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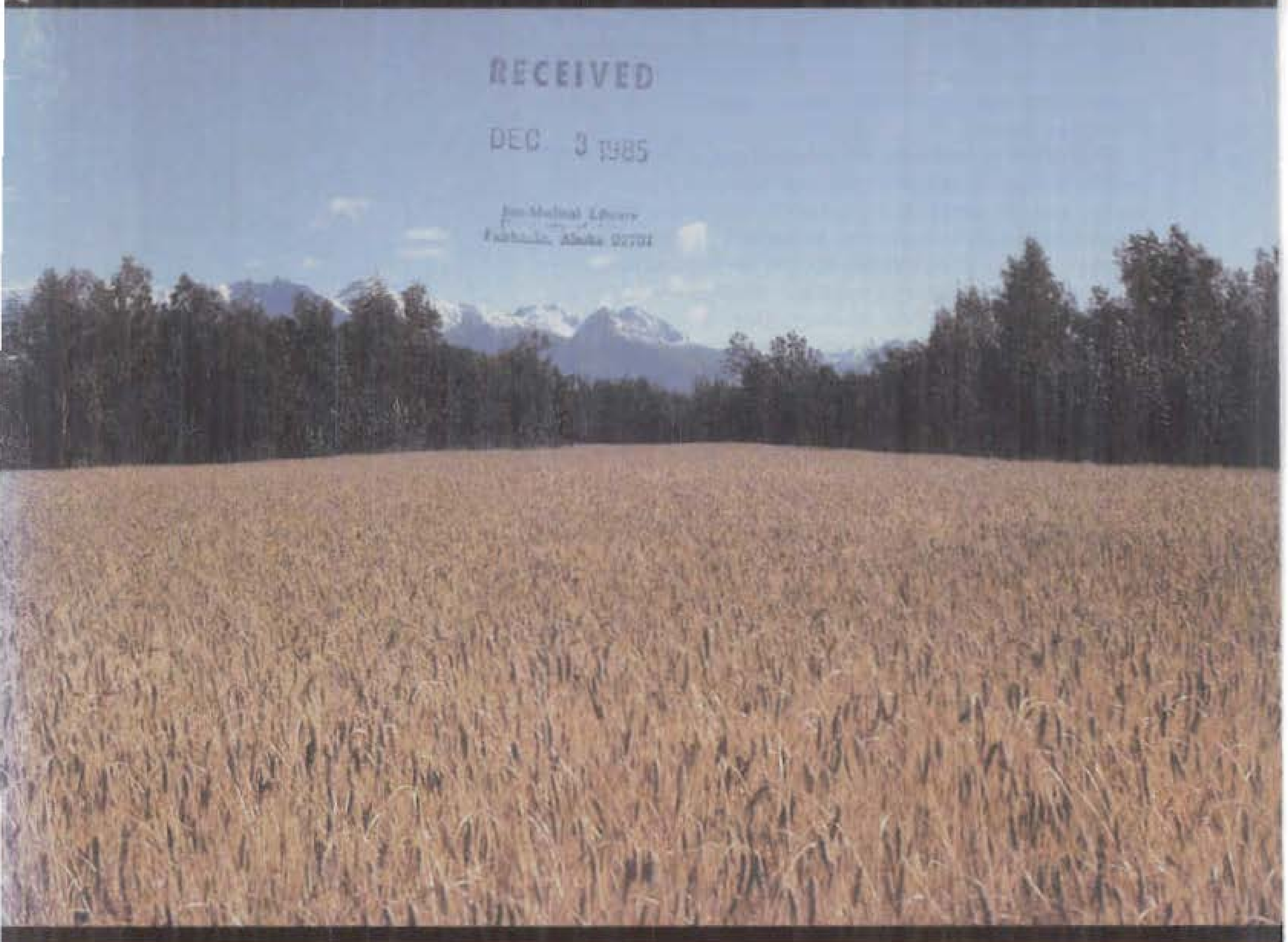

Agricultural and Forestry Experiment Station

School of Agriculture and Land Resources Management
University of Alaska-Fairbanks

Research and Teaching: A Partnership for the Future

In the tradition of land-grant universities, research and teaching in agriculture, forestry, and natural resources are linked directly within the School of Agriculture and Land Resources Management, University of Alaska-Fairbanks.

Successful research provides a fundamental base for the good management of farm, range, and forest lands and for the competitive production of agricultural and forest products. This issue of Agroborealis, *from the Agricultural and Forestry Experiment Station, provides some research results aimed toward this goal.*

To be effective, however, the development of new research and technology must be merged with the human factor. Since the experiment station is the research arm of the School of Agriculture and Land Resources Management, scientists who conduct research in agriculture, forestry, and natural resources also teach courses, present seminars, conduct field trips, and advise undergraduate and graduate students. Thus, students receive the latest information and skills related to agriculture, forestry, and land management from scientists who are perfecting them.

Three Bachelor of Science degree programs are offered by the school. These programs provide education in basic and applied sciences necessary for the successful management of crops, soils, water, livestock, forests, rangeland, and recreational land at high latitudes.

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As a resource state, Alaska's future lies in the economic and social benefits that can be derived from its natural resources. Learning the principles of natural-resources management provides a valuable education for challenging careers related to the management, production, or service aspects of agriculture, forestry, and other land resources in Alaska or elsewhere. In addition, knowledge of the basic sciences applied in these principles is fundamental to technologies of the future.

Those considering college may obtain more information about degree programs in Natural Resources Management by writing to the Dean, School of Agriculture and Land Resources Management, University of Alaska-Fairbanks, Fairbanks, Alaska 99775-0080.

James V. Drew

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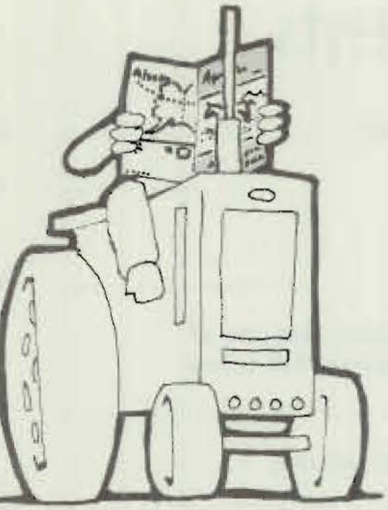
ABOUT THE COVER . . . *A seed-increase field of 'Weal' barley stands ripe in the sun in Alaska's Matanuska Valley. Weal, a hooded variety developed at the Palmer Research Center of the Alaska Agricultural and Forestry Experiment Station, serves a dual purpose in agricultural production in Alaska. It produces an above-average yield of high-quality grain for use as seed and livestock feed. As a component of annual forage mixtures, Weal contributes to enhanced feeding value and reduced moisture content of high-energy, improved-quality silage for the dairy industry. Early maturity and strong straw add to the popularity of Weal among grain and forage producers in Alaska.*



AFES Notes

Dr. Arthur L. Brundage, professor of animal science, retired from the Agricultural and Forestry Experiment Station in February after thirty-three years of service. Dr. Brundage's work has had a major impact on the development of the dairy industry in Alaska. His published research on the genetics and nutrition of dairy cattle has attracted national attention. In addition, he has been a leader in successfully introducing the technology of artificial insemination to Alaska's dairy industry in cooperation with a national dairy herd-improvement program. He is recognized as the foremost authority on dairy science in Alaska. His research contributions include extensive information on pasture management and utilization; the production, storage and utilization of barley; calf feeding and management; dairy cattle breeding; beef production; and laboratory evaluation of feeds.

Dr. Brundage earned his master of science degree in 1952 from the University of Minnesota and completed his Ph.D. there in 1955. Brundage joined the U.S. Department of Agriculture in 1952 with an appointment as dairy husbandman at the Palmer Research Center of the University of Alaska. Dr. Brundage has served as chair of the AFES Publications Committee and helped with the inception of *Agroborealis*. The University of Alaska-Fairbanks conferred emeritus status upon Dr. Brundage at its May 12, 1985, commencement.

Dr. Winston M. Laughlin retired recently from the Agricultural and Forestry Experiment Station after thirty-five years as a soils scientist. Dr. Laughlin was with the USDA Agricultural Research Service and had been stationed at the AFES Palmer Research Center. During his tenure at Palmer, Dr. Laughlin's work was mostly concerned with investigations of soil conditions and crop responses to fertilizers and other chemicals. In connection with this work, Dr. Laughlin was awarded the Distinguished Service Award in 1978 by the Alaska Association of Soil Conservation for his research on soil fertility in cropland areas of Alaska.

Dr. Laughlin has published extensively in scientific journals and has been a frequent contributor to AFES's *Agroborealis* and bulletin and circular series. Dr. Laughlin was also primarily responsible for building one of the most comprehensive research libraries in the state. That library, now housed at the AFES Palmer Research Center, will soon be moved to the Mat-Su Community College where it can be used by a greater number of students. Dr. Laughlin and his wife, Dorothy, will continue to make their home in Palmer where they are active in their church and community.

Dr. Marilyn Griffith, a new assistant professor of plant physiology, is conducting research on the low-temperature physiology of crop plants as well as supervising AFES's Horticulture Research Program. Dr. Griffith earned her B.S. in biological sciences from Mt. Holyoke College in Massachusetts, her M.F.S. from the Yale School of Forestry in New Haven, Connecticut, and her Ph.D. in plant physiology from the University of Minnesota at St. Paul. Her doctoral work was on low-temperature crop physiology,

. . . Continued on page 18

Barley Breeding In Alaska

By

Roscoe L. Taylor*

Introduction

Barley is a grass, called a cereal because the seed is the plant component most often utilized by man. It is commonly grown throughout the world. Although production is concentrated in midlatitude areas, barley performs well in high-latitude regions, including Alaska, and at higher elevations in tropical environments. The principal use of the crop worldwide is for livestock feed, although industrial malting for the production of beverages utilizes production from a significant acreage. Direct human consumption is limited in modern society; however, in some cultures, a major portion of the diet may still come from barley, largely varieties with naked kernels.

In this brief report we will examine the role barley breeding has played and will continue to play in the development of varieties adapted for production in Alaska. It should be recognized that breeding is only one phase of the total research program aimed at the continued expansion of successful barley production in this subarctic environment. Variety selection; seedbed preparation and planting; fertilizer practices; seeding methods; harvesting and threshing techniques; seed drying and storage; and control of weeds, insects, and diseases are among the many production problems which also will be assisted by field research. However, full utilization of the genetic potential of this grass species in Alaska requires the application of plant-breeding techniques to the total research effort. Let us now briefly examine barley as a world-wide resource and as a crop which may be exploited to benefit Alaskan agriculture.

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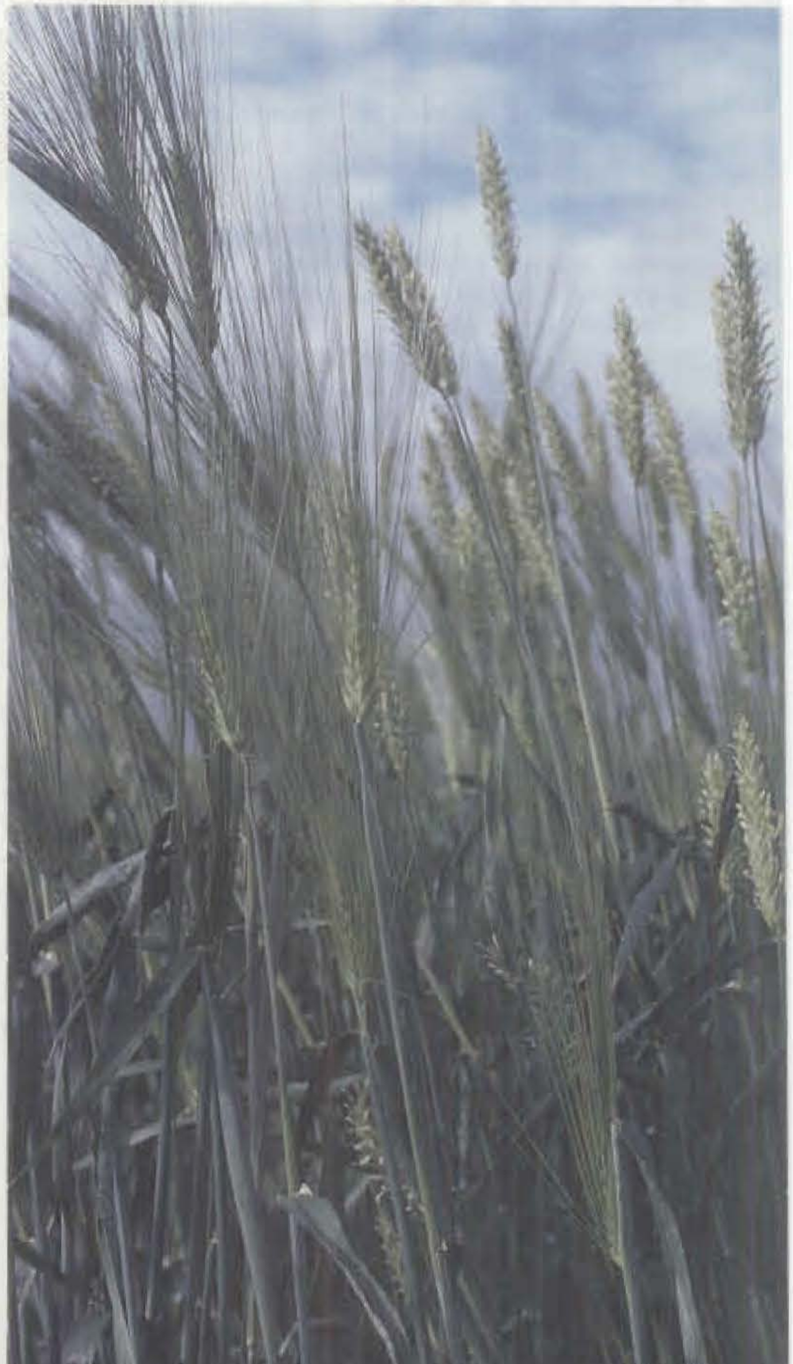

The difference between awned (left) and hooded (right) barley plants is readily visible in the field following crop heading. The more commonly grown awned varieties produce a long, frequently rough, hairlike growth at the end of each kernel. On a hooded variety this awn is replaced by a fleshy, shortened growth. Both appendages are removed from the kernels by harvest operations.

