crude protein, respectively, indicate herbaceous species have less nutrient quality than desirable.

The analyses reported in Table 28 show Canada milkvetch is a valuable forage even late in the season. Only when the crude protein content drops below about 18 percent does the phosphorus content

Table 24. Density of Canada milkvetch as determined from 1' x 100' transects in the clear-cut study area.

Treatment	Protected			Ex 1			Ex 2		
	1968	1969	1970	1968	1969	1970	1968	1969	1970
	(plants/100 sq. ft.)								
Seeded	205	70	13	115	168	23	119	--[1]	8
Unseeded	366	100	25	270	100	17	220	--	9

[1] No data available.

Table 25. Percentage change in density of Canada milkvetch on the study area (A) from 1968 to 1969, and (B) from 1968 to 1970 (based on number of plants per 100 sq. ft.)

Treatment	Protected		Ex 1		Ex 2
	A	B	A	B	B
Seeded	-65.9	-88.8	+46.0	-80.0	-93.3
Unseeded	-72.7	-93.2	-63.0	-93.7	-95.9
Ave. % Decrease	-69.3	-91.0	-9.5	-86.9	-94.6

Table 26. Density of Canada milkvetch under three regimes of forest canopy (data obtained in 1968).

Site		Open (0-20% crown cover)	CANOPY Intermediate (21-40% crown cover) (plants/100 sq. ft.)	Dense (41-100% crown cover)
A	(mature forest)	24	14	0
B	(mature forest)	24	6	0
C	(selective-cut)[1]	75	--[2]	--
D	(selective-cut)[1]	--	20	--
Ea	(burned)[1]	2	--	--
b	(logged)[1]	0	54	--
Fa	(selective-cut)[1]	125	65	--
b	(clear-cut)[1]	63	--	--

[1]Indicates disturbance since 1960.

[2]No data available.

Table 27. Nutrient analyses of Canada milkvetch at different stages of development.

Date	Plant Maturity[1]	Dry Matter %	Ash %	CP %	N %	Ca %	P %
12 July 1969	Young	94.73	6.56	23.33	3.73	0.95	0.25
12 July 1969	Intermediate	94.87	7.62	20.25	3.24	1.30	0.23
12 July 1969	Mature	94.55	7.89	19.79	3.17	1.20	0.22
14 Aug. 1969	Mature w/some regrowth	94.01	6.20	23.59	3.77	1.46	0.28

[1] Young = small plants without flowers.

Intermediate = flower stalks with buds only.

Mature = pods ripening.

Table 28. Nutrient analyses of mature Canada milkvetch plants.

	Dry Matter %	Ash %	CP %	N %	Ca %	P %
20 July 1966	--[1]	--	15.71	--	--	--
18 July 1968	93.93	5.45	16.34	2.61	0.96	0.14
12 July 1969	94.55	7.89	19.79	3.17	1.20	0.22
16 Aug 1968	94.06	4.15	13.09	2.10	0.91	0.11
14 Aug 1969	94.01	6.20	23.59	3.77	1.46	0.28
13 Sept 1965	--	--	21.43	--	--	--
26 Sept 1967	--	--	22.41	--	--	--
17 Sept 1968	93.62	6.70	25.77	4.12	1.60	0.26

[1]No data available.

fall below the desirable level. However, there are sufficient other kinds of forages to more than off-set this decrease.

Effects of Grazing on Canada Milkvetch

Plant Vigor

Plant height is influenced by environmental conditions as well as grazing by ruminant animals. Plants growing in shaded spots and on the upper slope of the experimental area were smaller and remained vegetative longer than those plants which grew on the bottom of the slope. This seemed to be true regardless of seeding treatment.

In 1968 the plants in Exclosure 2 appeared to be less vigorous than those in Exclosure 1. They did not mature as early and their stems remained more succulent throughout the growing season. The exact reverse of this situation occurred during the summer of 1969. Therefore, it was concluded that grazing by cattle and deer greatly lowers the vigor of this species.

Deer preferentially graze Canada milkvetch early in the spring, and continue to graze this species as long as it remains vegetative. In fact, deer grazing may prolong the vegetative stage so long that it does not initiate flower buds. On the other hand, cattle prefer to eat the inflorescences and upper leaves. And, the degree of use by cattle on this species seems to be related to the degree of use on associated species. Thus, Canada milkvetch will be heavily grazed, only if the associated grasses are also heavily grazed.

The increases in plant height from 1969 to 1970 reported in Table 29 are related to the absence of deer grazing in both exclosures. Grazing by deer in Exclosure 1 has occurred only in 1969. And, in the case of Exclosure 2 as the clear-cut has become older, use by deer has decreased.

Plants from areas grazed by both wild and domestic animals have a very stout caudex. The plants also have a rosette or hedged-like growth habit. The roots of these plants tend to be less numerous and shallower, which accounts for why these plants tend to wilt in late summer.

Cattle and deer grazing also decreases the vigor of stands of Canada milkvetch evidenced by the large increases in plants less than two inches tall. These data are reported in Table 30. The densities upon which these data are based are in Table 31. None of these plants were seedlings, but were shoots from rhizomes. These shoots do not often flower, but remain vegetative all season long.

The data of Table 30 also indicate Canada milkvetch is more competitive on the seeded plots. The species on the seeded plots are rather deeply rooted as compared to Canada milkvetch, so there is less competition for space and soil moisture than on the unseeded plots, which are dominated by shallow rooted annuals and short-lived

Table 29. Average height of ungrazed Canada milkvetch plants (measured to top of inflorescence).

	Protected[1]	Ex 1 (cattle only except 1969)	Ex 2 (cattle plus wildlife)
	(Inches)		
1968	17.1	9.9	6.8
1969	14.8	8.7	11.2
1970	17.2	14.8	12.7
	Percentage Change		
1968-1969	-13.4	-12.1	+64.7
1968-1970	+0.6	+59.6	+86.8

[1] Grazed by deer 18 April to 20 June 1969.

Table 30. Percentage of Canada milkvetch plants less than two inches tall.

	Seeded		Unseeded	
	1968	1970	1968	1970
Protected	30.2	3.3	9.8	17.9
Ex 1	17.5	24.2	15.5	18.2
Ex 2	21.0	32.4	11.8	39.0
	Percentage Change from 1968 to 1970			
Protected	-85.7		+82.6	
Ex 1	+38.3		+17.4	
Ex 2	+54.2		+230.5	

Table 31. Densities of Canada milkvetch upon which the data of Table 30 are based.

	(plants/100 sq. ft.)			
	Seeded		Unseeded	
	1968	1970	1968	1970
Protected	205	31	366	20
Fx 1	114	32	270	29
Ex 2	119	18	220	19

perennials.

The average dry weight yield per plant as given in Table 32 again shows that deer preferentially graze Canada milkvetch. The fact that the dry weight yield per plant decreased in Exclosure 1 by more than one-half and doubled in Exclosure 2 suggest this species might be used as an index for evaluating deer grazing on a given area.

Even though cattle do graze Canada milkvetch, there is not a marked influence on the vigor of the plants as evaluated from its reproductive potential. Only the combination of grazing by both cattle and wild game influence the number of blossoms produced per inflorescence. This is substantiated by the analyses reported in Table 33.

Yields

During 1966 and 1967 Exclosure 2 was grazed by cattle earlier in the season than Exclosure 1. Grazing began in Exclosure 1 on 13 August and 22 July in 1966 and 1967, and it began in Exclosure 2 on 15 July and 30 May, respectively. The years of highest use of the experimental area by wild game occurred during 1966 and 1967.

Canada milkvetch was undoubtedly heavily used in 1966 and 1967 while it was becoming established on the experimental area. This is particularly true for Exclosure 2 because this species was

Table 32. Average dry weight yield of Canada milkvetch per plant (plants harvested in mid-August).

