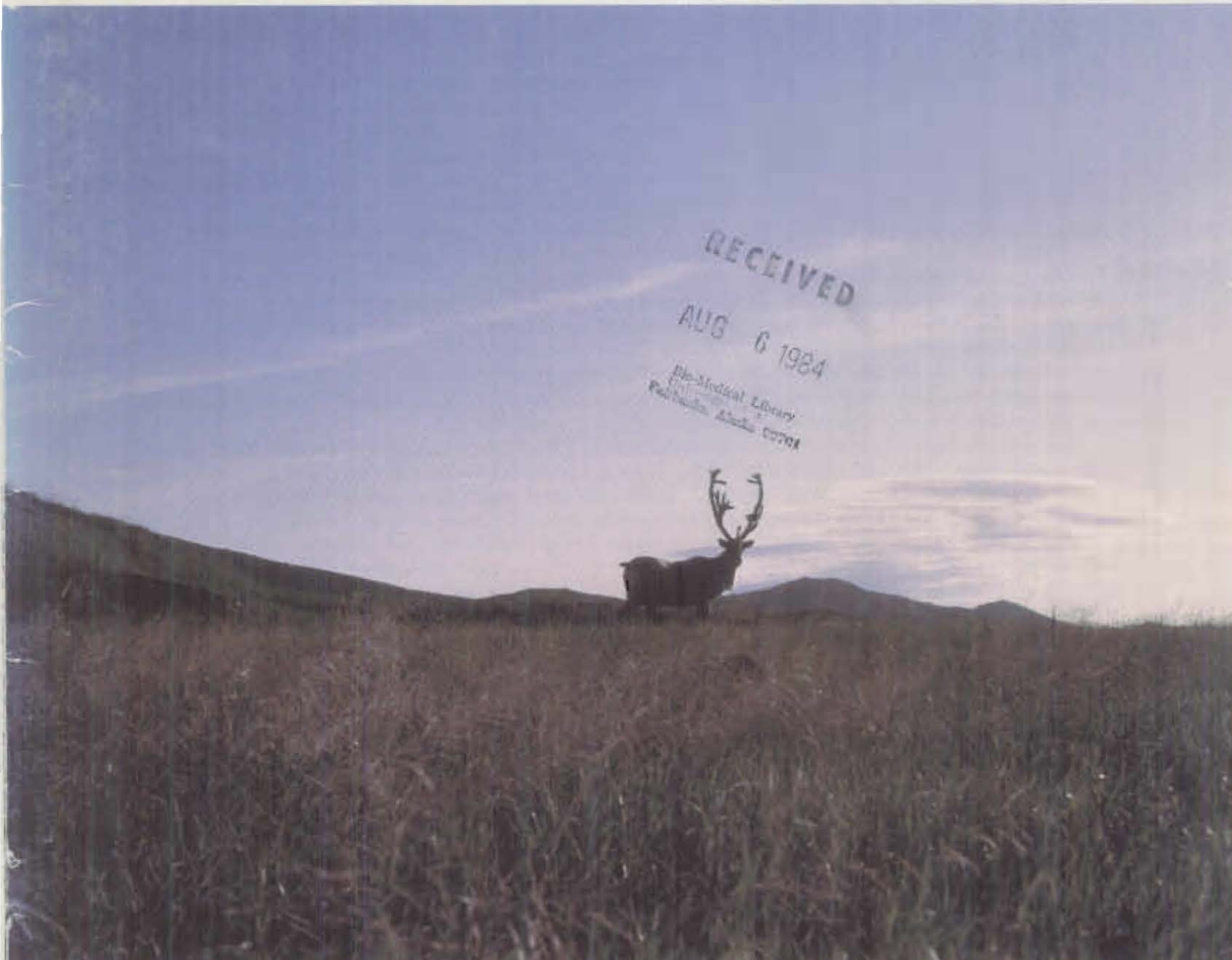
Agroborealis

Volume 16, Number 2, July 1984



Agricultural Experiment Station
University of Alaska - Fairbanks

From the Director's Desk:

A hallmark of progress in agriculture and forestry during the last century was the constant development and application of new technology. State agricultural experiment stations, in cooperation with the Federal government, made a major share of the discoveries in agricultural science that led to improved technology.

Current demands by consumers indicate an even greater need for new discoveries in agricultural science. Supplying abundant food and wood products at low cost to consumers means improving the productivity of crops and livestock, reducing losses from insects and diseases, decreasing soil erosion, increasing the efficiency of water use, and overcoming the vagaries of weather while also reducing the costs of producing and marketing agricultural products.

The Federal-state partnership that makes possible such advances in agricultural science was created in 1862 when President Abraham Lincoln signed the Morrill Act which established the land-grant colleges in the various states. In 1887, the Hatch Act was passed to establish agricultural experiment stations in those colleges. Finally, in 1914, the Cooperative Extension Service was established by the Smith-Lever Act to transfer the results of research in agriculture and forestry to producers. These acts formed what has been called the "trilogy of American ingenuity" — the blended roles of teaching, research, and extension in agricultural sciences in the land-grant colleges.

The effectiveness of these programs is recognized in Title XIV of the Agriculture and Food Act of 1981 as follows: "The partnership between the Federal government and the states . . . has been eminently successful. Cooperative research, extension, and teaching programs have provided the United States with the most productive and efficient food-producing systems in the world."

Agricultural experiment stations were established near Fairbanks and Palmer, Alaska, by the Federal government in 1906 and 1917, respectively. They were later transferred from Federal ownership to Alaska's land-grant college, the Alaska Agricultural College and School of Mines, after it opened in 1922. In 1935, this institution became the University of Alaska. Thus, the Alaska Agricultural Experiment Station is part of the nationwide system of state agricultural experiment stations in land-grant universities.

Part of the responsibility associated with this Federal-state partnership involves research, teaching, and extension to support the development of agriculture and forestry in Alaska. This development will require new biotechnology to control diseases, insects, and weeds and to enhance plant and animal growth. It will require improved cultivars with optimum genetic combinations for high yields as well as insect and disease resistance. Moreover, agricultural science must be made available to students in the classroom, and new technology must be transferred to producers through the linkage with the Cooperative Extension Service. Equally important is the feedback from producers through extension to researchers to identify the most critical research needs. The payoff begins when producers adopt a new technology.

Within the University of Alaska system, research and teaching in agricultural science are administered by the University of Alaska-Fairbanks, while the Cooperative Extension Service is administered by Community Colleges, Rural Education, and Extension, a separate component of the statewide system. The success of Alaska's agriculture and forestry will depend to a great extent on how well the cooperative functions of teaching, research, and extension at the University of Alaska are coordinated and brought to bear on the development and application of research findings.

James V. Drew

James V. Drew, Director

Agroborealis

July/1984

Volume 16 Number 2

Agricultural Experiment Station
School of Agriculture and
Land Resources Management
University of Alaska-Fairbanks

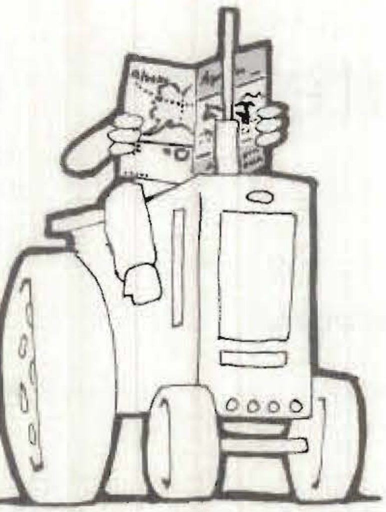
Agroborealis is published under the leadership of the AES Publications Committee: J. V. Drew, A. L. Brundage, L. J. Klebesadel, J. D. McKendrick, A. Jubenville, and S. H. Restad. Please address all correspondence regarding the magazine to: Mayo Murray, Managing Editor, Agricultural Experiment Station, University of Alaska, Fairbanks, Alaska 99701.

Managing Editor . . . . Mayo Murray
Composition. . . . . Tobi Campanella
Printed by Northern Printing, Anchorage, Alaska.

Agroborealis is published by the University of Alaska Agricultural Experiment Station, Fairbanks, Alaska 99701. A written request will include you on the mailing list. The Agricultural Experiment Station at the University of Alaska provides station publications and equal educational and employment opportunities to all without regard to race, color, religion, national origin, sex, age, physical handicap, or veteran status.

Table of Contents

ABOUT THE COVER . . . *Reclaiming surface mine spoils by planting various grasses has been a standard practice at the Usibelli Coal Mine near Healy, Alaska, for more than a decade. This July 1981 photo of a bull caribou grazing on a three-year old seeding at the Usibelli Coal Mine was taken by Dr. Charles Elliott, who received his Ph. D. Degree in reclamation ecology from the University of Alaska on May 13, 1984. The area was seeded to grasses and legumes. Of these, red fescue was the dominant survivor.* *See page 5 for related story.*



AES Notes

Dr. Francis H. Siddoway, visiting professor of agronomy at the Alaska Agricultural Experiment Station for the summers of 1981-1983, died March 9, 1984, in Phoenix, Arizona, while on vacation. Siddoway was born in 1922 in Rexburg, Idaho. After serving in World War II as a bomber pilot, he graduated from the University of Idaho in 1947 with a B.S. degree in agricultural economics; he received a M.S. degree in 1951 in agronomy from that same institution. He then attended Kansas State University where he was awarded the Ph.D. degree in soils physics; his doctoral research was on the effect of kind, amount, and placement of residue on control of wind erosion. While at Kansas State, he coauthored "The Wind Erosion Equation," one of the most frequently cited publications on wind erosion.

In 1963, Siddoway was appointed director of the Northern Plains Soil and Water Research Center in Sidney, Montana, where he directed research on soil conservation, hydrology, soils physics, soil chemistry, soil fertility, biometrics, irrigation, range, soil erosion, climatology, and crop production which resulted in more than 200 papers in national and international journals and popular publications. Siddoway also served on a number of advisory boards at both the state and national levels in the agricultural, scientific community.

Dr. Francis H. Siddoway

Although Siddoway retired in 1980, he continued to serve as a collaborator at the research center for more than three additional years. His work on soil conservation-tillage research while a visiting professor at the University of Alaska-Fairbanks will be invaluable in the future managment of agricultural lands in the Delta Junction area of interior Alaska.

Dr. Jenifer Huang McBeath, plant pathologist at the Agricultural Experiment Station, Fairbanks, has been named state coordinator of a newly formed Plant Pest Survey and Detection Committee. The committee includes entomologists, weed scientists, plant pathologists, and other specialists in Alaska involved in plant-pest management.

A grant was also given Dr. McBeath by the United States Dept. of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine Programs, to establish a computer-based network for storing and retrieving plant-pest data collected in the state. The network will become part of the national plant-pest data storing and retrieving system.

Dr. Chester J. Mirocha, plant pathologist with the University of Minnesota, spent a week-long visit at Dr. Jenifer Huang McBeath's laboratory on a sample-collection trip. Dr. Mirocha is a world-renowned expert on mycotoxins produced by *Fusarium spp.* Dr. Mirocha is collaborating with Dr. McBeath in the isolation of mycotoxin-producing Fusarium in Alaska.

Dr. Gary Laursen, mycologist, was recently awarded an 18-month contract from the Department of Energy to conduct research on "Decomposition in Arctic Terrestrial Environments: Rates and Quality." He will be working near Toolik Lake on the north slope of Alaska as part of a 13-project, multi investigator, integrated research effort. The site will be a watershed drainage where response, resistance, resilience, and recovery from disturbance within an Arctic ecosystem (R^4D) will be investigated. This will be a long-term project, perhaps as long as 10 years, involving incoming and outgoing projects.

Dr. Laursen will be traveling this summer in conjunction with other projects in addition to conducting field work. He is attending the sixth North American Conference on Mycorrhizae

continued on page 59

Evaluation of Plants Used for Stripmine Reclamation Near Healy, Alaska

By

Jay D. McKendrick*, Charles L. Elliott** and Charles P. Boddy***

Alaska has only one stripmine producing significant quantities of coal. However the large reserves within the state combined with recent interest by Pacific Rim markets forecast future expansions for the industry in Alaska. Those developments could eventually disturb sizable areas of land — land that must be reclaimed according to state and Federal law.

Establishment of a beneficial plant cover is an essential part of reclaiming disturbed land in order to ensure site stabilization and future use of the area (Nicholas and McGinnies, 1982). Replanting with species well adapted to the soil, climate, elevation, and exposure of the site has been recommended (Cook et al., 1974), not only for immediate revegetation, but also to establish a self-perpetuating cover which would require little or no maintenance activities. In the lower 48, there are chances for sharing knowledge, plant materials, and techniques among mines due to the similarity of environments within regions. Alaska's coal mines, existing in the boreal and, eventually, the Arctic zones, share few common environmental features with the rest of the U.S. coal producers. Thus, reclamation technology, plant materials, and experiences must be generated either within the state or borrowed from Siberian and northern Canadian sources.

State law requires that Alaska's stripmined areas be seeded to either native or approved introduced plant species (Alaska Statute 41.45). Using native plants would be the preferred reclamation strategy, since such plants would be well-adapted to the climate and wildlife uses of the area. However, availability of native plant seeds and technology for handling and planting the material is very limited. Although efforts are being made to resolve some of these deficiencies, immediate and long-term needs for using adapted and approved introduced species remain.

The process for identifying the best plant species involves a systematic screening of likely candidates and testing various planting and soil-cultivating techniques. The screening and

* Associate Professor, Agronomy, Palmer Research Center.
** Research Assistant, Agricultural Experiment Station, Fairbanks.
*** Usibelli Coal Mine, Inc., Healy.

This helicopter is used for fertilizing newly reseeded areas at the Usibelli Coal Mine near Healy, Alaska. The fertilizer spreader, seen suspended from the aircraft, is powered by its own gasoline-fueled engine. At the appropriate time, the pilot opens the spreader and applies a standard, high-nitrogen, granular-pellet fertilizer. Helicopters are also used for the distribution of the mixture of grasses, legumes, and annual mustards used in the revegetation of coal-mine spoils and roadways.

T. Heffernan

This mare and foal graze contentedly on an eight-year old surface-mining area which has been reclaimed at the Usibelli Coal Mine. The company has long engaged in a voluntary reclamation program which includes recontouring as well as reseeding. Slopes in the background are undisturbed and covered with indigenous plant communities.

testing are being conducted by other Alaska Agricultural Experiment Station investigators at the Usibelli Coal Mine. These tests commenced in 1980, mainly under sponsorship of the U.S. Department of Energy and the Usibelli Coal Mine, Inc. Because long-term stability is central to the reclamation goals, long-term plant performance must be known. This information can come from long-term experimental plantings or measurements of other plantings of known ages.

The Usibelli Mine, Inc., began a reclamation program in the 1970s (Weston, 1973). The project was directed by the late Stanley Weston, consultant from British Columbia, Canada. Seed mixes included grasses and legumes commonly available for pasture and forage crops (table 1). The earliest planting was 8 years old when the experiment station obtained the 1980 contract to investigate mine reclamation. Consequently, the various reclamation projects already established at the Usibelli Mine represented an invaluable test of long-term plant performance.

In 1980-81, six seedings, each of a different age, were evaluated for the presence of species which were applied in the mix or which naturally invaded. Two of the plantings, 1973 and 1978, were on abandoned roads. The other plantings, 1972, 1974, 1976, and 1979 were on former spoils. Plants were collected and identified according to Welsh (1974) and Heath, Metcalf, and Barnes (1973) during the summer season. The mining company provided lists of original seed mixes. Plant species occurring on each of the seedlings were collected and identified. Canopy cover was estimated in 50x50-cm plots, and biomass was measured by clipping and weighing annual growth of each major species. This article focuses on which seeded perennials become established. Results of other portions of the study will be reported elsewhere.

Results and Discussion

In terms of survival and stand development, red fescue, smooth brome, and bluejoint reedgrass were consistently outstanding grasses (see table). Red fescue and bluejoint both are native grasses and present throughout the boreal zone of Alaska, the regional environment in which the Usibelli Mine occurs. The accompanying photos illustrate the vigor and aesthetic values of these grasses at the mine.

Meadow foxtail, Kentucky bluegrass, timothy, and Canada bluegrass rated next in terms of survival, but were neither as consistent in survival nor as productive as the top three grasses. Other seeded species survived only in certain microhabitats or failed entirely (see table).

The usefulness of certain grasses for revegetation in Alaska has been reviewed by Mitchell (1982). Red fescue (particularly the variety 'Arctared'), 'Manchar' smooth brome, meadow foxtail, timothy, and 'Nugget' Kentucky bluegrass were recommended for Alaska's boreal zone. 'Boreal' red fescue, bluegrass, and meadow foxtail have also ranked well when cut frequently, (Mitchell, 1972), indicating such species might tolerate wildlife and domestic-livestock grazing.

Fertilizing soils has often proved essential for establishing (McKendrick and Mitchell, 1978) and maintaining vigorous grass stands in Alaska and elsewhere. Nitrogen and phosphorus fertilization is generally required for these soils. The ability of legumes to fix atmospheric nitrogen, thus enhancing soil fertility, makes inclusion of such plants an attractive choice for reclamation projects. Unfortunately, seeded legumes in the reclamation plantings have failed to establish either consistently or significantly at the Usibelli Mine (see table). Alfalfa and White Dutch clover were the only two species which survived among the nine perennial and one annual legume planted. Neither of the surviving species produced significant biomass throughout the seedings. Survivors occurred only in certain habitats.

Lupinus perenne was one of the seeded legumes. We are uncertain as to either its origin or taxonomic status, since the species is neither indigenous to the state nor commonly introduced for agricultural purposes. The other species were not ecotypes selected on the basis of their adaptation to Alaska's conditions. Due to significant variation within these species, it is likely that certain strains could outperform those seeded.

Nonlegume broadleaf plants were occasionally included in plantings (see table). Of the two species used, only field mus-

Table. Results of 1981 plant inventory on areas which had been seeded during six years at the Usibelli mine. "P" indicates species was planted; "S" indicates species was surviving in 1981; "V" indicates voluntary invasion and presence by that species in 1981.

Seeding years	1972	1973	1974	1976	1978	1979
Common name (Latin Name)	Origin/1981 status					
GRASSES						
Annual ryegrass (*Lolium multiflorum*)[1]	P	P	P	P	P	P
Boreal red fescue (*Festuca rubra*)[2]	P/S	P/S	P/S	P/S	P/S	P/S
Bluejoint reedgrass (*Calamagrostis canadensis*)[2]	P/S	P/S	P/S		P/S	P/S
Canada bluegrass (*Poa compressa*)			P/S	P/S	P/S	P/S
Crested wheatgrass (*Agropyron cristatum*)	P		P	P/S	P/S	P/S
Intermediate wheatgrass (*Agropyron intermedium*)		P		P		
Kentucky bluegrass (*Poa pratensis*)	P/S	P/S				
Manchar smooth bromegrass (*Bromus inermis*)	P/S	P/S	P/S	P/S	P/S	P/S
Meadow fescue (*Festuca elatior*)		P/S	P	P	P/S	P/S
Meadow foxtail (*Alopecuris pratensis*)	P	P/S	P	P	P/S	P/S
Perennial ryegrass (*Lolium perenne*)	P	P	P	P	P	P
Reed canarygrass (*Pharlaris arundinanceae*)	P	P/S	P	P/S	P/S	P/S
Siberian Wildrye (*Elymus sibericus*)					V	
Timothy (*Phleum pratense*)	P/S	P	P	PS	P/S	P/S
FORBS						
Legumes						
Alataswede red clover (*Trifolium pratense*)					P	
Alfalfa (*Medicago sativa*)	P	P/S	P	P/S	P/S	P
Alsike Clover (*Trifolium hybridum*)	P	P	P	P	P	P
Austrian winter peas (*Pisum sativum* subsp. *arvense*)[1]	P	P	P	P	P	P
Cicer milkvetch (*Astragalus cicer*)			P	P		
Hairy vetch (*Vicia villosa*)	P		P	P	P	P
Lupine (*Lupinus perenne*)			P		P	
Ladino clover (*Trifolium repens*)			P	P		
Leo bird's-foot trefoil (*Lotus corniculatus*)			P	P	P	
White Dutch clover (*Trifolium repens*)	P	P/S				
Nonlegumes						
Field mustard (*Brassica campestris*)[1]			P	P/S	P	P
Hedge mustard (*Sisymbrium offinale*)[1]				V		
Indian mustard (*Brassica juncea*)[1]				V		V
Lambsquarter (*Chenopodium album*)[1]			V	V	V	
Northern tansey mustard (*Descurania sophioides*)[1,2]				V		V
Pineapple weed (*Matricaria matricarioides*)[1]				V		
Peppergrass (*Lepidium densiflorum*)[1]					V	V
Wild buckwheat (*Eriogonum flavum*)					P	

[1] Annual species. [2] Native species.

tard persisted in 1981 along the abandoned road, which was seeded in 1976. Seven weedy plants invaded the seedings. Six of these were in the mustard family: hedge mustard, Indian mustard, northern tansey mustard, peppergrass, and shepherd's purse. Only one of these mustards is indigenous to Alaska — Northern tansey mustard. It is possible that seeds of these volunteers were included as contaminants among the various mixes planted at the mine. Fortunately, no noxious weeds occurred among those that persisted. The potential for introduction of noxious weeds exists and is a serious matter. Seed lots used for reclamation need to be selected carefully to avoid the problem.

Conclusions

Based on observations in this zone of Alaska, grass-seed mixtures for mine-spoil reclamation which consist of common agronomic plants should include red fescue, bluejoint reedgrass, and smooth brome to ensure long-term persistence of the seeded species. Varieties recommended by Mitchell (1982) would probably be better choices than using common seed stock. As various other native plant materials, such as shrubs and forbs, become available for reclamation, their seedlings' competitiveness with these grasses should be evaluated. To achieve certain ultimate land-use objectives and to encourage the eventual dominance of disturbed sites by other desired plants, there may be legitimate reasons for planting grass species which are not aggressive and which have poor long-term persistence. Lutz (1956) observed in his studies of natural plant communities in Alaska that heavy stands of bluejoint reedgrass could be very tenacious, resisting tree, shrub, and forb invasion for 100 years or more.□

Acknowledgments

We would like to express our thanks to Drs. Stanley L. Welsh (Brigham Young University, Provo, Utah), William W. Mitchell (Agricultural Experiment Station, Palmer) and David F. Murray (University of Alaska, Fairbanks) for their help in plant identification. William B. Collins and Frank Wooding of the Agricultural Experiment Station, UAF, helped us with forage-plant nomenclature. Funding for this research was provided by the U.S. Department of Energy; the Usibelli Coal Mine, Inc.; the state of Alaska, through its legislative appropriation to the University of Alaska's Agricultural Experiment Station; and by funds provided C. Elliott in the form of a National Wildlife Federation Conservation Fellowship and an Arctic Institute of North America Grant-in-Aid.

Literature Cited

Cook, C.W., R.M. Hyde, and P.L. Sims. 1974. Guidelines for revegetation and stabilization of surface-mined areas in the western states. Colorado State Univ. Range Science Series No. 16. 70 pp.

Heath, M.E., D.S. Metcalf, and R.F. Barnes. 1973. *Forages: The Science of Grassland Agriculture*, Third Edition. The Iowa State Univ. Press. Ames, Iowa. 755 pp.

Lutz, H.J. 1956. Ecological effects of forest fires in the interior of Alaska. U.S. Dept. Agric. Tech. Bul. 1133, 121 pp.

McKendrick J.D., and W.W. Mitchell. 1978. Fertilizing and seeding oil-damaged arctic tundra to effect vegetation recovery at Prudhoe Bay, Alaska. *Arctic 31*(3):296-304.

Mitchell, W.W. 1972. Red fescue and bluegrass rank high in frequent-cut test. *Agroborealis 4*(1):30-31.

_______. 1982. Grasses and their uses in Alaska. *Agroborealis 14*:34-37.

Nicholas, P.J., and W.J. McGinnies. 1982. An evaluation of seventeen grasses and two legumes for revegetation of soil and spoil on a coal strip mine. *J. Range Manage. 35*:288-293.

Welsh, S.L. 1974. *Anderson's flora of Alaska and Adjacent Parts of Canada.* Brigham Young University, Provo, Utah. 673 pp.

Weston, S. 1973. Revegetation of mining waste areas under arid, temperate, and permafrost conditions. Paper presented to 1973 Pacific-Southwest Mineral Industry Conference, AIME, April 25, 1973, Phoenix, Arizona. 22 pp.

Native Alaskan Pumpelly Bromegrass

Characteristics and Potential for Use

By

L.J. Klebesadel*

Introduction

The world abounds with a great diversity of grasses; botanists estimate there are about 5,000 different species worldwide. During the evolution of civilizations and the development of agriculture, certain grass species have been selected for artificial culture. Some, such as corn, rice, wheat, and barley, produce grain for food for humans and animals. Others, such as bromegrass, timothy, and orchardgrass, produce forage for livestock. Some, like bluegrasses and bentgrasses, are mowed short for turf. Numerous sod-forming grasses provide a vegetative cover to prevent soil erosion. Sugarcane and sorghum are grown for such processed products as sugar and molasses; and one species of grass, bamboo, is even used for fishpoles and furniture and in construction.

* **Professor, Agronomy, Agricultural Experiment Station, Palmer.**

The Bromegrasses

There are about sixty species worldwide in the grass genus *Bromus*; some are perennials, some biennials, and some annuals. Some of the annuals are considered weeds, but several of the perennials are valued as forage grasses.

About five species of bromegrass are native to Alaska, and all are perennials. The most widespread and abundant of these is pumpelly bromegrass (*B. pumpellianus*), a somewhat broad species considered by taxonomists to encompass two or three subspecies or taxonomic varieties (Hultén, 1968; Mitchell, 1967), see Figure 1.

A description of *B. pumpellianus* was first published almost 100 years ago (Lamson-Scribner, 1888) by the botanist Frank Lamson-Scribner who named the species after an American geologist, Raphael Pumpelly. The range of pumpelly brome in North America extends from Alaska east into Canada and south through western Canada to the states of Idaho, Colorado,

Figure 1. Pumpelly brome seed heads grow about as tall as those of smooth bromegrass, but top level or height of leaf growth in the native brome is usually lower than in smooth brome. These rows of pumpelly brome, planted 18 inches apart in June 1979, have grown together during the ensuing 4 years to form an almost-uniform sod. Photo 29 July 1983.

and South Dakota (Hitchcock, 1950). Its native range also occupies much of northeastern Asia, suggesting that the species probably originated on that continent (Elliott, 1949a) and successfully extended its range across the Beringian Isthmus or Land Bridge into North America before the ocean levels rose to separate the two continents.

Smooth Bromegrass

Pumpelly brome is closely related to smooth bromegrass (*B. inermis*), a valuable perennial forage grass, which is not native to North America. Smooth bromegrass was first introduced into the United States in 1884 from Hungary (Newell, 1973), and many subsequent introductions have come from various other sources in Europe and Asia. Two major types of smooth bromegrass, northern and southern, are recognized in North America (Hanson, 1972; Knowles and White, 1949; Newell, 1973; Smith, 1981; Thomas et al., 1958). The two types are differentiated by morphological, physiological, and behavorial differences, as well as ecological preference. These northern and southern types are believed to represent, respectively, the "meadow" and "steppe" types recognized in the U.S.S.R. (Wilsie, 1962).

Numerous named varieties of smooth bromegrass have been developed by plant breeders; these and regional strains have become widely adopted for forage production in the northern U.S. and Canada. This species' excellent palatability, high nutritive value, good drought tolerance, long life span, and versatility suit it for use in pastures, as a harvested forage (hay, haylage, silage, green-chop), and in plantings for soil cover and erosion control.