Origin of Barley

According to Harland (1979), the origin of barley as a cultivated crop remains a mystery, perhaps because domestication occurred prior to written history. Archaeological evidence indicates that barley was a cultivated crop prior to 3000 B.C. The importance of barley in ancient times is indicated by the apparent wide distribution of the earliest known "extension circular." These clay tablets (estimated publication date: 1700 B.C.) describe in considerable detail procedures to follow in a grain-production cycle, from soil preparation through harvest.

Varieties found in the wild today do not appear to be parental types of cultivated barley, suggesting that they all descended from plant types now extinct. Experts question whether the widely separated areas of extreme diversity of plant types existing today bear any realistic relationship to areas where cultivated barley originated. Of significance to the barley-improvement program in Alaska is that these areas, Ethiopia, Iran, Iraq, Turkey, and the southern Orient, are far removed from northern latitudes.

Barley in North America

Wiebe (1979) lists the earliest documented introduction of barley into North America as the second voyage of Columbus; it is referred to in a letter from Haiti to Spain written January 30, 1494. Since Haiti has a tropical climate in which barley does not perform well, this information is probably only of historical interest. A more realistic dating of barley introduction to North America is 1602, when production was recorded on islands off the coast of Massachusetts. Barley from this source, and other introductions from England and the European continent, appear to have spread throughout the colonial settlements, continuing westward with migrating settlers. Another source of barley in the United States was through Mexico where North African types, today well suited for production in Arizona and California, were introduced.

Barley in Alaska

The introduction of barley to Alaska probably dates to the Russian occupation, although documentation is lacking. If introduced then, no material survives from that period.

Dahl (1870) indicates that he was informed that barley had matured at Fort Yukon, and barley and oats were successfully raised near the settlement of St. Nicholas on Cook Inlet, the area of the city of Kenai today. Georgeson (1902-1926) details the barley variety testing program at various experimental sites in the early 1900s. Variety names listed suggest early recognition of the value of material from northern latitudes.

Barley production was especially successful at the Rampart Station where George Gasser (Restad 1979), a pioneer Alaskan agriculturist, concluded that the then just-developed art of plant breeding offered promise toward providing crop varieties with superior adaptation to Alaskan environments. In barley, this initial, modest, breeding program resulted in the development and release of the variety 'Trapmar' (Wooding 1979). Despite Trapmar's increasing obsolescence due to the availability of newer varieties and changes in management practices, particularly expanded use of commercial fertilizer, that variety continued to be utilized in Alaska well into the 1950s. During this period agricultural research activity in Alaska decreased to a relatively minor level.

Expanded Barley Research

Postwar interest in agriculture in the late 1940s and increased research support following the 1945 study of agricultural problems in Alaska (USDA 1949) spurred a renewal of barley developmental efforts. 'Edda' barley (Litzenberger and Bensin 1951), a Swedish variety exhibiting superior performance in Alaska, was released for production as a result of the testing program at that time. The USDA World Barley Collection, grown at Palmer in the early 1950s, provided additional materials with potential for Alaska. Other barley varieties of interest were obtained directly from Scandinavian sources. Another research study of this period (Guitard et al. 1965) involved the cooperative testing of cereal crops at two locations in Alaska and four locations in northwestern Canada and defined differences in variety performance between locations. These results provided insight into production deficiencies of the varieties available and focused attention on environmental factors of importance to successful grain production in northern areas.

A breeding program was initiated at the same time as performance information was being assembled on a wide range of barley materials. The goal was to develop varieties better adapted to the varied production environments within Alaska. The first tangible results of this effort, the varieties 'Lidal' (Taylor 1978a) and 'Weal' (Taylor 1978b), appeared in 1972. Lidal may be considered a replacement for Edda, with improved overall performance. Weal is a hooded variety, lacking the awns characteristic of most varieties, making it suitable for whole-plant harvest in forage mixtures.

Other additions to the adapted variety list, 'Datal,' 'Otal,' and 'Thual,' were released in 1981 (Taylor 1983). Datal is considerably shorter in stature than many varieties. Otal, similar to Lidal, is licensed for production in Canada, making seed available for import. Thual produces naked kernels, of interest to livestock producers interested in lowered fiber, as well as to the health-food industry. All of these varieties were selected as feed barleys possessing favorable combinations of early maturity and high yield under Alaskan conditions. At the present time a number of northern-adapted varieties from other areas are also utilized for production in Alaska.

Barley Breeding Today

A carefully designed barley-breeding program offers a proven technique for producing varietal improvements for commercial production in Alaska. Although varieties from other northern regions should be evaluated for performance here, only limited material from the total genetic base of barley is suitable for direct transfer to this environment. Barley originated in more temperate latitudes, where today, it has the greatest genetic diversity. The majority of the suitable variability can only be of use in Alaska through genetic transfer by breeding and selection. Breeding programs conducted throughout the world will continue to provide genetic stocks for evaluation for desirability under Alaska conditions.

Barley varieties have little utility in this environment unless farmers can dependably produce and harvest mature grain. The importance of early maturity to consistent field success cannot be overemphasized, although many other characteristics are also of vital importance. Grain yields must be sufficient for economic production; unfortunately, high grain yield and early maturity appear negatively related, a severe handicap to concurrent improvement in both characteristics. Successful breeding progress within other agronomic factors, such as lodging and shattering resistance, may offer indirect benefits in increased harvestable yields.

The recent change in crop production occasioned by the development of large farms, with extensive acreages frequently in continuous barley, has intensified barley disease problems. Currently available, early-maturing varieties have limited resistance to some leaf diseases which have the potential to cause severe losses in Alaska. Fortunately, resistant materials from breeding programs elsewhere are available to Alaska's breeding program. So-called composite crosses, where genetic materials are maintained in segregating fashion through male sterility factors, form the basis for selection of disease-resistant breeding stocks. Barley scald-resistant composite crosses CCXXXVI (Bockelman et al. 1980) and CCXXXVII (Baenziger et al. 1981) are of particular interest to Alaska. More recently, selections from CCXLIII (Bockelman et al. 1983), possessing resistance to both scald and net blotch, have entered the program. Very few scald-resistant materials have been located from northern latitudes (Webster et al. 1980), thus selection of resistant materials suitable for direct use in Alaska would be a fortunate occurrence. Adapted selections from hybrids between disease-resistant and early-maturing lines is currently the prime breeding objective.

Numerous other objectives which can be addressed through breeding research can be considered. Protein content has been high in barley grain produced in some areas of Alaska (Wooding and Knight 1972). Improved quality of protein in the grain may be of more significance, especially when the crop is largely utilized for livestock feed. Naked-kernel types with suitable performance would have a definite advantage over hulled varieties for some uses. The hooded character allows the diversified use of barley as an annual forage. Adapted varieties currently in production are six-rowed types, but the relative merit of two-rowed materials needs to be considered.

Questions are frequently forthcoming concerning malting quality of Alaska barley. Progress toward higher grain protein moves away from acceptance as malting barley. Further, the desire for bright, unweathered seed with virtually perfect germination for malting barleys may be difficult to attain in Alaska. Recent research indicated that reduced-tillage production systems may be economically beneficial in barley production, so investigation of performance variability of materials under different tillage treatments would be desirable.

The current increase in Alaskan barley production and the appearance of associated problems that should be addressed through breeding have proceeded at an accelerated pace in Alaska. Realistic solutions, in the form of new varieties, can also be produced at an expanded rate. When desirable, two generations of barley can be produced in the southern United States during an Alaskan winter. Utilization of techniques of this nature will be pursued when suitable breeding material, along with the necessary financial support, becomes available.

Futuristic Plant Breeding

Several new phrases, such as biotechnology, genetic engineering, gene transfer, and molecular genetics, have appeared recently in the popular press. All have promise as new procedures of genetic manipulation resulting in the dramatic improvement of plants and animals for human utilization. Suggested fruits of such research, nitrogen-fixing grasses, for example, may ultimately benefit barley production in Alaska. Participation in these investigations, however, is currently beyond budgetary limitations. In the short term, though, the application of conventional breeding methods to the genetic populations currently available will continue to be productive. □

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Barley Response to Phosphorus and Lime

Results of Applications to Horizons From Homestead Silt Loam

By

Winston M. Laughlin*

This greenhouse study was conducted to determine the cause for a barley crop failure on the Harold Kelton farm southwest of Wasilla in 1968. Individual plants were very short, failed to stool, and formed very small heads. This failure occurred after 5 years of growing barley successfully on a nearly level tract of Homestead silt loam. Each year a 10-20-10 fertilizer was applied at 250 lb per acre and water was added by sprinkler irrigation as needed. The only culture difference in 1968 was in the seedbed preparation. Each prior year the seedbed had been prepared by discing. In 1968 the area was plowed 5 to 6 inches deep for the first time, burying the A horizon and bringing up the lower layer of loess from the C horizon to become a dominant portion of the seedbed.

As soils develop over long time periods and are acted upon by such influences as weathering, leaching, and vegetation, they develop distinct layers that differ in color of organic matter, chemical composition or other factors. These soil layers are referred to as "horizons" and are identified by letters, i.e. the top-most layer is "A," the next "B," and the bottom the "C" horizon.

The Homestead series consists of a shallow, well-drained silty loess mantle over loose sand and gravel (Schoephorster 1968). Seven to 8 inches of soil in this area rests immediately on coarse, cobbly gravel.

Experimental Procedure

Bulk soil samples were taken from each of the A, B, and C horizons in an area of Homestead silt loam under aspen-birch-spruce forest adjacent to the barley field. The water pH of the three horizons was 5.4, 5.9, and 6.2 respectively. These bulk samples were taken to the greenhouse, screened to remove tree roots, and soil from each horizon was thoroughly mixed.

A $2 \times 3 \times 5$ factoral experiment replicated six times was designed to compare no lime vs lime (3T per acre), A, B, and C soil horizons, and five phosporus (P) rates (0, 44, 88, 176, and 352 lb P per acre; as expressed on the oxide basis, the same rates were 0, 100, 202, 403, and 806 lb P_2O_5 per acre). Greenhouse pots 5.5 in. in diameter at the top, were filled with the same weight of soil from the respective horizon. Limestone flour and the appropriate amount of P as treblesuperphosphate were mixed with the entire amount of soil in each pot. Sixteen, evenly spaced, Edda barley seeds were planted in each pot, and nitrogen and potassium were applied equally to the surface of all pots in water solution. All pots received an equivalent of N as ammonium nitrate (300 lb/A) and K as sulfate of potash (249 lb/A). After emerging, the barley was thinned to eight, evenly spaced plants per pot.

Five weeks after planting, all plants in each pot were cut at the soil surface and dry weights obtained. After harvest soil from each pot was screened, mixed thoroughly, and analyzed using a modified Morgan's procedure (Martin 1970).