	1968	1969
	(g/plant)	
Nursery area[1]	1.23	1.51
Protected[2]	0.59	0.25
Grazed Ex 1[2]	0.55	0.25
Ex 2	0.22	0.44

[1]Complete protection from grazing.

[2]Grazed by eight captive deer 18 April-20 June 1969; protected from cattle grazing summer, 1969.

Table 33. Statistical analyses of differences in numbers of blossoms per inflorescence on Canada milkvetch.

Grazing Treatment	Sample Size n	Mean $\bar{x}$	Standard Deviation s	Standard Error E
1. Protected	50	47.1	14.0712	1.99
2. Cattle only	50	45.3	11.7473	1.66
3. Cattle + wild game	50	29.5	9.8992	1.40

Standard error of difference between means (E_D)		$\frac{\text{Difference between means}}{E_D}$
Between 1 and 2	2.59	0.694
Between 1 and 3	2.43	7.24[1]
Between 2 and 3	2.17	7.74[1]

[1]Significant at 99% level.

grazed early in the spring by deer and elk alike, and because this exclosure was used by cattle in the season when they would most likely graze it. This is probably the reason why Canada milkvetch has never been as productive in Exclosure 2 as in Exclosure 1, even though the number of plants in either exclosure has probably been similar in any given year.

Data for the above comparisons are presented in Tables 34 and 35.

Table 34. Yields of Canada milkvetch (lbs./acre).

Date (mid-Aug.)	Protected	Grazed		Average
		Unseeded	Seeded	
		Ex 1		
1966	--[1]	755.2	327.6	541.4
1967	--	303.8	271.6	287.7
1968	253.1[2]	--	--	84.6
1969	257.0[2]	19.0	38.0	28.5
		Ex 1		
1966	--	50.1	54.3	52.2
1967	--	29.9	126.9	78.4
1968	63.3[3]	--	--	36.4
1969	26.0[3]	21.0	34.5	27.5

[1] No data available.

[2] Complete protection from grazing.

[3] Protected from cattle only.

Table 35. Average density of Canada milkvetch in clear-cut study area (based on plants per 96 sq. ft.).

Date (mid-Aug)	Protected	Grazed: Unseeded Bottom	Grazed: Unseeded Top	Grazed: Seeded Bottom	Grazed: Seeded Brma	Grazed: Seeded Elgl	Ave.
				Ex 1			
1968	271.0	--[1]	--	--	--	--	
1969	71.0	42.4	19.2	42.5	14.8	0.5	39.6
1970	27.0	23.0	3.8	29.5	7.0	4.5	13.6
				Ex 2			
1969	--	26.3	24.8	50.3	48.2	33.0	38.5
1970	--	20.2	8.0	24.5	8.0	12.0	14.5

[1] No data available.

SUMMARY AND CONCLUSIONS

The purpose of this study was to ascertain the features of the life history of Canada milkvetch and its response to range and forestry improvement practices in northeastern Oregon.

The field research was conducted on the experimental area maintained on the Hall Ranch of Eastern Oregon Experiment Station. This area was clear-cut and burned in 1963 and 1964, respectively. Initially, Canada milkvetch was a minor species on the study site, but in 1967 it became one of the most important forb species present. This highly palatable plant has high forage value and is capable of fixing atmospheric nitrogen.

Environmental measurements were recorded at locations within the experimental area and adjacent stand of mixed-coniferous forest.

Air temperatures were recorded at three feet and one foot above the ground. Analyses of the deviations in temperature as recorded in the clear-cut area from the temperatures in the mature forest are not as sensitive as analyses of the temperature differentials for differentiating the two environments. The minimum temperatures are the ones which can be used most reliably to differentiate the environment of the experimental area from that of the mature forest.

Tolo silt loam has a high saturation percentage and a high water holding capacity. These characteristics plus good soil depth, which is typical of this series, make this soil one of the most productive forest soils in northeastern Oregon and adjacent Washington.

There is a good correlation between milliamp readings obtained using gypsum soil moisture blocks and the soil moisture content of the soil. However, this relationship is not as good when Coleman soil-moisture units are used. The Coleman units can be recommended only if soil conditions cause the gypsum blocks to malfunction.

The forest canopy markedly affects the amount of moisture stored in the soil only when the amount of precipitation during the precipitation year (September-May) is low. The precipitation received during 1965-66 was only 14.4 inches, which is about 40 percent below the average. The forested sites averaged less than 50 percent of the total soil moisture possible to be stored, whereas, all the locations within the clear-cut approached 100 percent of the total possible.

The soil moisture trends throughout the growing season point out that grasses use considerably less soil moisture than trees. These data also indicate grazing can be used to reduce soil moisture losses via transpiration; thereby increasing the opportunity for young trees to become better established and grow with minimum competition for water, space, and light.

The soil pH in the forest canopy has remained stable. However, the pH in the experimental area is quite variable and has undergone several changes. Locations on which plant materials have not accumulated have the lowest pH values; those which have accumulations of litter have the highest pH values. The former locations have been grazed the heaviest, and the latter ones are only sparsely grazed.

The amount of soil temperature data obtained is not adequate to be used to characterize the differences between the environments of the clear-cut and the mature forest. However, a uniform stand of herbaceous species, such as Canada milkvetch, seems to create an environment which is stable enough to maintain soil temperatures at two inches deep similar to those recorded in the forest.

The taxonomy of Canada milkvetch according to Hitchcock et al. (1961) is considered to be correct. The range of this variety is much smaller than the type species, being restricted to the northeastern Oregon, southeastern Washington, and the northern Rocky Mountains in Idaho and adjacent Montana.

Canada milkvetch is an early growing species. Growth begins soon after snow melt and full vegetative growth is usually reached by early July. Flowering which begins early in June reaches a peak early in July. However, some plants may bloom as late as September. Only those flowers which are produced in late June and July produce pods, because cross pollination by a bumble bee (Bombus sp.) seems to be necessary. This is the period when the bumble bee is most active and it is the only insect observed to seek out and open Canada milkvetch blossoms. Ovaries of the flowers produced early or late in the season abort. This phenomenon was not observed on other legumes in the area, either native or introduced.

Canada milkvetch has a high reproductive potential which can be significantly influenced by deer grazing and a weevil species. However, this may be offset by effective vegetative reproduction. The reproductive potential is only moderately influenced by rodents.

The aerial shoots are deciduous at the end of each growth season. Every year new shoots arise from rhizomes which are most commonly found in the top six-eight inches of soil. Vegetative propagation is the most reliable form of reproduction in this species.

The tap root system of the seedling stage eventually gives way to the formation of a well developed rhizome system. The period of root growth was not determined because it is masked by growth of new shoots and flowering during the growing season. Perhaps root growth does not occur during the growing season, but occurs in late winter before spring growth begins.

Root nodulation coincided with the short period after vegetative growth was complete and before flowering. Maximum soil temperatures were also recorded during this same period of time. On the other hand, high air temperatures ($> 75°F$) greatly decreased the amount and size of nodules produced.

Nitrogen supplied at a rate equivalent to ten pounds per acre enhanced root nodulation and plant growth; whereas, 20 pounds decreased nodulation.

A carpet of moss invariably formed on surface of the pots containing soil from the study area. Roots growing into this layer were always nodulated, regardless of the state of nodulation or health of the remaining roots. Apparently these lower plants reduced the available nitrogen to a minimum level, which encourages nodule formation.

Only small amounts of Canada milkvetch seed were found to be residual in the soil. Therefore, the author is confident most of the plants of Canada milkvetch found immediately after disturbance originate from root stalks.

The principal seeds residual in soils from the mixed-coniferous forest belong to the Aveneae grass tribe.

The frequency, cover, and density of Canada milkvetch on the experimental area increased rapidly from 1965 to 1967; since then these parameters have decreased, approaching the values of 1965 in some cases.

The increase of Canada milkvetch is a function of the overstory canopy and soil disturbance. This species is typically found in disturbed soils at the edge of the forest and in disturbed soils of logged areas. The most vigorous and abundant growth of this species had been found on areas clear-cut and broadcast burned.