Smooth bromegrass was first planted for experimental evaluation in Alaska in 1902 at the Copper Center and Kenai experiment stations (Irwin, 1945). It was planted in numerous other trials during later years at experiment stations at Sitka, Rampart, Fairbanks, and Matanuska. Sources and adaptation of seed lots tested were not recorded and results varied at the different locations. However, at the interior stations it was generally hardy and dependable. Although bromegrass yielded poorly without fertilization, it was found to respond well to nitrate fertilizers.

Interspecific Hybridization

Both smooth brome and pumpelly brome are tall-growing, cool-season, rhizomatous (sod-forming) grasses. Where culture of the introduced smooth brome has brought it into contact with pumpelly brome in its native range in North America, the species have hybridized readily; the two are identical in chromosome number (2n = 56) (Elliott, 1949b; Mitchell, 1967). A major difference between the two species is the greater pubescence (minute hairiness) on several plant parts of pumpelly brome, in contrast to a general lack of hairiness in smooth brome. Resulting hybrid plants exhibit characteristics intermediate between the two parental species (Elliott, 1949a).

This genetic compatibility has been exploited in the development of the Alaskan bromegrass variety, 'Polar' (Hodgson et al., 1971; Wilton et al., 1966). Eleven of the sixteen parental clones of this synthetic variety are hybrids between smooth brome and Canadian or Alaskan plants of pumpelly brome. The other five clones are smooth brome. Incorporation of northern-adapted *B. pumpellianus* germplasm (from Alaska and Canada) into the variety Polar has conferred a higher level of winterhardiness for use in subarctic areas than is available in varieties of pure smooth brome (Wilton et al., 1966).

Alaska Collections

Beginning in the late 1950s, the Rockefeller Foundation funded a series of proposals submitted by the Agronomy Department of this Agricultural Experiment Station to collect seed, herbarium specimens, and living transplants of native grasses and legumes throughout Alaska. From these collections, individual plants were grown in observational nurseries over several years at the Matanuska Research Farm near Palmer. Included among the numerous species grown and evaluated for various purposes were a considerable number of collections of pumpelly bromegrass. On the basis of cumulative observations of agronomic merit in this native bromegrass, seed of selected lines was increased and the species has been evaluated in other, more comprehensive, studies (Klebesadel, 1970, 1971, 1973) and in additional investigations reported here.

The purpose of these studies was to delineate further the agronomic potentials and limitations of *B. pumpellianus* for various uses in Alaska. Results reported here are from several separate experiments conducted over several years at the Matanuska Research Farm.

Seedling Vigor

When planted at four different depths in soil, percentages of pumpelly brome seedlings that emerged from the various depths of seed placement were very similar to those for Polar bromegrass (table 1). However, average weights of pumpelly brome seedlings, when sampled 30 days after planting, were somewhat less than for Polar at the .25-, .5-, and 2-inch seeding depths; average weights for seedlings of both bromes were

Table 1. Emergence of counted seeds planted and seedling vigor of three grasses 30 days after planting as influenced by depth of seed placement.

Grass	Planting depth (in)	Per cent of emergence at .25" depth	Oven-dry wt per seedling (mg)
Pumpelly bromegrass:	.25	100	10.9
	.5	92	11.6
	1.0	94	11.0
	2.0	86	5.1
Polar bromegrass:	.25	100	16.4
	.5	102	14.3
	1.0	100	10.7
	2.0	88	10.1
Engmo timothy:	.25	100	4.8
	.5	107	5.2
	1.0	76	3.4
	2.0	14	0.9

Table 2. Mean forage yields of native Alaskan pumpelly bromegrass and other brome species and varieties in seeding year and during five subsequent years with two harvests per year. All dates and data are means of four separate tests, unless otherwise noted.

	Seeding yr.	First		Second		Third		Fourth		Fifth		
	29 Sept.	5 July	21 Sept	3 July	4 Oct	6 July	21 Sept	6 July	19 Sept	1 July	19 Sept	Total
	Tons dry matter/acre											
Pumpelly brome (*B. pumpellianus*):												
Native Alaskan	.15	1.49	.90	1.67	.84	2.11	.65	2.78	.63	2.51	.53	14.26
Smooth brome (*B. inermis*):												
Polar[1]	.69	1.48	1.20	1.31	1.20	2.02	1.23	2.48	.89	2.59	1.09	16.18
Manchar	.99	1.11	.91	.57	1.00	1.11	1.12	1.27	.90	1.92	1.23	12.13
Carlton[2]	.95	1.66	1.32	.80	1.32	1.44	1.49	1.85	1.29	2.52	1.03	15.67
Redpatch[2]	.96	.89	.77	.27	.88	.48	.54	.28	.08	.29	.41	5.85
Meadow brome (*B. biebersteinii*):												
Regar[2]	.88	.17	.22	.16	.47 (WK)[3]	---	---	---	---	---	---	1.90

[1]Predominantly hybrid (*B. inermis* x *B. pumpellianus*). [2] Included in three tests only. [3]No survival of Regar brome beyond third winter in any test.

similar when seeds were planted at the 1-inch depth. A further indication of less vigorous seedling growth of pumpelly brome, compared with smooth brome varieties, is seen in lower seeding-year forage yields of the native brome (table 2).

Both bromegrasses emerged much better from the deeper 1- and 2-inch planting depths than did the smaller-seeded 'Engmo' timothy. Moreover, at the early stage of seedling development sampled in this test, seedlings of both bromegrasses were much more vigorous than those of timothy, as indicated by weight of seedlings (table 1).

Vegetative Spread

Measurements of rapidity of lateral spread by underground stems (rhizomes) of three bromegrasses are summarized in Table 3. The smooth bromegrass 'Manchar' exhibited the greatest maximum extent of spread, as measured by the most distal emerging tillers in late May of the year after planting, for planting dates prior to mid-June. Spread of Manchar was generally less than that for Polar in rows planted later than mid-June.

Vegetative spread of pumpelly brome plants was less than with the varieties Polar and Manchar, especially with planting dates prior to July. Spread of the predominantly hybrid variety Polar was generally intermediate between *B. pumpellianus* and Manchar.

Table 3. Mean maximum width of spread of emerging tillers of bromegrass strains seeded in a 1-inch band on various dates during 1 year and measured 27 May of the following year. Each value represents the mean of forty measurements.

	Date planted							
Bromegrass	20 May	28 May	10 June	21 June	1 July	13 July	21 July	30[1] July
	Row width (in.)							
B. pumpellianus	13.1	11.3	9.6	6.9	5.3	3.6	2.3	2.0
Smooth Brome								
Polar	18.9	17.1	13.9	10.3	8.1	4.2	2.7	2.0
Manchar	20.2	18.3	15.1	8.8	6.8	3.8	2.2	2.0

[1]No rhizomatous spread of rows planted later than 30 July.

These results corroborate many general observations in numerous comparisons over many years wherein vegetative spread has been most rapid with Manchar and other introduced smooth brome varieties and least rapid with pumpelly brome. Rate of spread for Polar, representing hybridization between these species, is intermediate.

Forage Yields

A strain of native Alaskan pumpelly brome, representing only very modest selection for performance, was compared at Palmer in 6-year forage-production tests with the Alaskan variety Polar, the smooth brome varieties 'Carlton' and 'Redpatch' from Canada and Manchar from the Pacific Northwest states, and 'Regar' meadow brome (table 2). Two harvests were taken each of the 5 years after establishment. Pumpelly, Polar, and Manchar were included in four tests; and Carlton, Redpatch, and Regar in three.

Of the three bromes included in all four tests, Polar was the highest yielder, followed by pumpelly brome, then Manchar. Carlton from Canada produced approximately as much forage as Polar, but Redpatch, a variety of southern-type smooth brome from Canada, produced very low yields. Regar, a variety of meadow brome selected from an introduction from Turkey (Foster et al., 1966; Hanson, 1972), was not winterhardy and produced little forage.

Mitchell (1982) reported that, at this location, two strains of pumpelly brome were surpassed in forage yields by both Polar and Manchar in a 3-year comparison.

Forage-Yield Distribution

With two forage harvests per year, date of the first cutting exerts a dominant influence on the relative proportion of the total year's forage yield contributed by the first, versus the second, harvest. For example, harvest of the first cutting on 15 June will result in relatively less forage in the first cutting and more in the second (usually harvested in September) than when

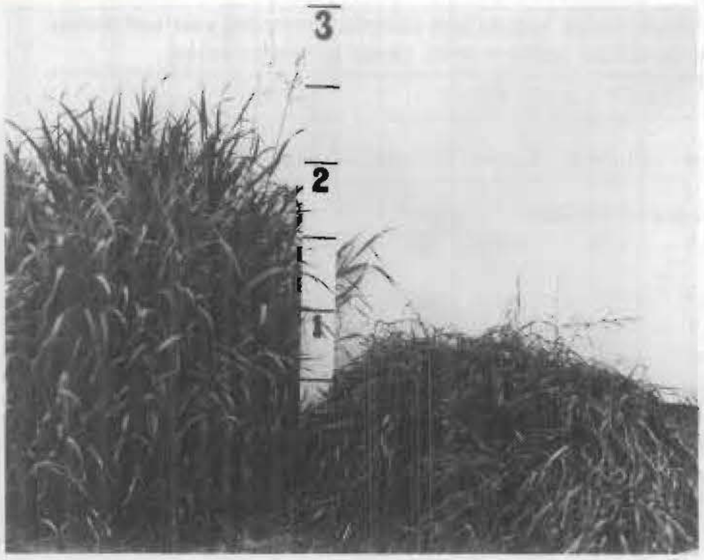


*Figure 2. Comparative growth in mid-October, following harvest of first growth in July of individual 5-year-old plants of Canadian commercial smooth bromegrass (*B. inermis*) (left) and native Alaskan pumpelly bromegrass (*B. pumpellianus*) (right) originating from Eagle (64.8° N). By mid-October, later than normal for a second-cutting forage harvest, the leafy growth of* B. pumpellianus, *containing few elongated culms, was becoming bleached and chlorotic while leaves on the many elongated culms in* B. inermis *continued dark green. Stake is 3 feet tall.*

the first cutting is taken on 1 July. (Forage yield is not the only variable of concern in farm practice, however. Quality of forage changes during grass growth and would be lower on 1 July than on 15 June).

Beyond the time-of-harvest influence on forage yield, however, there clearly were differences among the bromegrasses compared in per cent of total-year forage in the first and second harvests (table 3). Averaged over all cutting schedules in all years, pumpelly brome produced 74 per cent of total-year forage in the first cutting. In contrast, the three smooth brome varieties, Carlton, Manchar, and Redpatch, averaged only 55 per cent of the total year's forage in the first cutting. The predominantly hybrid Polar brome produced 63 per cent of total-year forage in the first cutting, intermediate between the two species. The extent to which this difference in yield distribution between the two species is simply normal growth pattern, rather than that influenced by differences in winter injury, is not readily apparent.

The tendency of pumpelly brome to produce a profusion of leafy growth but few elongated stems after midseason harvest is illustrated in the October comparison between a plant of Manchar brome and a pumpelly brome plant from Eagle, Alaska, in Figure 2. This growth behavior of subarctic-adapted pumpelly brome parallels that of the most winterhardy, northern-adapted timothy varieties (Engmo from northern Norway, 'Korpa' from Iceland). Like pumpelly brome, those varieties produce a dense growth of elongated stems in the first growth of the season, but mostly a mat of shorter, leafy growth following midseason harvest. In contrast, less winterhardy, more southern-adapted brome and timothy varieties produce another crop of elongated stems in the second growth of the season.

It is typical for pumpelly brome leaves in seeding-year stands, or in the second growth following midseason harvest, to bleach and become light green to yellowish in late September and October; this characteristic of foliar senescence during the winter-hardening period has been noted also in subarctic-adapted red fescue (Klebesadel et al., 1964).

Forage Quality

No known attempts have been made to plant pumpelly brome for use as a forage crop; however, it is grazed where livestock encounter it in native plant associations throughout its range (Johnston and Bezeau, 1962). There appears to be no reason that forage quality of pumpelly brome should not be roughly comparable to other bromegrasses, except perhaps very late in the year, after termination of the growing season, when second-growth leaves become yellowed.

Johnston and Bezeau (1962) sampled pumpelly brome and fifteen other native grasses in southwestern Alberta and reported chemical composition at five stages of development. Crude protein and carotene per cents were very favorable at the early, leafy growth stage for pumpelly brome.

Mitchell (1982) in Alaska found pumpelly brome herbage tended to be higher in calcium but lower in magnesium than Polar and Manchar brome; otherwise, quality indices such as nitrogen content were generally favorable.

Winter Hardiness

In the many field tests conducted here there have been no recorded instances of winterkill or even apparent winter injury with native pumpelly brome. The extreme winter hardiness of native Alaskan brome is a valuable attribute of this grass for use in Alaska, because a great many grasses used successfully elsewhere are not dependably winterhardy here (fig. 3).

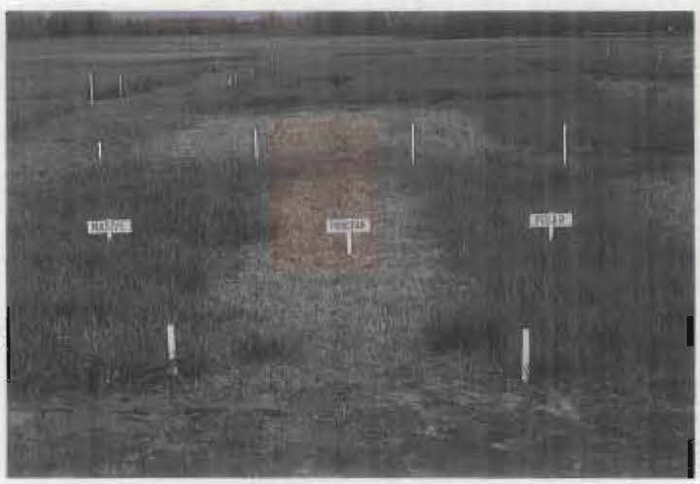


Figure 3. Comparative winter survival of three bromegrasses following an unusually severe winter at the Matanuska Research Farm: native Alaskan pumpelly brome (left), Manchar smooth brome from the Pacific Northwest area (center), and the Alaskan variety Polar (right), which incorporates some northern-adapted pumpelly brome in its parentage. (The clumps of living grass in the Manchar plot are Kentucky bluegrass present as contaminants).

Seed Yields

Pumpelly brome is a good seed producer, although, like other perennial bromes, it does not produce mature seed in Alaska during the year in which it is planted. Seed yields during the second year are, however, extremely influenced by date of planting during the previous year, with highest yields obtained from earliest planting dates (Klebesadel, 1970).

The pumpelly brome field shown being harvested for seed in 1980 in Figure 4 was planted on 2 July 1979 without concern for maximizing seed yield in 1980. The field yielded at the rate of 377 pounds per acre in 1980; earlier results indicate it would have produced more had it been planted in May or June.

Studies have shown (Clarke and Elliott, 1974; Hodgson, 1966) that the floral primordia of northern pumpelly brome begin initial development during late summer and autumn. These minute, embryonic seed heads overwinter in underground tiller branches, then gradually enlarge as they become fully developed and move upward inside the stems that elongate during May and early June of the following year.

Seed heads normally emerge during early June in the years after establishment, and seed is ripe for harvest from mid- to late August, depending on weather conditions during the growing season. Pumpelly brome seed matures about 1 week earlier than the variety Polar.

Mature seeds of pumpelly brome are dark purplish to black, in contrast to the lighter-brown seeds of smooth bromegrass (fig. 5). The papery seed coverings (lemma and palea) that shield the actual seeds (caryopses) from view in Figure 5 are somewhat translucent, but also carry some of the pigmentation of the seeds within. Seeds of Polar tend to be intermediate in coloration between the two parental species.

The larger of the two seed coverings (lemmas) in pumpelly brome possess an abundant, microscopic hairiness, while lemmas in smooth bromes exhibit an almost total absence of such pubescence. The hybrid Polar is intermediate in this characteristic as well.

Seeds per Pound

Numerous lots of 500 seeds each of pumpelly brome were counted and weighed from 4 different years' seed production from experimental plots. Calculations from these data indicate an average of 92,000 seeds per pound for this species. Smooth bromegrass seeds are slightly smaller (fig. 5) and average 136,000 per pound.

Counts of seed of the predominantly hybrid Polar, produced during several different years, indicate approximately 102,000 seeds per pound, intermediate between the two parental species. These data suggest that seeding rates of Polar and pumpelly brome should be commensurately higher than those of smooth brome to achieve equivalent stand densities during establishment.

Conclusions and Potential for Use

The pumpelly brome evaluated in the studies reported here possesses many valuable attributes including good seed production and seedling vigor, excellent winter hardiness, good forage production, long-lived stands, and sod-forming growth useful in binding soils against erosion. It represents a grass resource that may find use for forage production in areas subjected to extreme winter stresses. Further, it may prove valuable for revegetating disturbed areas where soil conditions are favorable for its growth and where rigorous winters preclude use of other, less winterhardy grasses.

This grass has already served in crosses with smooth brome to produce hybrid plants incorporated into the extremely winterhardy variety Polar. Plants used in those crosses were randomly selected, without emphasis on agronomic merits. Therefore, further crosses using selected, superior germplasm should result in superior hybrid materials. The extensive natural range of pumpelly brome in Alaska and the extent of variability noted among numerous collections evaluated suggest that there is considerable opportunity for artificial selection within the species. □

Figure 4. Combine harvest of pumpelly brome seed crop at Matanuska Research Farm on 27 August 1980.

Figure 5. Close-up comparison of seeds of different bromegrasses: Manchar and Carlton smooth brome, Polar hybrid brome, and native Alaskan pumpelly brome. Note larger, darker-colored seeds in pumpelly brome.

Acknowledgments

Early work contributing to this report was supported in part by funding from The Rockefeller Foundation under grants RF58108 and RF61036.

References

Clarke, J.M., and C.R. Elliott. 1974. Time of floral initiation in *Bromus* spp. *Canadian Journal of Plant Science 54*:475-477.

Elliott, F.C. 1949a. *Bromus inermis* and *B. pumpellianus* in North America. *Evolution 3*:142-149.

Elliott, F.C. 1949b. The cytology and fertility relations of *Bromus inermis* and some of its relatives. *Agronomy Journal 41*:298-303.

Foster, R.B., H.C. McKay, and E.W. Owens. 1966. Regar bromegrass. Idaho Agr. Exp. Sta. Bull. 470. 7 pp.

Hanson, A.A. 1972. Grass varieties in the United States. U.S. Department of Agriculture Handbook No. 170. 124 pp.

Hitchcock, A.S. 1950. (2nd ed., Rev.) Manual of the grasses of the United States. U.S. Department of Agriculture Misc. Pub. 200. 1051 pp.

Hodgson, H.J. 1966. Floral initiation in Alaskan Gramineae. *Botanical Gazette 127*:64-70.

Hodgson, H.J., A.C. Wilton, R.L. Taylor, and L.J. Klebesadel. 1971. Registration of Polar bromegrass. *Crop Science 11*: 939.

Hultén, E. 1968. *Flora of Alaska and Neighboring Territories.* Stanford Univ. Press, Stanford, Calif. 1008 pp.

Irwin, D.L. 1945. Forty-seven years of experimental work with grasses and legumes in Alaska. Alaska Agr. Exp. Sta. Bull. 12. 48 pp.

Johnston, A., and L.M. Bezeau. 1962. Chemical composition of range forage plants of the *Festuca scabrella* association. *Canadian Journal of Plant Science 42*:105-115.

Klebesadel, L.J. 1970. Influence of planting date and latitudinal provenance on winter survival, heading, and seed production of bromegrass and timothy in the Subarctic. *Crop Science 10*:594-598.

Klebesadel, L.J. 1971. Nyctoperiod modification during late summer and autumn affects winter survival and heading of grasses. *Crop Science 11*:507-511.

Klebesadel, L.J. 1973. Photoperiod/nyctoperiod pattern in autumn critical to grasses in Alaska. *Agroborealis 5*:14-15, 29.

Klebesadel, L.J., A.C. Wilton, R.L. Taylor, and J.J. Koranda. 1964. Fall growth behavior and winter survival of *Festuca rubra* and *Poa pratensis* in Alaska as influenced by latitude-of-adaptation. *Crop Science 4*:340-341.

Knowles, R.P., and W.J. White. 1949. The performance of southern strains of bromegrass in western Canada. *Scientific Agriculture 29*:437-450.

Lamson-Scribner, F. 1888. New or little-known grasses. *Torrey Botanical Club Bulletin 15*(1):8-10.

Mitchell, W.W. 1967. Taxonomic synopsis of *Bromus* section Bromopsis (Gramineae) in Alaska. *Canadian Journal of Botany 45*:1309-1313.

Mitchell, W.W. 1982. Forage yield and quality of indigenous and introduced grasses at Palmer, Alaska. *Agronomy Journal 74*:899-905.

Newell, L.C. 1973. Smooth bromegrass. IN: *Forages: The Science of Grassland Agriculture.* (Third ed.) The Iowa State Univ. Press, Ames, Iowa pp. 254-262.

Smith, D. 1981. Smooth bromegrass. IN: *Forage Management in the North*. (Fourth ed.) Kendall/Hunt Pub. Co., Dubuque, Iowa pp. 167-174.

Thomas, H.L., E.W. Hanson, and J.A. Jackobs. 1958. Varietal trials of smooth bromegrass in the North Central Region. North Central Reg. Pub. 93, and Univ. of Minnesota Agr. Exp. Sta. Misc. Rep. 32. 8 pp.

Wilsie, C.P. 1962. The ecotype concept. IN: *Crop Adaptation and Distribution*. W.H. Freeman and Co., San Francisco, CA. pp. 66-86.

Wilton, A.C., H.J. Hodgson, L.J. Klebesadel, and R.L. Taylor. 1966. Polar bromegrass, a new winterhardy forage for Alaska. Alaska Agr. Exp. Sta. Circ. 26. 7 pp.

Lingonberry Cultivation

By

Patricia S. Holloway*

Introduction

One of the distinguishing features of the Alaskan landscape is the variety and abundance of wild berry-producing plants found throughout the state. Among the most popular of these plants is the lingonberry, *Vaccinium vitis-idaea*, a plant that is common to most northern regions of the world. The lingonberry has long been recognized as a plant of considerable horticultural value, and for at least 20 years efforts have been made to domesticate this plant for sustained-yield, small-fruit production.

Lingonberries were first cultivated in 1789 (Rehder, 1940), but intensive efforts have been initiated only recently to develop a high-quality horticultural fruit crop. In the past, all fruit was collected from wild stands. In Europe, however, urban encroachment and changes in logging practices in major fruit-harvesting regions, lack of sufficient labor to harvest the fruit, uncontrollable fruit quality, and fluctuations in annual yields have combined to stimulate research into methods of lingonberry cultivation and improvement. In Alaska, efforts to increase the utilization of natural renewable resources and to develop potential uses for vast acreages of marginal lands have led to studies on the biology and cultivation of lingonberries.

Domestication of the lingonberry is potentially valuable in providing large quantities of high-quality berries for commercial processing. Cultivation practices can reduce labor costs and provide a reliable supply of berries for domestic and export markets for fresh and processed fruit. For the home gardener, domestication of the lingonberry can lead to the development of an attractive home-landscape plant that will produce an accessible crop of fruit for fall harvesting. However, considerable research is required, both for the development of a small-fruit industry and for home gardening use, if the lingonberry is to be effectively adapted from a wild plant into a cultivated, high-quality, horticultural crop.

The Wild Berry

The lingonberry is a member of the heath family, *Ericaceae*, and is related to the commercially produced cranberry, *Vaccinium macrocarpon*. Lingonberries grow throughout arctic America, extending southward to New England, the Great Lakes region, and British Columbia (Hultén, 1968; Munson, 1901). They are also prevalent throughout northern Europe and Asia.

The lingonberry, one of the most popular wild berry plants in Alaska, has been successfully developed into a major small-fruit crop of some economic importance in other parts of the world and is potentially valuable as such in Alaska.

* Assistant Professor, Horticulture, Agricultural Experiment Station, Fairbanks.

Figure 1. Blossoms of lingonberries.

Figure 2. Ripe fruit of lingonberries.

Hultén (1949) divides this circumpolar species into two races relating to adaptations to its ecologically diverse range. The lowland subspecies, *vitis-idaea*, occurs in Europe and northern Asia and joins the arctic-montane subspecies, *minus* in the mountains of Scandinavia. Subspecies *minus* grows in North America and Europe and is the race found in Alaska. Throughout this range, the lingonberry is known by more than twenty-five common names including cowberry, lowbush cranberry, foxberry, partridge berry, and mountain cranberry.

Lingonberries produce upright stems that originate from subterranean, horizontal rhizomes. Stems may appear singly, one or two per square meter, as in many *Sphagnum* sp. or tussock-forming bogs or in dense clones several meters in diameter as in some mixed spruce-hardwood forests. In Alaska, lingonberries have a diverse habitat, growing abundantly from dry roadside slopes with little or no developed organic-matter layer to acid-peat bogs, and from mature, shady forests to fully exposed alpine and arctic tundra slopes. They often occur in greatest abundance on top of decaying tree stumps in mature forests. Throughout its range, lingonberries appear to be most abundant in forested regions that have moist, acid soils, moderate shade, and a well-developed organic-matter layer (Ritchie, 1955; Viereck and Little, 1972).

In interior Alaska, the pink bell-shaped flowers of the lingonberry appear in early June with full bloom lasting from 19 to 27 days (fig. 1). Clusters of green berries ripen to a deep burgundy from late August through September, approximately 78-84 days after full bloom (fig. 2) (Holloway, 1982). The fruit is smaller, a deeper red, and more tart in flavor than the cultivated cranberry and is a source of potassium, calcium, magnesium, phosphorus, as well as carotene, B_1, B_2, folic acid and C vitamins (Heller and Scott, 1962). The fruit is also rich in benzoic acid and tannins and has a pH of 2.5 (Bandzaitene and Butkus, 1977; Stark et al., 1978). Lingonberries are a versatile addition to a variety of prepared foods and have been used successfully for many years in sauces, jam, bread, juice, and even ice cream.

One problem associated with all wild stands of lingonberries is the wide fluctuations in yield of ripe berries. Seasonal losses of flowers or immature fruit can be as high as 94 per cent of the total number of flowers produced in a stand. Losses may be attributed to cold temperatures, rain, or drought during flowering (Tear, 1972) and self pollination (Hall and Beil, 1970). In Alaska, hail storms during flowering can account for substantial losses of flowers and green fruit. Insufficient pollination by insects, principally bumble bees and honey bees, is also a factor in limiting fruit production. In a comparison of lingonberries that were caged to exclude insect pollinators and plants that were open-pollinated, fruit set was significantly higher in open-pollinated plants (table 1). Open-pollinated plants also produce larger fruit with a greater number of seeds per berry than caged plants (Holloway, 1982).

The initial attempts to improve lingonberries and to alleviate the wide fluctuations in yields involved the eradication of

Table 1. Effects of insect pollination on fruit set and development in lingonberries at two sites in the Fairbanks, Alaska, area.

Site	Treatment	Average number per stem: Flowers	Average number per stem: Fruit	Average berry diameter (cm)	Average berry weight (g)	Number of seeds per berry	Per cent fruit set
Chena Pump Road (elevation approximately 400')	Open-pollinated	5.7	2.2**	0.80**	0.27**	12.7	39.6**
	Caged	5.1	0.1	0.52	0.16	5.2	0.6
Gilmore Trail (elevation approximately 1200')	Open-pollinated	5.3	0.4**	0.39	0.13	8.9	9.4**
	Caged	4.9	0.0				0.0

**Means differ significantly, P = .01.

competing vegetation and the fertilization of wild stands. This research was begun in Alaska in 1965 by Dr. Arvo Kallio at the Agricultural Experiment Station in Fairbanks. Similar studies were reported in Finland by Dr. Aaro Lehmushovi. Both researchers found that fruit yield in wild stands can be improved substantially with fertilization. However, if these stands contain appreciable quantities of grasses and broad-leaved herbs, lingonberries often disappear from the area due to competition with those other plants that also benefit from fertilization (Kallio, unpub;[1] Lehmushovi, 1977 a, b). Crop improvement through manipulation of wild stands will require a vigorous program of weed control.