Results and Discussion

The horizon $\times$ P, lime $\times$ horizon, and P $\times$ lime interactions of both barley dry-matter yield and available P after cropping were all highly significant. A horizon $\times$ P interaction means that response to P rates varies with soil from one or more horizons.

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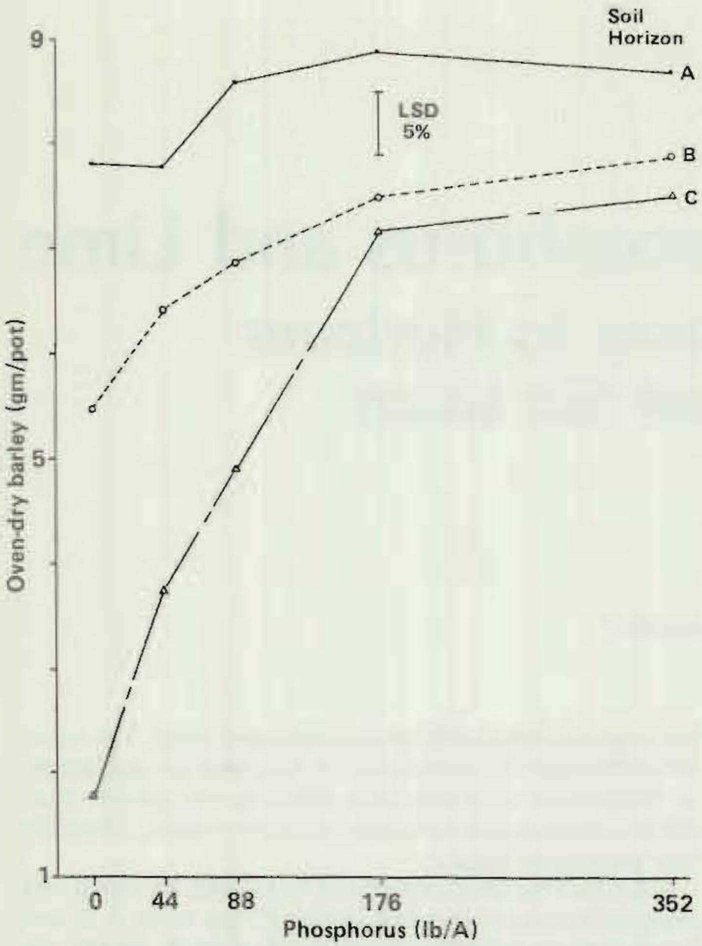

Figure 1. Effect of phosphorus application to soil from three horizons on Edda barley dry-matter yield (Homestead silt loam).

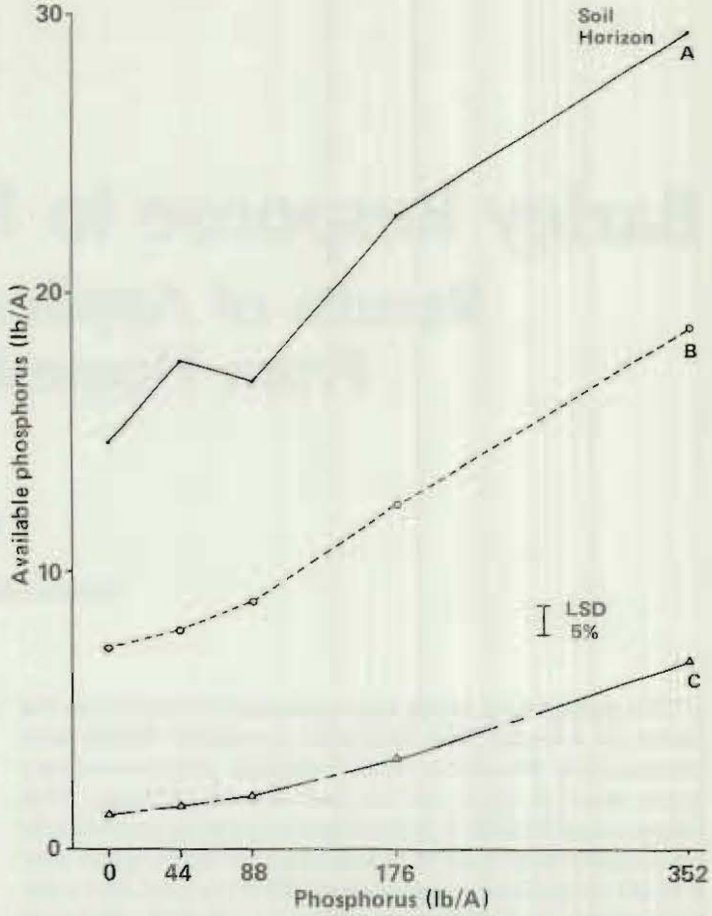

Figure 2. Effect of phosphorus application to soil from three horizons on the available P in the soil after cropping (Homestead silt loam).

Soil Horizons

Edda barley dry matter production decreased significantly with each increasing horizon depth when P was applied at 0, 44, and 88 lb per acre; horizon A produced significantly more oven-dry barley than did horizons B and C when 176 and 352 lb P per acre were applied (fig. 1). Table 1 also shows the significant depression of barley yield with each increasing horizon depth. These observations demonstrate that the barley growth was increasingly reduced by P unavailability when grown in soil from progressively lower horizons in the soil profile.

Available P decreased significantly after cropping with each increasing horizon depth at all P and at all lime rates (table 1, fig. 2). Available P in the three bulk-mixed samples prior to potting was 15.8, 7.0, and 1.8 lb P per acre for horizons A, B, and C, respectively. After cropping and with the highest P rate (352 lb/A), the increase in available P was 14, 11, and 5 lb P per acre for each increasing horizon depth, respectively.

Phosphorus

The barley response to P was relatively minor when grown on soil from horizon A; barley yield was only 12 per cent greater at 352 lb P per acre than at 0 lb per acre, and the only significant increase was between 44 and 88 lb P per acre (fig. 1). With the B horizon, both a) actual barley yields, and b) the rate of increasing yields with higher P rates, were intermediate between those obtained from the A and C horizons. Significant increases in barley yield occurred only between 0 and 44, 44 and 176, and 176 and 352 lb P per acre. Each increasing P rate applied to horizon C increased barley dry matter yield significantly (fig. 1). Figure 3 shows a significant increase in oven-dry barley yield with each increasing P rate when no lime was used;

Table 1. Effect of soil horizon on 'Edda' barley oven-dry yield and on available P in the soil after cropping. Homestead silt loam. (Means of 30 measurements)

Soil Horizon	Oven-dry matter per pot		Available P per acre	
	Lime (T/A)			
	0	3	0	3
	(grams)		(lbs.)	
A	7.23a*	9.49a	20.1a	21.6a
B	6.38b	7.15b	9.2b	13.0b
C	4.45c	5.57c	1.9c	4.0c

*Means within a column followed by the same letter are not significantly different at the 5% level of probability.

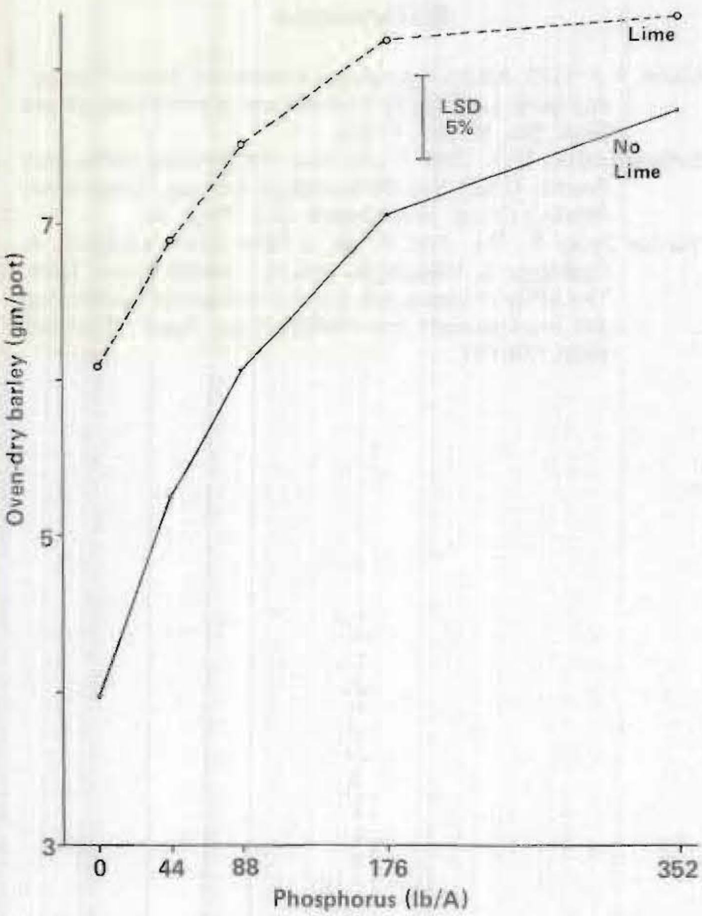

Figure 3. Effect of phosphorus application rates on Edda barley dry matter yield with and without added lime (Homestead silt loam).

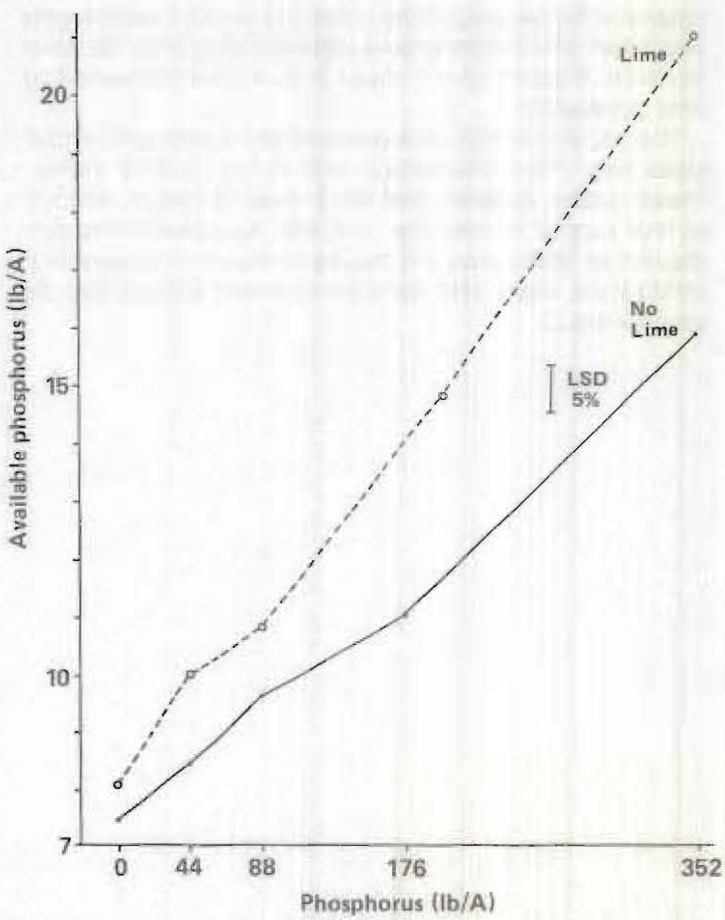

Figure 4. Effect of phosphorus application rates on available P after cropping with and without added lime (Homestead silt loam).

when lime was applied, yields increased with each increasing P rate through 176 lb P per acre.

Each increasing P rate increased the available P in horizon A significantly except between 44 and 88 lb per acre: each increasing P increment exceeding 44 lb P per acre increased the available P in horizon B; and each increasing P rate exceeding 88 lb P per acre increased the available P in horizon C (fig. 2). When no lime was applied, each increasing P rate through 176 lb per acre increased the available P in the soil after cropping; when lime was applied, each increasing P rate increased the available P (fig. 4).

Table 2. Effects of lime on oven-dry matter yield of 'Edda' barley and on available P in the soil after cropping. Homestead silt loam. (Means of 30 measurements)

Lime (T/A)	Oven-dry matter per pot			Available P per acre		
	Soil Horizon					
	A	B	C	A	B	C
	(grams)			(lbs.)		
0	7.23b*	6.38b	4.45b	20.1b	9.2b	1.9b
3	9.49a	7.15a	5.57a	21.6a	13.0a	4.0a

*Means within a column followed by the same letter are not significantly different at the 5% level of probability.