Canada milkvetch forage has high nutritive value throughout the growing season. This highly palatable forage is preferentially grazed by wild game and cattle. A grazing regime of cattle only does not affect plant vigor as much as cattle plus wild game. Under cattle grazing the degree of use on this species is related to the degree of use on associated species. Cattle prefer the succulent blossoms; whereas, deer graze the plant from the time it begins growth in the spring until they leave the area. Plant height, number of blossoms per inflorescence, dry weight yield per plant, and total yields can be used to evaluate the differences between the two grazing regimes. The plants are always more productive under a regime of cattle only than under a combination of cattle and big game.

Canada milkvetch is a hard seeded species. If the seeds are not pretreated an average of 6.5 percent per month for approximately four months will break dormancy, of which 4.5 percent will be sound seeds. The combination of hard seeds and the resultant slow germination may occur throughout the entire growth season. Those seeds which do not germinate remain hard and become a reservoir of seed in the soil. If the period of ideal conditions for germination is short, only a few seeds will germinate, also leaving a supply of seeds residual in the soil. Acid and heat treatments do increase germination, but these treatments also cause seeds to rot, which essentially eliminates seeds from being held over in the soil.

Clear-cutting followed by broadcast burning provides a fallow system which creates an ideal environment for establishment of Canada milkvetch. The year while the slash lies on the ground allows the soil to become fully charged with moisture. This increases the opportunity for better seedling establishment, and also minimizes the undesirable effects burning may have upon the properties of the soil. Germination data from moist heat experiments indicate more hard seed will be left in the soil if burning occurs in the spring and germination occurs while the temperatures are still cool. And, if burning occurs later in the season when the day time, air temperatures are rather warm, more seeds will rot than those under a lower temperature regime.

Seedling development is slow during the first season. Most of the growth occurs in the root system. This is advantageous because the plants are seldom grazed during the establishment stages. The seedlings are winter hardy and put on abundant growth the next spring. Growth begins soon after the snows melt, and because Canada milkvetch is preferred by wild game, it is often too heavily grazed to produce large, productive stands.

Calcium at rates of 120, 600, 1200 pounds to the acre seems to affect growth of Canada milkvetch similarly. This would indicate calcium is required as a nutrient and not as an amendment to change the pH of the soil.

It was intended to investigate the influence of iron, sulfur, calcium, and micronutrients upon nitrogen fixation, but not enough plants had sufficient nodules to obtain reliable results. Changes from cooler to warmer temperatures in the greenhouse during mid-April apparently were abrupt enough to interfere with nodulation.

More investigations are needed to evaluate the effect of fertilization upon growth and maintenance of this seral legume. The interactions of calcium with copper and cobalt may be a means of increasing the value of Canada milkvetch for forage production.

The acetylene reduction method can be used to evaluate nitrogen fixation in Canada milkvetch. However, the results obtained were not satisfactory probably because the plants had to be soaked in water in order to effectively remove the soil. Even though root development would not be typical, a growth medium such as pure sand would be more desirable from the standpoint of harvesting nodules.

As a colonizer species, Canada milkvetch does have large amounts of variance for fecundity, but does not meet the other criteria of effective dispersal or high somatic plasticity. The period of time it displays high interspecific competitive ability is so short that it suggests the problem may be nutritional. Perhaps there is a selective competition between the grasses and the legume for certain nutrients, in which the grasses are more successful. Some exploratory studies indicate that applications of iron or sulfur increase root growth. And, calcium was demonstrated to greatly affect vegetative growth and to some extent nodulation.

If a relationship does exist between nutrition and nodulation, it seems reasonable that fertilization with nutrients essential for root growth and nodulation may prolong the period in which Canada milkvetch is productive on clear-cut and burned areas of the Wallowa Mountains.

A carpet of mosses and liverworts was present on the experimental area during 1965-1967. As the grass seedings become established it was broken up to some extent. However, it was the trampling of the cattle which finally broke it up. This trampling prepares an ideal seedbed in Tolo soils. This encouraged the establishment of introduced and native herbaceous and woody species.

The most abundant and luxuriant growth of Canada milkvetch coincided with the years when the cryptogam layer was best developed. Perhaps in the natural sequence of events, the cryptogams utilize the surplus of nutrients released by burning, and nitrogen-fixing species such as Canada milkvetch follow to build up soil nitrogen. The invasion of this species would also encourage some development of soil structure in the surface layer of soil and build soil fertility. The presence of a legume greatly increases the nutritive value of the forage in the early successional stages. Perhaps future research on the nutritional requirements of Canada milkvetch will make it an even more valuable forage species by lengthening its productive period and increasing its competitiveness.

This research has again pointed out that forestry and range improvement practices must be coordinated and management intensified in order to maximize the biological potential of a given area and the income and/or services derived therefrom.

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APPENDICES

APPENDIX I. SPECIES LIST OF PLANTS FOUND IN STUDY AREAS

Symbol[1]	Scientific Name	Common Name

Grasses and Carexes

A. Annuals which increase with disturbance.

Brte	Bromus tectorum L.	Cheatgrass brome
Fepa	Festuca pacifica Piper	Pacific fescue
Brbr	Bromus brizaeformis, Fisch. & Mey.	Rattle brome

B. Perennials which are present in mature forest, which increase with disturbance.

Caro	Carex rossii Booth	Ross sedge
Caco	Carex concinnoides Mack.	Northwestern sedge
Cage	Carex geyeri. Booth	Elk sedge
Caru	Calamagrostis rubescens Buckl.	Pinegrass
Feoc	Festuca occidentalis Hook.	Western fescue
Trca	Trisetum canescens Buckl.	Tall trisetum
Mebu	Melica bulbosa Geyer	Oniongrass
Stcon	Stipa columbiana nelsonii (Scribn.) Hitchc.	Big subalpine needlegrass
Hoju	Hordeum jubatum L.	Foxtail barley
Deel	Deschampsia elongata (Hook.) Munro ex Benth.	Slender hairgrass
Popr	Poa pratensis L.	Kentucky bluegrass

C. Planted perennials (Elgl and Brma also native).

Dagl	Dactylis glomerata L.	Orchardgrass
Phpr	Phleum pratense L.	Timothy
Arel	Arrhenatherum elatius (L.O Presl.	Tall meadow oatgrass
Brin	Bromus inermis Leyss.	Smooth brome
Elgl	Elymus glaucus Buckl.	Blue wildrye
Brma	Bromus marginatus Nees	Mountain brome

D. Minor grass & grass-like species not sampled.

Agex	Agrostis exarata Trin.	Spike bentgrass
Poco	Poa compressa L.	Canada bluegrass
Sihy	Sitanion hystrix (Nutt.) J. G. Sm.	Bottlebrush squirreltail
Brmo	Bromus mollis L.	Soft brome
Agsc	Agrostis scabra Willd.	Winter bentgrass
Brra	Bromus racemosus L.	Smooth-flowered soft cheat
Juncu	Juncus spp.	Rush

Forbs

A. Plants found in mature forest, which increase with disturbance.

Ascam	Astragalus canadensis mortonii (Nutt.) Wats.	Canada milkvetch
Gnmi	Gnaphalium microcephalum Nutt.	Slender cudweed
Fraga	Frageria spp.	Strawberry
Acmil	Achillia millifolium lanulosa (Nutt.) Piper	Western yarrow
Arco	Arnica cordifolia Hook.	Heartleaf arnica
Lumuc2	Luzula multiflora comosa (F. Mey.) Fern & Wieg.	Hairy common woodrush
Trdu	Tragopogon dubius Scop.	Yellow salsify
Pogl	Potentilla glandulosa Lindl.	Gland cinquefoil
Libu	Lithophragma bulbifera Rydb.	Bulblet woodlandstar
Lupob	Lupinus polyphyllus burkei (Wats.) C. L. Hitchc.	Washington lupine
Gebi	Geranium bicknellii Britt.	Bicknell's geranium
Polem	Polemonium sp.	Jacob's ladder
Coca2	Conyza canadensis (L.) Crong.	Horseweed
Anlu	Antennaria luzuloides T. & G.	Rush pussytoes