Commercial Interests

In Scandinavia, Germany, and the Soviet Union, the lingonberry is a major small-fruit crop. Total annual consumption of berries in Sweden is estimated at 12 million kg (Fernquist, 1977), while in Finland annual yields of up to 20 million kg may reach the marketplace (Lehmushovi, 1977a). The major exporting countries in Europe are Sweden, Finland and the Soviet Union, and the primary importer is Germany (Statistical Offices of the European Communities, 1979). Sweden also exports fruit to the United States, but most of this is processed rather than fresh fruit. A liter of lingonberry sauce from Sweden sells in Alaska for $9.00-$12.00.

Berries are also collected commercially in Nova Scotia and Newfoundland, but production is low in comparison to Scandinavia. A small amount of fruit from these areas is imported into the United States, especially into east-coast and northern-midwest markets.

Lingonberries are commercially harvested on the east coast of Newfoundland, primarily on the Avalon and Bonavista Peninsulas (Hall, 1978). Prices paid to pickers in 1977 ranged from $0.22 to $0.27 per kg (Stark et al., 1978). Approximately one-third of the crop is retained in Newfoundland, while the remainder is exported to Europe and the United States. Exports for 1976 were 37,825 kg (Hall and Beil, 1970).

In 1914, berry harvesting in Newfoundland was a family enterprise with an average, daily, hand-picked yield of 113.6 kg. Following a cleaning process by winnowing, the berries were packed in water in 90-liter barrels (Torrey, 1914).

Currently, most of the crop is still hand harvested from wild stands, but in some regions a small hand rake is used (Hall, 1978). Some of the fruit is cleaned, frozen, and exported to the United States in plastic-lined cardboard cartons. In Minnesota, these frozen berries are thawed and packed in water in cottage cheese-type cartons. This process is an apparent attempt to emulate the more old-fashioned method of packing in water in wooden barrels.

Commercial harvest of lingonberries in Alaska averages less than 5000 kg annually. Several processors in southcentral Alaska produce such items as jam, sauce, and candy that are sold locally, chiefly to tourists. Fresh berries are sold sporadically at farmer's markets, but no measurable amount is exported. The fruit for processing is hand harvested from wild stands throughout Alaska, but primarily on the Kenai Peninsula. Processors rely on word-of-mouth to recruit pickers or advertise for fruit in local newspapers beginning in August and pay pickers from $0.78 to $1.00 per kg. An annual problem for many processors is finding enough pickers to harvest large quantities of clean fruit.

In the early 1920s, berries from Alaska were shipped to Seattle for $0.56 per kg, but prices were not competitive with European fruit selling for $0.18 per kg (Moore, unpub.).[2] Subsequent attempts to market fresh berries outside Alaska from Dillingham and Kokhanok Bay in the 1940s and 1950s also proved to be uneconomical (Marsh, unpub.).[3]

Products such as sauce, preserves, candy, jelly, juice, syrup and pickles are processed and marketed in Japan (Iwagaki et al., 1977), throughout Europe (*International Fruit World*, 1957; Liebster, 1975) and in Alaska. In Siberia, berries have been fermented and distilled with barley or rye or combined with honey to produce a wine (Munson, 1901). Combinations of berries with dairy products such as yogurt have not been accepted by European consumers (Muller, 1977), but lingonberry ice cream has been successfully test marketed (Pillsbury, unpub.).[4]

The leaves and stems of lingonberries are used as a source of pharmaceutical arbutin. In Rumania, arbutin is manufactured under the name, Idalbina, and is used to cure human intestinal disorders (Racz et al., 1962).

In most northern regions of the United States the plant is known commercially as an ornamental ground cover rather than a fruit crop (Rehder, 1940). However, no selections have been made for plant improvement.

Cultivation

The first cultivation experiments in Finland began in 1968 at the Institute of Horticulture in Piikkio (Lehmushovi and Hiirsalmi, 1973; Liebster, 1975). These experiments showed that plants growing in cultivated fields could yield nearly five times those growing in the wild (Liebster, 1975). Milled peat is a better substrate than sand or a 1:1 mixture of sand and peat. Mulching increases fruit yields, with a sand mulch being more effective than milled peat, gravel, straw, and unmulched mineral soil. Application of an 11-11-22 fertilizer at 10 kg per acre increases fruit yield but decreases berry size (Lehmushovi and Hiirsalmi, 1973; Liebster, 1975).

Trials in Sweden have shown that the best substrate is sandy, acidic (pH 5-6) soils with at least a 2 per cent organic matter content. Research with fertilizers has shown that the mineral nutrient requirements of lingonberries is very low, and fertilizer needs, in general, are very small. Large quantities of nitrogen (up to 12 g per m^2) decrease shoot growth, yield, and berry weight on most soil types, and only positively influence lingonberry growth on nutrient deficient sandy soils (Fernqvist, 1977; Ingestad, 1973).

In 1979 research was begun to determine the optimum substrate for cultivation of lingonberries in Alaska (Holloway et

[1] Kallio, Arvo. 1965. Agricultural Experiment Station, University of Alaska, Fairbanks.

[2] Moore, J.D. 1958. Kokhanok Bay, Alaska.

[3] Marsh, C.F. 1966. Agricultural Research Center, Agricultural Experiment Station, Palmer.

[4] Pillsbury, H.W. 1958. Cooperative Extension Service, USDA, Palmer.

al., 1982b). Vegetative growth was observed for 3 years on plants grown in four unsterilized, native Alaskan substrates: coarsely-ground Lemeta peat; Fairbanks silt loam soil; a mixture (1:1) of peat and silt loam soil; and washed, Chena, very fine, sandy loam soil. Plants grown in peat showed the greatest increase in vegetative growth as exemplified by plant dry weight (table 2). The leaves on plants grown in peat remained green throughout the entire experiment, while the leaves of plants in all other treatments showed varying degrees of chlorosis followed by reddening and necrosis. High pH and low organic-matter content of the silt loam soil, sandy soil, and soil-peat mixture probably contributed to poor growth on these substrates. This study showed that agricultural soils, as exemplified by the silt loam soil, and sandy alluvial soils are not appropriate for lingonberry cultivation. Incorporation of peat into agricultural soils improves growth only slightly. Future experiments with lingonberry cultivation should be conducted on a substrate composed entirely of peat.

Table 2. Dry weight of lingonberries grown in four Alaskan substrates for three growing seasons.

Substrate	Dry weight (mg)			
	Vertical Stems	Leaves	Rhizomes	Roots
sandy loam soil	35.3b*	66.3b	119.8b	12.4a
silt loam soil	44.4b	55.9b	119.7b	3.5b
silt loam-peat mixture	38.7b	68.7b	121.5b	7.0b
peat	70.8a	176.1a	161.9a	17.5a

*a,b. Mean separation by Duncan's new multiple range test, 5 per cent level.

Additional experiments were designed to determine if lingonberries could be grown in full sunlight in cultivated fields (Holloway et al., 1982a). Lingonberries were grown under four treatments: 0, 44, 56, and 73 per cent shade provided by various thicknesses of polypropylene shade cloth. Following three growing seasons, the greatest vegetative growth occurred in the unshaded plants (table 3). The only measurable increase in growth that occurred in any of the shaded plants was an increase in plant height in the 73 per cent shade treatment. This study has shown that it should be possible to grow lingonberries in full sunlight in cultivated fields without provisions for shading to enhance plant establishment. In addition, in modification of wild stands to promote maximum vegetative growth, cover by shrubs and trees should be eliminated and weed growth minimized.

Table 3. Dry weight of lingonberries grown under 0, 44, 56 and 73 per cent shade for three growing seasons.

Per cent Shade	Dry weight (mg)			
	Vertical Stems	Leaves	Rhizomes	Roots
0	191.5a*	474.3a	309.6a	53.4a
44	92.8b	223.2b	142.7b	21.2b
56	103.0b	241.8b	170.5b	16.4b
73	108.8b	266.6b	165.4b	17.1b

*a,b. Mean separation by Duncan's new multiple range test, 5 per cent level.

Propagation

Investigations into methods of lingonberry propagation are necessary for this plant's establishment in cultivated fields. Requirements for seed propagation are well established (Densmore, 1974; Hall and Beil, 1970; Lehmushovi, 1975), however, experimental broadcast seeding in Fairbanks has been unsuccessful. Greater benefits are obtained when seed is germinated and grown in controlled environments from which seedling transplants are obtained. Seeds germinate slowly when extracted from ripe berries and sown onto a finely milled peat substrate. They should be stratified for 30 days at 4°C prior to sowing to enhance germination which generally takes 10 to 14 days. Plants from seeds will flower and produce fruit 3 to 6 years after seedling establishment.

Propagation by vegetative cuttings is generally an effective method of obtaining genetic uniformity and high-quality plants. Stem cuttings taken during the dormant period root in about 2-3 weeks. However, rooted stem cuttings fail to produce rhizomes from which new shoots arise. Growth seems to be limited to increased branching and development of the original stem with little vegetative expansion (fig. 3). Propagation using rhizome cuttings shows no such disadvantage, and may be the only method of effectively propagating lingonberries vegetatively.

The quickest method for planting a cultivated field is by transplanting clumps of established lingonberry plants from wild stands. The size of the transplants determines their subsequent survival, with those containing few individual stems exhibiting the greatest mortality. The use of larger sections increases plant survival but also increases the chances of transplanting unwanted native vegetation into the cultivated field. Establishing cultivated fields by this method should be used only when breeding experiments or selection for superior strains is anticipated since much of the variability in the growth and fruit production exhibited in wild stands will be transferred to the cultivated field.

Conclusion

In general, the basic criteria for beginning a cultivated field of lingonberries include acid peat substrates, plenty of moisture, and little or no shade. Plants should be started from seed or rhizome cuttings in the greenhouse and transplanted into the field in spring. The fields should be irrigated throughout the summer to increase transplant survival and promote rhizome production. Fertilizer should be used sparingly, and applied only in several small quantities spread out over a long period.

These studies have just begun to penetrate the complexities of adapting the wild lingonberry into a cultivated crop. Much has been learned from the research in Alaska, Scandinavia, and the Soviet Union. Studies should be continued to determine specific cultural requirements for local growing conditions. Further experimentation with fertilization, irrigation, weed control, and identification and control of diseases is necessary to provide complete knowledge into the development of this plant. Intensive investigations through controlled-environment experimentation are also necessary to determine mineral nutrient requirements and general physiological adaptations of the lingonberry. This research will enhance its domestication into a high-quality, sustained-yield horticultural fruit crop for Alaska.□

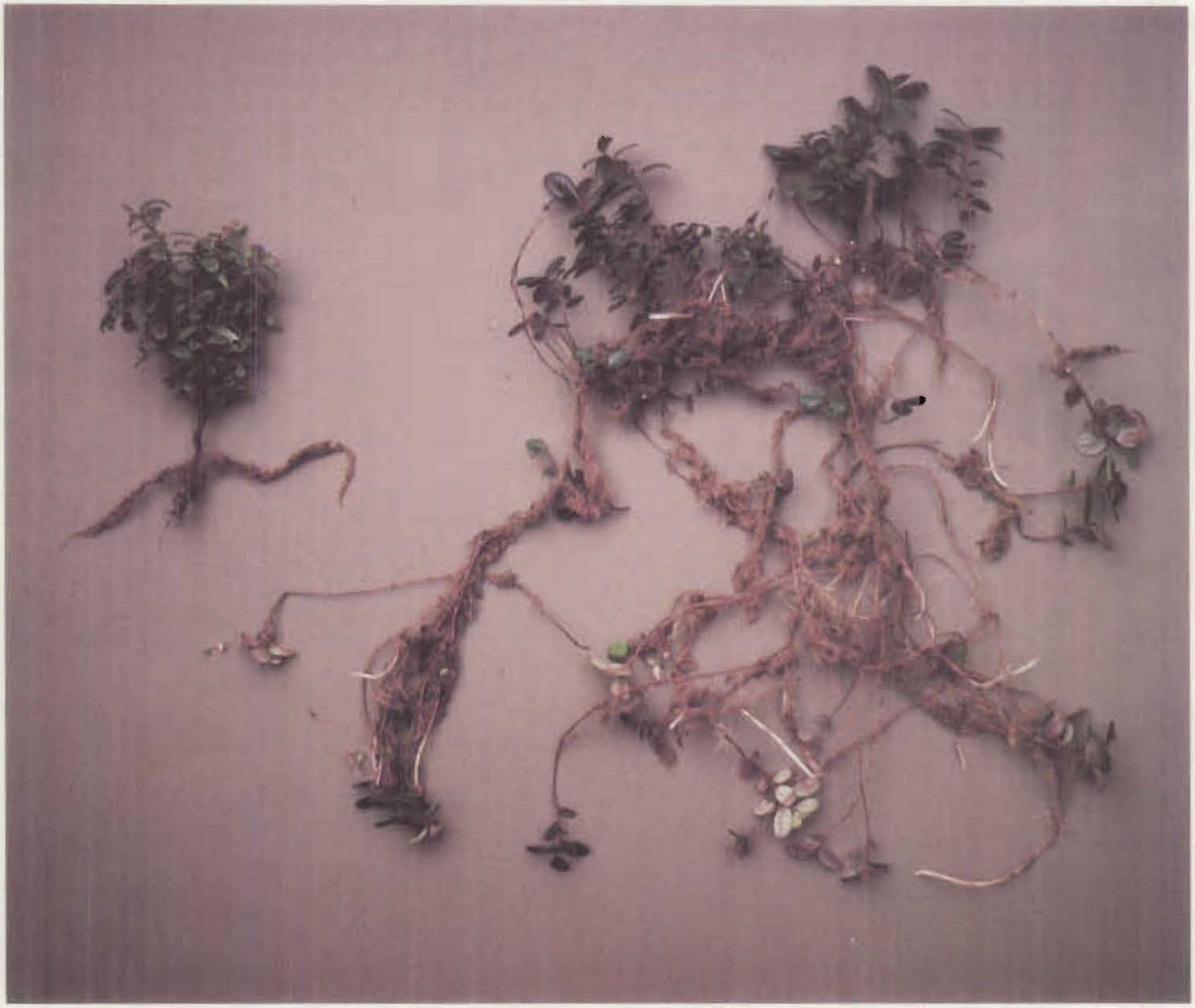


Figure 3. Lingonberry plant on the left is a 2-year-old stem cutting while plant on the right is a 2-year-old seedling.

References

Bandzaitene, Z.Yu., and V.F. Butkus. 1977. Biological and biochemical characteristics of red bilberry. Part 5. The content of N, P, K, Ca, Fe, Mn, Cu, Mg, Na, B and ash in the fruits and seeds. *Trudy Akedemii Nauk Litovskoi SSR, B. 2*(78): 31-38. (English summary)

Densmore, R.V. 1974. Germination requirements of *Vaccinium vitis-idaea, Rosa acicularis* and *Viburnum edule*. M.S. Thesis. Univ. of Alaska, Fairbanks.

Fernqvist, I. 1977. Results of experiments with cowberries and blueberries in Sweden. *Acta Hortic. 61*:295-300.

Hall, I.V. 1978. *Vaccinium* species of horticultural importance in Canada. *Hort. Abstracts* (Review). *48*(6):441-445.

Hall, I.V., and C.E. Bell. 1970. Seed germination, pollination and growth of *Vaccinium vitis-idaea* var. *minus* Lodd. *Can. J. Pl. Sci. 50*:731-732.

Heller, C., and E. Scott. 1962. *The Alaska Dietary Survey 1956-1961*. U.S. Dept. of Health, Education and Welfare. U.S. Govt. Print. Off., Washington, D.C.

Holloway, P.S. 1982. Studies on vegetative and reproductive growth of lingonberry, *Vaccinium vitis-idaea* L. Ph.D. Thesis. Univ. of Minnesota, St. Paul, MN.

Holloway, P.S., R.M. Van Veldhuizen, C. Stushnoff and D.K. Wildung. 1982a. Effects of light intensity on vegetative growth of lingonberries. *Can. J. Plant Sci. 62*:965-968.

Holloway, P.S., R.M. Van Veldhuizen, C. Stushnoff and D.K. Wildung. 1982b. Vegetative growth and nutrient levels of lingonberries grown in four Alaskan substrates. *Can. J. Plant Sci. 62*:969-977.

Hultén, E. 1949. On the races in the Scandinavian flora. *Svensk. Bot. Tidskr. 43*(2/3):383-406.

Hultén, E. 1968. *Flora of Alaska and Neighboring Territories*. Stanford Univ. Press, California.

Ingestad, T. 1973. Mineral nutrient requirements of *Vaccinium vitis-idaea* and *Vaccinium myrtillus. Physiol. Plant. 29*: 239-246.

International Fruit World. 1957. Red whortleberries, a northern specialty. *16*(1):259-60,263,265.

Iwagaki, H., S. Ishikawa, T. Tamada, and H. Koike. 1977. The present status of blueberry work and wild *Vaccinium* spp. in Japan. *Acta Hortic. 61*:331-334.

Lehmushovi, A. 1975. Methods of propagating the cowberry. *Ann. Agric. Fenn. 14*(4):325-333.

Lehmushovi, A. 1977a. Some aspects of the cowberry, *Vaccinium vitis-idaea*, trials in Finland. *Ann. Agric. Fenn. 16* (1):57-63.

Lehmushovi, A. 1977b. Trials with the cowberry in Finland. *Acta Hortic. 61*:301-308.

Lehmushovi, A., and H. Hiirsalmi. 1973. Cultivation experiment with the cowberry: Significance of substrate, liming, fertilization and shade. *Ann. Agric. Fenn. 12*(2):95-101.

Liebster, G. 1975. Growing red whortleberries (*Vaccinium vitis-idaea*) on cultivated land—a new objective of experimental and research work in fruit growing. *Erwerbsobstbau. 17* (3,4):39-42, 58-61. (Transl. from German)

Muller, H.P. 1977. The use of *Vaccinium* fruits in the dairy industry. *Acta Hortic. 61*:343-347.

Munson, W.M. 1901. The horticultural status of the genus *Vaccinium*. Maine Agric. Exp. Sta. Bull No. 76.

Racz, G., I. Fuzi, and L. Fulop. 1962. A method for the determination of the arbutin contents of cowberry leaves (*Folium vitis-idaea*). *Rumanian Med. Rev. 6*(1):88-90. Abstr.

Rehder, A. 1940. *Manual of Cultivated Trees and Shrubs*. MacMillan Pub. Co., Inc., New York.

Ritchie, J.C. 1955. Biological flora of the British Isles. *Vaccinium vitis-idaea* L. *J. Ecol. 43*:701-708.

Stark, R., I.V. Hall, and P.A. Hendrickson. 1978. *The Partridgeberry of Newfoundland*. Canadex. Horticultural Crops, Agriculture Canada No. 230.

Statistical Office of the European Communities . 1979. *Analytical Tables of Foreign Trade*. Eurostat, Luxembourg. 107, 388.

Tear, J. 1972. Vegetative growth and fruit production in wild and cultivate cowberry. Ph.D. Thesis. Institute of Horticulture, Alnarp, Sweden. (Transl. from Swedish).

Torrey, G.S. 1914. *The Partridge Berry*. Dept. of Agric. and Mines. St. Johns, Newfoundland.

Viereck, L.A., and E.L. Little, Jr. 1972. *Alaska Trees and Shrubs*. Agric. Handbook No. 410. Forest Service, USDA, Washington, D.C.

Monitoring the Activity of Root Maggots

By

David P. Bleicher*

Introduction

Root maggots of the genus *Delia* (Diptera: Anthomyiidae) are the most important insect pests of *Brassica* crops (radish, turnip, broccoli, cabbage, etc.) in Alaska. Feeding by immature (larval) stages of the pest results in surface scars and feeding tunnels on root crops (fig. 1), rendering produce unacceptable for market. Infestation of stem Brassicas results in a decrease in yield and quality of produce (fig. 2). Younger plants may be killed. Root maggots can be controlled effectively by timely application of appropriate pesticides. However, those involved with *Brassica* crop production and concerned with control of root maggots should consider the seasonal activities of the pest when developing control strategies (Bleicher, 1982).

Many species of *Delia* have been collected in Alaska, but not all are considered to be of economic importance to the production of plants of the family Brassicaceae (Cruciferae). *D. floralis* Fallen (turnip maggot) is most abundant and widely distributed. Its host range is limited to members of the Brassicaceae. Where there is no commercial or subsistence production of host plants, low-level endemic populations survive on wild mustards (Washburn, 1953). *D. platura* Meigen (seed corn maggot) is a more general feeder but is conspicuous as a low-level pest of Brassicas. Reports suggest that it is found in greater numbers in the moderate climates of southern coastal areas although its range of occurrence is greater (Chamberlin, 1949; Huckett, 1965; Washburn, 1953). Where it occurs, *D. platura* is generally found in association with *D. floralis*. Although *D. radicum* L. (cabbage maggot) occurs in Alaska, the extent of its range and importance to production is not presently known. It has, however, been collected and implicated as an incitant of severe damage in one location in the Matanuska Valley.

Early reports (pre-1944) of root maggot injury in Alaska describe damage as the result of *D. radicum* activity. However, this determination was apparently not based on taxonomic confirmation.

Chamberlin (1945) examined the species composition of root maggots in Alaska. Larvae collected from cultivated *Brassica* hosts were reared to adult and identified as *D. floralis* and *D. platura*. It was concluded that, in terms of numbers and economic significance, *D. floralis* is the more important species, a conclusion with which Washburn (1953) agrees. Neither Chamberlin nor Washburn report the collection of *D. radicum*. In 1982, however, severe root maggot infestation was observed in radish at one location in the Matanuska Valley early in the season at the time when *Delia* at all other monitored locations were just becoming active. Larvae and adults were collected and determined to be *D. radicum* (D.P. Bleicher[1]).

* Research Entomologist, Agricultural Experiment Station, Palmer.

[1] This determination was made as the result of a study conducted by David P. Bleicher, unpublished.

Figure 1. Root maggot damage to turnip.

Figure 2. Root maggot damage to cabbage. Note complete destruction of tap root.

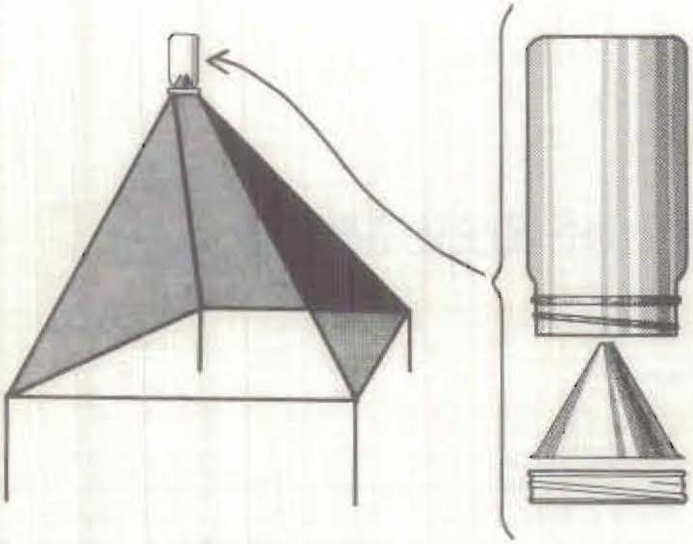


Figure 3. Trap used to monitor emergence and flight activity of Delia *flies.*

Figure 4. Baited traps were set around the perimeter of a mixed plot of Brassica *crop plants.*

There are apparent similarities between root maggot populations in Alaska and other circumpolar regions. Lein (1955) discussed the species composition of cabbage root flies and their importance in Norway. *D. floralis* is more numerous than *D. radicum*, and the importance of *D. radicum* becomes less in Norway's northern districts. Also, *D. platura* commonly occurs in low numbers in association with the other two species.

Observations of the emergence of *D. radicum* and *D. floralis* adults from overwintering pupae have been reported by Lein (1955) and Rygg (1962) in Norway and by Varis (1960) in Finland. Depending on latitude, first appearance of adults may occur from May 7 to June 10 for *D. radicum* with the development of two generations each season in areas in which they appear earlier. First emergence of *D. floralis* may occur from June 11 to July 4. In all locations a single generation matures each year.

The life history of root maggots in southcentral Alaska has been addressed by Chamberlin (1949). Adults begin to emerge from overwintered pupae in late May to early June for a period of 5 to 6 weeks with peak emergence occurring during the latter part of June. This is based on emergence under screen cages over tilled and undisturbed ground containing infested *Brassica* root crops. Oviposition begins during the same period, with eggs hatching within 7 to 10 days. Larvae complete development to pupal stage approximately 4 weeks after hatching. Overwintering occurs in the pupal stage. A single generation develops each season.

Root maggots are controlled with insecticides in Alaska. Commercial growers make prophylactic applications of insecticides throughout the season, beginning with a preplant, soil-incorporated, broadcast treatment and continuing with post-emergence, foliar-spray applications at regular intervals. This intensive insecticide program protects crops from root maggot damage, but it is expensive and, in most cases, unnecessary. Timing the insecticide applications to coincide with adult flight or ovipositional activity may result in fewer treatments.

A study was initiated in 1978 to determine the emergence, seasonal flight activity, and ovipositional activity of adult root maggots, with particular reference to *D. floralis*.

Materials and Methods

General

All observations were made at the Agricultural Experiment Station's Research Center at Palmer during the 1979 and 1982 field seasons. Traps were employed to monitor adult emergence and flight activity. They were pyramidal in shape, covered 1 m^2 at the base, and were 1 m long on the sides. Legs, 30 cm in length allowed the base to be raised, yet securely anchored the trap. Traps were constructed of welded ¼-inch steel-rod frames covered with olive, nylon mesh. An inverted 1-quart glass jar fitted with a wire-mesh cone with a small aperture at its top was secured to the apex of the trap (fig. 3). Adult flies having a tendency to fly upwards in attempting escape are funneled through the small screen cone and into the jar.

Adult Emergence

In 1980 and 1982, traps were placed over undisturbed soil that in the previous year was sown to turnip, broccoli, and rutabaga and allowed to become infested with root maggots. Traps were set flush to the ground and soil was mounded around the bases to ensure the capture of adults as they emerged. Traps were set during the first week in May. Four were set in 1980, and three in 1982. The specimens were removed for identification each Monday, Wednesday, and Friday throughout the season.

Adult Activity

Adult activity was monitored during the summers of 1979, 1980, and 1981. Traps were baited, and their bases were set 10 cm above the soil surface allowing for the entrance of attracted flies (fig. 4). Baits consisted of transplanted liners of cauliflower var. Snowmound, turnip var. Purple Top White, and meat meal. Fifty grams of meat meal was wrapped in a fine nylon mesh to form a sachet for each trap. This was then enclosed in a 15-cm cube constructed of ¼-inch hardware cloth and secured to a post driven into the ground. Six traps were set in 1979 and 1980 and five in 1981 around the perimiter of the study plot. In 1979, traps were monitored every second day and every Monday, Wednesday, and Friday in 1980 and 1981.

Figure 5. Delia *eggs on radish.*

Oviposition

Oviposition by root maggots on three varieties of *Brassica* crop plants was monitored in 1979, 1980, and 1981. Study plots were randomly seeded in rows to turnip var. Purple Top White Globe, broccoli var. Waltham 29, and rutabaga var. Burpee's Purple Top Yellow.

In 1979, a destructive sampling technique was used in an extensive planting. *Delia* eggs were counted on ten randomly selected plants of each variety (fig. 5). Plants were removed as eggs were counted. Egg counts were made every second day.

In 1980 and 1981, ten plants of each variety were randomly selected and marked. Eggs were removed as they were counted so that the same plants could be monitored through the season. Counts were made each Monday, Wednesday, and Friday.