Lime

Lime application increased yields of oven-dry barley grown on soil from all three horizons and also the available P in the soil from all three horizons after cropping (table 2). Greater differences between the limed and unlimed yields occurred with barley grown on soil from horizon A than from horizons B and C, which may reflect lime benefits in addition to that of making P more available; however, differences in available P after cropping were greater in soils from horizons B and C than from horizon A which may indicate lime as decreasing available Iron (Fe) and Aluminum (Al) which fix P.

Conclusions

Evidence from this greenhouse experiment suggests that the 1968 barley crop failure resulted from phosphorus deficiency that occurred when soil from just above the gravel substratum was brought up to the surface by deeper tillage than had been done during the five previous years.

This Homestead silt loam and related soils have the capacity to "fix," or render unavailable to plants, large quantities of P (Vander Zaag et al. 1979). The amount of fixation is not as great in the A horizon which is more highly weathered and contains more organic matter than the lower horizons. Fixation of P in these soils is also decreased by lime application.

This soil and related soils predominate in new agricultural areas near Point MacKenzie and in the Susitna Valley. These results illustrate that land-clearing should remove as little topsoil as possible, and that successful crop production on these soils will require provision of adequate P fertilization; costs and benefits of liming should also be considered.□

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Soil-Temperature Monitoring Network In Alaska

By

Chien-Lu Ping*

Introduction

In order to gather a broad database to characterize the soil-temperature regimes and to serve the purpose of soil classification and land-capability classification, the University of Alaska Agricultural and Forestry Experiment Station (AFES) has initiated a soil-temperature monitoring network and signed a cooperative agreement with the U.S. Department of Agriculture Soil Conservation Service (USDA-SCS) to coordinate the study in Alaska. The objective of this article is to report on the methods, procedures, and progress of soil-temperature monitoring in Alaska.

The temperature of a soil is one of its important properties. Within limits, soil temperature controls biological, physical, and chemical processes which in turn control plant growth and soil formation (Smith et al. 1964); therefore, soil temperature affects every aspect of land use. Soil temperature is generally ignored by land users until such data are critically needed, yet there is no quick method of obtaining such information. The understanding of soil temperature depends on long-term observation and study.

The temperature regime of a soil is the result of the interaction of many factors. Soil temperature varies with such soil factors as depth, texture, moisture, and organic matter content; such vegetation factors as cover type and thickness of organic mat; such location factors as latitude, elevation, slope, and aspect; and such climatic factors as air temperature, snow cover, evapotranspiration rate, precipitation, and wind. Since 1965, soil temperature has been used in soil classification and soil surveys in the United States. In Alaska, there are two soil-temperature regimes generally recognized in the Soil Taxonomy (Soil Survey Staff 1975). *Crylic* soils are defined as those with a mean annual soil temperature between 32° and 47°F at a depth of 20 inches. *Pergelic* soils are those with a mean annual soil temperature of 32°F or lower. Most pergelic soils are underlain by permafrost. However, such separation is not clear-cut. Recent evidence (Clark 1984) indicates that there may be a large area of interior Alaska in which soil temperature fluctuates between these two temperature regimes as a result of fire succession.

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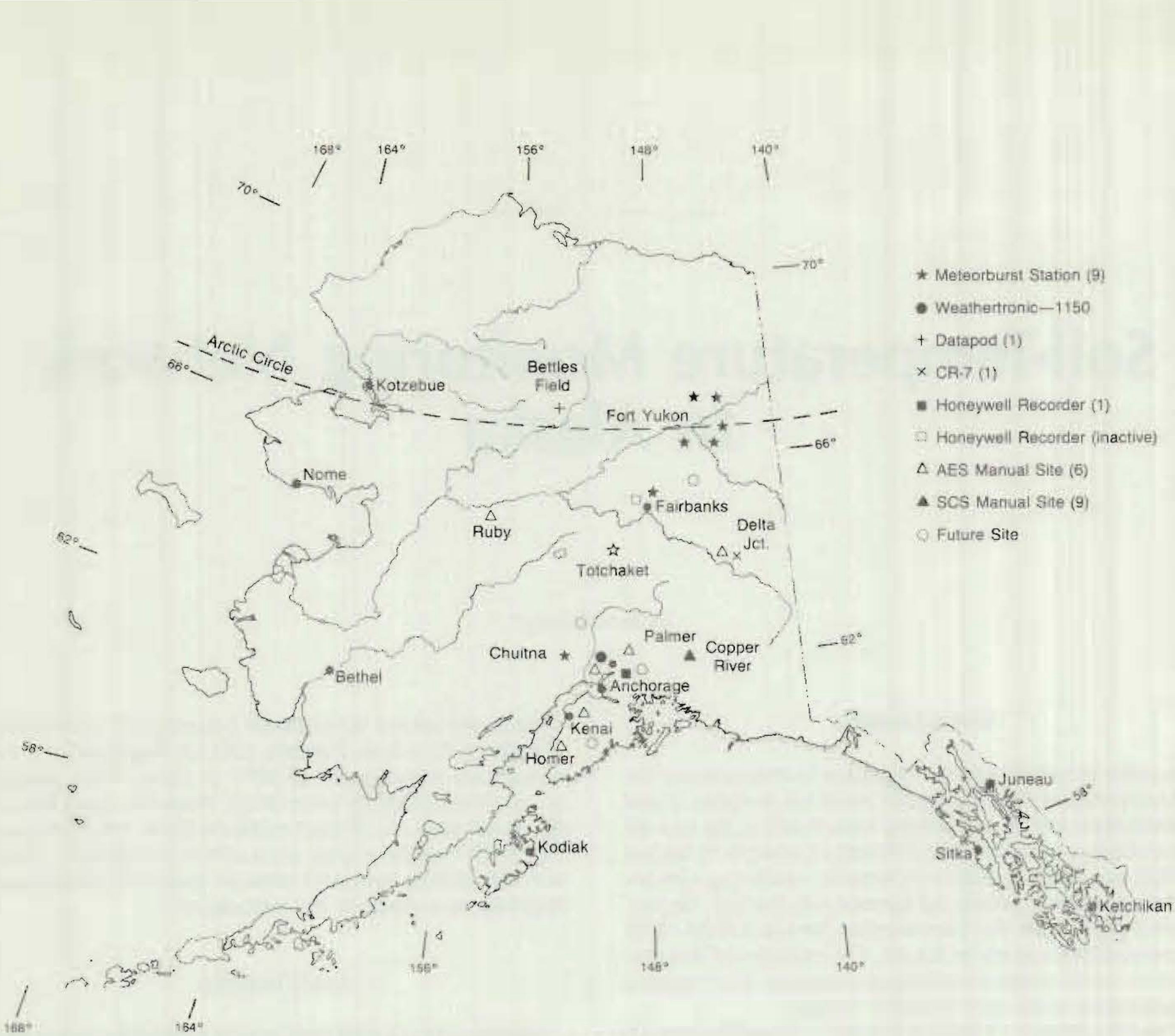
Justification

Alaska covers a total land area of 375 million acres lying primarily in the Arctic and subarctic zones as described by Linell and Tedrow (1981). Most of the state is underlain by either continuous or discontinuous permafrost except for the Aleutian Islands, and southcentral and southeast Alaska where ground is seasonally frozen (Washburn 1973).

In the past, most soil-temperature studies were devoted to the thermal regimes of the permafrost zones (for design and construction of deep structures), and research in some isolated remote sites (Linell and Tedrow 1981). Studies of soil temperature in the zone of seasonally frozen ground are abundant elsewhere (Rieger 1983) but are generally lacking in Alaska. At this time, there are two stations operated by AFES on a year-round basis where soil temperatures are recorded at different depths—Fairbanks and Palmer. Rieger (1983) has questioned the fact that soil temperature alone is enough to characterize the thermal regimes of Alaskan soils because of their generally high latitude positions. In the soil classification systems of both the USSR and Canada, the soil-temperature classes are related to heat units defined as degree days above a specific temperature. Alaska has much in common with these two countries in terms of ecological-genetic factors of soil formation due to its similarly high latitude. Therefore,



Soil-temperature monitoring site locations in Alaska (correct as of 9/84).

besides soil temperature, heat units are also important in soil interpretation (classification) and agronomic practice. Nonetheless, atmospheric and soil heat units are derived from air and soil temperatures respectively; therefore, the measurements of both air and soil temperatures are important.

In Alaska, a base temperature of 40°F is adapted to calculate the growing-degree days (GDD) (Branton and Shaw 1973), and this heat unit is generally based on air temperature. However, research done in the taiga forest in interior Alaska has revealed that many parameters of biological activities are closely correlated with soil degree days measured at 4 inches with 32°F base. Such parameters include forest-floor thickness (Van Cleve et al. 1981), seasonal moisture content in the forest floor (Van Cleve et al. 1983), forest-floor decomposition rate (Fox and Van Cleve 1983), and root elongation rate (Tryon and Chapin 1983). To the agronomist, a depth of 4 inches is also the rooting zone, thus soil temperature and growing-degree days are important in terms of crop suitability and variety selection. Therefore, I recommend that, at future Alaska soil-temperature monitoring sites, a 4-inch probe be mounted at a depth of 4 inches in addition to that at 20 inches which is used for soil classification.

Even though growing-degree days provide valuable information for crop production, they are still indirect measurements of solar energy which is the real activating force on the plant (Allen 1978). Therefore, pyranometers are being added to some of the new soil-temperature monitoring sites.

Soil-Temperature Monitoring Network

In order to gather soil temperature information on a year-round basis in areas of agricultural and other potential intensive land uses, a monitoring network was initiated and organized in the summer of 1984. (See map, above.) This monitoring network requires the cooperation of AFES, Soil Conservation Service, Cooperative Extension Service, farmers, and the U.S. Weather Service. The network includes twenty-six newly set monitoring stations in addition to the existing two weather stations covering a broad area from the Kenai Peninsula to north of the Arctic Circle. Additional monitoring stations installed through other research projects are also briefly introduced here because of their importance for information exchanges in the future.

At each soil-temperature monitoring station, the soil was fully described and sampled before temperature probes were installed. The soil sample will be analyzed to help classify the soil. The vegetation and duff layer thickness of each site were recorded. The physiographic features such as elevation, slope, azimuth, and geographic position were also noted. The monitoring sites will be chosen in order to cover not only all major agricultural areas in the state but a wide latitudinal distribution (60°N to 68°N), altitude variation (50 to 3280 feet above sea level), vegetation cover, and many other environmental factors as well. The monitoring network is composed of several different systems:

Snow Survey System (SNOTEL). AFES entered into a cooperative agreement with SCS to expand the use of the SNOTEL system by adding soil-temperature probes and pyranometers to its regular weather data-collecting capacity. SNOTEL is an automated snowpack telemetry system which provides depths of snowpack, rainfall, wind, and temperature data from remote or high mountain areas. SCS has used SNOTEL for approximately seven years for snow surveys and forecasting spring and summer stream flow and water yield. The SNOTEL system relies on battery-powered VHF radio to transmit data using meteorburst technology (Crook 1984). The technique takes advantage of the billions of meteorites that enter the earth's atmosphere daily. As each meteor particle heats and burns when entering the atmosphere at 50 to 75 miles above the earth's surface, it forms a long, cigar-shaped trail of ionized gases. During their brief existence (a few seconds), these ionized trails will reflect radio signals. Nine of the SNOTEL stations are now equipped with thermistor soil-temperature probes and six with pyranometers. They are located in the Yukon Flats (five sites), Totchaket, Fairbanks, Chuitna Plateau, and Indian Pass (Chugach Mt.). The probes were buried at 4 and 20 inches under both native vegetation and a cleared field. Two more thermistor sites will be equipped in 1985—one on Mt. Ryan north of Fairbanks and the other on the Kenai Peninsula.

Datapod System. There is one snow-survey station in Bettles Field using an Omini Datapod which collects and stores data instead of transmitting upon collection. The battery-powered Datapod has two channels. It reads data every minute and records daily maximum, minimum, and average values on chips. The thermistor probes are set at 4 and 20 inches under native vegetation.

Weathertronics System. AFES has acquired two Weathertronics-1150 automated weather stations. One of them has been installed on the University of Alaska Experiment Farm at Pt. MacKenzie, and the other one has been installed on the test plot next to the AFES Palmer Research Center. The Weathertronics-1150 is multichanneled and has been programmed to monitor daily air temperature, relative humidity, wind direction and speed, and total hemispheric and net radiation. Soil-temperature probes at 4 inches under both grassed and fallow plots will be installed in the summer of 1985.

The Weathertronics and Honeywell systems are part of the agricultural-engineering program directed by Lee Allen at the Palmer Research Center to study the agricultural climate and to contribute such information to the National Weather Service.