B. Major species associated with extreme disturbance.

Civu	Circium vulgare (Savi) Airy-Shaw	Bull thistle
Eppa	Epilobium paniculatum Nutt. ex T. & G.	Autumn willowweed
Ruac	Rumex acetosella L.	Sheep sorrel
Copa	Collinsia parviflora Lindl.	Little flower collinsia
Epan	Epilobium angustifolium L.	Fireweed
Cogr2	Collomia grandiflora Doug ex Lindl.	Largeflower collomia

C. Minor species associated with extreme disturbance.

Veth	Verbascum thapsis L.	Glannel mullein
Phhe	Phacelia heterophylla Pursh	Varied-leaf phacelia
Bor.	Boraginaceae	
Craf	Cryptantha afinis (Gray) Greene	Slender cryptantha
Cru.	Cruciferae	
Descu	Descuriania sp.	Tansey-mustard
Lase	Lactuca serriola L.	Prickly lettuce

D. Species associated with mature forest under intermediate and open canopies.

Viada	Viola adunca adunca Sm.	Hook Violet
Anor	Anenome oregana Gray	Oregon anemone
Thfe	Thalictrum fendlerii Engelm. ex Gray	Fendler meadowrue
Gatr	Galium triflorum Engelm. ex Gray.	Fragrant bedstraw
Mope	Montia perfoliata (Donn) How.	Miners lettuce
Taof	Taraxacum officinale L.	Dandelion
Lathy	Lathyrus sp.	Pea vine
Arma3	Arenaria macrophylla Hook.	Bigleaf sandwort
Frpu	Fritellaria pudica (Pursh) Spreng.	Yellow bells
Trifo	Trifolium spp.	Clover

Forbs

E. Minor species not sampled.

Epgl	Epilobium glaberrium Barb.	Smooth willow-herb
Gnpa	Gnaphalium palustre Nutt.	Lowland cudweed
Goob	Goodyera oblongifolia Raf.	Rattlesnake plantain
Ciar	Circium arvense (L.) Scop.	Canada thistle
Poav	Polygonum aviculare L.	Prostrate knotweed
Lepe	Lepidium perfoliatum L.	Yellow-flowered peppergrass
Ospu	Osmorhiza purpurea (C. &R.) Suksd.	Purplish sweet cicely
Pima	Plantago major L.	Common plantain
Nadw	Nararretia dwaricata (Torr.) Greene	Short-stemmed navarretia
Smst	Smilicina stellata (L.) Dest.	False Solomon's seal
Sest	Sedum stenopetallum Pursh	Wormleaf stonecrop
Frige	Frigeron sp.	Daisy fleabane
Pogr	Potentilla gracilis Dougl. ex Hook.	Beauty cinquefoil
Podo	Polygonum douglasii Greene	Douglas knotweed
Anlu	Antennaria luzuloides T. & G.	Rush pussytoes
Sial	Sisymbrium altissimum L.	Tumblemustard
Senec	Senecio sp.	Ragwort
Amara	Amaranthus sp.	Pigweed
Saoc	Sanquisorba occidentalis Nutt.	Western burnet
Vese	Veronica serphyllifolia humifosa L.	Speedwell
Ergrp	Erythronium grandiflorum pallidum St. John	Pale lamstougue fawnlily
Argl	Arabis glabra (L.) Bernh.	Towermustard rockcress
Thmov	Thermopsis montana venosa (Fastw.) Jeps.	Shasta thermopsis
Maex	Madia exigua (J. E. Sm.) Gray.	Little tarweed
Ptag	Pteridium aquilinum (L.) Kuhn	Bracken
Stell	Stellaria sp.	Starwort
Smila	Smilicina sp.	False Solomon's seal
Adbi	Adenocaulon bicolor Hook.	Trailplant
Hial2	Hieracium albertinum Farr.	Western hawk weed
Prvu	Prunella vulgaris L.	Common selfheal
Ranum	Ranunculus sp.	Buttercup

Shrubs

A. Major shrub species-usually increase rapidly with disturbance.

Cesa	Ceanothus sanguineus Pursh	Redstem ceanothus
Phma	Physocarpus malvaceus (Greene) Kuntze	Mallow ninebark
Sphel	Spiraea betulifolia lucida (Dougl.) C. L. Hitch.	Birchleaf spirea
Cevev	Ceanothus velutinus velutinus Dougl. ex Hook.	Snowbrush ceanothus
Salix	Salix spp.	Willow
Hodi	Holodiscus discolor (Pursh) Maxim.	Creambrush rockspirea
Syal	Symphoricarpos albus (L.) Blake	Common Snowberry
Rivi	Ribes viscosissimum Pursh	Sticky current
Ricec	Ribes cereum cereum Dougl.	Wax current

Shrubs

B. Minor shrub species

Amal	Amelanchier alnifolia Nutt.	Saskatoon serviceberry
Sace	Sambucus cerulea Raf.	Blueberry elder
Rogy	Rosa gymnocarpa Nutt.	Baldhip rose
Bere	Berberis repens Lindl.	Creeping western barberry
Vame	Vaccinium membranaceum Dougl. ex Hook.	Big whortleberry

C. Minor shrub species not sampled.

Rupa	Rubus parviflorus Nutt.	Western thimbleberry
Phle2	Philadelpheus lewisii Pursh	Lewis mockorange
Acgl	Acer glabrum Torr.	Rocky mountain maple
Pamy	Pachistima myrsinites (Pursh) Raf.	Myrtle pachistima
Chumo	Chimaphila umbellata occidentalis (Rydb.) Blake	Western pipsisewa
Libol	Linnaea borealis longiflora Torr.	Longtube twinflower

Trees

Psmeg	Pseudotsuga menziesii glauca (Beissn.) Franco	Interior Douglas-fir
Pien	Picea engelmannii Parry	Engelmann spruce
Pipo	Pinus ponderosa Laws	Ponderosa pine
Pimo	Pinus monticola Dougl. ex D. Don	Western white pine
Laoc	Larix occidentalis Nutt.	Western larch
Abgr	Abies grandis (Dougl.) Lindl.	Grand fir

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[1] Symbols are according to Garrison, Skovlin, and Poulton (1967).

APPENDIX II. DESCRIPTION OF TOLO SILT LOAM FROM EXCLOSURE 1 OF EXPERIMENTAL AREA

	1-0"	Burned duff layer.
A1	0-9"	Dark brown (10YR3/3, moist), silt loam, very weak medium sub-angular structure; loose, friable, non-sticky, non-plastic; gradual smooth boundary.
C	9-25"	Dark yellowish brown (10YR4/4, moist) silt loam; structureless; loose, friable, non-sticky, non-plastic, abrupt smooth boundary.
II B	25-42"	Dark reddish brown (5YR4/3, moist), clay loam; structureless; friable, sticky, plastic; many fine tubular pores; clear smooth boundary.
II C	42-60"	Brown (7.5YR4/2, moist), silty clay loam; structureless; friable, sticky, plastic; many fine tubular pores.

APPENDIX III. Average Air Temperature as Recorded on Clear-cut Study Area and Adjacent Stand of Mature Coniferous Forest.