Identification

All adults collected from the cone traps were field sorted to Anthomyiid-like flies. These specimens were mounted and labeled. Using a synopsis of taxonomic characters based on the keys of Huckett (1965) and Brooks (1959) *Delia* spp. were separated. Because of variability in characters used at the species level a number of male specimens were used to spot check identifications by dissection and examinations of genitalia.

Results and Discussion

Table 1 shows the relative abundance of *Delia* spp. that emerged from overwintering pupae under traps over the root maggot-infested *Brassica* plot. *D. floralis* is clearly the most important. *D. florilega* Zett. and *D. platura* occurred in low numbers. No *D. radicum* were collected.

Table 1. Emergence trap collection totals for male *Delia* spp.

Species	1980 (4 traps)	1982 (3 traps)
D. floralis	233	210
D. platura	1	3
D. florilega	0	1
D. radicum	0	0

Both males and females of *D. floralis* were first collected on June 19 in 1980 (fig. 6). Male emergence increased at a greater rate. Peak emergence for females followed males by 7 days. No *D. floralis* were collected after July 16.

In 1982, first emergence of males preceded that of females by 12 days (fig. 7). Low numbers of males were collected on June 2 and 4. Their rate of emergence did not become great until June 9. As in 1980, male emergence peaked and declined early. Females were first collected June 14. More than 99 per cent of the total females were collected by July 30. Single individuals were collected on August 4 and 6.

Figure 8 summarizes the adult flight activity of *Delia floralis* for 1979, 1980, and 1981. The trend of activity is generally similar from year to year; however, there are distinctive shifts in the periods of activity. Early activity parallels that of emergence, with male populations being active earlier than females. Dates for first observation of males ranged from June 3 in 1981 to June 11 in 1980. First observation of females ranged from June 9 in 1979 to June 21 in 1980. Females continue a high

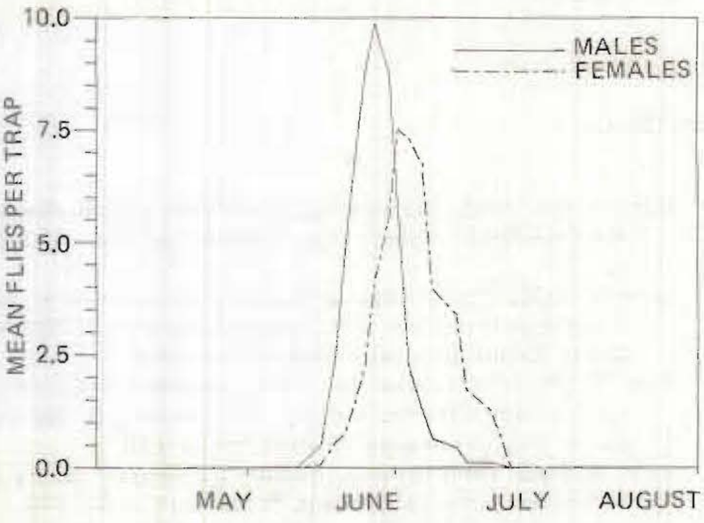


Figure 6. Adult D. floralis *emergence, 1980.*

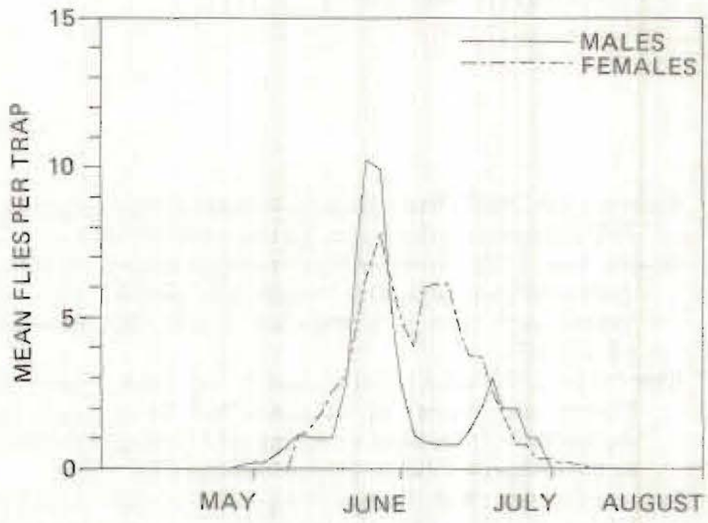


Figure 7. Adult D. floralis *emergence, 1982.*

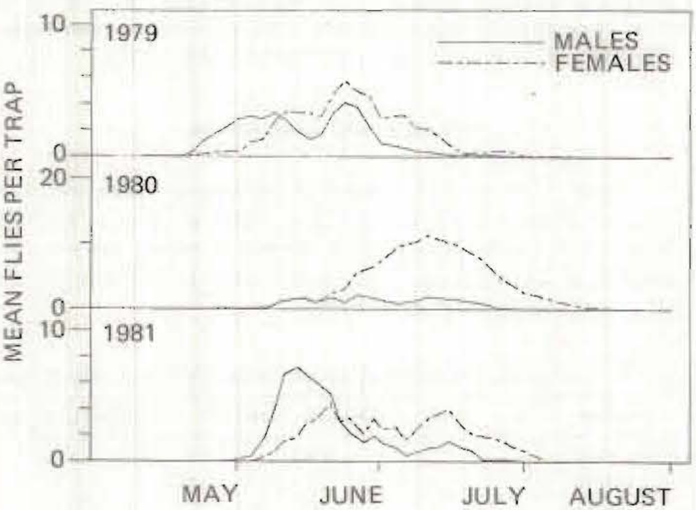


Figure 8. Flight activity of D. floralis.

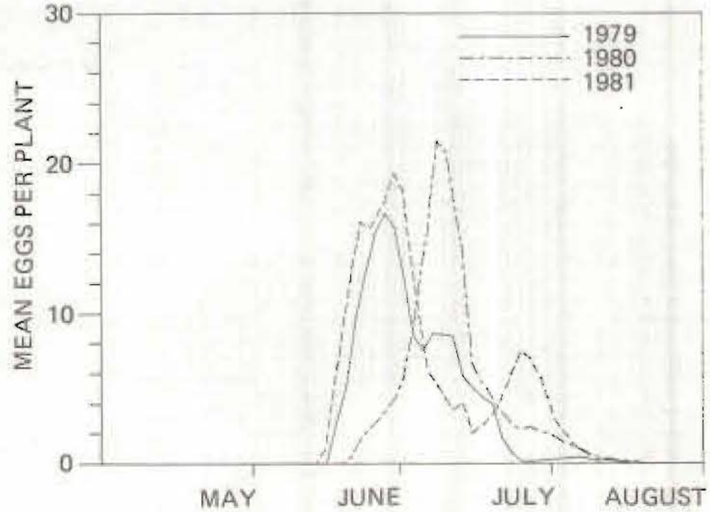


Figure 9. Delia *oviposition.*

level of activity later in the season. Last observations of activity for the 3 years were August 8, 18, and 5, respectively.

Although the time of first observation of eggs varies by only 4 days, the patterns from year to year vary considerably (fig. 9). In 1979 and 1981, the number of eggs per plant increased greatly in a short time with peak oviposition occurring only 10 days after first observance in 1979 and 14 days after in 1981. The increase in the oviposition rate in 1980 was more gradual, peaking 20 days after first emergence. The differences in the duration of high-level oviposition is significant. In 1979, this period lasted 32 days in contrast to 46 and 49 days in 1980 and 1981, a difference of 14 to 17 days. This suggests a decreased period of insecticide need in some years depending on economic threshold levels on the crops being grown.

Conclusions

The information gained through this study points out inefficiencies in currently used root maggot-control practices in Alaska and suggests improvements.

Because *D. floralis* emerges later in the spring, insecticides applied at the time of planting (in May) would lose effectiveness before oviposition in mid-June. Delaying application of material of short residual effectiveness until oviposition begins may mean that fewer applications would be necessary. This is also an important consideration when using a substance with greater residual effectiveness but which carries with it labeled restrictions on the number of applications which should be made in a season.

Depending on the crop being grown, insecticides may not be necessary as late in the season in some years as in others. Although economic thresholds are not known for *D. floralis* on Brassicas at various stages of maturity, it is expected that mature stem Brassicas might tolerate the activity associated with low levels of oviposition late in the season. This would indicate a further reduction in insecticide application.

Root maggot-control programs based on the seasonal activity of the pest and characteristics of the available insecticides will result in control that will not only prove effective but more efficient. ▫

Literature Cited

Bleicher, D.P. 1982. Root Maggots in Alaskan Home Gardens. P-330 Cooperative Extension Service, Univ. of Alaska.

Brooks, A.R. 1959. Identification of the root maggots (Diptera: Anthomyiidae) attacking cruciferous garden crops in Canada, with notes on biology and control. *Can. Entomol. 83*:109-120.

Chamberlin, J.C. 1945. Annual Report for 1945. Project 9. Control and Biology of Cutworms and Other Insects of Agricultural Importance in Alaska with Special Reference to the Matanuska Valley. Univ. of Alaska, AES. 198pp.

Chamberlin, J.C. 1949. Insects of Agricultural and Household Importance in Alaska with Suggestions for their Control. Circ. 9, Alaska Ag. Exp. Stn., USDA.

Huckett, H.C. 1965. The Muscidae of Northern Canada, Alaska, and Greenland (Diptera). Mem. Entomol. Soc. Can. 42. 369 pp.

Lein, H. 1955. The Cabbage Root Flies, Contributions to the Knowledge of Biology and Control in Norway (in Norwegian w. English summary). Statens Platevern 9.

Rygg, T. 1962. The Cabbage Root Flies: Investigations Concerning Emergence Periods and Control in Norway (in Norwegian w. English summary). Statens Platevern 19.

Varis, A. 1960. Bekjempelse av Kalfluer (Norwegian). Sartryck ur Nordisk Jordbrugsforskining. Supplement 1: 307-310.

Washburn, R.H. 1953. Root maggots in Alaska. Proc. 4th Alaskan Sci. Conf., A.A.A.S., Alaska Div.

Rhizoctonia Disease of Potato

By

Donald E. Carling*

Introduction

Rhizoctonia disease, or "Rhizoc," is a common disease of potatoes. This disease was first reported in Germany in 1858 (Kuhn, 1858) and subsequently has been observed in most areas of the world in which potatoes are grown. Rhizoctonia disease is also known as "black scurf," after the dark brown-to-black, irregularly shaped sclerotia that form on mature potato tubers (see Symptoms, below).

Rhizoctonia disease is considered by some growers to be a nuisance disease, but one of no significant economic importance. Others say it is responsible for significant decreases in yield as well as a general reduction in grade quality of the harvested crop. Current and future studies at the Agricultural Experiment Station in Palmer are aimed at discovering the true impact of Rhizoctonia disease on potatoes in Alaska.

The disease is caused by the fungus *Rhizoctonia solani* Kuhn, the perfect state of which is *Thanatephorus cucumeris* (Frank) Donk (1981). Related isolates of *R. solani* are capable of anastomosing (hyphal fusion) with one another, and the species has been subdivided on the basis of this capability. Five major anastomosis groups have been identified, and all *R. solani* isolates pathogenic to potatoes have proven to be members of the same group, anastomosis group-3 (AG-3). AG-3 isolates are not generally thought to be pathogenic on plants other than potatoes, although barley is a reported exception (Murray, 1981). If barley is indeed a host for *R. solani* AG-3 (further research will be required to establish this), barley would be a poor choice as a rotation crop for potatoes.

Symptoms

Foliar symptoms of Rhizoctonia disease may include rolling of leaves and a general chlorosis (yellowing) of vines and leaves. Stunting of foliage also can be a common symptom, and wilting is sometimes observed in severely infected plants. Although not a foliar symptom per se, aerial tubers (fig. 1) provide additional above-ground evidence of Rhizoctonia disease, and this symptom is frequently observed in commercial potato fields in southcentral Alaska, as well as in other parts of the state. Aerial tubers form in the leaf axils of above-ground stems and take on some of the general characteristics of tubers as they

* Assistant Professor, Horticulture, Agricultural Experiment Station, Palmer.

Figure 1. Aerial tubers form in leaf axils of R. solani*-infected plant. Tightly clustered tubers at soil line are also indicative of rhizoctonia disease on below-ground portions of the plant.*

Figure 2. R. solani *causes lesions or cankers to form on roots and stem of potato plants. The lesions are light to dark brown and vary in size depending on virulence of the fungus, environmental conditions, and time of infection.*

Figure 3. Sclerotia are masses of R. solani *mycelia that form on tubers at season's end. They easily survive the winter in storage and quickly infect newly developing plants if present on the seed piece.*

Figure 4. Grey-white mycelia form on the stem bases later in the growing season. This growth does no harm to the plant, but indicates destructive activity by the fungus below ground.

form underground. General foliar symptoms, as well as aerial tubers, can be indications of problems other than Rhizoctonia infection, (i.e., rolled leaves can indicate blackleg, virus infection, environmental stress, etc.), and one must look for other symptoms and signs to confirm the presence of rhizoctonia disease.

Other symptoms and signs providing more conclusive evidence of Rhizoctonia disease include cankers (lesions), sclerotia, and mycelia. Each is important because it provides a direct and unmistakable indication of the presence of *R. solani*. Cankers (fig. 2) are areas of necrotic (dead) tissues and may form on basal stems, roots, or stolons. They vary from reddish brown to dark brown in color and may be superficial or deep. Larger cankers may girdle stolons or basal stems, thus killing translocating tissues and interrupting the flow of materials from place to place within the plant. Canker formation and resulting girdling of stolons and basal stems is thought to lead, indirectly, to aerial tuber formation.

Sclerotia (fig. 3), sometimes called "the dirt that won't wash off," are masses of fungal tissue which form on tuber surfaces at the end of the growing season. Sclerotia are reproductive propagules of *R. solani* and can serve as an excellent inoculum source for the developing plant if present on seed tubers. Sclerotia do form on potatoes grown in Alaska, but not to the extent they do in more temperate regions where growing seasons are longer. Studies have shown that sclerotia form in greatest numbers after vines die, although some develop prior to vine death. The short growing season here in Alaska does not permit potato plants to senesce and die naturally, and vine killing (mechanical or chemical) is generally not practiced, also due to the short growing season. The Matanuska Valley's 1983 growing season was relatively long and warm, favoring sclerotia formation; as a result, above-average numbers of sclerotia were observed on the harvested crop.

The whitish-gray mat of mycelium (fig. 4) that forms on the stems just above the soil line is a manifestation of the sexual (perfect) stage of *R. solani*. The mat is powdery or dusty in appearance, but is easily rubbed off and does no damage to the stem tissues below. In southcentral Alaska, mycelia begin to appear in late summer when the cooler, wetter conditions favor its development. The presence of mycelia indicates *R. solani* activity below the soil line.

Disease Development and Inoculum Sources

The potato plant may be attacked by *R. solani* at any time during the growing season. However, disease damage is likely to be greatest if the attack occurs during early phases of growth, as developing tissues are more susceptible to fungal attack than mature tissues. The time of attack and extent of damage depend upon environmental conditions as well as upon the source and quantity of inoculum. If inoculum density is high and environmental factors (cool and wet) favor fungal development, plant damage will be great. If inoculum density is low and the environment relatively warm and dry, damage to the plants will be small.

Studies have shown that *R. solani* will infect potato plants at temperatures from 54-65°F (Richards, 1921). The optimum temperature for potato emergence is 75°F, and temperatures in the 50-55°F range can delay plant emergence by 10-15 days. Delayed emergence gives *R. solani* an extended period of time to invade and then damage or kill the sprout during the most vulnerable stage of development.

In Alaska, cool soil temperatures are the rule. During emergence and other early growth stages, soil temperatures may be 20°F or more below the 75°F optimum for emergence. The detrimental effect low temperatures have on plant development combined with the fact that *R. solani* actually prefers the lower temperature creates an obvious early-season advantage for the fungus. In more temperate regions, where soil temperatures warm rapidly as the season progresses, *R. solani* damage is often limited to the early-season phase of the disease (sprout killing and sprout injury). In Alaska, however, it is unusual to find sustained soil temperatures at 2- to 4-inch depths above 65°F at any time during the growing season. This relatively low, maximum temperature permits *R. solani* to function as an active pathogen throughout the growing season, thus it is available to attack roots and stolons that develop at any time during the season.

Rhizoctonia inoculum can be soil or seed borne. When soil borne, the fungus survives as a saprophyte in association with organic debris in the soil. The soil-borne (saprophytic) phase may become pathogenic when a host potato plant becomes available. When inoculum is seed borne, it is found on the surface of the seed piece in the form of sclerotia (fig. 3) or mycelia and is introduced into the field with the seed.

There has been some disagreement over the years as to the relative importance of these two sources of inoculum. Soil-borne inoculum is of considerable importance in cool, wet areas, especially in fields where potatoes are cropped year after year. Cool, moist conditions permit continuous growth and development by the saprophytic phase of the fungus. It is possible that *R. solani* AG-3 may be able to survive for years under these soil conditions, even in the absence of a host potato plant, then be available to attack a potato plant as soon as it is planted. Monocropping further increases the importance of soil-borne inoculum by contributing to the maintenance of a high inoculum density. Soil-borne inoculum is of less importance in warmer, dryer areas as *R. solani* AG-3 is not able to survive extended periods of time in the absence of a potato crop under these soil conditions (Weinhold et al., 1982).

Seed-borne inoculum is an effective inoculum source under all environmental conditions. It is acknowledged to be the inoculum source most capable of causing economically significant damage to a potato crop. When seed borne, the fungus is guaranteed to be in close proximity to the plant during its most vulnerable stages of growth. Sprout pruning (fig. 2) frequently results from the use of infected seed, and the extent of sprout pruning will be greater if soil conditions are cool and wet. At the very least, some sprouts will be injured and emergence will be delayed. At worst, emergence may be prevented.

The Alaskan soil environment permits both sources of inoculum to be important factors in disease development. The cool soils permit extended survival of the soil-borne (saprophytic) phase. Also, the cool, moist, growing conditions that generally prevail in the early part of the growing season make it probable that seed-borne inoculum will damage or kill the emerging sprouts.

Figure 5. Sprout pruning is the most serious phase of this disease. This seed piece, dug from the ground at harvest time, produced ten or more sprouts during the season, all of which were killed by R. solani. *This plant did not emerge.*

Current Research

A field study conducted in 1983 at the Matanuska Farm near Palmer was designed to quantitate the destructive potential of *R. solani* AG-3. In the same study, a chemical seed-piece treatment (thiophanate methyl) and a chemical soil treatment (PCNB) were evaluated as *R. solani* control agents. Potato plants were exposed to either a low or high rate of *R. solani* AG-3 inoculum and compared with noninoculated plants. Inoculum consisted of barley kernels colonized with fungus. Kernels were placed 1 inch above the seed in the planting hole at planting time. Inoculation was considered necessary to ensure infection of some plants so that meaningful comparisons could be made. Three potato varieties were included in the study: Bakeking, Kennebec, and Alaska 114. Data presented in Figures 6-8 are for the variety Kennebec only, as all three varieties responded to treatments in a similar manner.

Inoculation had a devastating effect on plant emergence. Fifty-seven per cent of the plants inoculated at the low rate failed to emerge, compared with only 2.2 per cent of the noninoculated plants (fig. 6). Emergence failure in nearly all cases was due to sprout pruning and killing by *R. solani* AG-3 (fig. 5). Failure to emerge was also very high (33 per cent) at the high inoculation rate, but less than at the low rate. There is no obvious explanation for the greater emergence at the higher inoculation rate, but the data are consistent with other reports (Baker and Martinson, 1969; Sanford, 1941) that describe a lower incidence of disease when inoculum density is raised above a critical point. In any case, it is clear that inoculation with low or high rates of *R. solani* AG-3 resulted in large reductions in stand.

Inoculated plants that did manage to emerge in spite of *R. solani* were less vigorous than noninoculated plants. This is illustrated by the comparative number of stems per plant (fig.

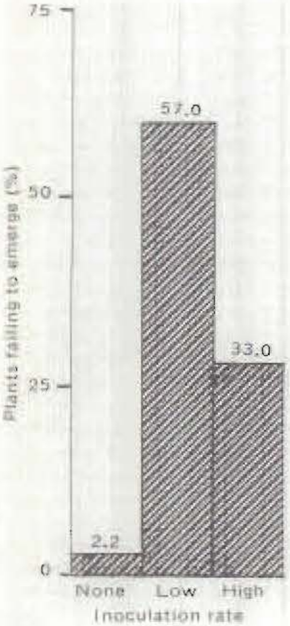


Figure 6. Emergence of potato plants (var. Kennebec) exposed to three rates of R. solani *AG-3 inoculum. Inoculum consisted of barley kernels colonized by the fungus.*

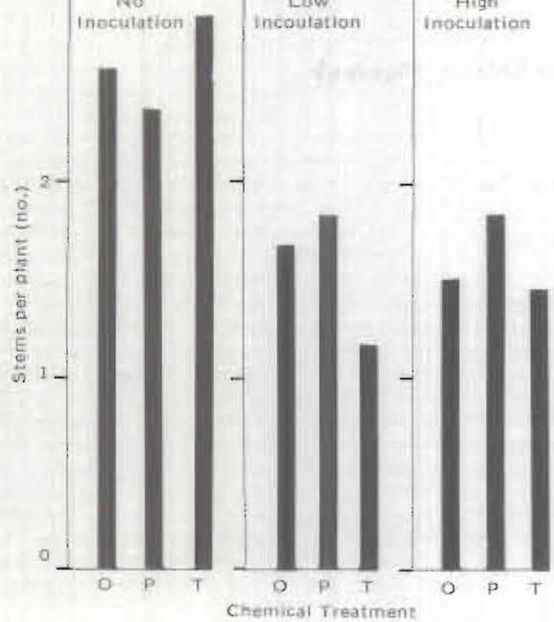


Figure 7. The effect of seed or soil treatment and inoculation rate on potato plants (var. Kennebec) stem production. Inoculum consisted of R. solani *AG-3 colonized barley kernels. Chemical treatments: O = none, P = PCNB, T = thiophanate methyl.*

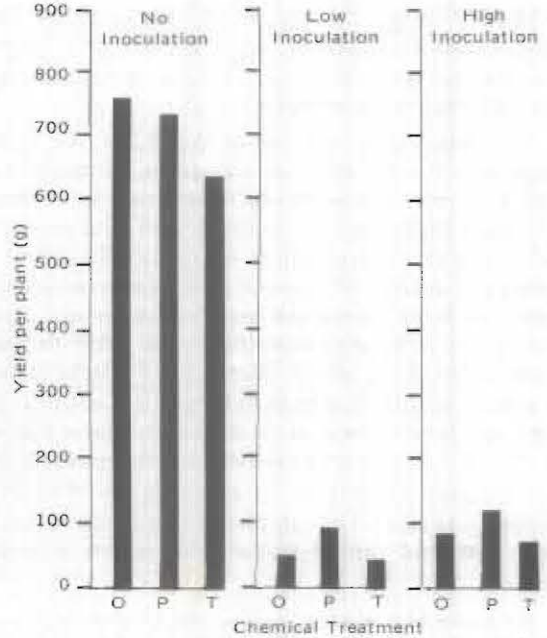


Figure 8. The effect of seed or soil treatment on yield of no. 1 tubers by potato plants (var. Kennebec) subjected to different quantities of R. solani *AG-3 inoculum. Inoculum consisted of* R. solani *colonized barley kernels. Chemical treatments : O = none, P = PCNB, T = thiophanate methyl.*

8). In Figure 7, we summarize the average number of stems per emerged plants. Noninoculated treatments averaged more than 2.5 stems per plant, while inoculated treatments averaged less than 1.6 stems per plant. Also, stems of inoculated plants were generally small, chlorotic, and prone to wilting. This reflects the presence of cankers (fig. 2) on the below-ground portion of the stems.

Of course the most important question is what effect did *R. solani* have on yield? Yield data are summarized in Figure 7. The average yield of inoculated plants (low or high rate) was less than 15 per cent that of the noninoculated plants, regardless of chemical treatment.

Data indicate that the chemical controls (PCNB and thiophanate methyl) were not effective in neutralizing the yield-reducing potential of *R. solani* in this study, and indeed they were not. However, it must be pointed out that, in this study, the deck was stacked against the plant. The seed pieces were planted very deep (more than 6"), and the quantities of *R. solani* inoculum introduced were probably greater than one would ordinarily find in field soil (although not greater than can be found on heavily infected seed). In this sense, the experimental conditions did not accurately reflect a typical level of *R. solani* stress which a potato plant would encounter in the field. However, these data do illustrate the yield-reducing potential of *R. solani* under conditions favoring the fungus.

Summary

Control of rhizoctonia disease is best acheived with the use of uninfected seed, chemical treatment of seed or soil, and crop rotation. Of these methods, the use of clean seed is perhaps the most important. Those planting on newly cleared lands are advised to use care in selecting seed. Seed and soil treatment and crop rotation are also useful methods of managing rhizoctonia disease, as each is effective in decreasing soil populations of the fungus. In future studies, we hope to identify the most-effective seed and soil treatments, and establish practical crop-rotation cycles for seed and table-stock production. ▫

Literature Cited

Baker, R., and C.A. Martinson. 1969. Epidemiology of diseases caused by *Rhizoctonia solani*. IN: J.R. Parmeter, ed. *Rhizoctonia solani: Biology and Pathology*. Univ. of California Press. Berkeley. pp. 172-188.

Frank, J.A. 1981. Rhizoctonia canker (black scurf). IN: W.J. Hooker, ed. *Compendium of Potato Diseases*, American Phytopathological Society, St. Paul, MN. pp. 52-54.

Kuhn, J. 1858. Der schorf oder grind der Kurtoffel. in die Krankhuten Kulturgewachse, Ihre ursachen and ihre vertutung. Besselmann, Berlin. 312 pp.

Murray, D.I.L. 1981. *Rhizoctonia solani* causing barley stunt disorder. *Trans. Br. Mycol. Soc. 76*(3):383-395.

Richards, B.L. 1921. Pathogenicity of *Corticium vagum* on the potato as affected by soil temperatures. *J. Agric. Res. 21*: 450-482.

Sanford, G.B. 1941. Studies of *Rhizoctonia solani* Kuhn V. virulence in steam sterilized and natural soil. *Can. J. Res. 19*: 1-8.

Weinhold, A.R., T. Bowman, and D.H. Hall. 1982. Rhizoctonia disease of potato: Effect on yield and control by seed tuber treatment. *Plant Disease 66*:815-818.

Frost Seeding of Rapeseed

By

Charles W. Knight* and Stephen D. Sparrow**

Introduction

Rapeseed is a promising oilseed crop for Alaska. Previous research has shown that the growing season in interior Alaska is long enough for short-season cultivars of spring rapeseed to reach maturity (Lewis and Knight, 1982; Wooding et al., 1978). It is important, however, to get the crop up early in the season to ensure that it has adequate time to mature before autumn frosts. Two important factors in getting the crop off to an early start are the preparation of a good seedbed and the conservation of adequate moisture for seed germination. The seedbed should be firm, with fertilizer and herbicide incorporated well into the soil. Since the seed is very small, depth of seeding should not exceed 1 inch. In interior Alaska where spring rains are sparse and crops usually rely on soil moisture for germination, it is difficult to prepare an adequate seedbed in the spring and still conserve enough moisture in the surface soil to initiate germination. Consequently, seeds often lie in dry soil waiting for small, and often infrequent, rain showers to supply sufficient moisture for germination. This can result in uneven emergence and delayed harvest.

* Instructor of Agronomy, Agricultural Experiment Station, Fairbanks.

** Assistant Professor of Agronomy, Agricultural Experiment Station, Fairbanks.

Early-planted rapeseed produces mature pods early. In years with dry springs, however, midsummer rains may stimulate secondary growth resulting in uneven maturity.