Honeywell System. AFES has two automated Honeywell weather stations, one located at the AFES Research Center in Fairbanks and the other at the AFES Research Center in Palmer. The sensors at each site include copper-constantan thermocouples and leads, and the recording instrument includes a Northrup potentiometer. In Fairbanks, thermocouples were buried at 8, 20, 40, 60, 83, and 96 inches under undisturbed soil cleared of vegetation. Soil temperatures at different depths were recorded between 1963 and 1969, and the recorder has been inactive since. In Palmer, they were buried at 2, 4, 8, 20, 40, 60, and 120 inches under both fallow and grassed plots. The recording started in 1962 and is still going today, except that the 60- and 120-inch probes have been inactive since 1972. Soil temperatures were recorded daily in both locations. AFES also maintains a Campbell CR-7 automated weather station on the University of Alaska tillage study plots near Delta Junction (Cullum and Lewis 1985), and it monitors soil temperature daily at 0, 2, 6, 12, 20, 37 and 40 inches under different tillage practices.

Manual System. In order to determine the soil-temperature regimes of the permafrost soils affected by fire (Clark 1984), SCS has set up nine soil-temperature probes (thermistors) in the Copper River Basin area since 1983, and has been recording the data on a monthly basis. This system consists of two thermistors buried at 4 and 20 inches. The end of the lead has telephone plug adaptors which extend out of the ground through a PVC tube. Soil temperatures can be read easily with a digital thermometer (resistor). This method proves to be inexpensive and effective and provides important information concerning soil temperatures and farm management. In the summer of 1984, AFES set up manual stations in Delta Junction, Ruby, Pt. MacKenzie, Soldotna, and Homer, with the help and cooperation of the SCS party leader, and district conservationists, extension agents, and farm managers. Thermistor probes were buried at 4 and 20 inches under both cleared field and native vegetation, and soil temperatures are recorded weekly at all stations. A manual station located at the AFES Matanuska Farm is equipped with copper-constanton thermocouples installed at 4, 20 and 40 inches under native vegetation, cleared, and grassed plots.

A SNOTEL station located in Indian Pass in the Chugach Mountains, east of Anchorage.

A pit was dug at each site, and the soil profile was described. A sample of each horizon was taken for analysis. This site is on the south slopes of Lookout Mt. near Homer.

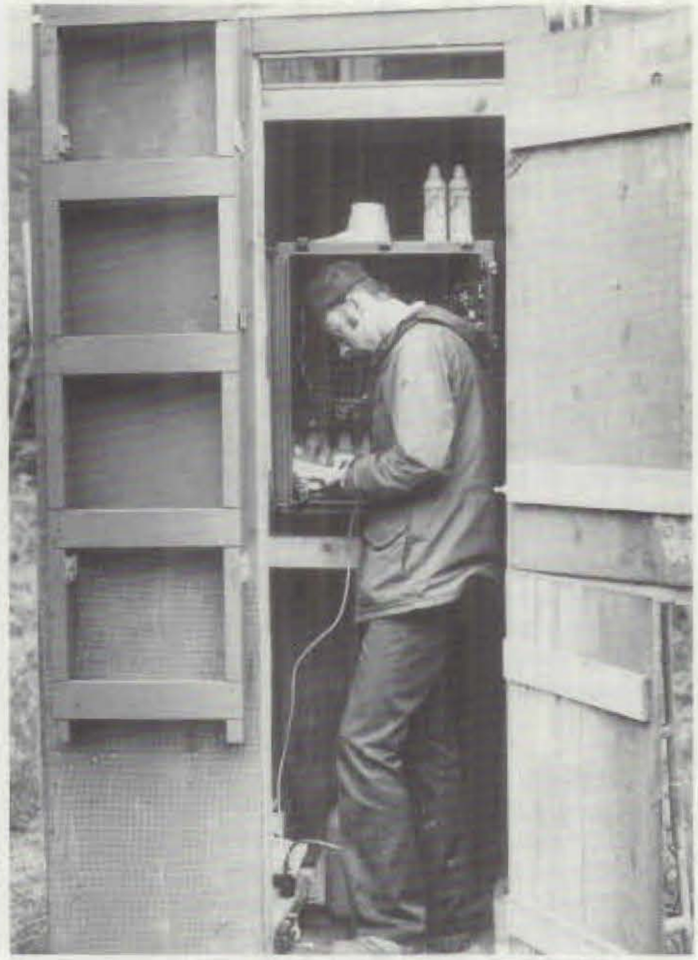
Conclusion

Based on existing records of soil-temperature data from the AFES Research Centers in Fairbanks and Palmer, the seasonal and yearly soil-temperature fluctuation patterns of the Tanana and Bodenburg soil series will be analyzed to relate them to such other environmental pararneters as air temperature, snow cover, wind, and management practices. The results are expected to be released in the near future.

As for the newly installed sites, at least 4 years of data are required to obtain representative average values for statistical analysis. The data will be used to calibrate the soil-temperature regimes of established and proposed soil series in the state and to study the effect of land-clearing and cultivation on soil-temperature regime and classification. After statewide data are assembled, correlations between soil temperature and climatic and environmental factors will be determined by regression analysis. The regression equation will then be used to predict soil-temperature regimes for areas where climatic data are available but soil-temperature data are lacking. The predicting equation will enable us to construct a soil-thermal regime map for use in preparing and modifying the National Cooperative Soil Survey soil and land classification systems, and it will expand our knowledge in the soil-vegetation-climate ecosystem.

Soil climate is defined by both soil temperature and soil moisture. The SNOTEL system is capable of adding devices for monitoring soil moisture. The gypsum block is being considered for soil-moisture monitoring in the near future. The University of Alaska Agricultural and Forestry Experiment Station has joined the Western Research Coordination Committee (WRCC-50) to study soil-climate-vegetation in the western states. The objectives of this committee are to evaluate taxonomic and field criteria for identifying soil-moisture and soil-temperature regimes (soil climate) and their use for predicting vegetation potential. Baseline data for testing, modifying, or reformulating soil-climate concepts and criteria for identifying soil-moisture and temperature regimes will also be developed. Soil temperature is one of the major concerns of this committee. Through this committee, the exchange of methods, procedures, and database-management systems will enhance the research on soil temperature in Alaska.□

Thermistor soil-temperature probes were positioned at 4- and 10-inch depths at a site in the Yukon Flats.



SCS snow survey crew member, Jason Restad, connects cables to the instrument panel of a SNOTEL station. The outside ladder and the two-piece door provide winter access when the snow blocks the lower entrance.

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AFES Notes continued

winter rye in particular. As an Isaac Walton Killam Post-Doctoral Fellow, Dr. Griffith engaged in research at the University of British Columbia in 1981-82. She was again awarded an Isaac Walton Killam Fellowship in 1982, at which time she began conducting research at the University of Western Ontario where she continued until 1984 when she came to Alaska.

Dr. Griffith is making her home in Fairbanks with her husband Tim Thorne, a UAF English major and a leader of a local blue-grass band.

Dr. Patricia S. Holloway, assistant professor of horticulture, has joined the faculty of the School of Agriculture and Land Resources Management. Her teaching emphasis is on the cultivation and propagation of Alaska native plants for uses as fruit crops and ornamentals. Both greenhouse and field production are being examined.

Dr. Holloway received her B.A. degree in biology from Millersville University at Millersville, Pennsylvania. Her M.S. and Ph.D. degrees are both in horticulture; she received the former from Washington State University at Pullman and the latter from the University of Minnesota at St. Paul. Her Ph.D. work was on the cultivation of lingonberries.

Dr. Holloway is a member of the Alaska Horticultural Association, the Alaska Native Plant Society, the International Plant Propagators Society, the American Society for Horticultural Science, and the American Pomological Society. In addition to her professional duties, Dr. Holloway also volunteers her time for the Tanana Valley Fair where she serves as a vegetable judge.

Verlan L. Cochran has joined the staff of the Agricultural and Forestry Experiment Station as an affiliate professor of agronomy. Mr. Cochran is assigned to the USDA-ARS Subarctic Agricultural Research Unit. He came to Alaska after nineteen years at Pullman, Washington, where he was a member of the affiliate faculty at Washington State University. While at Pullman, Mr. Cochran's work was with conservation tillage and nutrient cycling. Mr. Cochran's work in Alaska will be on nutrient cycling and water relations in conservation tillage research. He will conduct most of his studies in the Delta Junction area, where one of Alaska's largest agricultural developments is underway.

Mr. Cochran received his B.S. in soils from California Polytechnic Institute at San Luis Obispo and his M.S., also in soils, from WSU at Pullman. Joining Mr. Cochran in Alaska are his wife, Diana, and sons, Dean and Vince. The family enjoys cross-country skiing, fishing, and camping and is looking forward to the many outdoor-recreation opportunities Alaska has to offer.

Dr. Elena Bautista Sparrow, affiliate associate professor of soil microbiology is working on three research projects at AFES. With her husband, Dr. Stephen Sparrow, assistant professor of agronomy, and Dr. Gary Laursen, visiting assistant professor of mycology, she is measuring microbial biomass using ATP assay methods. With Dr. Sparrow, she is studying the long-term effects of oil spills on soil microflora. The third project is with Dr. Laursen, and they are studying litter decomposition at Toolik Lake.

Dr. Elena Sparrow received her B.S. in agriculture from the University of the Phillipines, her M.S. in soil microbiology from Cornell, and her Ph.D. in agronomy with emphasis in soil microbiology from Colorado State at Fort Collins in 1973. The Sparrows have two children, Eric Paul and Emmalisa, and have made their home in Fairbanks for several years.

Dr. Glenn P. Juday, visiting associate professor of plant ecology has been named president-elect of the Natural Areas Association (NAA). NAA is a rapidly growing (ca. 700 members now) association of professionals, both researchers and administrators, who work in the emerging field of natural-areas conservation, research, and management. NAA originated, and still has its largest membership, in the midwestern states, where some state natural-area programs are among the largest natural-resource agencies. Dr. Juday will assume the office of president at the September 1985 annual meeting in Ohio.

Dr. Carla Kirts, assistant professor of agricultural education, has been awarded a grant by the UAF Faculty Small

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Automated Environmental Data Collection For Research in Remote Locations

By

Robert F. Cullum* and Carol E. Lewis**

Introduction

Production of agricultural crops is dependent upon many environmental factors. Of particular importance are soil and atmospheric conditions. The influence of these factors on production of food and fiber has been a topic of several recent national meetings including the Application of Weather Data to Agriculture and Forest Production Workshop, Anaheim, California, 1981, and the American Society of Agricultural Engineering National Meetings, 1981 and 1984. Papers presented focused on research, extension, and educational needs for quantifying timely as well as 'real time' weather and other environmental data which can impact decisions affecting production of agricultural crops (Curry et al. 1981, Hubbard et al. 1983, Mishoe et al. 1982, Snyder 1983).

Those currently involved in agricultural production in the United States have access to many sources of local weather information from both the public and private sectors. Indications are, however, that the National Weather Service will not be expanding further in providing local weather information specifically for agriculture but is consolidating and reducing its programs to a more regional focus (Hubbard et al. 1983). Additionally, data pertaining only to weather conditions may not provide all the information necessary to accurately assess conditions concerning crop production (Thompson et al. 1984). Other environmental factors such as soil temperatures and the solar budget will be important.

The increasing possibility that collection of weather data and data relating to other environmental conditions will be performed by farmers or other private-sector individuals presents a challenge to persons involved in research, extension, and educational activities. Meteorologists, engineers, and other scientists are becoming more involved in the use of automated dataloggers and microprocessors in their own research. Information concerning the data, as well as the methods used to collect them, is important to the farming community. A major objective of persons in extension and educational activities should be to become involved in the dissemination of this information to individuals through such programs as radio and television broadcasts, extension workshops, consulting services, and creation of instructional software to help individuals use dataloggers and microprocessors.

This paper describes the installation and operational requirements of an automated datalogger/microcomputer system. The datalogger is used to collect data in analog form concerning soil and air temperatures, solar radiation, relative humidity, and wind speed in conjunction with soil- and water-conservation research in the Delta Junction area of interior Alaska. The microcomputer is used to convert these analog signals into digital signals. The digital signals are then processed through basic arithmetic functions to obtain the various sensor readings: averages, maxima, or minima. These data are collected and transferred onto cassette tapes where they remain until retrieval and analyses can be conducted using a personal computer.

This system could be used by agricultural producers or various agencies to obtain data of a similar nature. The estimated cost of the datalogger/microcomputer system ranges from $1000 to $9000 per unit dependent on the number of channels required and the number and type of sensors to be installed.