	Mature Mixed-Coniferous Forest											
	Maximum						Minimum					
	3 ft.			1 ft.			3 ft.			1 ft.		
Date[1]	1967	1968	1969	1967	1968	1969	1967	1968	1969	1967	1968	1969
6/19	84	98	85	86	86	94	52	50	44	54	52	43
6/26	85	90	72	89	90	77	40	59	40	43	59	40
7/3	91	93	77	93	93	80	45	50	34	43	51	38
7/10	90	94	92	86	93	92	42	52	40	45	53	41
7/17	98	93	98	100	94	87	49	40	40	51	42	40
7/24	90	89	92	91	90	91	44	39	60	48	40	50
7/31	90	95	90	91	94	89	48	48	42	51	50	42
8/7	91	90	81	92	90	90	45	46	41	48	47	40
8/14	93	85	92	94	84	92	44	50	38	47	51	39
8/21	96	60	93	98	62	90	52	43	41	54	40	41
8/28	86	72	--[2]	90	72	--	44	37	--	47	39	--
9/4	93	--	--	95	--	--	50	--	--	52	--	--
9/11	90	84	--	92	82	--	40	38	--	41	40	--
	Clear-cut Study Area											
	Maximum						Minimum					
	3 ft.			1 ft.			3 ft.			1 ft.		
Date	1967	1968	1969	1967	1968	1969	1967	1968	1969	1967	1968	1969
6/19	94	102	90	91	90	88	54	53	42	51	51	43
6/26	87	86	70	85	87	72	40	40	38	38	38	39
7/3	93	96	75	92	93	80	45	54	41	38	43	37
7/10	90	99	95	90	97	93	41	53	40	38	49	38
7/17	107	98	95	103	99	84	50	38	40	40	41	34
7/24	97	93	94	99	98	92	45	40	50	40	34	43
7/31	95	99	101	98	99	98	46	50	41	41	40	39
8/7	100	95	94	101	94	92	44	47	40	43	39	38
7/14	101	92	100	102	92	98	44	50	37	40	42	33
8/21	104	70	94	103	73	94	53	40	40	51	37	35
8/28	93	84	104	95	81	102	45	39	34	40	33	35
9/4	102	--	99	102	--	90	49	--	32	45	--	29
9/11	97	94	86	99	93	97	41	39	48	41	32	42

1 Approximate date, only one or two days deviation from the date given for any one year. 2 Data not available.

APPENDIX IV. Analyses of Air Temperature Differentials as Determined per Pettit (1968).

Source of Variance	S. S.	D. F.	M. S.
		Maximum Temperatures 1967	
Plant cover	15.385	1	15.384
Dates	42.616	12	3.551
Residual	56.615	12	4.718
Total	114.616	25	
		Minimum Temperatures 1967	
Plant cover	246.154	1	246.154
Dates	64.385	12	5.365
Residual	44.846	12	3.737
Total	355.385	25	
		Maximum Temperatures 1968	
Plant cover	0.041	1	0.041
Dates	314.458	11	28.587
Residual	21.459	11	1.951
Total	335.958	23	
		Minimum Temperatures 1968	
Plant cover	186.864	1	186.864
Dates	109.455	10	10.945
Residual	126.676	10	12.664
Total	422.955	21	
		Maximum Temperatures 1969	
Plant cover	21.333	1	21.333
Dates	333.111	8	41.639
Residual	147.667	8	18.458
Total	502.111	17	
		Minimum Temperatures 1969	
Plant cover	60.500	1	60.500
Dates	33.111	8	4.139
Residual	48.000	8	6.000
Total	141.611	17	

APPENDIX V. Temperature Deviations (in °F) of the Environment of the Clear-cut from that of the Undisturbed Forest.

	Maximum Temperatures 3 ft. above ground		
Dates	1967	1968	1969
6/19	10	4	5
6/26	2	-4	-2
7/3	2	3	2
7/10	0	5	3
7/17	9	5	-3
7/24	7	4	2
7/31	5	4	11
8/7	9	5	3
8/14	8	7	8
8/21	8	10	1

Source of Variance	S. S.	D. F.	M. S.
Plant cover	78.6	2	39.300
Dates	230.0	9	25.555
Residual	154.1	18	8.561
Total	462.7	29	

	Maximum Temperatures 1 ft. above ground		
Dates	1967	1968	1968
6/19	5	4	-6
6/26	-4	-3	-5
7/3	-1	0	0
7/10	4	4	1
7/17	3	5	-3
7/24	8	8	1
7/31	7	5	11
8/7	9	4	2
8/14	8	8	6
8/21	5	11	4

Source of Variance	S. S.	D. F.	M. S.
Plant cover	77.267	2	38.633
Dates	388.967	9	43.219
Residual	488.733	18	27.151
Total	954.967	29	

	Minimum Temperatures 3 ft. above ground		
Dates	1967	1968	1969
6/19	2	3	-2
6/26	0	-19	-2
7/3	0	4	7
7/10	-1	1	0
7/17	1	-2	0
7/24	1	1	-1
7/31	-2	2	-1
8/7	-1	1	-1
8/14	0	0	-1
8/21	1	-3	-1

Source of Variance	S. S.	D. F.	M. S.
Plant cover	9.8	2	4.90
Dates	191.2	9	21.24
Residual	268.2	18	14.90
Total	469.2	29	

APPENDIX V. Continued.

Dates	Minimum Temperatures 1 ft. above ground 1967	1968	1969
6/19	3	-1	0
6/26	-5	-21	-1
7/3	-5	-8	-1
7/10	-7	-4	-3
7/17	-11	-1	-6
7/24	-8	-6	-7
7/31	-10	-10	-3
8/7	-5	-8	-2
8/14	-7	-9	-6
8/21	-3	-3	-6

Source of Variance	S. S.	D. F.	M. S.
Plant cover	66.47	2	33.285
Dates	194.14	9	21.571
Residual	312.86	18	17.381
Total	573.47	29	

APPENDIX VI. Percentage of Soil Moisture (Oven-dry Weight Basis)

	1966 6/20	1967 6/19	1968 6/18	1969 6/21	1970 6/29	1966 7/4	1967 7/3	1968 7/5	1969 7/11	1970 7/4	1966 7/18	1967 7/17
	Location No. 1: Ex 1 Plot 4, seeded with Brma; dominated by Ceve, Phma, and Brma.											
0-6	54.0	40.0	40.0	39.0	39.0	33.3	38.0	38.0	39.0	39.0	21.3	14.0
6-12	40.7	40.0	39.5	39.0	39.0	31.7	39.5	38.0	39.0	39.0	20.8	33.0
12-24	33.6	40.0	39.5	--[1]	--	27.2	40.0	39.0	--	--	22.7	38.0
24-36	25.5	39.5	39.5	36.0	39.0	23.8	39.0	38.0	39.0	39.0	24.1	37.5
	Location No. 2: Ex 1 Plot 4, bottom of slope, seeded with mixture, dominated by Phpr and Dagl.											
0-6	39.2	38.0	38.5	38.0	39.0	21.4	36.0	35.5	39.0	37.0	11.7	10.5
6-12	31.8	39.5	39.0	39.0	39.0	18.2	37.5	36.5	39.9	38.0	14.7	12.5
12-24	28.7	38.0	40.0	39.5	38.0	20.9	38.5	38.0	39.0	39.0	12.5	35.0
24-36	23.0	38.0	39.5	39.5	37.0	36.6	39.0	38.0	39.0	39.0	20.1	38.0
	Location No. 3: Ex 1 Plot 4, bottom of slope, unseeded; dominated by Deel and Caro.											
0-6	48.7	40.0	39.0	39.0	39.0	59.6	35.0	28.5	39.0	39.0	22.8	9.0
6-12	46.5	40.0	40.0	39.0	39.0	36.1	39.5	37.5	39.0	39.0	24.0	29.5
12-24	25.4	40.0	39.5	39.0	39.0	37.6	39.5	38.0	39.5	39.0	31.2	38.0
24-36	25.6	40.0	40.0	39.0	39.0	26.9	40.0	39.0	39.5	39.0	25.1	39.5
	Forest Site No. 1: Bottom of slope dominated by Hodi, Rogy with Caru and Fraga.											
0-6	30.8	38.0	37.5	39.0	--[2]	18.8	39.5	30.0	39.0	--	18.0	35.5
6-12	26.3	39.0	38.0	40.0	--	19.4	40.0	33.0	39.0	--	14.6	36.5
12-24	19.0	38.0	35.0	39.0	--	16.6	39.0	29.5	38.0	--	14.9	36.5
24-36	18.9	39.0	36.0	39.0	--	15.3	39.0	25.5	38.0	--	9.7	34.5
36-48	--	38.0	31.0	34.5	--	18.2	38.0	18.5	32.0	--	15.8	29.5
	Forest Site No. 2: Mid-slope; dominated by Phma, Rogy with Caru, Fraga and Thfe.											
0-6	19.2	38.0	32.0	37.0	--	17.9	37.5	19.0	37.0	--	18.4	29.5
6-12	17.3	36.0	33.5	37.5	--	17.0	37.0	23.5	37.0	--	14.3	33.0
12-24	15.0	36.0	33.5	38.0	--	12.5	37.5	24.5	37.0	--	14.2	33.5
24-36	13.8	38.0	34.5	38.0	--	12.7	38.0	32.0	37.5	--	13.2	38.0
36-48	--	36.5	21.0	36.0	--	12.3	37.5	20.0	36.0	--	--	38.0