In major rapeseed-producing areas of Canada, the crop is usually planted on land which was fallowed the previous summer. In this situation, the fertilizer and herbicide are incorporated during the autumn prior to spring planting. This practice allows spring planting with minimum soil disturbance and maximum conservation of soil moisture.

Since rapeseed is notorious for producing large quantities of volunteer plants in the year following crop production, it is apparent that many seeds remain viable after shattering onto the soil in the autumn and lying there all winter. Considering recent advances in the design of no-till grain drills which permit planting in very hard, untilled soils, and the fact that rapeseed must not be planted more than 1 inch deep, the question arises, "Can a successful crop of rapeseed be produced by planting with a no-till drill in late autumn or early spring while the ground is frozen?" *Brassica campestris*, the species of rapeseed best adapted to interior Alaska, germinates well in cold soil and has good resistance to spring frost. If this crop could be planted successfully during late autumn or early spring, the following benefits could result:

a) fertilizer could be applied in the fall and incorporated without concern about losing moisture or creating a loose seedbed;

b) depth of seeding could easily be kept to less than 1 inch in frozen soil;

c) maximum use of the short growing season would occur as the seed would be in the soil, ready to germinate, when permitted by sufficient warming;

d) no cultivation would be required in the spring, allowing maximum conservation of the soil moisture accumulated from snowmelt;

e) planting while the ground is frozen would allow a farmer to spread out his work load and relieve him of the pressure of having to seed all his ground in the short spring planting period.

We have been unable to find any reports of studies in which "frost seeding" or "dormancy seeding" has been tried with rapeseed. However, several scientists have reported successful results from seeding spring cereal grains and other crops in frozen soils in the northern United States and Canada (Grafius and Wolfe, 1960; Kephart, 1980; Krall, 1977; Stoskopf et al., 1968; Stoskopf et al, 1967).

Methods

This study was initiated near Delta Junction, Alaska, in the autumn of 1982 to evaluate the practice of seeding spring rapeseed into frozen soils. A site was selected on fallowed ground and no herbicide was required. A seedbed was prepared in mid-September by first broadcasting a fertilizer blend consisting of nitrogen (N), phosphorus (P), potassium (K), sulfur (S), and boron(B), equivalent to 89 lb/A N, 50 lb/A P_2O_5, 50 lb/A K_2O, 24 lb/A S, and 2 lb/A B and then incorporating it into the soil with two tandem disking operations. A cultipacker was then drawn over the area to smooth and firm the seedbed. A Haybuster MicroSeeder was used to plant two cultivars of rapeseed, 'Candle' and 'Tobin', at weekly intervals starting 28 September and continuing through 12 October, after which the snow was too deep to operate the seeder effectively. Weekly plantings were resumed on 5 April 1983, when most of the snow had melted from the field, and continued through 10 May (a normal date for spring seeding). A seeding rate of 6 lbs/A was used.

Once the rapeseed began to emerge, notes were taken at 2-week intervals to compare rates of emergence and plant stands. On 14 June, six population counts were made at random within each plot. From midsummer through harvest, crop-maturity notes were taken at 2-week intervals. The plots were harvested on 6 October 1983. Only two replications were harvested. Harvesting operations were halted because of heavy snowfall.

Results

At the time of the 28 September planting, the soil temperature at the 1-inch depth was about 40°F. The soil was frozen for

Population counts were taken for all treatments soon after emergence.

Table. Plant populations and seed yield for two cultivars of rapeseed planted on various dates.

	'Candle'				'Tobin'			
Planting date	plant population (plants/m^2)	per cent population*	seed yield (bu/acre)	per cent yield**	plant population (plants/m^2)	per cent population*	seed yield (bu/acre)	per cent yield**
28 Sep 82	18	9.6	8.3	46.4	12	3.9	8.9	68.5
5 Oct 82	35	18.2	14.6	81.4	38	12.2	14.4	110.6
12 Oct 82	22	11.6	8.2	45.8	22	7.2	11.3	86.8
5 Apr 83	72	37.2	11.9	66.2	165	53.1	14.7	112.8
12 Apr 83	109	56.4	12.4	69.1	267	86.0	12.9	99.2
19 Apr 83	90	46.3	13.1	72.9	213	68.8	10.3	79.0
26 Apr 83	106	54.9	17.2	96.0	239	77.0	13.9	106.5
3 May 83	132	68.3	22.8	127.2	278	89.6	16.9	129.5
10 May 83	193	100.0	17.9	100.0	310	100.0	13.1	100.0
Overall Average			14.0				12.9	

*Seed yield expressed as per cent of seed yield for the 10 May planting date.

**Plant population expressed as per cent of population for the 10 May planting date. Plant populations counted 14 June.

the other autumn plantings and for the first two spring plantings. The soil was very wet in the low spots on the 19 April planting, and, though it had dried considerably, it was still moist at the .5- to 1-inch depth for the 26 April and 10 May plantings. The soil began warming rapidly after mid-April, and by 10 May the soil temperature at the 1-inch depth was 65-70°F.

Rainfall was below normal for the months of May, June, and early July. During early July, rapeseed plants showed signs of severe water stress. By 18 July, seasonal precipitation was approximately 2.5 inches below average. Two inches of rainfall during the week of 18 July, followed by near-normal precipitation through the end of the growing season, resulted in a total growing-season precipitation of approximately 1 inch below average.

Plants from the three autumn plantings and the first three spring plantings all began to emerge at about the same time during the last week of April. Plants in all plots had emerged by the third week of May. At this time, stands for the autumn seedings and first spring seeding were noticeably poorer than for the later plantings. Stands for Tobin were generally better than for Candle. The emergence in the autumn-seeded plots was much more uneven than in the spring-seeded plots, with plants emerging over a period of 6 weeks. Results of the stand observations were substantiated by plant-population counts made on 14 June (see table). Plant populations, which varied from about 12 to 300 plants/m^2, were lowest for the autumn plantings and increased as the planting date progressed from early April until 10 May.

Fall-seeded rapeseed (left) resulted in a very low plant population compared to that planted in the spring (right) in the still-frozen soil.

The goal of research on rapeseed is to develop production practices that will provide optimum yields for growers.

Fall planting in frozen ground can be accomplished with a no-till grain drill such as this Haybuster Microseeder.

Plants began flowering by the middle of June with the early plantings (autumn and first four spring plantings) flowering before the later plantings. The autumn plantings were highly variable, however, with some of the plants flowering much earlier than other plants in the same plot. By late July, lower pods on the early-planted rapeseed had begun to turn brown, and many plants had quit flowering. The uneven maturity for the autumn-seeded plots was still evident.

With the onset of the rains in late July, all plants exhibited new growth and began flowering again. After mid-August, there was so much new growth that there was no visible difference in maturity between planting dates. Late flowering on the new growth resulted in pods which did not mature fully before being killed by freezing in late September. Thus, the rapeseed was not ready for harvest until early October, much later than would be expected for rapeseed in a year with normal rainfall patterns.

Yields were low; with an overall average of 13.5 bu/A (see table). There was very little correlation between planting date and yield or plant population and yield, although for both rapeseed varieties, yields were considerably higher for the 3 May planting date than for any other planting date.

Discussion

Since this study has only been conducted for 1 year and the rainfall pattern during the growing season for that year was unfavorable, and since yield data are based on only two replications, the results must be considered preliminary. However, a few interesting observations are worth noting. The fact that plant population had very little influence on yield indicates that, within limits, rapeseed has a tremendous potential to compensate for thin stands. Similar results have been found in other studies (Adolphe, 1974; Lewis and Knight, 1982).

Rapeseed planted on 5 April resulted in considerably higher plant populations than that planted on 12 October. Since the soil was frozen on both planting dates and was continuously frozen between the planting dates, the explanation for the difference in plant populations is elusive. The most plausible explanation is that this difference is due to wind erosion of the seedbed during early winter months. Since all seedbed preparation was conducted in the autumn, the soil was finely worked and packed, destroying most surface clods and burying most crop residues prior to winter. The rapeseed was planted in the top .5 inch of frozen soil, and considerable desiccation occurred in this top layer of soil. The fine, dry surface was extremely susceptible to wind erosion during early winter before the field was covered with snow and anytime during the winter when snow may have been blown off the field. Some erosion of this type was noted in this study. Wind erosion may have blown the seeds completely away in some areas and may have buried them too deeply for emergence in other areas.

Another factor which may have affected plant populations was the absence of a seed treatment for protection against fungal infections. Rapeseed of high germination has been shown to benefit little or not at all from seed treatment against seed and seedling rots or blights (Saskatchewan Agriculture, 1979). Under these abnormal planting conditions, however, germination and early growth may be retarded by low soil temperatures and a fungicide may prove beneficial. The absence of fungicides, however, would not explain population differences between autumn and spring plantings, because fungi are not likely to attack the seed while the ground is frozen. We have not ruled out the possibility that fungal infections may have reduced populations of early-germinating seedlings by causing damping off during the early spring when the soil was moist from melting snow.

Spring freezing is a concern in many areas where early spring seeding has been attempted. Interior Alaska is somewhat unique in its spring freezing patterns due to the daylength at that time of year. The area experiences essentially one freezeup period in the autumn and one breakup period in the spring with little intermittent freezing and thawing in between. By the time the soil is warm enough in the spring for seeds to germinate (late April), the daylength is about 16 hours and increasing rapidly. Consequently, the diurnal temperature fluctuations are not as great as might be experienced in the spring in more temperate regions. Some seeds from early plantings may have germinated early and died before emergence due to freezing of the soil. However, there was no visual evidence of frost damage on any of the emerged seedlings.

Summary

The first year of this study, though far from conclusive, has produced many favorable results indicating that dormancy seeding of rapeseed in interior Alaska may be practical. Management techniques need to be refined which would provide more protection of the seedbed from wind erosion and protection of the seed from possible fungal infections. Also, the practice of frost-seeding of rapeseed needs to be evaluated over several years to determine whether this practice can be recommended for interior Alaska.

This study is being continued and can be observed at the UAF Agricultural Experiment Station's field near Delta Junction, Alaska. ▫

References

Adolphe, D. 1974. Canola, Canada's rapeseed crop. Rapeseed Association of Canada, Winnipeg, Manitoba.

Grafius, J.E., and D.E. Wolfe. 1960. Frost sowing of spring oats and barley. *Mich. State Univ. Quart. Bull. 42*:482-483.

Kephart, K.D. 1980. Examination of frost seeding spring small grains and alternate crops in Eastern Montana. M.S. Degree thesis, Agronomy Dept., Montana State University, Bozeman, Montana.

Krall, J.L. 1977. Planting in the cold ground. *Now 14*:8-10.

Lewis, C.E., and C.W. Knight. 1982. Rapeseed response to seeding rate, row spacing, and nitrogen application. *Agroborealis 14*:50-51.

Saskatchewan Agriculture. 1979. Cereal and oilseed seed treatments 1979. Saskatchewan Agriculture, Plant Industry Branch, Plant Protection Section. 4 pp.

Stoskopf, N.C., G.W. Anderson, E. Reinbergs, and G.E. Jones. 1968. Increased yields from cereals sown on frozen soil. *Can. J. Plant Sci. 48*:428-430.

Stoskopf, N.C., E. Reinbergs, and G.E. Jones. 1967. Frost seeding. *Crops and Soils 19*:12-13.

Wooding, F.J., C.E. Lewis, and S.D. Sparrow. 1978. An oilseed crop looks promising for Interior Alaska. *Agroborealis 10*:35-38.

Conservation-Tillage and Residue-Management Systems For Interior Alaska

By

F.H. Siddoway*, C.E. Lewis**, and R.F. Cullum***

Introduction

The protection of soil from loss by wind erosion is becoming a major concern in interior Alaska as large, contiguous areas are cleared for the production of small grains. There are a number of methods by which losses of soil from wind erosion can be reduced. These include the use of windbreaks, grass strips, strip cropping, and contour cropping. One of the most effective methods, however, is conservation tillage which considers management of the soil resource itself. Conservation tillage includes the use of reduced tillage systems that create as good an environment as possible for the crop and optimize conservation of soil and water resources, consistent with sound economic practices. Conservation tillage is synonymous with maximum or optimum retention of residues on the soil surface and the utilization of herbicides to control weeds where tillage is not or cannot be performed (Wittmuss et al., 1973).

The Agricultural Experiment Station began conservation-tillage research in the Delta Junction area of interior Alaska in 1980.[1] The main thrust of the Experiment Station's research was to evaluate no tillage, minimum tillage and maximum tillage within the crop-rotation system of rapeseed-barley-fallow as well as in continuously cropped barley. The study was completed in 1982 (Lewis, 1983).

Among other results, the study indicated that interior Alaska's annual precipitation[2] of 10 to 12 inches is usually adequate to grow a short-season crop such as barley every year on the same land. Evaporation rates are low relative to areas in the conterminous 48 states with similar precipitation regimes. Average yields for continuously cropped barley in the 3-year study were 1.07 T/acre, 1.06 T/acre, and .99 T/acre for plots which had undergone maximum tillage, minimum tillage, and no tillage, respectively.

[1] Delta Junction is the location of the Delta Agricultural Project, an area of 81,000 acres used primarily for the production of barley.

[2] This includes all moisture from snow and rainfall which falls during the growing season, some of which is stored over winter (17-year average, May through August, of 7.8 in.).

*** Visiting Professor, Agronomy, Agricultural Experiment Station (deceased).**

**** Associate Professor, Resource Management, Agricultural Experiment Station.**

***** Assistant Professor, Agricultural Engineering, Agricultural Experiment Station.**

It was determined that further research concerning conservation-tillage and residue-management systems specific to the annual production of barley would be beneficial. Therefore, a new study was initiated in 1982 to address the following elements of large-scale agriculture in interior Alaska.

Short Growing Season

Barley production under the environmental conditions of Alaska's interior requires proper management of soil and crop residues. Management systems must involve land preparation techniques which require as little time as possible in order to ensure early seeding (early to mid-May) in a moist, firm seedbed. This will increase the probability of early, uniform germination resulting in early, uniform maturity of the crop.

Marginal Water Supply

Enough surface-soil water must be present to ensure good seed germination and sustenance of early plant growth through the May-June period which is, on the average, quite dry.[3] Excessive tillage accelerates drying of the surface soil, and germination is often delayed until moisture is replenished. Residues remaining on the surface decrease evaporation rates of soil water and may, therefore, be a factor in enhanced germination.

Serious Wind-Erosion Potential

The silt-loam soils of interior Alaska are highly susceptible to wind erosion because of the tendency of clods to break down to their single-grain structure, thus increasing the erosion hazard on open fields which are exposed to strong seasonal winds. In the absence of well-designed shelter belts, plant residues must be relied upon to control wind erosion. Approximately 2000 lb/acre of straw lying on the surface and 1000 lb/acre of standing stubble, or some combination thereof, is needed to control wind erosion on these highly erodible soils. These quantities are easily attained under annual cropping. In fact, residues may be excessive and could be harvested for feed and bedding, tilled into the soil, or used to provide heat for grain drying.

[3] Average for the May-June period over 17 years has been 3.5 inches.

Infertile Soils

Most of the necessary plant nutrients on land which has been newly cleared must be supplied by commercial fertilizers at a considerable cost to attain crop-production goals. The plant nutrients in the grain are removed from the soil with the harvest, but the nutrients in the residue will eventually be recycled through a subsequent crop. For example, the straw from a 60 bu/acre barley crop contains the following plant nutrients: nitrogen equal to 30 lbs/acre N, phosphorus equal to 8 lbs/acre P_2O_5, potassium equal to 65 lbs/acre K_2O, and sulfur equal to 7 lbs/acre S (McLelland, 1982). When left on the field, these nutrients will, in time, reduce the quantity of commercial fertilizers required to achieve production goals. The straw residues also supply organic matter, in short supply in many mineral soils in Alaska, which will increase the water-holding capacity of the soil and help stabilize it against erosive forces.

Weeds and Diseases

Introduced weed species (Conn and DeLapp, 1983) and diseases may become serious with time under monoculture although newly cleared land is generally free of weeds and soil-borne diseases that affect barley. The presence of surface straw creates an environment favorable for disease incidence in barley in that it provides a host site for plant pathogens and insect vectors that transmit these pathogens. In addition, residues on the surface may provide entrapment for wind-borne weed seeds, increasing weed populations. Leachates and/or decomposed products from these residues may have a negative impact on these populations, however.

Cool Soils

One of the limiting factors in crop production in interior Alaska is cool soils. Cool soils extend the time from seeding to seedling emergence and possibly restrict depth of root development and availability of both water and nutrients. Standing stubble holds snow in place over winter that would otherwise be blown off open fields, thus providing an insulating cover which decreases soil heat loss over winter. Further evidence demonstrates that soil with standing stubble, in the absence of loose straw on the ground surface, warms faster in the spring than does soil which has an equal amount of snow cover but which is devoid of vegetative cover (Aase and Siddoway, 1980). The additional insulation provided by loose straw on the soil surface in spring, whether there is stubble or not, could delay thawing, seedbed preparation, seeding, and, possibly, germination.

Study Design

The current tillage and residue-management research includes three types of residue-management systems, four types of tillage, and three types of grain planters compatible with these systems. Treatments are randomized in a split-split plot design (fig. 1). There are four replications.

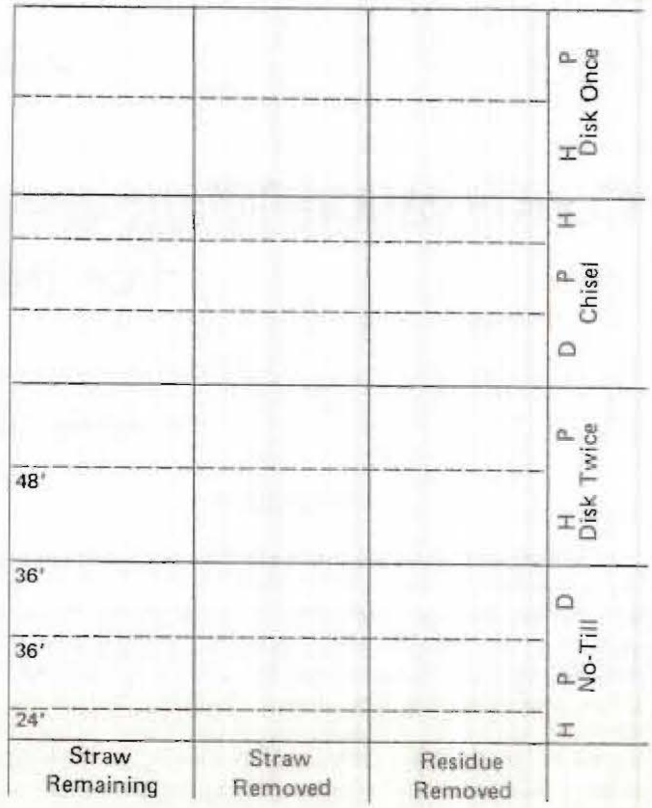


Figure 1. Diagram of treatments in one of four replications of a split-split plot conservation-tillage design for continuous barley production. The planters are designated by hoe drill (H), disker seeder (D), and double-disk, press-wheel drill (P).

The three residue-management treatments cover the following range of possible quantities and distribution of stubble and straw.

1. *Residue removed.* The stubble remaining after harvest is cut as close to the ground as possible, and the residue is raked, baled, and removed from the plots.
2. *Straw removed.* Barley is harvested with a combine equipped with a chopper and spreader. The remaining stubble is 6 to 8 inches high. After harvest, the loose straw is raked, baled, and removed from the plots.
3. *Straw remaining.* Barley is harvested with a combine equipped with a chopper and spreader. The remaining stubble is 6 to 8 inches high. The loose straw remains on the plots.

The four tillage treatments are classified by the degree of soil disturbance.

1. *Maximum tillage.* The plots are disked once in the fall. In the spring, they are disked again and packed prior to seeding.
2. *Minimum tillage I.* The plots are disked in the spring and packed prior to seeding (fig. 2).
3. *Minimum tillage II.* The plots are chiseled in the fall using sweeps. In the spring, prior to seeding, they are packed (fig. 3).
4. *No tillage.* The seedbed is not disturbed before seeding.

Both minimum-tillage-I and no-tillage treatments leave the residue treatments undisturbed through the winter. Thus, the snow-retention capability of stubble versus no stubble can be

Figure 2. A tandem disk is used in the spring to perform minimum tillage just prior to seeding.

Figure 3. A packer used prior to seeding on plots which are tilled helps firm the seedbed.

Figure 4. The double-disk, press-wheel drill disturbs the soil only enough to place seed and fertilizer in a slot formed by the disks.

Figure 5. When the hoe drill is used, considerable soil disturbance occurs. Press wheels on the drill, however, ensure good contact between seed and soil.

evaluated. Maximum tillage alters all residue treatments to the extent of precluding snow retention. Minimum tillage II, however, may leave enough residue to hold snow.

The three types of planters disturb the soil to varying degrees, thus further modifying the residue and tillage treatments. The effect of two of the planters is evaluated on all tillage treatments.

1. *Double-disk, press-wheel drill* (fig. 4). This drill disturbs the soil very little. The double disks, placed 7 inches apart, merely open a slot in the soil into which seed and fertilizer drop.

2. *Hoe, press-wheel drill* (fig. 5). This drill causes considerable soil disturbance. A ridge-furrow effect is created by hoe openers placed 8 inches apart. The dry, surface soil is displaced, and seed and fertilizer are placed in the moist soil beneath.

The third planter is evaluated only on the minimum-tillage-II and no-tillage treatments.

3. *Disker seeder* (fig. 6). This planter also disturbs the soil considerably. Soil is displaced in one direction. Seed and

Figure 6. The disker seeder does not place the seed in straight rows. The visual effect is similar to that achieved when broadcast seeding. A packer can be pulled behind the disker or used as a separate implement to ensure a firm seedbed.

fertilizer are dropped through tubes next to each disk on a gang of disks. The disks are placed 7 inches apart. Packing is accomplished with a separate implement.

The no-tillage system is considered the best soil-management practice for erosion control purposes. Its success in terms of crop production, however, depends to a large extent on how well the planters perform in surface residue.

Barley variety, fertilizer rates, and pesticides are not considered variables in the tillage and residue-management study. In any given year, the same barley variety and fertilizer rates are used in all plots. Fertilizer rates are those recommended by the Agricultural Experiment Station and are altered only if soil tests and crop response indicate a need for change. Control of weeds and diseases varies by tillage and residue treatment. Weeds and diseases will be present under all residue and tillage treatments but are expected to be more severe under no tillage. Chemical control is more intensive as the amount of tillage decreases.

In addition to the most important experimental measurement, yield, other interpretive measurements are included to help explain why yields vary by treatment and from year to year. Only when the process of obtaining specific yields in a given year can be understood can decisions for further improvement be made.

The quantity of residue will probably affect the incidence and severity of diseases. The monitoring of incidences of plant diseases by treatment permits one to estimate the effects on yield and provides information about residue-disease associations. Likewise, monitoring of weed populations, including number and species, determines the effectiveness of tillage and herbicides for weed control.

In interior Alaska, where the growing season is short, interception and utilization of the limited solar radiation is critical. Environmental measurements made during the growing season determine solar radiation received and reflected, air and soil temperatures, humidity, and wind speed. These data will be used to relate crop and soil response from the tillage and residue treatments to rate of soil thawing and warm-up, germination, rate of crop growth and ripening, and depth of rooting. Over a period of years, these measurements will also serve as a valuable data base with which to predict the suitability of other areas for agricultural development.

Soil-chemical properties such as acidity, plant-available nutrients, and organic matter are measured to correlate with crop response and to determine the effect of treatments on soil constituents over time. If Alaskan experience parallels that of other grain-producing areas we can assume that fertility management will be quite different on soils which have been cropped for 10 years than on newly cleared land.

The role of soil water for crop production has been assumed somewhat unimportant in Alaska due to our relatively low evaporation rates, shallow rooting depths, and frequent summer rains. However, there are extended periods of dry weather in which soil water must be relied upon for crop growth. To obtain a better understanding of the interactions of soil water and plant growth, a system of soil-access tubes has been installed on one replication of the study. With this system, soil water can be monitored and determined throughout the year at 1-foot intervals to a depth of 3 feet by the neutron-scattering method. These measurements will provide an understanding of the dynamics of soil water and its significance for plant growth.

Establishment of the New Study

The tillage and residue-management study is located within the Delta Agricultural Project at Mile 1408 on the Alaska Highway. The site, selected in early 1982, is on soils consisting of Volkmar and Beales silt loam which had not been previously cropped. The topography is slightly rolling. It is typical of land used for barley production in the Delta Project.

The intent in 1982 was to clear the land of moss and roots and provide stubble and crop residues for establishment of the tillage and residue treatments for the 1983 season. A harvestable grain crop was considered secondary.

In mid-June, 'Lidal' barley treated with Vitavax[4] was seeded. Prior to seeding, the area was broadcast fertilized with 117 lb/acre 46-0-0 (urea), 100 lb/acre 21-0-0-24 (ammonium sulfate), and 100 lb/acre 0-0-60 (potassium chloride). A starter fertilizer, 11-51-0 (monoammonium phosphate) was banded with the seed at a rate of 100 lb/acre.

The barley did not mature sufficiently to harvest. The crop was swathed in mid-September.

Baseline soil samples were taken in October 1982. The results are shown in Table 1.

Table 1. Baseline Soil Sample Results

Depth	pH	Total Available N (ppm)	Extractable P (ppm)	Total Exchangeable K (ppm)	Organic Matter (%)
0-2 inches	5.83	26.4	29.0	136	10.72
2-4 inches	5.60	13.0	11.7	72	9.91
4-6 inches	5.80	9.7	10.7	49	3.95
6-36 inches	6.32	8.6	5.7	33	.32

Second-Year Methods

In mid-April 1983, straw was baled and removed on both the straw-removed and straw-remaining plots. Straw and stubble had become extremely matted over the winter due, in part, to trampling by bison. Delayed thawing occurred on all plots, but was most evident on those on which residue was to be removed. The residue on these plots was burned to remove as much as possible. As a result, only two residue treatments in 1983 could be established.[5]

All plots were fertilized in late April with the same blend and at the same rate as in 1982. All spring disking and packing operations were completed as per the study design. The chisel operation which will, in the future, be conducted in the fall left an unacceptable seedbed when conducted in the spring. This tillage method was abandoned and, for the 1983 season, was replaced with no tillage.

The tillage design includes the use of a disker seeder. The seeder, however, arrived after the 1983 planting season and will be used initially in 1984.

[4] Vitavax, trade name for a mixture of lindane, thiram, and carbathiin, manufactured by Uniroyal.

[5] Residue measurements prior to tillage indicated 2900 lb/acre remained on those plots with straw removed and 1150 lb/acre remained on those which had been burned.

Table 2. Yields and Test Weights on Plots Planted with the Hoe Drill[a]

Treatment	Yield (Tons/A)	Yield (BU/A)[b]	Test Weight (LB/BU)
Residue removed	1.22	51	42.1
Straw removed[c]	1.17	49	43.7

[a]Maximum tillage was performed on all hoe-drill plots.
[b]Calculated using 48 lb/bu as standard.
[c]Straw was removed from both straw-removed and straw-remaining plots.

Seeding dates for the plots where the double-disk drill and the hoe drill were used were May 4 and May 6, respectively. There was excessive plugging of the tubes on the hoe drill caused by moss in the seedbed. To enable effective use of the hoe drill, all plots to which this drill was assigned were chiseled once with 3-inch twisted points and disked three times prior to seeding. Thus, the hoe-drill plots received only a maximum tillage treatment.

The barley variety 'Lidal' was treated with Granox[6] and seeded at a rate of 100 lb/acre viable seed. Both drills were set for seeding at a depth of approximately 2 inches. The best depth control was obtained with the double-disk drill. Depth control was poor on the hoe drill due to excessive tillage resulting in some seeding at depths below 2 inches.