The Datalogger/Microcomputer System

An automated datalogger was installed in May of 1983 located at a remote site near Delta Junction, Alaska, 120 miles from Fairbanks. The system is used for recording and processing environmental data required for evaluation of the various residue-management/conservation-tillage

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Figure 1. View of the CR7 datalogger installed in conservation tillage research at the UAF Agricultural and Forestry Experiment Station tracts near Delta Junction.

systems associated with soil- and water-conservation research at the site (Siddoway et al. 1984)

The system which has been installed is a Campbell Scientific CR7 datalogger (fig. 1). The CR7 is a compact unit which combines the ability to make precision measurements with the ability to control timing of these measurements using multiple processors housed in a single 12-volt, battery-operated unit which can be continuously recharged by solar collectors. The unit contains a control module which stores and processes signals received and an input-output (I/O) module which governs the manner in which signals are received from the environmental sensors.

The functions of the control module include the ability to make measurements in real-time, linearization of data, conversion of data to selected engineering units, processing of data with instructions which have been selected and/or programmed by the user, data storage, and telecommunications. The control module can also be interfaced with keyboard/display units such as those found on personal or home computers, printers which will provide a hard copy of the data being collected, or cassette-tape recorders.

The I/O module has a variety of functions. These include the ability to make analog to digital conversions, amplifier-gain selection, input-mode selection (single-ended or differential), signal integration, self calibration, and complex sequencing of measurements. The I/O module contains seventy analog-differential input channels (140 single-ended), four pulse-counting channels, and ten excitation channels to accomodate the various sensors selected by the user.

The CR7 datalogger is directly connected to a cassette-tape recorder. Because of its remote location, it is not convenient to use either a telecommunications network or a personal computer for direct retrieval of data being collected. Rather, the data are transferred and stored on cassette tapes and retrieved for permanent storage on an IBM-personal computer (IBM-PC) located in Fairbanks. Communications between the IBM-PC and the CR7 are accomplished by using the American Standard Code for Information Interchange (ASCII), even parity, and 300 bauds per second. Communications are controlled by Pascal software.

Environmental Parameters

There are four categories of data being collected in conjunction with soil- and water-conservation research. Each requires different types of sensors and different types of input channels in the CR7. Listed in Table 1 are the data categories, types of data, sensors being used, and input channels required.

Program for the CR7

The CR7 datalogger is programmed to output daily information on several environmental and weather parameters. The intervals at which data are received from the sensors, however, will vary.

During normal operation throughout the major portion of the growing season, all sensors are read hourly, the information is stored in the memory, and daily maxima and minima are calculated and recorded on cassette tapes. The Julian day is recorded for cataloguing purposes. A total of 178 data words are stored in the CR7 each day.

During four periods in the growing season, diurnal readings are taken. These periods correspond to four

Table 1. Data Categories and Sensors Used

Data Category	Sensor	Type Input Channel
Incoming short-wave radiation	Li-Cor silicon pyranometers	Analog differential input
Reflected short-wave radiation	Li-Cor silicon pyranometers	Analog differential input
Albedo	Kipps shielded silicon	Analog differential input
Air temperature at 5.0 ft above ground level	Fenwal thermistor, radiation shielded natural aspiration	Analog differential input
Relative humidity at 5.0 ft above ground level	Physical chemical "Pope Cell" with temperature compensation	Analog differential input excitation
Wind speed at 7.0 ft above crop canopy	Met One cup anemometer	Pulse input
Soil temperatures at 0, 2, 6, 12, 20, 30, 36, and 42 inches from soil surface	Type T thermocouples	Analog differential input

Table 2. Data Recorded from the 1984 Growing Season with the CR7 Datalogger.

Date and Measurement	Ambient Air Temp. (°F)	Temperatures at Depth from Surface (°F)								Relative Humidity (%)	Incident Radiation (Watt/ft²)	Reflective Radiation (Watt/ft²)	Albedo (-)	Wind Speed* (mph)
		0-in	2-in	6-in	12-in	20-in	30-in	36-in	42-in					
June 21														
Maximum	74.6	80.0	62.8	57.2	53.6	48.2	43.5	40.8	38.8	70.2	71.00	16.50	0.23	3.2
Minimum	71.4	57.6	60.4	53.6	50.0	46.8	42.1	39.2	37.2	45.6	1.37	1.32	0.96	1.0*
July 21														
Maximum	68.0	79.3	60.4	58.1	54.9	51.4	47.8	45.5	44.1	89.0	54.81	14.61	0.26	2.1
Minimum	48.4	43.0	53.1	52.9	52.2	49.8	46.0	43.9	42.4	40.3	0.32	0.09	0.28	1.0*
August 21														
Maximum	62.8	62.6	58.1	55.4	53.2	50.7	48.0	46.2	50.9	81.4	60.01	14.63	0.24	4.1
Minimum	41.0	46.0	44.2	43.8	43.2	45.9	40.8	42.2	41.9	58.3	0.40	0.40	1.00	1.0*

*Met One wind speed sensor defaults to 1.0 mph as minimum value.

stages of maturity in barley, the crop used in soil- and water-conservation research. They are: end of tillering, end of jointing, flowering, and maturity. Soil-temperature and solar-radiation sensors are read every 10 minutes, and hourly maxima and minima are recorded.

After harvest, all sensors other than the thermopiles (a series of thermocouples placed at different positions on wooden dowels) measuring soil temperatures at 0, 2, 6, 12, 20, 30, 36, and 42 inches and the ambient temperature sensor are removed. No further diurnal measurements are made. Daily maxima, minima, and averages are processed from hourly readings and recorded on cassette tapes.

A sample of the type of data that can be obtained through the CR7 instrumentation is shown in Table 2. Results from three days during the growing season include the maxima and minima of ambient temperature and of soil temperatures from one thermopile at 0, 2, 6, 12, 20, 30, 36, and 42 inches. Also, maxima and minima for both incident and reflective solar radiation, wind speed, relative humidity, and albedo (the ratio of reflective shortwave to incident shortwave) are shown. The success rate of data retrieval since June, 1983, has exceeded 90 per cent.

For soil temperatures, there is a total of sixteen thermopiles with thermocouples at 0, 2, and 6 inches from soil surface and two thermopiles with sensors at 0, 6, 12, 20, 30, 36, and 42 inches from soil surface. Each pair of thermopiles corresponds to different tillage and crop-residue treatments.

One 60-minute cassette can record 45 days of data from the CR7 when it is operated in the normal mode, that is, recording only daily maxima and minima. The cassette tapes are changed biweekly, however. Data from cassette tapes are recorded permanently by transfer through the C20 interface installed in line with the asynchronous communication adapter of the IBM-PC. These data are stored on floppy disks and can be analyzed further at the discretion of the user. In the case of data from soil- and water-conservation research, further analyses are performed by using the mainframe Honeywell or Vax system at the University of Alaska, Fairbanks. After data have been transferred from cassette tapes, the tapes can be reused or retained to provide a backup file.

Plots of daily maximum and minimum air temperatures are an example of the type of data generated by the CR7 datalogger (fig. 2). Note that the ambient temperature never was above 77°F and below 31°F during the 1984 growing season. The daily range was within 10 degrees. The graphs indicate the highest temperatures occurred on June 20 and the lowest temperatures occurred on September 11.

System Maintenance

Proper operation and instrument maintenance are critical to recording data which are reliable. A list of routine instrument maintenance for the system follows:

Daily (when possible):
1. Check tape recorder
2. Check pyranometer mounts for leveling

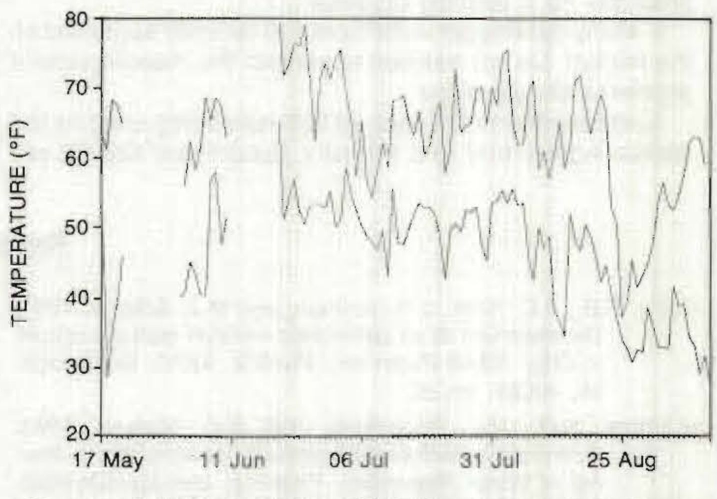

Figure 2. Ambient maximum and minimum temperatures at experimental tracts near Delta Junction for 1984 growing season. (Breaks in the line graphs are due to missing data).

Biweekly:

1. Check CR7 battery level
2. Change cassette tapes

Annually:

1. Calibrate pyranometers
2. Calibrate anemometer
3. Change relative humidity sensor element
4. Check and service the CR7 unit

The relative humidity sensor elements have a one-year lifetime. The Met One anemometer requires annual maintenance with biannual bearing replacement. Instrument maintenance can be performed during noncritical times of the year.

Problems Encountered and Recommendations

During the two years of operation in Delta Junction, the performance of the CR7 was quite satisfactory. The availability of updated manuals for programming the CR7 unit and for troubleshooting aided in its use.

There were problems encountered in the past two years. These, along with corrections which were implemented, are given in Table 3. They are categorized in terms of the system itself, system maintenance, and operation.

Several recommendations can be made to potential users of datalogger/microcomputer units:

1. Some form of shelter should be provided for the datalogger unit throughout the growing season to keep out dust and rain.

2. If the unit is to be used throughout the winter, some type of insulated shelter should be used.

3. Datalogger units are capable of accumulating massive amounts of data. Trials will indicate the frequency of scanning the sensors.

4. Interfaces to a microcomputer are specialized. It is best to contact persons who have used dataloggers and microcomputers prior to determining the system most appropriate for a specific purpose.

5. Many datalogger units have just recently appeared on the market. Do not hesitate to contact the manufacturer if problems should occur.

Automated systems such as that now being used by the Alaska Agricultural and Forestry Experiment Station are new in the state. With aid from extension and educational programs, these systems should provide valuable information for making decisions concerning crop production. In a state or even a region such as Alaska's interior where weather and other environmental conditions are highly variable, uses of such systems can provide guidance to the agricultural producer.□

Table 3. CR7 Problems Encountered during Field Operations

Problems	Corrections
System	
Internal batteries would not hold a charge.	A solar collector was attached to a 12-volt external battery which was connected to the internal battery. Finally factory repair was required, but the problem has not been solved.
Battery leads corroded.	The leads were replaced.
Temperature sensor became inaccurate	All excess thermal-free solder and flux were removed from the thermocouple leads to make sure contact between the copper and constantan wire was only at the location where each measurement was to be made.
Cassette tape did not transmit all data to the IBM-PC.	The tape recorder heads were adjusted.
Relay cable between the CR-7 and the cassette tape was defective.	Factory repair was required.
Maintenance	
Tape recorder	Change batteries every 2 months.
Relative humidity sensor	Change every year.
Clock	Check and reset monthly.
Operational	
Remoteness	The system should be checked at least biweekly when the cassette tape is removed. Winter checks are infrequent due to difficult accessibility.