APPENDIX VI. Continued.

	1968 7/15	1969 7/18	1970 7/17	1966 8/1	1967 7/31	1968 7/30	1969 8/1	1970 8/1	1966 8/15	1967 8/14	1968 8/16	1969 8/15
	Location No. 1: Ex 1 Plot 4, seeded with Brma; dominated by Ceve, Phma, and Brma.											
0-6	32.0	38.0	32.0	14.1	5.0	5.5	28.0	22.5	13.6	5.0	3.0	8.0
6-12	36.0	39.0	34.0	12.7	9.0	11.0	34.5	11.0	14.3	4.5	4.0	8.5
12-24	38.0	--	--	15.0	27.5	31.5	--	--	12.2	9.0	10.0	--
24-36	37.0	39.0	34.5	19.6	29.0	32.0	36.0	30.0	18.8	12.0	20.0	32.0
	Location No. 2: Ex 1 Plot 4, bottom of slope, seeded with mixture, dominated by Phpr and Dagl.											
0-6	28.0	37.5	35.0	10.6	4.0	7.0	32.0	23.0	10.5	2.5	10.5	10.5
6-12	34.5	36.5	36.0	11.9	5.0	12.0	36.0	32.0	13.9	3.5	4.0	15.0
12-24	36.5	39.0	37.0	8.2	20.0	31.5	37.5	35.0	14.1	10.0	17.5	34.0
24-36	38.0	39.0	39.0	14.6	34.0	36.0	38.5	37.0	15.9	22.0	26.5	34.5
	Location No. 3: Ex 1 Plot 4, bottom of slope, unseeded; dominated by Deel and Caro.											
0-6	13.5	38.0	--	16.9	5.0	5.5	31.5	--	12.3	3.0	9.0	10.0
6-12	36.5	39.0	37.0	16.7	9.0	26.5	37.5	30.0	14.5	5.5	10.5	32.0
12-24	37.0	39.0	37.0	16.4	29.0	31.5	39.0	37.0	12.9	16.0	18.0	36.0
24-36	39.0	39.0	39.0	16.1	38.0	37.5	39.0	39.0	18.0	35.5	36.0	39.0
	Forest Site No. 1: Bottom of slope dominated by Hodi, Rogy with Caru and Fraga.											
0-6	14.5	36.0	--	12.1	20.5	5.0	19.0	--	15.8	8.5	3.0	5.0
6-12	17.5	37.5	--	12.2	21.0	6.0	21.0	--	13.6	9.0	3.5	6.5
12-24	21.0	35.0	--	12.8	26.5	7.5	21.5	--	13.0	12.5	4.0	7.0
24-36	17.5	32.0	--	12.4	24.0	9.5	18.0	--	14.1	15.5	5.0	9.0
36-48	15.0	22.0	--	16.6	21.5	9.0	15.0	--	16.8	15.0	5.0	9.5
	Forest Site No. 2: Mid-slope; dominated by Phma, Rogy with Caru, Fraga and Thfe.											
0-6	9.0	25.0	--	13.3	17.5	5.0	9.0	--	13.7	9.0	3.5	4.0
6-12	11.0	31.0	--	13.2	20.5	5.0	11.5	--	12.6	7.0	3.0	4.0
12-24	15.0	32.0	--	11.4	35.5	21.0	30.0	--	12.7	11.5	3.5	5.0
24-36	29.0	36.0	--	11.4	35.5	21.0	30.0	--	12.7	30.0	11.0	14.0
36-48	19.0	34.0	--	12.0	35.0	15.0	31.0	--	13.6	32.0	10.0	25.0

APPENDIX VI. Continued

	1970 8/14	1966 8/29	1967 8/28	1968 8/30	1969 8/29	1970 8/28	1967 9/11	1968 9/17	1969 9/10	1970 9/11
Location No. 1: Ex 1 Plot 4, seeded with Brma; dominated by Ceve, Phma, and Brma.										
0-6	4.0	15.3	3.0	24.0	3.0	3.0	2.0	4.5	3.0	37.0
6-12	25.0	11.9	3.0	14.0	3.0	2.0	2.0	5.0	3.0	18.0
12-24	--	13.8	4.0	10.0	--	--	3.0	7.0	--	--
24-36	22.0	15.1	6.0	16.0	21.0	8.0	4.5	12.0	13.0	9.0
Location No. 2: Ex 1 Plot 4, bottom of slope, seeded with mixture, dominated by Phpr and Dagl.										
0-6	7.0	10.2	2.0	28.5	4.0	3.0	1.5	22.0	3.0	34.0
6-12	11.0	11.5	3.0	25.0	4.0	4.0	3.0	7.5	3.0	31.0
12-24	32.0	13.1	6.0	16.5	28.0	26.0	4.5	11.0	20.0	18.5
24-36	36.0	13.4	14.5	26.5	34.5	35.0	11.0	21.0	29.0	30.0
Location No. 3: Ex 1 Plot 4, bottom of slope, unseeded; dominated by Deel and Caro.										
0-6	7.0	13.8	2.0	31.0	4.0	4.0	1.5	33.0	3.0	35.0
6-12	23.0	15.7	4.0	28.0	17.5	8.0	3.0	15.0	10.5	15.0
12-24	35.0	13.0	7.5	16.0	32.0	29.0	5.0	19.0	26.5	25.0
24-36	37.0	17.3	30.0	35.0	38.0	36.0	24.0	34.5	34.5	34.5
Forest Site No. 1: Bottom of slope dominated by Hodi, Rogv with Caru and Fraga.										
0-6	--	24.6	5.0	20.0	--	--	3.5	30.0	--	--
6-12	--	13.6	4.5	12.0	--	--	3.0	3.5	--	--
12-24	--	12.6	5.5	3.0	--	--	3.5	2.5	--	--
24-36	--	13.6	9.5	4.0	--	--	5.0	3.0	--	--
36-48	--	15.4	10.5	4.0	--	--	7.0	3.5	--	--
Forest Site No. 2: Mid-slope; dominated by Phma, Rogv with Caru, Fraga and Thfe.										
0-6	--	10.4	4.5	15.0	--	--	3.0	25.5	--	--
6-12	--	11.3	5.0	3.5	--	--	3.0	2.0	--	--
12-24	--	10.4	5.0	2.0	--	--	2.5	1.5	--	--
24-36	--	12.1	19.0	7.0	--	--	11.0	5.0	--	--
36-48	--	13.7	26.5	7.5	--	--	22.0	6.0	--	--

[1] Block damaged by rodent.

[2] No data available; forested areas were logged August, 1969.

APPENDIX VII. Soil Temperature Deviations from Temperatures of the Uncut Forest Recorded at Two Inches Deep.