Broadleaf weeds were controlled using Buctril[7] applied at a rate of 20 oz/acre before the crop reached the boot stage. Lambsquarter was the primary annual weed present. Areas existed where populations of perennial native grasses were high. These were treated with Roundup[8] in the fall at a rate of 1.0 qt/acre. The achieved control did not affect the 1983 crop.

Installation of instrumentation for environmental measurements was completed by the end of June. Both the data logger used for environmental measurements and the neutron-scattering system used to measure soil moisture were regarded as being in the "field-check" stage of operation during the 1983 season.

Plots were harvested on September 15. Yield samples were taken from each plot using a plot combine with a header 4 feet wide to harvest a 75-foot strip. The remainder of the crop was direct combined using a combine equipped with a straw chopper and spreader. The three residue treatments were established after harvest, according to the study design.

Fall disking and chiseling were done on September 23. Use of 3-inch twisted points on the chisel caused a rough seedbed. These plots were smoothed by disking twice. Tillage depth on all plots was approximately 4 inches.

Discussion

The tillage and residue-management research in 1983 was the first year of a 5-year study involving continuous barley. The first-year results are not conclusive. However, yields and test weights are of interest as are various observations of crop and equipment performance on new lands.

The yields and test weights for those plots seeded with the hoe drill are shown in Table 2, and those for plots seeded with the double disk drill in Table 3. All test weights were low. Grain from tillers which began emerging in mid-July did not mature by harvest. As a result, a portion of the grain harvested was light in weight. Low test weights are a manifestation of this late maturity. The highest yields were attained on those plots on which the hoe drill was used. It is possible that the extreme tillage needed to enable use of this drill contributed to early warming of the soil and thus to higher germination in the early spring. Overall, yields differed little. It is encouraging that all exceeded 1.0 T/acre.

Soil-moisture measurements taken during July through mid-September indicated that moisture level in the top 1 foot of soil remained relatively constant at approximately 32 per cent by weight. Below the top 1 foot, moisture was highly variable. This was almost exclusively due to textural variation which varies from silt loam to thin sandy loam.

Frost depth in late April prior to seeding averaged 2.5 inches. By mid-May, temperatures at the 2.5 inch depth had reached 42° to 55°F, the highest being on the maximum-tillage plots with residue removed. Throughout the growing season, soil temperatures in the 0- to 12-inch zone did not rise above 60°F and ranged from 55° to 60°F for all treatments. By harvest, temperatures in this zone had dropped to an average of 40°F.

Although not a part of a study design, field experience in 1983 with use of conservation tillage and residue-management techniques on new lands proved valuable. Observations indicate that:

1) Early seeding by itself does not guarantee uniform germination and early maturity. Loose surface soil and a rough surface make it impossible to place seed at a proper, uniform depth. The consequence is variable seedling emergence and a mixture of ripe and green barley at harvest

Table 3. Yields and Test Weights on Plots Planted with the Double-Disk Drill[a]

Treatment	Yield (Tons/A)	Yield (BU/A)[b]	Test Weight (LB/BU)
Maximum Tillage:			
Residue Removed	1.07	45	40.3
Straw Removed[c]	1.13	47	40.9
Minimum Tillage I:			
Residue Removed	1.17	49	44.0
Straw Removed[c]	1.19	50	44.3
No Tillage:			
Residue Removed	1.06	49	44.0
Straw Removed[c]	1.10	46	42.7
Average Over All Tillage Treatments:			
Residue Removed	1.10	45	42.5
Straw Removed[c]	1.14	48	42.6
Average Over All Residue Treatments:			
Maximum Tillage	1.10	46	40.6
Minimum Tillage I	1.18	49	44.2
No Tillage	1.08	45	42.9

[a]The minimum-tillage-II treatment was not included in 1983.
[b]Calculated using 48 lb/bu standard.
[c]Straw was removed from both straw removed and straw remaining plots.

[6]*Granox, trade name for a mixture containing 30% maneb, 30% captan, 1% sodium molybdate, manufactured by ICI America.*
[7]*Buctril, trade name for bromoxynil, manufactured by Rhone-Poulene, Inc.*
[8]*Roundup, trade name for glyphosate, manufactured by Monsanto.*

time. The barley crop had three stages of maturity in 1983. A portion of the barley germinated during May when moisture was adequate. Another portion germinated in early July following a droughty June. Tillers began emerging in mid-July. Whether accomplished by packing, shallow initial tillage, or press wheel drills, the seedbed should be firm in order to facilitate drilling at constant depth and to ensure that moist soil is firmly in contact with the seed.

2) Before attempting no tillage as a method of production on new land, native perennial vegetation should be eradicated by tillage and/or herbicides. Perennial grasses in the no-tillage plots reduced yield, and application of Roundup in late August had little effect.

3) A properly fertilized, dense stand of barley will reduce the number of secondary tillers. In 1983, secondary tillers were induced by the heavy July rain.

4) Excessive tillage of the maximum-tillage plots dried the soil in the tilled layer to the extent that growth was retarded during the dry, early part of the growing season. Even with the advent of July rains, the plants never fully recovered.

5) Presence of moss in the soil precluded use of sweeps on the chisel. When twisted points were used, the seedbed was exceedingly rough. It is likely that, until moss is broken up sufficiently, the chisel with twisted points will have to be used in combination with a tandem disk.

6) Cool soil temperatures throughout the growing season are likely to be a rule rather than an exception. The conservation-tillage and residue-management system which leaves enough stubble to trap snow in the winter and which removes as much straw as possible is expected to contribute to early soil warming in the spring.

Many of the methods involved in current tillage and residue-management research are time-related phenomena. In subsequent years, results will become more definitive both in terms of crop productivity and soil-conservation practices. The research will grow in value with time and lead to sound crop production and soil-management systems. ▫

References Cited

Aase, J.K., and F.H. Siddoway. 1980. Stubble height effects on seasonal microclimate, water balance, and plant development of no-till winter wheat. *Agr. Meteorol. 21*:1-20.

Conn, J.S., and J.A. DeLapp. 1983. Weed species shifts with increasing field age in Alaska. *Weed Science 31*:520-524.

McLelland, M.B. 1982. Barley production in Alberta. Alberta Agr., 36 pp.

Lewis, C.E. 1983. Conservation-tillage research in interior Alaska. *Agroborealis 15*:4-10.

Wittmus, H.D., G.B. Triplett, and B.W. Greb. 1973. Concepts of conservation tillage systems using surface mulches. IN: *Conservation Tillage*, Soil Cons. Soc. of Am., Ankeny, IA. pp. 1-4.

Figure 1. Reindeer herd on the open range before slaughter.

Factors Affecting the Palatability Of Reindeer Meat

By

John Brooks III* and William B. Collins**

Introduction

Meat is the primary product of Alaska's reindeer industry, and herders are interested in expanding the marketing of their meat beyond the local outlets to specialty markets elsewhere. Unfortunately, little is known about those factors which affect the palatability and nutritional value of reindeer meat. In addition to the herders' need to know more about these factors, local retailers are interested in learning what animal characteristics and management practices are responsible for the wide variation they see in the meat they buy from producers. For both of these reasons, certain criteria relating to live characteristics and/or management histories and post-kill handling must be established which will aid in the production of meat with predictable palatability and marketability. Obviously, it is in the best interests of the industry as a whole to produce a high-quality product which is both nutritious and appealing to the consumer in terms of appearance and palatability.

The overall objective of the project discussed here was to examine the effects of live-animal characteristics, condition, sex, and age, on palatability (carcass organoleptic quality). This preliminary information will provide a basis for further studies which should address the effects of animal characteristics and management, slaughter, and processing practices on the production, quality, and marketability of reindeer meat.

In this study, we hypothesized that reindeer sex, age, and condition are related to meat palatability. These factors are currently the basis for USDA livestock-quality grading systems (USDA 1982), with sex (intact male, castrate, or female) and age being the first and second hierarchical levels, respectively, in that system. There is a further breakdown as to animal con-

* Research Assistant, Range Science, Agricultural Experiment Station, Kotzebue.

** Assistant Professor, Range Management, Agricultural Experiment Station, Fairbanks.

dition within each age class. Based on these three criteria, carcasses are given a quality grade which reflects the palatability that can be expected from that carcass. Our objective was to determine the relationships of sex, age, and condition to palatability of loin chop steaks.

A second objective was to determine the effect of meat color on palatability. We were particularly interested in the development of very dark meat (dark-cutters) in reindeer, a phenomenon which is thought to occur as the result of preslaughter stress. Chemical changes in the carcass, of which dark-cutter characteristics might be indicative, were also investigated.

Methods

Reindeer meat samples were obtained from cercasses during the 1982 NANA fall slaughter near Kotzebue, Alaska. Part of the herd was in the slaughter area approximatly 3 weeks before slaughter. Immediatly prior to slaughter, an additional group was driven 60 miles under adverse weather conditions to the slaughter area. After resting a minimum of 48 hours, animals were killed with a small-caliber rifle shot to the brain while on snow-covered ground. They were then dragged by snowmachine to a butchering area approximately .5 miles away where they were field dressed, skinned, and hung to freeze at temperatures ranging between 0 and -10°F.

Sixteen castrate males and eighteen cows were selected immediately after kill and tagged for identification. An attempt was made to obtain animals representative of a wide range of condition and age for each sex class. Age was determined by cross-section analysis of lower incisors (Matson and Matson, 1982). Animals condition was estimated by measurement of the backfat thickness at four points on the rump and four points above the loin. These values were averaged to provide a mean estimate of animal condition based on fat reserves expressed as inches of backfat. Sample cuts were obtained in the field by splitting the carcass in half and cutting out a portion of the loin. Loin cuts were later trimmed into .75-inch chop steaks with a meat saw and stored at -10°C.

Prospective panelists were prescreened by interview, and twelve qualifying individuals were then selected on the basis of their discriminating ability demonstrated in triangle tests (Cross et al., 1978). Panelists were also given a training session prior to evaluation of the samples. Sensory attributes were described as follows (Amerine et al., 1965):

1. Juiciness – impression of wetness produced by release of meat fluid
2. Flavor – intensity
3. Tenderness – energy required to masticate a meat sample into a state ready for swallowing
4. Overall acceptability – desirability.

All panelists were residents of Kotzebue, Alaska, and had previously eaten reindeer or caribou. They ranged in age from 28 to 55 and exhibited no health problems that would interfere with sensory evaluation.

The loin steaks were thawed in a cooler which was at 40-45°F for 18-24 hours or until the internal temperature of the steaks reached 40-45°F. Individual loin steaks were identically illuminated and photographed to record differences in the color of the thawed meat. Steaks were given color scores of 1 for light (light red color), 2 for medium (medium dark red), and 3 for dark (very dark red or purplish black). The pH of each steak was determined with a standardized electronic pH meter. Mercury thermometers were used to measure temperatures. At each session, steaks were broiled on a commercial gas broiler to an internal temperature of 176°F. Each steak was turned once when the internal temperature reached 122°F. Preliminary studies were conducted to determine thaw and cooking time.

The loin steaks were cut into .5 x .5 x .75" samples after removal of all bone, subcutaneous fat and connective tissue. Steaks were assigned at random to six sensory sessions. Location of a sample for individual panelists was random. Samples were placed in white cups that had been coded with three-digit random numbers. The cups were covered and placed in warmed sand to control temperature variation prior to sampling by panelists.

Sensory sessions were conducted from 2:15 to 3:00 p.m. on 3 consecutive days. One series of six samples, including a warm-up sample, were presented to each panelist per session. The order of presentation was randomized for each panelist. Score sheets were precoded to indicate the order of sampling. Samples, score sheets, and room-temperature rinsing water were presented to each panelist, seated in individual booths under white light. Samples were scored on an 8-point hedonic scale for each of the attributes, with 8 being extremely tender, juicy, intense, or desirable, and 1 being extremely tough, dry, bland, or undesirable. The mean sensory panel scores were calculated for each carcass and used for subsequent statistical analysis. Multiple linear regression (Dixon, 1981) was used to analyze the relationship of the hedonic palatability scores.

Results

For purposes of presentation and discussion, the mean palatability scores were categorized into three classes (table 1). Palatability scores of 6 and greater were very desirable, scores of 5 were desirable, and scores of 4 or less were undesirable. Of the dependent variables, overall acceptability was most highly correlated with tenderness ($r = .855$, $p < .01$) (table 2). In addition, tenderness was correlated with flavor ($r = .399$, $p < .05$). However, juiciness was not well correlated ($p < .05$) with any of the other palatability scores. Although not as strong, these relationships are in general agreement with Jost et al. (1983) who found high correlations among the same palatability traits. The high correlation between tenderness and overall acceptability suggests that tenderness has the most influence on the overall acceptability of the product.

Juiciness

The mean hedonic juiciness scores for each carcass varied considerably, ranging from 3 to 7 with an overall mean of 4.68. The resultant multiple-regression equation (table 3) had a low multiple correlation of 0.361 ($p < 0.20$). Increasing age accounted for most of the multiple correlation with increasing juiciness (66 per cent). The simple correlation matrix (table 2) indicates animal sex had little effect on juiciness. Although animal condition was not highly related ($r = .149$), it was additive to age in the multiple-regression equation. Examination of the means (table 1) indicates that animals in the "very-juicy" class

Table 1. Summary of loin palatability characteristics and reindeer sex, age, and condition.[1]

Palatability Class	Variable		Juiciness		Flavor		Tenderness		Acceptability	
			Castrate	Female	Castrate	Female	Castrate	Female	Castrate	Female
Very Desirable[2]	Age (yrs)	Mean	3.75	7.50	3.25	6.17	3.50	5.80	3.50	5.8
		Sd[5]	0.50	1.41	0.50	2.07	0	2.25	0	2.1
		n[6]	4.00	2.00	4.00	6.00	5.00	13.00	7.00	15.0
	Condition	Mean	2.58	1.65	2.24	2.38	2.20	2.09	2.29	1.9
		Sd	0.81	0.74	0.53	0.95	0	2.25	0.83	1.5
		n	4.00	2.00	4.00	6.00	5.00	13.00	7.00	15.0
Moderately Desirable[3]	Age (yrs)	Mean	3.25	6.10	3.77	5.60	4.17	5.50	3.50	4.8
		Sd	5.00	2.12	0.79	2.18	1.15	1.41	1.22	0.5
		n	4.00	10.00	11.00	10.00	3.00	4.00	8.00	3.0
	Condition	Mean	2.62	2.01	2.48	1.69	2.62	1.33	2.31	1.2
		Sd	0.66	1.32	0.69	1.33	1.15	1.41	0.75	0.7
		n	4.00	10.00	11.00	10.00	3.00	4.00	8.00	3.0
Undesirable[4]	Age (yrs)	Mean	3.50	4.30	1.50	4.50	3.25	4.50	3.50	0
		Sd	1.20	1.17	0	0	1.04	0	0	0
		n	8.00	6.00	1.00	2.00	8.00	1.00	1.00	0
	Condition	Mean	2.01	1.60	0.65	0.94	2.25	0.52	2.12	0
		Sd	0.75	1.21	0	0.59	1.04	0	0	0
		n	8.00	6.00	1.00	2.00	8.00	1.00	1.00	0

[1] Condition is expressed as average back fat depth in cm. [2] On a scale of 1 to 8, palatability averaged above 5.5. [3] On a scale of 1 to 8, palatability averaged between 4.5 and 5.5. [4] On a scale of 1 to 8, palatability averaged less than 4.5. [5] Sd = Standard deviation. [6] n = Number of carcasses in each group.

Table 2. Correlation matrix of reindeer sex, age, and condition to palatability of reindeer loin steaks.[1]

	Sex	Age	Condition	Juiciness	Flavor	Tenderness	Acceptability
Sex	1.000[2]						
Age	0.575	1.000					
Condition	−0.231	−0.031	1.000				
Juiciness	−0.072	0.238	0.149	1.000			
Flavor	0.030	0.187	0.314	0.276	1.000		
Tenderness	0.436	0.317	−0.020	0.265	0.399	1.000	
Acceptability	0.436	0.233	−0.030	0.266	0.298	0.298	1.000

[1] Each correlation coefficient indicates the strength of the relationship. The nearer the value is to −1 or +1, the stronger the relationship; values near 0 indicate little or no relationship. For example, the relationship between sex and tenderness is 0.436, which indicates sex accounts for a relatively large part of the variation in tenderness. However, sex has a very low correlation with flavor (0.030), indicating that it has little or no effect on flavor intensity.
[2] $r = .33$ ($p < .05$); $r = .43$ ($p < .01$); $r = .15$ ($p < .20$).

Table 3. Summary of multiple-regression analysis for correlation of reindeer sex, age, and condition to meat-palatability characteristics.[1]

Palatability	Intercept	Sex	Age	Condition	R[5]	Sd[6]	P[4]
		Variable					
Juiciness	4.358	−0.541	0.206	0.092	0.361	0.955	0.235
	SEE[2]	0.415	0.107	0.168			
	Std Reg Coef[3]	−0.281	0.402	0.097			
	P[4]	0.202	0.065	0.585			
Flavor	4.562	−0.018	0.064	0.183	0.371	0.577	0.212
	SEE	0.101	0.065	0.251			
	Std Reg Coef	−0.015	0.206	0.317			
	P	0.944	0.333	0.082			
Tenderness	3.550	0.890	0.050	0.840	0.447	1.050	0.080
	SEE	0.460	0.120	0.180			
	Std Reg Coef	0.400	0.090	0.080			
	P	0.060	0.670	0.650			
Desirability	4.747	0.562	−0.012	0.047	0.436	0.561	0.080
	SEE	0.099	0.063	0.244			
	Std Reg Coef	0.477	−0.039	0.080			
	P	0.030	0.849	0.640			

[1] These equations include the variables sex, age and condition to predict meat palitability characteristics. The P value (Probability value) indicates the importance of the variable sex, age or condition to each equation. In general, the smaller the P value the more important the variable is to the equation. For example, sex (p value = 0.060) is the most important variable in the tenderness equation. [2] SEE = Standard Error of the Estimate. [3] Std Reg Coef = Standard error of the regression coefficient. [4] P = Probability value. [5] R = Multiple correlation coefficient. [6] Sd = Standard deviation.

were fatter than animals in the "moderately juicy" to "dry" classes. The castrates varied little in age between palatability classes, but the females tended to become juicier as they got older; hence, the higher correlation between increasing age and juiciness. Those samples judged "undesirable" by the panelists were from animals of the poorest condition for both castrates and females.

Flavor

Carcasses had a narrow range in flavor intensity, from 4 to 6, with a mean flavor score of 5.21. The resultant multiple-regression equation (table 3) had a low level of significance ($r = 0.371$, $p < 0.21$). Unlike juiciness, flavor intensity is unaffected by sex or age. Rather, animal condition contributed the most to the correlation between animal characteristics and flavor ($r - 0.317$). Mean values shown in Table 1 support the observation that samples judged "desirable" and "very desirable" came from carcasses in the best condition, while samples with an "undesirable" flavor came from carcasses in very poor condition.

Tenderness

Samples were judged to have a relatively wide range in tenderness intensity, 3 to 7, the mean being 5.30. The resultant multiple-regression equation (table 3) was correlated ($r = 0.450$, $p < 0.08$) to palatability. Sex was the most important variable ($r = 0.436$), females being more tender than castrates. Sex alone accounted for 100 per cent of the correlation that was evident in the multiple-regression equation. Although less important, age was also correlated with tenderness ($r = .317$). However, it was not additive to sex, suggesting that multicolinearity between sex and age confounded the interpretation of the actual importance of age to tenderness. At best, age was 73 per cent as effective as sex in determing tenderness. Unlike juiciness and flavor, animal condition was not related to tenderness ($r = -0.02$). Examination of the mean values (table 2) indicates that very desirable and moderately desirable carcasses came from females of moderate age and good to excellent condition.

Overall Acceptability

As with tenderness, overall acceptability was most highly correlated to animal sex (partial correlation = 0.436), with females being correlated to increasing overall acceptability and castrates to decreasing overall acceptability. Carcasses ranged from 5 to 7 in overall acceptability, with the data heavily weighted toward the mean overall acceptability score of 5.65. The resultant multiple-regression equation (table 3) had a relatively high level of significance ($r = 0.443$, $p > 0.08$). The relatively high level of intercorrelation between animal sex and age makes it difficult to determine the actual importance of age to overall acceptability. Comparison of sex-condition regressions and age-condition regressions indicates that age was related to desirability along the same dimension as sex but was only 53 per cent as effective as sex in estimation of overall desirability. Examination of the mean values in Table 1 indicate there is little difference in age and condition between moderately acceptable and very acceptable castrate carcasses, whereas there was a considerable range in the females, with older, fatter animals being the most preferred of the females.

Of the palatability factors considered, tenderness was most important in determining overall acceptability of a chop steak. Sex was the most important animal characteristic, females being preferred over castrated males. It is also evident that sex, age, and animal condition explain only 13, 14, 20, and 19 per cent of the total overall variation observed in juiciness, flavor intensity, tenderness, and overall acceptability, respectively.

Color and pH

Meats in light and medium-red color classes did not differ in pH values ($p > .05$), but meat in the dark-color class was significantly higher in pH than either light or medium red ($p > .05$). (table 4)). Since no differences in pH were observed between light- and medium-color classes, these classes were combined to form a "normal-color" class. The dark-color class was termed "dark cutter" to signify its similarity to dark-colored beef carcasses termed dark-cutters. These two color classes were used for further comparisons of the effects of color and pH on palatability (table 5). There were no differences in juiciness or flavor intensity between the normal or dark-cutter classes ($p > .01$), but dark-cutters were tougher and scored lower in overall acceptability ($p > .01$) than normal-colored steaks. The pH was

Table 4. Mean pH of reindeer loin steaks in different color classes.

Color Class	Color Score	n[1]	Mean pH	Sd [2]
Light red	1	6	5.58a[3]	0.06
Medium red	2	18	5.61a	0.10
Dark red	3	10	5.78b	0.15

[1] n = number of carcasses in each group. [2] Sd = standard deviation. [3] Means followed by different letters are significantly different ($p > .05$).

Table 5. Palatability scores for loin steaks from normal and dark-cutter color classes.

Color Class	n[1]	Juiciness		Flavor		Tenderness		Desirability	
		Mean	Sd[2]	Mean	Sd	Mean	Sd	Mean	Sd
Normal	23	4.7a[3]	0.93	5.3a	0.56	5.78a	0.90	5.78a	0.46
Dark-Cutter	10	4.7a	1.16	5.0a	0.67	4.30b	0.95	5.20b	0.63

[1] n = Number of carcasses in group. [2] Sd = Standard deviation. [3] Means within columns which are followed by different letters are significantly different ($p < .05$). $F_{1,31\ 0.95} = 5.57$.

Figure 2. This method of skinning and eviscerating reindeer is used in western Alaska.

Figure 3. This is a typical slaughter area with racks for cooling carcasses.

slightly more important than age in correlation with tenderness (table 6).

Table 6. Partial correlation matrix of pH and reindeer characteristics to tenderness.[1]

	Sex	Age	Condition	pH	Tenderness
Sex	1.000[2]				
Age	0.575	1.000			
Condition	−0.231	−0.031	1.000		
pH	0.235	−0.195	0.047	1.000	
Tenderness	0.436	0.317	−0.020	−0.445	1.000

[1] Each correlation coefficient indicates the strength of the relationship between the two variables. The larger the value (on range of 0 to 1 or −1), the stronger the relationship. For example, the relationship between pH and tenderness is −0.445, which indicates that pH accounts for a relatively large part of the variation in tenderness, whereas condition (−0.020) is of little or no importance.

[2] $r = .43\ (p > .01)$; $r = .33\ (p > .05)$; $r = .15\ (p > .20)$

Discussion

Methods used in reindeer slaughter are very similar to locally used methods of caribou slaughter. The slaughter generally occurs on the open, snow-covered range (fig. 1) with the animal sometimes being transported to a sheltered area for evisceration and skinning (fig. 2). This method of killing is thought to cause relatively little stress to the animals immediately prior to slaughter, as opposed to slaughter during a roundup. Local producers believe that prevention of preslaughter stress will lessen the chances of adverse flavor. If adequate space is used, the snow-covered tundra provides a relatively clean environment for slaughter. Temperatures at slaughter time are usually well below freezing, resulting in rapidly cooled and frozen carcasses. The skinned carcasses are sometimes hung on racks in the field to facilitate cleaning of the body cavity and to promote even cooling and freezing (fig. 3). The frozen carcasses are kept whole, split in half by cutting from spine to belly midway down the back, or quartered. The carcasses are then placed in cotton mesh and sold wholesale. Local commercial outlets cut the meat following procedures similar to those outlined by Luick (1980) (fig. 4). The majority of the meat is sold frozen as stew-meat chunks or as steaks (loin, round, and shoulder). It is interesting to note that it is not sold as hamburger or roasts to local consumers. Barbecue reindeer ribs are sometimes sold as a fast-food delicacy in the local Alaska Commercial Company store. In addition, local restaurants serve reindeer meat as a specialty item to tourists in the form of chop steaks and roasts.

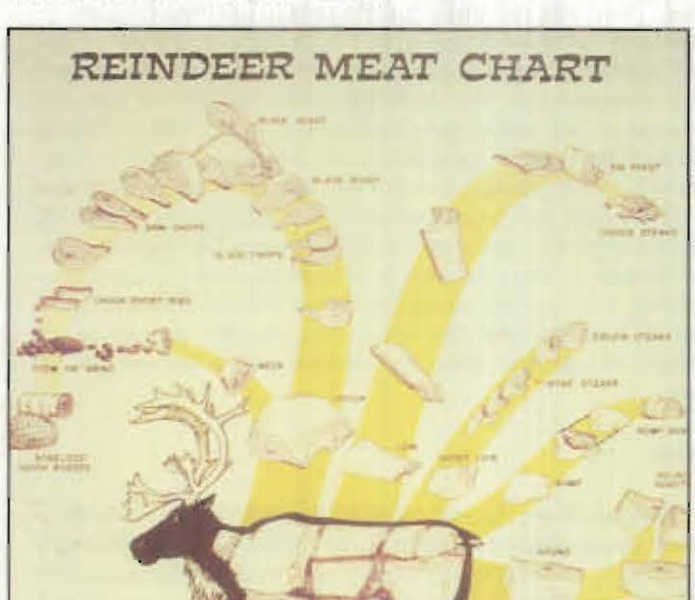


Figure 4. This poster (after Luick, 1983) illustrates the commercial method of cutting reindeer carcasses.

Demand

Local demand by both white and Native ethnic groups is very high. The average retail store can easily sell the equivalent of one reindeer carcass a day. The short slaughter season, inadequate freezer space, and high consumption rate results in a relatively short season of reindeer-meat availability (4 to 5 months). Local institutions have indicated considerable interest in utilizing reindeer meat in their food programs, but they are not allowed to do so because the absence of acceptable health and quality standards precludes inspection and grading of the meat.

Juiciness

Reindeer meat, and venison in general, has little, if any, marbling of the lean and contains only 7 to 15 per cent intermuscular fat as compared to 5 to 30 per cent in beef (Blaylock et al., 1967; Wookey et al., 1969). Thus, venison is generally considered more nutritious by fat-conscious nutritionists. Juiciness is generally related to intermuscular fat content. Thus, reindeer is generally dryer than beef and other domestic livestock.

It is interesting to note that juiciness was best correlated with increase in age, animal condition being of secondary importance. There was no apparent difference in juiciness between females and castrated males. This relationship is difficult to explain since juiciness is generally considered most dependent upon intermuscular fat. Although intermuscular fat was not measured in this study, data by Blaylock et al. (1967) indicate that increased age is correlated with increasing levels of intermuscular fat in reindeer (from 7 per cent in 4-month-old fawns to 15 per cent in 3.5-year-old adults). It could be hypothesized that the dynamic nature of the subcutaneous fat layer throughout the year prevents correlation of intermuscular fat levels with juiciness. Thus, increasing age may be an indirect indicator of increasing intermuscular fat, accounting for the correlation of juiciness to age and weak correlations with subcutaneous fat depth.