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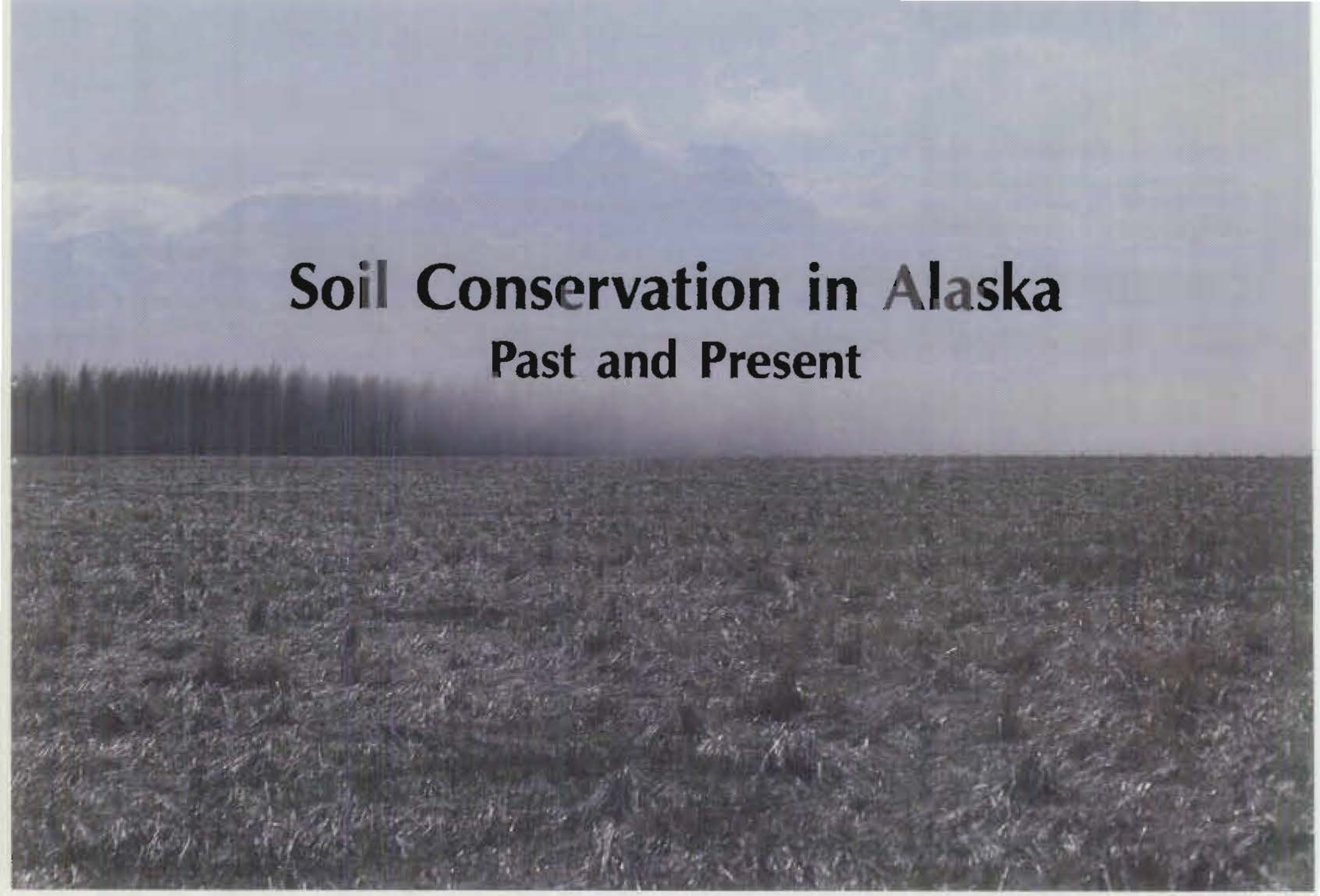

Soil Conservation in Alaska
Past and Present

Wind erosion can be a problem in certain parts of Alaska. Here soil is being blown from an unprotected field at Delta Junction.

By

Roger L. Boyer*

Editor's note: *Nineteen eighty-five marks the Soil Conservation Service's fiftieth year of service in the United States and thirty-eighth year of service in Alaska. It is appropriate in this golden-anniversary year to discuss the important and often unrecognized work of this Federal agency, particularly in reference to the developing structure of Alaska's agriculture.*

Production of cultivated crops on large, contiguous blocks of land did not begin in Alaska until the late 1970s when the state began sales of land conveyed to it by the Federal government under the Statehood Act. The land was sold to private individuals for use in the production of agricultural products. As land was cleared and production began, it was evident that continuing and increased assistance from the Soil Conservation Service would be needed to assist farmers in implementing techniques to prevent erosion of the soil by wind and water which would reduce its productive capacity and to protect the quality of the environment from excessive run-off water and wind-blown sedimentation.

One aspect of the Soil Conservation Service program in Alaska is cooperation with the Agriculture and Forestry Experiment Station in research concerning conservation tillage. The use of tillage methods which minimally disturb the surface of the soil is an important tool for the farmer in preventing sheet erosion by both wind and water. A number of different aspects of this cooperative research have been reported in earlier issues of Agroborealis (Knight et al. 1979, Knight and Lewis 1981, Lewis 1983, Knight 1983, Boyer 1983, Siddoway et al. 1984). Soil Conservation Service personnel perform an essential role helping to design experiments, aiding with data collection, and in disseminating information to farmers.

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The following article by Roger L. Boyer, District Conservationist in Delta Junction located in Alaska's interior, relates the history of the Soil Conservation Service, its objectives and functions and its ongoing efforts in aiding conservation of soil and water resources in the state. He actively participates in conservation-tillage research in Alaska's interior and continues to work effectively with area farmers and others interested in resource conservation. Mr. Boyer was invited to contribute to Agroborealis *by the Agricultural and Forestry Experiment Station.*

Introduction

The Russian settlements of the 1730s made some of the earliest attempts at farming in the state. Over 200 years later, the gold rush firmly established agriculture in the interior (Burton 1974, Logsdon 1983). The soil- and water-conservation movement in the "Lower 48" states was given its impetus by the Great Depression and the dust bowl period of the mid-1930s. This movement led to the formation of the U.S. Soil Conservation Service (SCS) in 1935 (Sampson 1985). It was in 1935, and, as a direct result of those events, that the Matanuska Colony near Palmer was established. This was the first government-organized attempt to foster agriculture in Alaska. Farmers from the midwestern dust bowl area were imported to establish dairy farming. The venture was successful at first, but eventually urban pressure resulted in many subdivisions of those early farms by the 1970s. It was not until 1947, however, that the soil- and water-conservation movement came to Alaska, the first soil-conservation districts began, and SCS offices were opened. Since then, many changes have taken place, and the soil-conservation movement in Alaska has become firmly established.

World War II led to a sharp increase in population and a growing demand for locally grown agricultural products. By the mid-1970s, the state began to understand the need for self-sufficiency, especially in food production. A portion of the revenues earned from sales of state-owned oil was set aside to develop such renewable resources as agriculture and forestry.

Marketing has long been the major obstacle in attaining a viable agricultural industry. The Matanuska Colony gave rise to one of the first agricultural marketing efforts (Andrews and Johnson 1956). Currently, the Pacific Rim countries are regarded as the best potential for Alaskan products, including agriculture (Carney et al. 1978, Thomas 1979).

Distribution of Alaska's Agricultural Land

Alaskan agriculture has historically been small in scale. The Matanuska Colonists were given 40 acres per unit. The Federal homesteading program limited farm sizes to 160 acres. Most agricultural economists agree that farms of this size are not truly economically viable, especially when grain production is involved (Lewis and Wooding 1978). The size of parcels released began to increase. In the 1960s, there were 25,000 acres released by the state in sizes ranging from 100 to 320 acres. In 1978 and 1981, the state released land in interior Alaska near Delta Junction in farms ranging from 800 to 3600 acres designated specifically for the production of small grains and related crops. In 1980 land was sold in southcentral Alaska near Pt. MacKenzie, in parcels sized to support dairy farms with up to 200 milking head.

Even if the philosophy prior to the 1960s had been to sell or distribute large blocks of land to private individuals, a significant deterrent was the lack of available land. As recently as 1959 the Federal government still owned nearly 99 per cent of all Alaskan land (Epps 1978). This had only improved to 97 per cent by 1977. The passage of the Alaska Native Claims Settlement Act by the U.S. Congress in 1971 cleared the way for more private ownership, but many legal issues prevented the state from gaining clear title to the 104 million acres of land to which it was entitled as a result of the Alaska Statehood Act of 1958. In the early 1960s, the state obtained title and began transferring ownership of some land to the private sector. In 1978 and in the following years, this transfer was intensified (Thomas et al. 1983).

When the state received its land entitlement from the Federal government, it began transferring land not only to the private sector, but to the organized boroughs as well. The Matanuska-Susitna Borough, not far from Anchorage, contains some 14 million acres. It has begun its own program of agricultural land sales. Recently, two other boroughs—Kenai Peninsula and Fairbanks North Star—have initiated similar agricultural land disposal programs.

Conservation Districts in Alaska

The territorial government passed legislation in 1947 allowing the formation of a statewide soil conservation district and locally organized subdistricts. At one time there were fourteen such subdistricts. This move prompted the SCS to establish offices, first in Palmer and Fairbanks. The office in Homer was opened in 1950. The Palmer office served the Matanuska Valley and the area south of the Alaska Range, while the Fairbanks office served the area north of the Alaska Range, primarily the Tanana Valley. The Homer field office was responsible for the Kenai Peninsula, Kodiak Island, and the Aleutian Chain. Alaska's fourth field office opened in 1978 at Delta Junction, as a response to the newly developing agriculture in that area.

In 1983 the state legislature passed a new soil- and water-conservation law which changed the subdistricts, now numbering nine, into full districts. The statewide district was preserved, and it kept its former jurisdiction over the area not covered by the local districts. Its board of directors was also given advisory responsiblities to the Commissioner of the Alaska Department of Natural Resources (DNR) with

Early conservation practices often utilized available materials, as shown by this erosion-control structure made out of logs.

Melting of buried ice blocks in the soil causes thermokarst pitting. These present unique management problems.

its members being appointed by the governor. The new name, "Soil and Water Conservation Districts" reflected an added interest in water quality protection.

Each district (a state-authorized unit of government) and SCS (an agency of the the U.S. Department of Agriculture) enjoy a unique cooperative relationship. The local district's board of supervisors provides local input, the policy in directing conservation programs. SCS carries out the technical aspects of their programs and goals. The two agencies function separately, yet together, with the common goal of getting conservation practices on the land. As a result of this relationship, each local district's activities are tailored to the problems and needs of the immediate area.

Even though each district has its own specific program, they do share some common objectives:

•Assist land owners with the wise use and development of their land.

•Sponsor, develop, promote, and expand important areawide conservation practices.

•Promote conservation awareness in the public.

•Promote conservation practices in nonfarm areas and on nonfarm land.

To assist the district in achieving these objectives SCS has established the following long-term objectives for itself:

•Reduce or prevent excessive soil erosion.

•Reduce or prevent upstream flood damages and monitor water quality.

•Improve or maintain the production of cropland, pasture, range, forest, and fish and wildlife habitat.

•Strengthen conservation districts and their interagency partnerships.

•Conserve rural and urban resources.

•Develop resource data for land-use planning and decisions.

•Improve technical standards and administrative management.

Another important feature about districts is that they have organized themselves on the state and national levels so that they might have a better voice in political issues. The Alaska Association of Soil and Water Conservation Districts (AASWCD) was formally established in the fall of 1967, with the acceptance of their newly written bylaws. The National Association of Soil and Water Conservation Districts (NACD) was formed in 1946. Since districts are part of the government, as is SCS, they cannot lobby. However AASWCD and NACD are not part of the government, and have been very active in promoting conservation through political action.

Conservation Efforts

Early conservation work in Alaska centered on providing assistance to developing farms and working on soil-management problems. Soil erosion was considered to be of minor consequence and was only briefly mentioned in early publications. One publication described a new type of erosion — thermokarst pitting (melting of buried ice blocks) which occurred near Fairbanks (Agricultural Research Administration 1949). Conservationists provided technical information for a variety of practices such as crop rotation, contour farming, hayland seedings, grazing systems, proper land clearing, and surface-water disposal systems. Early Alaskan farmers were more concerned with "proving up" on their homesteads (bringing land into production) than with conservation. Even though they were primarily concerned with expanding production, early farmers were apparently quite conservative and tended to clear small areas of land, thus precluding extensive wind or water erosion. A major contribution by the subdistricts was their insistence on proper land clearing. Poor or careless techniques at the time of clearing often resulted in large volumes of soil being mixed into the stump rows (called berm piles). This soil then impeded burning, a

Proper land-clearing methods will always be important when developing farmland.

If windbreaks are not left at the time of clearing or are destroyed, they must be re-established either by planting or some other acceptable means.

necessary step in the eventual elimination of the berm piles. Another common, but poor, practice which was and still is discouraged by local districts is the stacking of berms into or too close to standing timber, thus creating an instant fire hazard at the time of berm removal.

The sale of state land, beginning in 1978, marked a new era in soil and water conservation for Alaska. Under the land-disposal program, only "agricultural rights" were conveyed and the lands that were sold were required to have a conservation plan developed and maintained. This bold new approach was designed to prevent speculation of land values based on development rights and the loss of good farmland to urban encroachment. Subdivision of the land into parcels smaller than 40 acres was prohibited, and the land could be put to agricultural uses only. The mandatory soil- and water-conservation plan, developed through soil- and water-conservation districts, provided for at least partial protection of these lands for future generations.