	Date	Dominant Vegetation Cesa and Ascam	Ascam	Phpr-Dagl	Actual Temperature of Forest
		(Number of degrees deviation in °C)			(°C)
1966	6-27	3	7	2	15
	7-4	1	10	2	18
	7-11	0	8	1	19
	7-18	5	5	4	18
	7-25	1	1	4	21
	8-1	2	1	4	22
	8-8	6	5	5	21
	8-15	2	0	3	21
	8-22	5	0	2	21
	8-29	5	4	3	21
	9-5	5	1	3	17
	9-12	3	2	2	19
1967	7-18	6	0	1	20
	7-25	6	1	1	19
	8-1	6	0	2	19
	8-8	6	1	1	19
	8-15	8	1	4	20
	8-22	9	2	1	22
	8-29	8	3	2	18
	9-5	9	3	3	20
	9-12	10	2	1	19

APPENDIX VIII. Soil Samples Used in Residual Seed Study.

Size Fraction	Ex 1 Unseeded	Ex 1 Seeded	Nursery Area	Site A	Site B	Site F
			Sample a - duff layer			
	782 g	223 g	368 g	847 g	454 g	340 g
1	21.2%	26.6%	32.4%	33.0%	32.8%	16.5%
2	9.8	18.0	8.6	6.7	17.9	12.1
4	60.7	35.6	51.3	51.7	36.3	60.8
			Sample b - interface between duff and mineral soil			
	1042 g	690 g	559 g	1177 g	1036 g	627 g
1	20.2%	18.5%	19.6%	23.5%	26.0%	15.0%
2	8.8	11.0	8.2	8.5	19.0	11.1
3	39.0	11.0	10.2	10.7	17.0	9.3
4	32.0	59.5	62.0	57.3	37.0	64.6
			Sample c - mineral soil			
	1339 g	1303 g	1247 g	2023 g	1684 g	787 g
1	23.8%	10.0%	20.3%	18.8%	25.0%	16.8%
2	9.7	10.7	9.5	7.0	23.8	10.9
3	13.6	12.3	8.6	10.2	14.0	9.7
4	52.9	67.0	61.6	64.0	37.2	62.6

APPENDIX IX. Percentage Cover by Species on Clear-cut Study Area.

(June, 1968)

	Ex 1					Ex 2				
	Bottom Seeded	Brma	Elgl	Bottom Unseeded	Top Unseeded	Bottom Seeded	Brma	Elgl	Bottom Unseeded	Top Unseeded
<u>Grasses and Carexes</u>										
Brte	2.76	2.43	0.06	17.30	22.56	1.81	0.72	1.84	8.17	7.74
Fepa			0.06		0.06		0.12		0.12	
Brbr							0.12		0.12	
Caro	8.28	1.97	2.39	11.95	6.94	0.50	11.32	8.45	14.70	9.40
Caco	1.06	0.19	0.50	0.88	2.13	0.90	0.69	0.93	14.00	1.65
Cage	0.75	0.81		0.53			0.19	0.19	0.12	0.69
Caru	0.69	0.61		0.47		3.75			0.12	0.12
Feoc	0.12			0.35	0.96		0.35	2.24	0.31	0.97
Trca				0.06						0.19
Mebu										0.19
Stcon				0.69	0.69					
Hoju				0.12						
Deel	0.12		0.06	0.84	1.00		0.53		8.88	0.65
Popr	0.28		0.69		0.89	0.06	0.06		3.00	0.19
Dagl	17.59		0.22	18.66	0.12	14.45			1.34	0.06
Phpr	11.25			4.01	0.06	3.44	0.12	0.59	0.12	0.06
Arel	8.02		0.69	3.45	0.12	8.69		2.03	0.40	0.19
Brin	2.69			1.19		0.56			0.42	
Elgl		0.88	39.90	0.40	0.38			27.36		0.31
Brma		16.98			2.97	0.12	12.70	0.22	0.06	0.12
<u>Forbs</u>										
Ascam	7.80	2.62	7.80	4.84	11.69	4.60	3.25	4.06	5.02	5.23
Gnmi					0.44	0.12			0.22	0.12
Fraga	3.40	0.53	0.40	3.87	1.25	0.88	2.00	1.72	0.84	2.48
Acmil	0.06	0.87	0.25	0.06	1.88		0.84	0.78	0.19	0.19

APPENDIX IX. Continued.

	(June, 1968)									
			Ex 1					Ex 2		
	Bottom Seeded	Brma	Elgl	Bottom Unseeded	Top Unseeded	Bottom Seeded	Brma	Elgl	Bottom Unseeded	Top Unseeded
Forbs										
Arco	0.18	1.25	1.00	0.18	0.68		0.50	0.66	0.35	0.31
Lumuc2		0.06								
Trdu				0.47						
Pogl	0.22									
Libu		0.18	0.06							
Lupob		0.06								
Gebi					0.12					
Polem		0.19								
Coca2		0.12								
Anlu									0.13	
Civu	2.00	1.31	1.31	12.40	23.37	5.18	8.65	8.00	13.37	14.65
Eppa	0.81	3.53	2.10	7.45	17.99	0.38	4.53	0.62	1.40	2.06
Ruac	0.50		0.12	0.40	0.17	0.06	2.44	3.10	0.20	1.00
Copa	1.81	4.74	2.06	0.31	2.47	0.47	0.69	0.65	1.50	1.47
Epan										0.12
Cogr2		0.25					0.06	0.25		
Veth			0.06		0.05		0.25		0.35	0.40
Phhe	0.12	0.19	0.12	0.40	0.34	0.06	0.06		1.32	0.25
Bor.							0.06			
Craf					0.06		0.19		0.97	
Cru.		0.06			0.06					
Descu		0.06			0.06					
Lase		0.12	0.12	0.06	0.50					
Viada	1.31	0.31	0.25	0.25	0.43	0.06	0.50	0.39	0.47	0.50
Anor	0.31	0.50	0.38	0.25	0.44		0.06	0.37		0.06
Thfe	0.12		0.06	0.75	0.06			0.54		

APPENDIX IX. Continued.

	(June, 1968)									
			Ex 1					Ex 2		
	Bottom Seeded	Brma	Elgl	Bottom Unseeded	Top Unseeded	Bottom Seeded	Brma	Elgl	Bottom Unseeded	Top Unseeded
<u>Forbs</u>										
Gatr		0.02								
Mope	0.19	0.75	1.40	0.31	2.47		0.12	0.12	0.12	
Toof	0.50	0.06					0.06	0.12		
Lathy						0.12	0.12	0.06		
Arma[3]		0.44	0.19				0.12		0.25	
Frpu		0.44	0.06							
Trifo	0.06									
<u>Shrubs</u>										
Cesa	0.25	14.76	1.50	0.89	0.40	0.12	3.44	1.85		3.10
Phma	0.35	10.79	3.59	0.28	2.48		0.40	0.17	0.28	0.65
Spbel	1.09	1.00	0.79	0.84	1.10		0.06	1.31	0.31	0.84
Cevev	0.40	0.06	0.35	2.42	0.59	0.22		1.39		
Salix	0.19		0.06	0.06	0.28	0.06	0.22	0.06		0.28
Hodi									0.06	
Syal	0.47	0.34		0.28				0.12		
Rivi	0.19			0.53		0.06			0.19	0.19
Ricec		0.06							0.06	
Amal								0.06		
Sace					0.47					
Rogy	0.22	0.19	0.12		0.12		0.06	0.06	0.06	
Bere	0.22			0.47						
Vame	0.06									
Total	76.44	69.73	68.78	98.67	108.85	46.67	55.60	70.31	79.54	56.43

APPENDIX X. Germination of Canada Milkvetch.