Flavor

Because of the narrow range of flavor intensity observed in the carcasses sampled, animal factors affecting flavor intensity are difficult to determine. At best, sex and age seem to have little, if any, effect, and the condition of the animal may have a minor effect. On the other hand, management and processing techniques – cooling rate, storage and cooking methods – are probably more important in determination of flavor intensity. It is also possible that our panelists were not trained well enough to detect differences in flavor intensity. Differences in juiciness and tenderness were more evident to the palate.

Tenderness

The increase in tenderness observed in females versus castrates may be due to a common practice of late castration. Males are generally castrated as adults, 2 to 3 years of age, the major objectives being to prevent unpleasant rut flavor while taking advantage of the increased growth rate and efficiency of intact males during the early part of life (Seideman et al., 1982). Intact males are generally considered to be tougher than females in other domestic species (Seideman et al., 1982). This has not been investigated in reindeer, but it does not seem that late castration improves tenderness of the meat to equal that of females.

It is of interest to note that the most common USDA indicator of meat tenderness, animal condition, is not correlated to tenderness in reindeer. Jost et al. (1983) support this observation by concluding that marbling of the lean has little effect on tenderenss. Rather, rate of carcass cooling immediately *post mortem* and associated cold shortening before *rigor mortis* sets in are thought to be primary factors related to meat tenderness.

Overall Acceptability

As with tenderness, females were considered to be more acceptable than castrates. The significant correlation ($p < .000$) between tenderenss and overall acceptability suggests that tenderness is the most important palatability characteristic in determining overall acceptability of a chop steak.

Figure 5 illustrates a well-conditioned female which scored high in overall acceptability. Figure 6 illustrates an average-finished castrate male which scored lower than the aforementioned female in acceptability. The carcass in Figure 7 illustrates the smooth, even, thin finish of a young (yearling) castrate male as opposed to the patchy fat-deposition patterns of the older females and castrates.

Within the age classes considered, age was apparently only of secondary importance in determination of overall palatability. However, Blaylock et al. (1967) indicated that very young age classes (4-month-old fawns) are highly preferred over older age classes. This would be consistent with the well-known desirable palatability characteristics of veal versus mature beef. Slaughter of reindeer fawns is practiced in Scandinavian countries where limited range precludes raising of all the fawns. This limitation does not confront Alaska's reindeer herds, thus, there is little motive for fawn slaughter (Arobio et al., 1979).

Meat Color

Color and associated textures are known to affect the marketability of thawed meat (Amerine et al., 1966). In Kotzebue and Nome, as in most areas, meat color is important in its purchase (Sauers, pers. comm.[1]), but reindeer meat (unlike beef, pork and lamb) is usually sold in a frozen state. Frozen reindeer meat in general has a uniformly dark, purplish-black color which prevents the detection of dark-cutters prior to thawing in the consumer's home. After purchasing a dark-cutter, a consumer may be reluctant to continue to buy the product. The long-term marketability of reindeer meat may thus be adversely affected by such sales.

Dark-cutters were correlated with a higher pH than was found in chop steaks of normal color, see Figures 8 and 9. This is thought to be a consequence of the following *post mortem* biochemical reactions (Forrest et al., 1975). Following animal death, glycogen, the normal source of energy in muscle tissue, is

[1] C. Sauers, 1983. Alaska Commercial Company.

Figure 5. Carcass of a well-conditioned, highly acceptable cow.

Figure 6. Carcass of a well-conditioned castrate male with relatively low acceptability.

Figure 7. Carcass of a thinly finished, young (yearling) castrate male.

broken down to form lactic acid which causes a lowering of pH. Glycogen deficiency often occurs when animals are stressed (excited, poor nutrition, extreme environmental conditions) and slaughtered before they have sufficient time to replenish their muscle glycogen. This will result in a decreased production of lactic acid and consequently less decrease in pH than in carcasses having normal glycogen levels. The relatively small changes in pH levels of stressed animals results in minimal structural change to muscles and pigments, thereby allowing the meat to remain a dark-purplish color with a sticky texture.

It is known that if the stress factor responsible for the dark-cutter syndrome is removed, the muscle glycogen and consequent post rigor pH, color, and texture return to normal levels. Although the basic biochemical pathways are understood, little is known, especially with deer species, concerning the type and duration of stress required to develop the dark-cutter syndrome or the time and conditions required for recovery. Recent evidence by McVeigh et al. (1982) suggests that a behavorial stress created by adding new bulls to a bull pen requires a minimum of 7 to 10 days for muscle glycogen to return to normal levels. Based on this information, it is probable that the animals exhibiting the dark-cutter syndrome were from the group that were driven to the Kotzebue area immediately prior to slaughter.

In most species of livestock, palatability of dark-cutters is not thought to be affected (Forrest et al., 1975). However, in this study, tenderness was significantly lower in the dark-cutter class (table 5). It is hypothesized that this may be due to the interaction of rate and extent of glycolysis (onset of rigor) and the rapid freezing of the carcasses during the slaughter. Our initial observations indicate that carcasses handled in such a Manner produce undesirably colored chop steaks having a higher pH than more acceptable, normally colored steaks. Palatability scores also indicate that dark-cutters were tougher and lower in overall acceptability than were chop steaks with normal color.

Because reindeer carcasses are normally frozen and stored immediately after slaughter, and since their true color is difficult to ascertain when frozen, it is impossible to determine visu-

Figure 8. Thawed loin chop steaks with normal color (pH of 5.54).

Figure 9. Thawed loin chop steaks from a dark cutter (pH of 5.90).

ally which carcasses are most likely dark-cutters. However, given that the pH of dark cutters is higher than in normal meat, a measure of pH may permit identification of such carcasses to be identified prior to cutting. Such carcasses could then be reserved for those cuts where color and/or toughness are not of great importance to marketability, i.e., stew meat, sausage, or hamburger. Proper identification of dark cutters would help ensure that the customer would be purchasing (even if frozen) meat with normal, desirable color and with acceptable palatability characteristics. When cooked, the color of the meat cannot be determined, although toughness may remain.

Effects of Rapid Freezing of Carcasses

Lochner et al. (1980) suggested that cold shortening is the major cause of toughness in meat. They also suggested that the effects of *post mortem* treatements can override such factors as breed, age, and preslaughter state in determining eating quality. Cold shortening refers to a physical shrinking of sarcomers (muscle fibers). This occurs in carcasses which have been chilled or frozen too quickly prior to *rigor mortis*. Rapid thawing can also cause this problem. As mentioned before, a fall in muscle pH is an indicator of *post mortem* glycolysis and onset of rigor. Davey et al. (1976) and Lochner et al. (1980) suggested that substantial cold shortening and associated decrease in tenderness occur if meat cools to less than 61°F before the completion of *rigor mortis* (18 to 48 hr.). To date, the effects and implications of cold shortening in reindeer have not been examined. However, the unique freezing environment of outdoor slaughter methods points to the probability that cold shortening is contributing to the toughness of some reindeer meat.

The effects of cold shortening during cold outdoor slaughter could be minimized by controlling the cooling rate of the carcasses. This might be accomplished by slaughtering during warmer days earlier in the fall or by use of an artificial environment, such as a portable, insulated container or tent. However, these options may be prohibitive, as slaughter sites are sometimes remote and snow is required for snowmachine travel and relatively sanitary slaughter conditions. A more viable option may be to accelerate the process of glycolysis so that rigor mortis is completed before the carcass cools and cold shortening can occur. Electrical stimulation is known to increase substantially the rate of glycolysis (Lochner et al., 1980; Davey et al., 1976) and to effect a considerable increase (100 per cent) in tenderness (Chrystall and Hagyard, 1976; Riley et al., 1980). Electrical stimulation also results in a lighter, more acceptable color. Electrical stimulation could probably be implemented under current slaughter techniques, since the equipment is quite portable.

Summary

The results of this study are in general agreement with Jost et al. (1983) who suggested that animal age, sex, and condition explain only a portion of the variation in the ultimate palatability of meat. Our data indicate that such management factors as preslaughter stress and cold shortening may be of primary importance in the ultimate palatability of reindeer meat. The high incidence of dark-cutters was as expected, since prehandling stress is important in current slaughter methods.

It is in the best, long-term interest of the industry to strive to produce a high-quality product which is both nutritious and highly acceptable to the consumer in terms of appearance and palatability. Some of the questions raised by this study indicate a need for further examination of factors affecting the marketability of reindeer meat. These questions include, what is the prevalence and importance of cold shortening under current slaughter methods, particularly as it may affect tenderness? Can electrical stimulation be used to decrease the effects of cold shortening and result in more palatable meat? How important are various types (nutritional versus excitement) and duration of stress on the development of the dark-cutter syndrome? How much and what kinds of rest or calming are required to recover from the dark-cutter syndrome? Does castration of males at a late age improve carcass palatability over uncastrated males? What is the relationship of intermuscular fat and age to juiciness?□

Bibliography

Amerine, M.A., R.M. Pangborne, and E.B. Roessler. 1965. *Principles of Sensory Evaluation of Food*. Academic Press, New York, NY. 602 pp.

Arobio, E.L., W.C. Thomas, and W.G. Workman. 1979. Mathematical programming for considering management options in Alaska reindeer herding. IN: *Proc. 2nd Int'l. Reindeer/Caribou Symp.*, Roros, Norway. Eds: Reimers, E., Gaare, E., and Skjenneberg, S.

Blaylock, D.M., D.A. Cramer, and L.E. Wookey. 1967. Effect of animal age and sex on certain qualities of reindeer meat. Unpublished. Dept. Animal Sci., Colorado State University, Fort Collins. 9 pp.

Chrystall, B.B., and C.J. Hagyard. 1976. Electrical stimulation and lamb tenderness. *New Zealand J. Agric. Res. 19*:7-11.

Cross, R.H., H.F. Bernholdt, M.E. Dikeman, B.E. Green, W.G. Moody, R. Staggs, and R.V. West. 1978. Guidelines for cookery and sensory evaluation of meat. American Meat Science Association, Chicago. 24 pp.

Davey, C.L., K.V. Gilbert, and W.A. Carse. 1976. Carcass electrical stimulation to prevent cold shortening toughness in beef. *New Zealand J. Agri. Res. 19*:13-18.

Dixon, W.J. 1981. *BMDP Statistical Software*. University of California Press, Berkeley. 725 pp.

Forrest, J.C., E.D. Aberle, H.B. Henddrik, M.D. Judge, and R.A. Merkel. 1975. *Principles of Meat Science*. W.H. Freeman and Company, San Francisco. 417 pp.

Jost, L.K., C.A. Dinkel, and W.J. Costello. 1983. Beef tenderness and palatability as influenced by chemical measures and quality and yield grade factors. *J. Animal Sci. 56*(5): 1007-1087.

Lochner, J.V., R.G. Kauffman, and B.B. Marsh. 1980. Early post-mortem cooling rate and beef tenderness. *Meat Science 4*:227-241.

Luick, J.R. 1982. Reindeer Meat Chart. Univ. of Alaska, Fairbanks.

Matson, G., and J. Matson. 1982. Tooth cementum age analysis. Progress Report 4. Milltown, Montana.

McVeigh, J.M., P.V. Tarrant, and M.G. Harrington. 1982. Behavioral stress and skeletal muscle glycogen metabolism in young bulls. *J. Anim. Sci. 54*(4):790-795.

Riley, R.R., J.W. Savell, G.C. Smith, and M. Shelton. 1980. Quality, appearance and tenderness of electrically stimulated lamb. *J. Food Sci. 45*:119-121.

Seideman, S.C., H.R. Cross, R.R. Oltjen, and B.D. Schanbacher. 1982. Utilization of the intact male for red meat production: a review. *J. Animal Sci. 55*(4)826-840.

USDA. 1982. Meats, prepared meats and meat products (grading, certification and standards). USDA Ag. Mktg. Serv. 28 pp.

Wookey, K.L., L.E. Wookey, D.A. Cramer, and M.D. Blaylock. 1969. Considerations involved in palatability of reindeer. 20th Alaska Science Conference, University of Alaska, Fairbanks.

One of the benefits of retaining certain lands in agricultural use may be "the preservation of a visible, perhaps romantic, lifestyle."

Alaska's Agricultural Lands
Some Issues in Public Policy

By

William G. Workman* and Steven D. Beasley**

An issue of significant political importance in many regions of the United States and other parts of the world concerns the conversion of crop lands to residential and other nonagricultural public and commercial uses. Concern for this shifting pattern of land use has spawned a number of government-sponsored programs to slow this trend. Among the policy instruments introduced to address the goal of crop land preservation are property-tax incentives (e.g. use-value assessments), agricultural zoning, government purchase of development rights on agricultural lands, and, in Alaska, the sale of agricultural rights only in selected state and local government land-disposal programs.

The rationale for the introduction of extra-market mechanisms to influence land-use patterns stems from the alleged failure of private land markets to produce socially desirable allocations of land resources. While this issue has resulted in a significant number of position papers and conference proceedings[1] and in great political rhetoric, the topic remains controversial, and empirical evidence of a suboptimal agricultural land base is thin indeed. Rather, a typical approach of authors writing in support of nonmarket sanctions has been to warn of the *possibility* that the private land market might fail to meet long-term agricultural production-capacity requirements and then to proceed to evaluate various policy instruments with respect to their relative strengths and weaknesses in achieving food- and fiber-production capacity goals. The most obvious shortcoming of this approach is, of course, the implicit equating

* **Associate Professor, Economics, Agricultural Experiment Station, Fairbanks.**

** **Graduate Research Assistant, University of Alaska, Fairbanks.**

[1] *See, for example, the following: NALS. 1981.* National Agricultural Lands Study. Final Report. *U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C.; U.S. Senate. 1981.* Agriculture Land Availability: Papers on the Supply and Demand for Agricultural Lands in the United States. *Committee on Agriculture, Nutrition and Forestry, 97th Congress, 1st Session. July; William A. Fischel. 1982. The urbanization of agricultural land: A review of the National Agricultural Lands Study.* Land Economics, *58(2); Philip M. Raup. 1982. An agricultural critique of the National Agricultural Lands Study.* Land Economics, *58(2).*

A shifting pattern of land use has spawned a number of government-sponsored programs to preserve crop lands.

of "requirements" with economic demand that stems from discounting the role that prices play in determining commodity and resource-use patterns.

Aside from the issue of national and/or global inadequacies of agricultural land bases, state and local entities often express a desire to maintain or expand the agricultural sector for the purpose of stabilizing economic activity patterns or of broadening the industrial base of an economy. These latter concerns seem to more appropriately apply to the Alaskan situation. The primary argument advanced by advocates of an expansion of the state's agricultural industry relates to our current heavy reliance on the petroleum industry to support activities in both the private and public sectors. Concern for the future of Alaska's economy has given rise to suggestions for a broadening of the economic base which emphasize the increased development of renewable sources of income including agricultural activities. Public support for this position has contributed to the emergence of agricultural projects in the Big Delta area and at Point MacKenzie and in the disposal of agricultural lands by the state and borough governments in other parts of the state.

In addition to the interest expressed in broadening the economic base, it is not uncommon to encounter the argument that agriculture should be expanded since only about 5 per cent of the food consumed in Alaska is produced in-state. Related to this point is the suggestion that, by reducing our food imports, we become less vulnerable to potential disruptions in the delivery system linking Alaska with current food sources. Let us briefly examine these issues.

There is nothing intrinsically wrong with being only 5 per cent (or any other per cent) self-sufficient in food or any other commodity. There are, after all, many classes of items that Alaskans purchase for which we are entirely dependent on outside sources. Nearly all of our clothing is imported. Drugs and other medicines are produced elsewhere, as are automobiles, airplanes and outboard motors. Presumably, the least expensive way in which to satisfy Alaskans' desires for these purchases is to import them. Similarly, the least-cost method of satisfying the state's food demands is likely to be some combination of imported and local production. No one knows for sure what this combination might be but, if markets are operating efficiently, it is probably close to our present mix. If relative costs change in the future, then market forces will reflect the new set of cost conditions and the efficient proportion of in-state food production will also change. The important consideration from a policy viewpoint is that all costs, including backing by the public sector, should be reflected in any analysis aimed at identifying Alaska's optimal level of self-sufficiency in food.

The issue of our vulnerability to interruptions in food shipments can likewise be analyzed using a framework that considers cost-effectiveness. If it is determined that Alaskan food wholesalers and retailers hold suboptimal inventories of food, given the reliability of the transport system, then some public measures may be required to ensure against an unexpected disruption in supply.[2] Among the means available are encouragement of greater in-state food production, state support for either private or public food-warehousing facilities, and financial backing for an emergency food transport mechanism that could be activated in the event that traditional supply lines were broken. It would seem to be in the state's best interest to accomplish its goal of continuous food availability with the least expenditure of resources. Achieving this objective may involve a combination of these various measures as well as others.

Discouraging Conversion

While the opening of new lands for agricultural development may be the dominant reflection of public attention on the role that this industry will play in the state's economic future, increased concern with the preservation of existing farm acreages is another dimension of this same interest. In Alaska, the process of farmland conversion is most readily apparent in the Matanuska Valley. The old colony and homestead areas are currently under intense development pressure due to the population growth of the region and the consequential increase in demand for suburban housing. Many of the affected areas have been under continuous cultivation since the early part of this century and are often referred to as the showcase of Alaska's agriculture. Area residents are concerned with what has been described by one local official as the "loss of the heart

[2]*Why might these wholesalers and retailers hold socially inefficient stocks? One reason may be that the individual firm views the riskiness of shipment disruption differently than does the rest of the Alaska society. For example, a firm that stockpiles food in anticipation of a shipment interruption at some unknown future date may not have a free rein over how this inventory is utilized should the disruption occur. If the firm realizes this, its incentive to stockpile is reduced. It follows that the social benefits of increasing the security of food supplies exceed the private (firm) benefits and some government action may be called for to address this divergence. These issues are discussed with reference to U.S. energy policy is John E. Tilton. 1976. The public role in energy research and development. IN: Robert J. Kalter and William A. Vogely (editors).* Energy Supply and Government Policy. *Cornell University Press.*

of agriculture in Alaska" and with the alteration of the unique scenic beauty of these areas in farm use (Thurlow, unpublished).[3]

These concerns have resulted in actions by both the state and Matanuska-Susitna Borough governments to resist the conversion pressures on existing farmlands and to encourage agricultural use of newly disposed lands. Regarding the latter both the state and the borough have implemented procedures designed to classify and dispose of arable lands for agricultural use only. The borough's actions are said to reflect the desires expressed in a recent area-wide survey in which residents gave agricultural development the highest priority in ranking resource-development options for the region (Planning, Inc., 1983).

Regarding the protection of existing farmlands, a policy currently in use is the state-funded, borough-implemented property tax-deferral program. Agricultural lands are assessed, for property-tax purposes, according to their productivity in agriculture rather than at their fair market value. The state compensates the borough for the tax revenues foregone from this assessment procedure. Farmland owners who receive at least 10 per cent of their annual gross income from farming are eligible to participate in the program. If, however, the farm property is converted to a nonagricultural use, the owner must repay the state a penalty tax plus accumulated interest. Currently, there are some 11,000 acres of land in the Matanuska-Susitna Borough covered by the farm tax-deferral program (Planning, Inc., 1983).

Recently, interest has focused on a relatively new institutional mechanism to slow the loss of agricultural lands to other uses. This method, which has been adopted in some of the eastern states and in King County, Washington, involves the public purchase of nonagricultural development rights on agricultural lands currently held in the private sector. Under a voluntary arrangement, interested farmers could offer to forfeit the right to subdivide their acreage in exchange for a compensating payment. This payment would presumably represent the differential between the fair market value of the land held in fee simple title and the value of the land as a productive resource in agriculture. Such a program is designed to remove the farmers' incentives to subdivide their lands by making available to them potential capital gains created by development pressures.

Interest in development rights purchase programs in Alaska is reflected in actions by both state and local governments. In 1978, the Alaska Department of Natural Resources asked the Agricultural Experiment Station (AES) to evaluate such a program(Workman et al., 1979; Workman et al., 1980). This past year, the Matanuska-Susitna Borough Assembly passed a resolution urging the state and local government to develop cooperatively a policy and mechanism that would allow the purchase of agricultural preservation easements (*Frontiersman*, 1983). Subsequently, bills were introduced in both the house (HB 148) and senate (SB 237) of state government to fund such a program, but neither reached the chamber floor. A unique feature of the proposed program for Alaska is the form of compensation to the land owner. In recognition of the state's significant inventory of potentially arable land, it was proposed that new agricultural lands be made available to program participants with cash payments being made only to make up any difference between the value of the easement and the value of the newly awarded parcel.

Development rights-purchase programs can undoubtedly be effective in preserving agricultural lands. Yet such programs need not be hampered by the same inequities that characterize agricultural-zoning procedures. However, as was pointed out in the earlier AES study (Workman et al., 1979; Workman et al., 1980), such programs are potentially very expensive, a fact which no doubt contributed to the lack of progress of the bills introduced in the legislature. For example, the AES study estimated an asking price of $3,400 per acre for development rights on agricultural lands statewide and $3,600 per acre in the Matanuska-Susitna region. The obvious question that must be addressed is, How do these cost estimates compare with the magnitude of benefits that might flow from such a program? Is the rate of return on public resources required to finance such an effort competitive with what could be earned by equal expenditures in other investments? Alternatively, if the objective of a government-sponsored program is to preserve a critical mass of agricultural resources such that the industry can remain or become viable in a particular region such as the Matanuska and Susitna Valleys, is a development rights-purchase program the least-cost means of achieving this goal? The latter point is particularly relevant since the existing acreage in agriculture may contribute only modestly to this critical mass when one considers the amount of potentially arable land in the region and the option that the state and borough governments have to release only the agricultural rights to these new lands in their disposal programs.

Failure in the Rural Land Market?

Just as the literature relating to the national and global adequacy of an agricultural land base reveals vast differences of opinion on this issue, controversy surrounds the advisability of extra-market means to preserve the agricultural base of small local areas.[4] Fundamental to these debates is the efficacy with which private land markets function to provide efficient and equitable patterns of resource use. While "market failure" has been suggested as the justification for public intervention in land-use decisions, the removal of the market from the allocation task and the substitution of essentially nonmarket criteria characteristic of many agricultural land-preservation programs should be accompanied by some specific rationale. Consideration of the nature of the food and fiber commodities that are produced by agricultural enterprises suggests that allegations of market power concentration or externalities leading to sub-optimal quantities of land devoted to agriculture clearly lack validity.

At the local level, however, there may be a concern with an income-distribution implication of agricultural-land conversion. To the extent that specialized resources are employed either at the farm level or elsewhere in the infrastructure of the agricultural industry, the owners of these resources have a vested

[3] *Thurlow, Gary. Matanuska-Susitna Borough mayor.*

[4] *See B. Delworth Gardner. 1977. The economics of agricultural land preservation.* American Journal of Agricultural Economics *59(5). Gardner's clear statement of these issues led us to borrow shamelessly in our development of this and the following two paragraphs.*

interest in maintaining the industry. For example, there may be some immobile farm workers whose absence of skills outside the agricultural industry would prevent their adjusting easily to the changing economic scene. One must face the issue, however, of whether retaining land in agriculture is the least-cost method of providing these individuals with an acceptable standard of living. It may be that publicly financed programs of economic assistance and/or retraining could achieve this end more efficiently.

Other resources and decision makers across the spectrum of agriculture — farm operators, processors, suppliers, transporters, government agency personnel and university professors in agricultural disciplines — also have obvious stakes in a viable agricultural industry. However, these are generally not low-income people, so the concern for the equity consequences of land conversion may not be as great. In addition, they are typically mobile so can adjust to changing land-use patterns. In any case, the income-distribution argument does not seem particularly relevant to the Alaska situation since any nonland agricultural inputs that are displaced by land conversion in the Palmer-Wasilla area can most likely be utilized in the newly developing agricultural areas in the state.

What, then, is the nature of the market failure that might cause objection to unfettered exchange in the rural land market? Raup (1982) has indicated that, at the national level, the concern for lost environmental amenities associated with the presence of agricultural activities at the urban fringe was the major impetus in the 1960s for increased public involvement in land-use planning and the advocated restrictions on agricultural-land conversion. We have argued elsewhere (Workman et al., 1979) that open space is only one of several "external benefits" that might accrue to Alaskans from the decision by agricultural-land owners to keep their land either uncleared or in agricultural use. Other benefits in this class are the maintenance of wildlife habitat, watershed protection, and the preservation of a visible, perhaps romantic, lifestyle. Since farmers are not in a position to demand compensation for supplying these benefits, they have little incentive to provide the socially optimal quantities of these environmental amenities.

The environmental effects of allowing land at the urban fringe to remain in agricultural use are known in the economist's jargon as "public" or "collective" goods. As such, these benefits have two distinguishing characteristics: (1)the impracticability of excluding the consumer who does not pay for the good (i.e. "nonexclusiveness"), and (2)consumption by one consumer does not reduce the quantity available to others (i.e. "nonrivalry") (Mishan, 1969). These qualities make it difficult for market transactions to result in socially desirable amounts of the collective good. First, on the supply side, the nonrivalry characteristic suggests that the cost of making the good available to one more beneficiary is zero. This means that the socially efficient price to charge for the good is also zero. But, at a zero price, obviously no private businessman, a farmer in this case, would be willing to invest in supplying the good. On the demand side, since no one can be excluded from consumption, whether or not he pays for the good, individuals have no incentive to reveal their true willingness to pay for the good. Provided the good were made available, an individual could benefit from its presence and become a "free rider."

Alaska has a great abundance of open space and related environmental amenities to offer its residents. Since market signals are absent with regard to the production of these collective goods, there is little evidence available as to how much these amenities are worth. It seems reasonable, however, that the highest value would be placed on these benefits in situations where they are in short supply. In relatively urbanized areas, these benefits may take on high value indeed. The importance of the environmental effects of agricultural-land preservation is reflected in the criteria by which choices among qualified parcels would be made in the previously discussed proposed Matanuska-Susitna Borough development rights-purchase program: (1) agricultural productivity, (2) susceptibility to conversion and (3) contribution to attractiveness of the area (Planning, Inc., 1983). Based on these considerations and the associated attraction of tourists, the old colony area has been singled out as a priority for preservation.

But what is the value of preserving the amenity benefits — the environmental advantages as well as the historical values — of these agricultural lands? Certainly if public expenditures are to be made in this effort, some notion of the return on this investment would be helpful to policy makers. The Agricultural Experiment Station is currently involved in a study designed to shed some light on this issue. Employing state-of-the-art techniques for valuing collective-good, environmental amenities, researchers are hoping to furnish borough and state officials with useful data on which to judge proposed farmland retention programs in southcentral Alaska and statewide.

Conclusion

The general position taken in this essay is that the public policies and programs mentioned here as well as any others aimed at redirecting resource allocations should be scrutinized regarding their costs and, where possible, benefits. In many cases, this examination will require a significant research commitment in order that decision makers have access to objective information on which to base their analyses and choices. The payoff to Alaskans from this approach in examining actions affecting the state's industries, including agriculture, is the increased likelihood of the various sectors of the economy realizing their potential and contributing the maximum amount to Alaska's economic future. ▫

References

Frontiersman. 1983. January 13.

Mishan, E.J. 1969. The relationship between joint products, collective goods, and external effects. *Journal of Political Economy 77*(3).

Planning, Inc. 1983. *Agricultural Report to the Matanuska-Susitna Borough*.

Raup, Philip M. 1982. An agricultural critique of the National Agricultural Lands Study. *Land Economics 58*(2).

Workman, W.G., Edward L. Arobio, and Anthony F. Gasbarro. 1979. *An Examination of a Development Rights Purchase Program for Alaska Agricultural Lands*. Final Report to Alaska Department of Natural Resources.