	Temperature Regimes													
	86 F° - 16 hour day; 68 F° - 8 hour night							68°F - 16 hour day; 38°F - 8 hour night						
	Seed Treatments Before Germination[1]													
	a	b	c	d	e	f	g	a	b	c	d	e	f	g
	Percentage Germinated Seeds													
1.	32	71	59	77	66	48	34	33	50	48	65	55	38	40
2.	53	75	60	45	61	66	56	38	37	46	73	69	52	61
3.	43	72	38	83	55	52	51	45	67	27	71	61	79	54
4.	51	77	60	68	53	75	46	45	72	38	77	52	83	58
	Percentage Hard Seeds													
1.	44	7	33	10	2	4	3	61	3	37	23	11	3	4
2.	40	22	33	3	3	1	1	52	0	38	16	13	20	5
3.	32	5	34	9	2	4	1	50	0	57	17	18	15	3
4.	37	0	32	8	4	2	0	44	0	42	14	14	7	3
	Percentage Decayed Seeds													
1.	24	22	8	13	32	48	63	6	47	15	12	34	59	56
2.	7	3	7	52	36	33	43	10	63	16	11	18	28	34
3.	25	23	28	8	43	44	48	4	33	16	12	21	6	43
4.	12	23	8	24	43	23	54	11	28	20	9	34	10	39

[1] a. untreated seeds
b. hot water soak for 12 hours
c. 100°F for 10 minutes
d. 200°F for 10 minutes
e. 400°F for 10 minutes
f. 600°F for 5 minutes
g. 800°F for 5 minutes

APPENDIX XI. Effect of Calcium, Copper, and Cobalt Upon Analyses of Calcium, Phosphorus, and Crude Protein in Shoots of Canada Milkvetch. (16 September 1968 - 28 January 1970).

	Ca				Cu			Co		
	0	1	2	3	0	1	2	0	1	2
Dry wt. (9)	1.8	6.0	2.8	6.5	1.8	5.8	--[1]	1.8	2.8	--
% Ca	0.97	1.10	1.05	1.25	0.97	1.41	--	0.97	0.96	--
% P	0.27	0.15	0.27	0.19	0.27	0.21	--	0.27	0.24	--
% CP	16.63	14.88	14.78	18.43	16.63	16.58	--	16.63	17.21	--

	Cu 1		Cu 2	
	Co 1	Co 2	Co 1	Co 2
Dry wt. (9)	4.2	--	--	--
% Ca	1.09	--	--	--
% P	0.24	--	--	--
% CP	17.50	--	--	--

	Ca 1				Ca 2				Ca 3			
	Co 1	Co 2	Co 1	Co 2	Cu 1	Cu 2	Co 1	Co 2	Cu 1	Cu 2	Co 1	Co 2
Dry wt. (9)	4.3	--	2.5	--	4.0	--	3.2	--	5.3	--	4.8	--
% Ca	1.09	--	0.99	--	1.41	--	1.02	--	1.16	--	1.47	--
% P	0.18	--	0.24	--	0.16	--	0.20	--	0.17	--	0.21	--
% CP	16.29	--	14.79	--	15.75	--	15.23	--	17.17	--	18.14	--

	Ca 1				Ca 2				Ca 3			
	Cu 1 Co 1	Cu 1 Co 2	Cu 2 Co 1	Cu 2 Co 2	Cu 1 Co 1	Cu 1 Co 2	Cu 2 Co 1	Cu 2 Co 2	Cu 1 Co 1	Cu 1 Co 2	Cu 2 Co 1	Cu 2 Co 2
Dry wt. (9)	2.8	--	--	--	4.0	--	--	--	2.8	1.7	--	--
% Ca	1.27	--	--	--	1.19	--	--	--	1.03	0.83	--	--
% P	0.19	--	--	--	0.17	--	--	--	0.22	0.20	--	--
% CP	--[2]	--	--	--	17.89	--	--	--	15.94	--	--	--

[1]Plants died or did not grow.

[2]Not enough material for analysis.

APPENDIX XII. Effect of Calcium, Copper, and Cobalt Upon Analyses of Calcium, and Phosphorus in Shoots of Canada Milkvetch (Regrowth: 29 January to 13 June 1970).

	Ca				Cu			Co		
	0	1	2	3	0	1	2	0	1	2
Dry wt. (9)	3.2	8.8	8.0	8.2	3.2	9.0	--[1]	3.2	6.0	--
% Ca	0.86	0.83	1.04	1.08	0.86	1.11	--	0.86	0.83	--
% P	0.27	0.20	0.17	0.19	0.27	0.18	--	0.27	0.22	--

	Cu 1		Cu 2	
	Co 1	Co 2	Co 1	Co 2
Dry wt. (9)	4.7	--	--	--
% Ca	0.86	--	--	--
% P	0.26	--	--	--

	Ca 1				Ca 2				Ca 3			
	Cu 1	Cu 2	Co 1	Co 2	Cu 1	Cu 2	Co 1	Co 2	Cu 1	Cu 2	Co 1	Co 2
Dry wt. (9)	6.7	--	7.8	1.5	7.0	--	5.2	--	9.3	--	5.5	--
% Ca	0.74	--	1.01	--	0.82	--	0.92	--	0.84	--	0.89	--
% P	0.19	--	0.21	--	0.17	--	0.22	--	0.17	--	0.19	--

	Ca 1				Ca 2				Ca 3			
	Cu 1 Co 1	Cu 1 Co 2	Cu 2 Co 1	Cu 2 Co 2	Cu 1 Co 1	Cu 1 Co 2	Cu 2 Co 1	Cu 2 Co 2	Cu 1 Co 1	Cu 1 Co 2	Cu 2 Co 1	Cu 2 Co 2
Dry wt. (9)	7.5	--	1.2	--	6.0	--	--	--	5.5	1.2	--	--
% Ca	1.10	--	—[2]	--	0.92	--	--	--	1.08	--	--	--
% P	0.20	--	—	--	0.23	--	--	--	0.21	--	--	--

[1] Plants died or did not grow.
[2] Not enough tissue for analyses.

APPENDIX XIII. Effect of Calcium, Copper, and Cobalt Upon Analyses of Calcium and Phosphorus in Roots of Canada Milkvetch (harvested 13 June 1970).

	Ca				Cu			Co		
	0	1	2	3	0	1	2	0	1	2
Dry wt. (9)	4.5	13.5	17.2	14.8	4.5	20.2	--[1]	4.5	9.0	--
% Ca	0.39	0.43	0.46	0.38	0.39	0.42	--	0.39	0.32	--
% P	0.14	0.18	0.17	0.15	0.14	0.13	--	0.14	0.18	--

	Cu 1		Cu 2	
	Co 1	Co 2	Co 1	Co 2
Dry wt. (9)	9.3	--	--	--
% Ca	0.46	--	--	--
% P	0.18	--	--	--

	Ca 1				Ca 2				Ca 3			
	Cu 1	Cu 2	Co 1	Co 2	Cu 1	Cu 2	Co 1	Co 2	Cu 1	Cu 2	Co 1	Co 2
Dry wt. (9)	7.3	--	23.3	--	13.5	--	6.5	--	15.7	--	10.2	--
% Ca	0.30	--	0.40	--	0.35	--	0.35	--	0.41	--	0.38	--
% P	0.16	--	0.16	--	0.19	--	0.19	--	0.21	--	0.18	--

	Ca 1				Ca 2				Ca 3			
	Cu 1 Co 1	Cu 1 Co 2	Cu 2 Co 1	Cu 2 Co 2	Cu 1 Co 1	Cu 1 Co 2	Cu 2 Co 1	Cu 2 Co 2	Cu 1 Co 1	Cu 1 Co 2	Cu 2 Co 1	Cu 2 Co 2
Dry wt. (9)	9.0	--	1.5	--	10.3	--	--	--	11.5	1.0	--	--
% Ca	0.33	--	--[2]	--	0.37	--	--	--	0.45	--	--	--
% P	0.20	--	--	--	0.16	--	--	--	0.17	--	--	--

[1] Plants died or did not grow.

[2] Not enough tissue for analyses.