Workman, W.G., Edward L. Arobio, and Anthony F. Gasbarro. 1980. Will Alaskan farmers sell the development rights to their land? *Agroborealis 12*(1):19-22.

White spruce house logs such as these bring the highest market prices.

Forest Management for Interior Alaska
Can Products Justify Costs?

By

Edmond C. Packee*

Interior Alaska forests constitute a renewable resource which is currently underutilized. Through appropriate fiber utilization and the development of an efficient industrial infrastructure, these forests have the potential to:

1. supply more of the wood-fiber demands of interior and southcentral Alaska and reduce the magnitude of high-cost imports from the forty-eight conterminous states and Canada;
2. provide an export market which would enhance regional and state economies and benefit the national trade balance;
3. provide employment opportunities in a relatively stable industry for skilled and semiskilled workers.

This paper presents a preliminary overview of the forest-products potential of the Alaskan spruce-hardwood forest and identifies the economic realities of forest management which must be considered. Emphasis is on fiber production; however, this should not be construed as ignoring other uses of Interior forests. Multiple use is fully recognized and the integration of all uses is the ultimate goal.

* Assistant Professor, Forest Management, Agricultural Experiment Station, Fairbanks.

Economic Considerations

A successful forest industry, whether a large corporate complex or a small family business, depends upon satisfactory profits obtained from operations. Good forest management involves expenditures of money and manpower; similarly, the operation of an efficient sawmill or other forest-products plant requires the expenditure of money and manpower. These two activites, forest management to produce the raw materials (trees for fiber) and the conversion of the raw material to useful products, are intimately related. Ultimately, the consumer determines the profitability of the forestry operation.

Worrell (1952) recognized five stages of forest production:

1. primary production of the raw material (the growing of the fiber as trees);
2. harvest of the raw material (logging);
3. processing of the raw material (logs or the entire tree) into products (firewood, boards, waferboard, paper);
4. distribution and marketing of products (transportation, storage, and advertising); and
5. purchase and use of the products by the consumer.

Worrell's stages emphasize the interrelationship of forest management, product manufacture, and the consumer; he clearly

Nearly mature white spruce stands such as this one contain house logs, sawlogs, pulp logs, and firewood.

identifies the importance of the consumer in determining the price and hence the profitability of the forest industry.

Harvestable interior Alaska forests can be considered old growth, their presence a free gift; that is, no deliberate outlay of money or manpower has produced these stands of timber. Until recently, management has constituted little more than cutting and moving onto another stand. Little thought has been given management for future stands – no real investment of money and manpower. Once the old-growth stands have been cut, Alaska's interior will have to depend upon the management of its timber-growing capability or imports.

Recently, Sedjo (1982) compared rotation age, growth rate, and yield of plantations of various species in various regions of the world and then compared the economics of production; these comparisons are presented in Tables 1 and 2. In Table 1, note the long rotation period (the time for trees to reach maturity) for Finland which has rotations similar to those feasible in interior Alaska. Even the Douglas-fir region of the Pacific northwest, with its highly productive forests, has rotations which do not compare well with other regions of the world. Rotation provides an indication of the time required to carry an economic investment to maturity – the time of harvest.

Growth rates are expressed as the mean annual increment (m.a.i.) which is the average annual volume growth of a tree or stand from time of establishment to rotation age. Again, Table 1 shows the mean annual increment for Norway spruce in Finland to be less than one-half to one-fifth those found elsewhere. Farr (1967) provides a mean annual increment figure for natural (unmanaged) white spruce stands of 51.2 cu. ft. per acre per year on the best sites in Alaska. With good management, however, the mean annual increment on such sites in Alaska could reach levels greater than that given for Finland. Nevertheless, the timber capability of Alaskan and Finnish forest sites is comparatively low.

Although the total commercial yield of fiber per acre at rotation age for some species and locations is less than that for Finland, over the same period of time the yields in other regions of the world are greater. This is demonstrated by using the pulpwood regime for Caribbean pine in Brazil with a rotation age of 12 years and a total yield at harvest of only 2,744 cu. ft. per acre. In contrast, Norway spruce in Finland has a rotation age of 50 years and a yield of 3,573 cu. ft. per acre. However, in Brazil, the forest manager can produce four rotations of pine in the same period as one rotation of spruce in Finland for a total commercial yield of 10,976 cu. ft. per acre.

In Sweden, the mean annual increment for the country is only 42.9 cu. ft. per acre per year, and even with that low level of productivity, there is a thriving forest industry (National

Table 1. Comparison of rotations, growth rate (m.a.i.) and yields for plantations of several species in several regions of the world (from Sedjo, 1982).

Country/Species	Pulpwood Regime Rotation (yrs.)	Pulpwood Regime M.A.I. (cu.ft./A/yr.)	Pulpwood Regime Yield (cu.ft./A)	Sawlog Regime Rotation (yrs.)	Sawlog Regime M.A.I. (cu.ft./A/yr.)	Sawlog Regime Yield (cu.ft./A)
United States – South						
Loblolly pine	30	170.1	5,097	35	177.2	6,201
Loblolly pine–high site	29	256.2	7,689	35	253.0	8,863
United States – Northwest						
Douglas-fir	40	182.2	7,289	50	205.8	10,304
Douglas-fir–high site	30	194.4	5,830	40	285.8	11,447
Brazil						
Caribbean pine	12	228.7	2,744	16	228.7	3,659
Eucalyptus	7,13,18	357.3	6,788	19	357.3	6,788
Loblolly pine	12	285.8	3,430	20	285.8	5,717
Chile						
Monterey pine	25	314.4	7,632	32	314.4	10,051
Australia						
Monterey pine	29	295.7	8,574	35	248.7	8,703
New Zealand						
Monterey pine	18	357.3	6,431	27	357.3	9,647
Borneo						
Caribbean pine	15	200.1	3,001	20	192.9	3,859
Finland						
Norway spruce	50	71.5	3,573	80	71.5	5,717

Table 2. Comparison of forest-management costs in 1979 dollars and return on investment for plantations of several species in several regions of the world (from Sedjo, 1982).

Country/Species	Establishment Cost/Acre ($)	Pulpwood Regime Subsequent Costs/Acre ($)	Pulpwood Regime Rate of Return (%)	Pulpwood Regime Cost/cu.ft. ($)	Integrated Regime Subsequent Costs/Acre ($)	Integrated Regime Rate of Return (%)	Integrated Regime Cost/cu.ft. ($)
United States – South							
Loblolly pine	266.17	139.15	12.02	.080	149.15	12.45	.067
Loblolly pine – high site	266.17	139.15	13.91	.053	149.15	14.12	.047
United States – Northwest							
Douglas-fir	558.65	438.65	5.45	.137	877.50	6.12	.139
Douglas-fir – high site	558.65	413.65	7.24	.167	852.50	8.29	.123
Brazil							
Caribbean pine	277.50	370.00	17.89	.236	430.00	20.44	.193
Eucalyptus	523.00	647.80	20.16	.172	647.80	15.54	.172
Loblolly pine	530.00	382.80	15.57	.266	502.80	17.53	.181
Chile							
Monterey pine	176.62	97.47	23.39	.036	114.38	12.50	.029
Australia							
Monterey pine	651.56	173.73	10.68	.096	192.51	10.06	.097
New Zealand							
Monterey pine	456.33	445.46	11.90	.140	567.40	13.11	.106
Borneo							
Caribbean pine	277.50	415.00	12.94	.231	490.00	14.73	.199
Finland							
Norway spruce	456.00	126.72	4.61	.163	156.72	5.57	.107

Board of Forestry, 1977). Assuming levels of productivity for forest fiber in Alaska at least equal to that of Scandinavia and considering distance to markets and productivities elsewhere, one must ask, "In spite of the success in Scandinavia, why invest capital in forest management in the interior of Alaska when there are more lucrative opportunities elsewhere with apparent lower risk?"

Table 2 compares the establishment costs and subsequent costs of intensive management in terms of 1979 dollars and the anticipated rate of return on investment. Immediately, one sees the rate of return on the Finnish spruce plantations to be much less than most of the other locations. However, it is not significantly less than the figures given for average growing conditions in the Pacific Northwest.

The initial investment required to establish a plantation of spruce in Finland is slightly above average for the twelve cases presented. Subsequent management costs are well below average. When all management costs are considered, only the southern United States and Chile have a per-acre cost lower than Finland. More importantly, the cost to produce 1 cubic foot of wood under the integrated regime (multiproduct) in Finland is competitive with all Pacific Rim countries except Chile and is much less expensive than the production of Douglas-fir in the Pacific Northwest. This implies a lower risk of capital per unit of fiber produced.

Because of the infancy of the forest industry in Alaska's interior, no reliable forest-management or manufacturing costs are available. Preliminary information suggests that certain costs are considerably below those for the Pacific Northwest and interior British Columbia. Based on the Finnish example and assuming similar costs and growing capability, Alaska has an opportunity to produce fiber for its own use in what appears to be an excellent profit situation. In addition, certain high-quality, high-value products (furniture blanks, panelling, lumber) could be manufactured from native Alaskan species for export. Obviously, a management regime for pulpwood does not appear to be as attractive as an integrated regime producing a range of products.

That an in-state demand exists for Alaskan products is obvious; all one needs to do is visit a local lumberyard. Carloads of spruce lumber from British Columbia (Prince George, Smithers, Quesnel) are a common sight. Lumber is trucked in from Watson Lake, Yukon, to Fairbanks and Anchorage, distances in excess of 800 miles. Paper birch is occasionally imported from Michigan.

The demand for Alaskan products outside the state is undefined. Our competitors, British Columbia, Washington, and Oregon, export the same species or similar species for the same uses to Pacific Rim countries. The question then is not "Is there a demand?" but, "Can interior Alaska compete?" Earlier it was suggested that we could manage the forests and probably manufacture products for as low or lower costs than the Northwest competitors. Also, shipping to the Orient takes four to five days less from Anchorage than from Seattle, Washington, or Vancouver, British Columbia. The differential from Prince Rupert, British Columbia, is not as great, but still exists. Interior British Columbia white spruce and lodgepole pine lumber travels to Prince Rupert by rail, distances of 200 to more than 500 miles; the rail distance from Fairbanks to Seward is approximately 470 miles. Thus, Alaska is no further away from Pacific Rim countries, and the shorter shipping distances should mean lower shipping costs.

The large amount of old-growth available for harvest in interior Alaska is a definite asset. Emphasis is on "available" — timber must be committed to harvest. The large acreage in private ownership (native corporations), the new Tanana Valley State Forest, and other acreage set aside for timber production provide a reasonably secure timber base. Such a supply of timber is an important consideration for locating a new converting plant. It does not first require the establishment of a new forest followed by capital outlay for a converting plant as is the case in Brazil, Chile, Borneo, and Australia. That initial supply of timber not only decreases the capital investment, but greatly decreases the risk. Also, Alaska provides a better risk in terms of political stability than many of the more lucrative areas suitable for forest management.

Forest Species

The spruce-hardwood forest of the interior of Alaska is relatively poor in species composition. Only seven tree species occur naturally: tamarack or larch, white spruce, black spruce, paper birch, quaking aspen, balsam poplar, and western black cottonwood. In the adjacent Yukon territory, two additional conifers occur: subalpine fir and lodgepole pine; of these, only lodgepole pine has sufficient value as a source of quality fiber to be considered for management in the Interior of Alaska.

One of the most critical management decisions that the land manager makes is the selection of the species for management on a specific site. Not only does the manager have to know the ecological requirements of each species and be able to identify the conditions of the specific site he plans to manage, he must know the potential markets for each species and the kind of log or tree required to produce products of the highest quality. Only then can he make a site-specific prescription as to the species or mixture of species most suitable. It is not enough to grow trees for yield. The yield of subalpine fir often exceeds the yield of lodgepole pine, but the quality of its fiber is such that it is considered inferior to lodgepole pine for lumber, plywood, some pulp processes, and even firewood. The initial choice of species for each specific site will affect the ultimate profitability of the industry.

Table 3 identifies potential uses of the species. At this time, it is difficult to rank the species for each use. A large part of the ranking exercise can be done through a survey of the literature. However, the literature can cause confusion as in the case of per-cord heating values. In this situation, the values and ranks of Canadian data (Greaves and Schwarz, 1951) do not agree with those commonly accepted in the United States (Summitt and Silker, 1980).

In selecting the species for the site, the manager should opt for a species that has the most end-product options and highest values for end products; he then must determine the capability of the site to grow that species. Essentially, the manager is matching the best products to the growing capacity of the site — he is attempting to maximize profits. The managed forests of interior Alaska will consist of a mixture of kinds of stands — pure stands and mixed stands, different species, different number of trees per acre, and different rotation ages.

Table 3. Potential commercial uses of several native, Interior, Alaskan tree Species.

Use	Paper Birch	Quaking Aspen	Balsam Poplar	Black Cottonwood	Larch	Black Spruce	White Spruce
Building material							
House logs					x	x	x
Construction lumber					x	x	x
Siding					x	x	x
Poles					x	x	x
Waferboard	x	x	x	x	x		
Particleboard	x	x	x	x	x	x	x
Finishing materials							
Boards	x	x	?	x	x	x	x
Paneling	x	x	x	x	x	x	x
Flooring	x				x		
Molding	x	x					
Veneer	x	x	x	x	x	x	x
Cabinets	x	x			x		x
Furniture components	x	x	?	?			x
Pulp and paper							
Chips	x	x	x	x	x	x	x
Kraft pulp	x	x	x	x	x	x	x
Thermomechanical pulp	x	x	x	x	?	x	x
Newsprint	x	x	x	x	?	x	x

Use	Paper Birch	Quaking Aspen	Balsam Poplar	Black Cottonwood	Larch	Black Spruce	White Spruce
Agriculture							
Posts					x	x	x
Bedding	x	x	x	x			
Feed	?	x					
Energy							
Firewood	x	x	x	x	x	x	x
Hog fuel *	x	x	x	x	x	x	x
Pressed-wood logs					x	x	x
Miscellaneous							
Transmission poles					x	x	
Railroad ties					x	x	x
Export cants	x	x			x	x	x
Caskets	x						
Novelties	x						
Specialty items	x	x	x				
Christmas trees						x	x
Birch syrup	x						
Perfume/oils	x					x	x

*Hog fuel: sawmill waste not otherwise used, such as slabs, edgings, trimmings, defective boards, and miscuts, which has been chipped into small, roughly sized pieces to be used for fuel; the chipping machine is known as the "hog", hence the term "hog fuel."

Forest Management

Forest management is the application of business methods and technical forestry knowledge to the operation of a forest property to produce goods. Roth (1974) stated that the task of forest management is, "To build up, put in order, and keep in order a forest business." In Alaska, the task today is the same as that given for the United States in 1914, ". . . to take a piece of Wild Woods and convert this gradually into a forest business which shall produce timber, as much and as good as the land and climate permit, and to have this timber in such a condition of age and arrangement that a crop may be cut each year, and thus income secured in keeping with the investment."

There are two categories of forest-management activities. Basic management activities include all essential activities for the orderly running of the business to meet specified goals. Optional management activities are those practices which can be used at the discretion of the manager to produce additional increments of wood or value.

Basic management activities include: site classification, inventory, management of data (record keeping), protection, and, in Alaska, because of the Forest Act, regeneration. Optional management activities include: site preparation, stand release, nutrition, tree improvement, thinning, and more refined or special basic-management activities. A management plan will identify for each specific site a minimum-management goal and an optimum goal and then list basic, mandatory activities and optional activities for the manager to consider for implementation to achieve the specified optimum goal. For sites with a particular timber-growing capability, with similar environmental limitations, and having similar access, the land manager should prescribe the same combination of basic and optional management activities — such a combination comprises a management regime. The regime should be the most economical capable of achieving the goal.

A site for which the management objective is aspen might have a management regime consisting of basic activities with clearcutting and natural regeneration. On the other hand, a site with a high timber-growing capability near the converting plant might have a management goal of 6,000 cu. ft. of white spruce per acre by a rotation age of 80 years. The management regime would consist of basic activities including:

1. clearcutting and artificial regeneration;
2. optional activities including site preparation such as prescribed broadcast burn;
3. planting of large, bareroot, genetically improved seedlings;
4. stand release from grass, by use of herbicides;
5. thinning at 40 years for fence posts and firewood, and at 60 years for sawlogs;

6. final harvest at 80 years for sawlogs and poles; and

7. fertilization with nitrogen and sulfur five growing seasons before each thinning and the final harvest.

The cost of such activites is treated as an investment and must be recovered with interest. Because of the social good (employment) brought about by intensive management, governments frequently provide tax incentives or outright grants or subsidies. Examples of subsidies or grants include up to 50 per cent or more of the costs of road building and thinning in Finland and from 30 to 90 per cent of the costs of planting, stand tending, thinning, and road building in Sweden (Gasbarro, 1982).

Conclusions

There is strong evidence to support the statement. "Products can justify the cost of good forest management in interior Alaska." Although growth rates and rotation ages are considerably less attractive than those attainable elsewhere in the world, when the risks of doing business are considered, the return on investment is acceptable. Market demand for Alaska's forest products is well established as demonstrated by competitors in Canada and the "Lower 48;" markets exist within Alaska as well as abroad. Interior Alaska's raw materials offer better access to many markets than those of competitors.

To be successful, the industry must become competitive. Forest management must be practiced in a business-like manner; "old-growth" must be used wisely to retire the development debt; and converting plants must be highly efficient and manufacture quality products. A real effort must be made to obtain the necessary share of the market.

Basic timber management should have as its goal production of maximum, practicable, per-acre yields of usable wood fiber. Available forestry knowledge must be applied. Information developed elsewhere must be transferred and tested in Alaska. A greater emphasis on applied research — solving the problems of the land manager — is essential. Management and research efforts must be coordinated to achieve the most benefits in the shortest time frame. ▫

Literature Cited

Farr, W.A. 1967. Growth and yield of well-stocked white spruce stands in Alaska. USDA For. Serv. Research Paper PNW-33. 30 pp.

Gasbarro, A. 1982. Forestry in Sweden and Finland: Its applicability to interior Alaska. *Agroborealis 14*:16-24.

Greaves, C., and H. Schwartz. 1951. The chemical utilization of wood. IN: *Canadian Woods: Their Properties and Uses*. Canadian Ministry of Resources and Development, Forestry Branch, Forest Products Laboratories Division, Ottawa. pp. 209-234.

National Board of Forestry. 1977. Swedish forest. Facts about Swedish forestry and wood industries. Sweden National Board of Forestry, Jonkoping, Sweden. 85 pp.

Roth, F. 1914. Forest regulation. Ann Arbor, Michigan 218 pp.

Sedjo, R. 1982. Intensive forest management options in the Pacific Northwest in comparison with opportunities in other regions and countries. Univ. British Columbia H.R. MacMillan Lectureship in Forestry (23 March 1982), Vancouver, British Columbia, Canada. 16 pp.

Summitt, R., and A. Silker. 1980. *Wood*. CRC Handbook of materials science. Vol. 4. CRC Press, Inc. Boca Raton, Florida. 459 pp.

Worrell, A. 1959. *Economics of American Forestry*. John Wiley and Sons, Inc., New York. 441 pp.

in Oregon for delivery of a paper entitled, "Arctic and subarctic truffles: Their speciation, range extension, associations, and spore vectors." In August, Dr. Laursen delivers a paper in Switzerland, entitled "The genus *Hygrophorus* (Agaricales) in Arctic and subarctic Alaska," at the Second International Symposium on Arctic and Alpine Mycology (ISAM-II) of which he is co-chairman. In September he will deliver an invited paper, "The Tricholomataceae of Arctic Alaska: A floristic treatment," to the European Workshop on the Tricholomataceae being held in Parma, Italy.

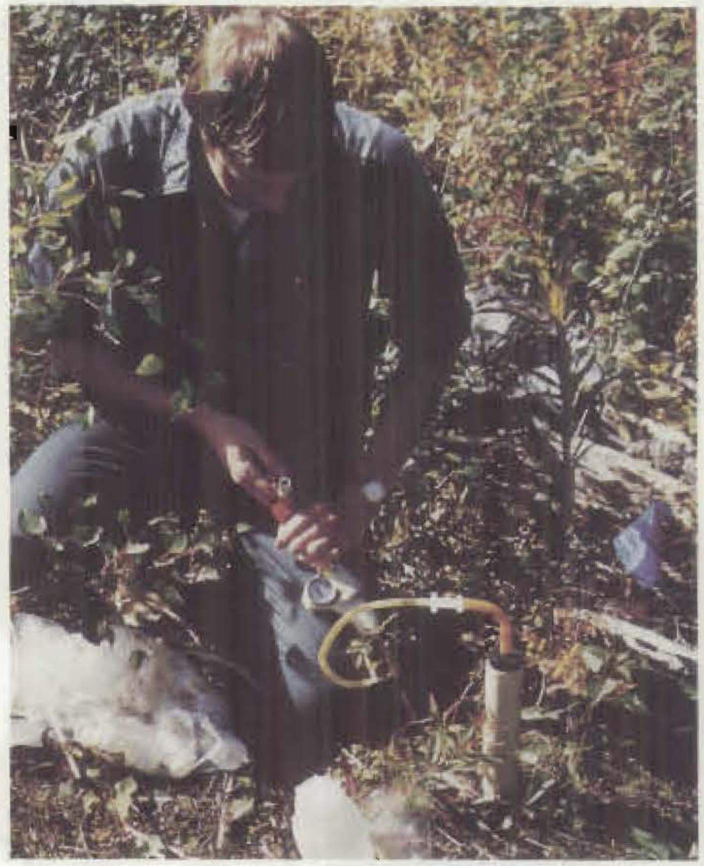
Dr. Laursen has also participated in a number of regional and local activites. The Rural Alaskan Orientation Program permitted a visit to the village of Barrow where educational needs in the biological sciences were discussed with science teachers. Public lectures on Arctic mushrooms were given to several classes and at the Naval Arctic Research Laboratory. Two Fairbanks community lectures on fungi of interior Alaska were also given as part of the Tanana Valley Community College's Science Seminar Series and for the Alaska Native Plant Society.

Andrew McLean Gordon will receive the interdisciplinary Ph.D. degree in August from the University of Alaska-Fairbanks, with a major in forest soils. His doctoral dissertation, "Seasonal Patterns of Nitrogen Mineralization and Nitrification Following Harvesting in the White Spruce Forest of Interior Alaska," was based on his research activites in the Bonanza Creek Experimental Forest near Fairbanks.

Dr. Gordon was awarded a B.Sc.F. degree in 1978 by the University of New Brunswick at Fredericton. Gordon entered the graduate-studies program at the University of Alaska-Fairbanks after a year's employment as a forester in northern Ontario with the Ontario Ministry of Natural Resources and Domtar, Inc.

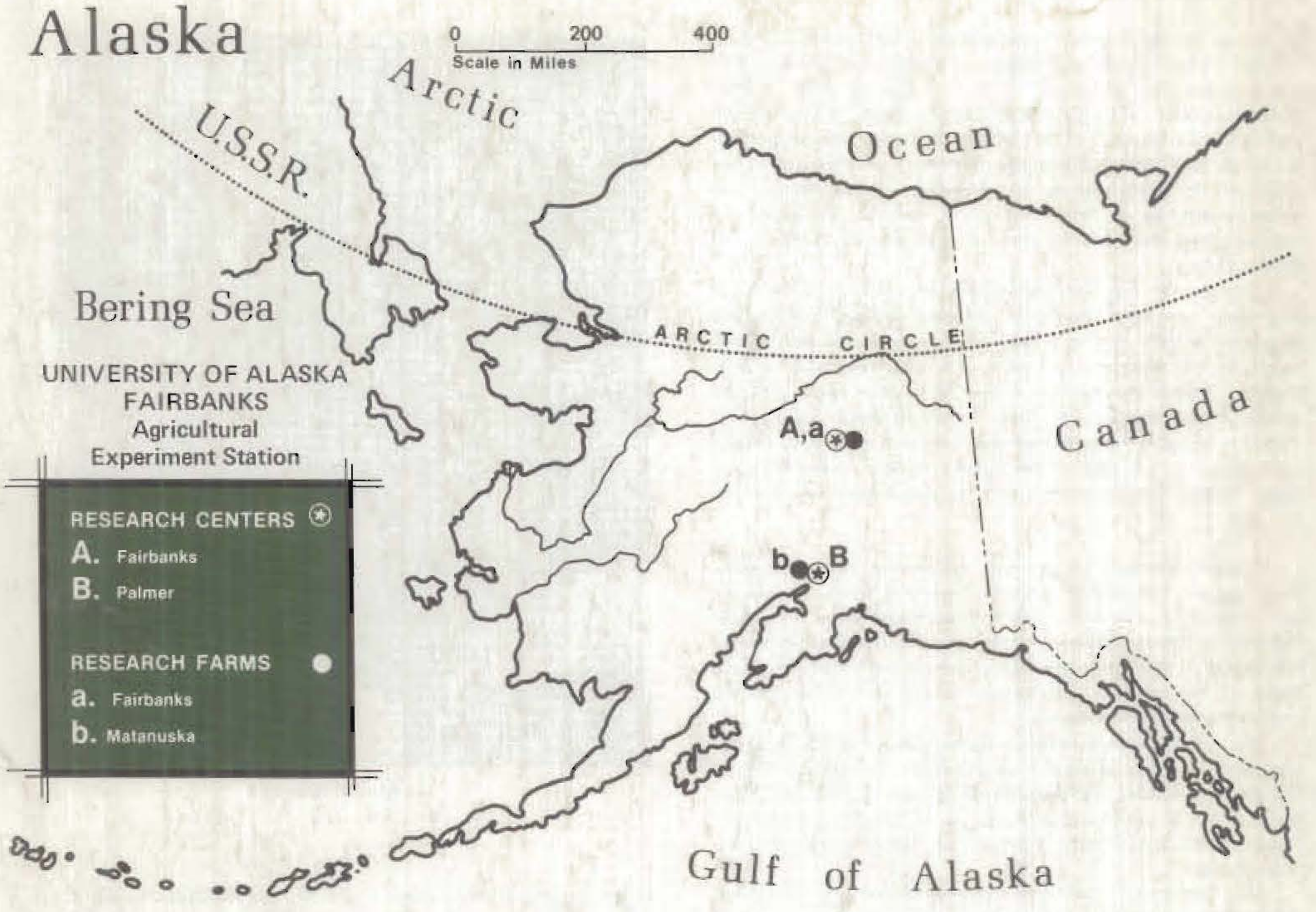
Dr. Gordon's initial work at the University of Alaska-Fairbanks was supported by the Canadian Government's Natural Sciences and Engineering Research Council. He was also the recipient for two years of a Natural Resources Scholarship awarded by UAF. In addition, his research was supported by McIntyre-Stennis funding.

Gordon will leave Fairbanks shortly for the University of Guelph in Guelph, Ontario, where he will join the faculty as an assistant professor of forestry. He will be working on riparian vegetation ecology, agroforestry, and forest-nitrogen cycling relationships.



Dr. Andrew M. Gordon

Gordon continues a family tradition in his choice of careers: his father, Alan G. Gordon, is a forester working on forest-nutrient cycling relationships for the Ontario provincial government. He also serves as an adjunct professor of forest genetics at the University of Toronto.



Agricultural Experiment Station
University of Alaska-Fairbanks
Fairbanks, Alaska 99701

J. V. Drew, Director

Publication

Address correction requested
Return postage guaranteed

POSTAGE PAID
U.S. DEPARTMENT OF
AGRICULTURE
AGR 101
THIRD CLASS
BULK RATE

U.S.MAIL

AG
UA094

BIOM
BIO-MEDICAL LIBRARY
UNIVERSITY OF ALASKA
FAIRBANKS AK 99701

If you do not desire to continue receiving this publication, please check here ☐; cut off this label and return it to the above address Your name will be removed from the mailing list.