Today's farmers are much more receptive, not only to the need for conservation, but to new and somewhat innovative conservation techniques. In offering assistance on newly developing farms, SCS and districts are truly implementing the adage that "an ounce of prevention is worth a pound of cure." The local soil- and water-conservation district and SCS assist the new landowner to formulate and implement a conservation plan which helps prevent many problems before they occur. Practices in present plans include windbreaks (left at the time of clearing and/or replanted), greenbelts, grassed waterways, hayland seeding and management, conservation tillage, cover crops, strip cropping, and proper grazing systems.

The role of the state's soil- and water-conservation districts has changed through time, as the emphasis on agriculture and the need for strong conservation measures has increased. More traditional methods of getting the job done in a voluntary fashion are now supplemented by the new mandatory conservation program applicable to all state sales of new lands. Districts also work in an advisory capacity to the state's Division of Agriculture, which enforces conservation regulations. Most recently, the districts have entered into a cooperative agreement with the Alaska Department of Environmental Conservation (DEC) to assist in identifying and solving water-quality problems associated with agriculture. Each district uses a checklist, prepared in cooperation with district cooperators, to review each conservation. This ensures that a cooperator's land does not contribute to existing or potential water-quality problems. When problems or violations of state water quality standards are encountered, the district works with the cooperator to correct the deficiency voluntarily.

The Soil Conservation Service has an increasingly important role in helping the people of Alaska develop and protect their natural resources. A very extensive snow-survey program manages a network of over 230 snow-survey sites throughout the state (Clagett et al. 1985). Data are used, for example, to forecast peak stream flows and spring flooding and make water-supply forecasts for municipalities. Another related program is basin or area planning. SCS has been assisting the state in preparing flood-hazard and flood-management studies for the major river basins. In conjunction with this work, resource inventories (soils, vegetation, range, etc.) have been made at the request of the state for use by DNR in preparing area and basin plans in cooperation with other state agencies.

Another important role of SCS in cooperation with the Alaska Division of Agriculture has been the assistance to the Native peoples in developing their natural resources. Many bush communities intend to develop small-scale agricultural projects for local food production. Soil and range surveys and on-site investigations are methods which SCS uses to help all state residents, DNR, and other agencies in developing and planning the best use of their natural resources. Of particular interest has been the extensive soil and range surveys conducted on the Seward Peninsula for the reindeer herders (Epps and Thomas 1983, Swanson 1983).

The Delta Experience

The land transfers (from Federal to state) sparked widespread interest in the potential and future of all Alaskan lands. The state moved aggressively to explore the resource potentials of the newly acquired lands. As a result, the SCS Soil Survey Program became very important to state planners charged with determining the use of the land. The Salcha-Big Delta Soil Survey (Schoephorster 1973) had attracted widespread interest in resource values. Local citizens worked together to prepare the Delta Land Management Planning Study (Alaska Division of Lands 1976) and then revise it several years later (Alaska Department of Natural Resources 1982). A significant result was the identification and allocation of over 100,000 acres for agriculture. Over 60,000 acres were sold in one contiguous area containing twenty-two parcels of land ranging from 1900 to 3500 acres in size in 1978. This was the first major project effort to establish a more stable agricultural industry (Alaska Department of Natural Resources 1978). A nearby small-farm area, released earlier in 1978, had 60 parcels ranging from 20 to 280 acres. Over 100,000 acres of agricultural land have been sold in the area since the original 60,000 acres were released. Prior to these sales, a maximum of about 6,000 acres had been farmed at any one time.

Remote telemetry sites like this one provide valuable snow pack and water data to many resource agencies in Alaska.

The Salcha-Big Delta District and SCS helped to ensure that a soil-conservation program was incorporated into the project development. The Delta area, known for its strong winds, had significant potential for wind erosion. For this reason, a conservation program was established which incorporated mandatory windbreaks, spaced at one-quarter mile intervals, and voluntary use of conservation tillage systems, which protect the soil from erosion by using a mulch of the previous year's crop residue. The windbreaks were established at the time of clearing. However, many were burned by wildfires shortly after being established. The District and SCS initiated a program to rededicate leave strips and/or replant trees.

A major oversight, however, was the lack of planning for an adequate drainage and water erosion-control system for the project area. Potential water-erosion and flooding problems were largely ignored by the planners, even though a drainage system for the original Clearwater homesteading area located nearby had been proposed (Soil Conservation Service 1964). Efforts were made by SCS to include an adequate water-disposal system in the project plan, but to no avail, even though flooding was documented for the scheduled project area by published flood-hazard maps (Soil Conservation Service 1978). A comprehensive plan is now being developed to mitigate problems associated with erosion of river banks, over-bank stream flooding, and gully erosion (Soil Conservation Service 1983). This is a cooperative effort by SCS and the Salcha-Big Delta District. One of the goals of the plan is to prevent pollution of Clearwater Creek, a pristine, nonglacial stream which originates from underground springs in close proximity to the newly developing agricultural project. Extreme care is being taken to preserve its integrity. This district project has received widespread support by the general public.

Drainage was, and still can be, an important consideration when developing new farmland.

Permanent vegetative cover used for hay production also prevents wind and water erosion.

Water-caused erosion can be serious, especially on newly developed land, where not all conservation practices are firmly established.

The force of water erosion can also cause damage to such man-made structures as culverts and roadbeds.

Stream-bank erosion, although not usually a farmer's problem is of concern to SCS, the local districts, and governmental entities that control the land.

The mandatory windbreaks on farms in the Delta area are an important first step in preventing wind erosion. But the windbreaks must be spaced close together to completely protect the field.

Summary

The U.S. Soil Conservation Service came to Alaska in the late 1940s. The territory at that time was organized into a single conservation district with local subdistricts. SCS provided traditional technical asistance to cooperators. With newly developing agriculture, emphasis was placed on preventing problems, rather than correcting them.

There was increased interest in the early 1970s to make Alaska agriculturally self-sufficient. Approximately 150,000 acres of state-owned land with agricultural potential were transferred to the private sector by 1984.

An important requirement accompanying land sales was the mandatory conservation plan to be developed by the farmer in conjunction with the local conservation district. Despite extensive planning, new agricultrual areas have experienced some of the traditional conservation problems. Remedial action has been required.

These problems are being addressed by SCS and the local districts, along with the application of techniques new to Alaska. A major concern to conservation officials are the proposed fiscal cuts which would threaten the future of soil and water conservation. The future of agriculture in Alaska and the nation is directly dependent upon the wise use of soil. Conservation of that resource is vital. □

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Beach Wildrye

Characteristics and Uses of a Native Alaskan Grass Of Uniquely Coastal Distribution

By

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Introduction

Beach wildrye (*Elymus mollis* Trin.) is a tall-growing, coarse, leafy, perennial grass (fig. 1) with a unique geographic range. Furthermore, it has an unusual array of specialized uses, both current and past. Information on beach wildrye consists largely of brief comments in a number of publications, many of which are out of print or not generally available. This report compiles information from numerous sources and previously unpublished data to summarize much of what is known about this grass in Alaska.

Common Names

It is not unusual for a plant species to be referred to by different common names in various parts of the world. This grass, however, has garnered a considerable list of common names; these include "dunegrass" (Welsh 1974); "American dunegrass" (Hitchcock 1950); "lymegrass" (Porsild and Cody 1980); "beach ryegrass" (Anderson 1959); "sea lymegrass," " siegle de mer" (rye of the sea), "strand wheat" (Fernald 1950); "strand oats," "wild wheat," "sand-meal grass" (Anonymous 1983); "dune wildrye" (Schwendiman and Hawk 1973); "beach rye" (Irwin 1945); and "beach wild-rye" (Aamodt and Savage 1949). This report uses the common name "beach wildrye."

Name Confusion

Grasses within the genus *Elymus* generally are called "wildryes." Because of name similarities, there is sometimes confusion between these grasses and the cereal rye (*Secale cereale*), as well with the ryegrasses, which are

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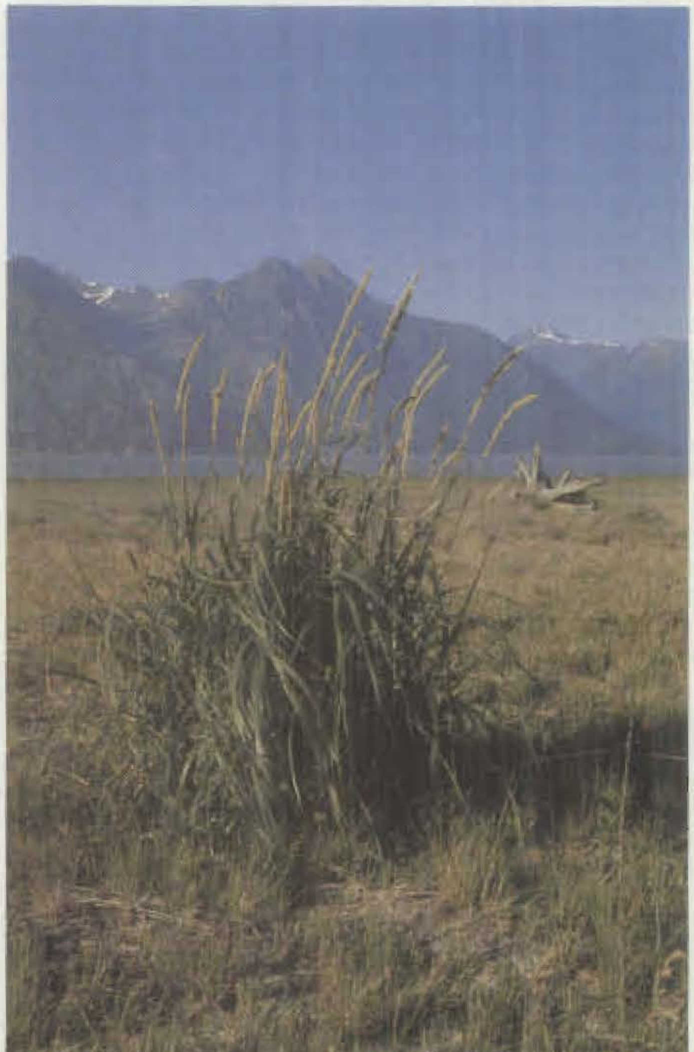

Figure 1. Individual plant of beach wildrye on tidal flats along Turnagain Arm in southcentral Alaska. Height at topmost seed heads is about 44 to 48 inches tall.

quite different and belong to the genus *Lolium*. A totally different grass, called American beachgrass *(Ammophila breviligulata* Fernald), adds to the confusion. American beachgrass occurs on coastal sands from Newfoundland to North Carolina and in the Great Lakes region. Although this grass occupies the same type of coastal habitat as beach wildrye, the more southern geographic range of American beachgrass causes it to be far removed from Alaska (Hitchcock 1950).

Taxonomy and Relationships

The plant genus name *Elymus* traces to the Greek language. One source states that it derives from the word *elumos*, an old name for a kind of grain (Hitchcock 1950). Another claims its origin as *elyo*, meaning "rolled up," descriptive of the fact that each grain or seed is tightly embraced by two seed husks, called the lemma and palea (Fernald 1950).

Taxonomically, the genus *Elymus* is part of the grass family called Hordeae, which also includes genera embracing such major world crops as wheat (*Triticum*), barley (*Hordeum*), rye (*Secale*), and the wheatgrasses (*Agropyron*); this last-named genus includes several important forage species, and the aforementioned cereals provide forage as well as pasturage at immature growth stages. Hitchcock (1950) lists twenty-three species of *Elymus* that are native to the conterminous forty-eight states, all perennials. About six of these species, including *E. mollis*, are also native to Alaska (Anderson 1959, Hultén 1968, Klebesadel 1969, and Welsh 1974).

Botanists are not in agreement concerning the nomenclature and relationships of beach wildrye on a worldwide basis. The beach wildrye of North America is considered by some taxonomists to be a separate species first described in the 1820s (Hitchcock 1950), and identified by the Latin binomial *Elymus mollis* Trin. (Anderson 1959, Welsh 1974). Anderson and Welsh believe it to be a separate species, taxonomically distinct from the material called *E. arenarius* L., which ranges in northern Europe, eastward to the Ob River of the U.S.S.R.

Komarov (1934) and Hitchcock (1950) decided the North American beach wildrye is identical to that of eastern Asia, calling both *E. mollis*. Others consider North American beach wildrye to be a subspecies within the Eurasian *Elymus arenarius* (Fernald 1950, Hultén 1968, Polunin 1959, Porsild and Cody 1980).

Hybrids with Other Species

Natural hybrids have been found between beach wildrye and several other grasses; these include an interspecific cross with northern wildrye (*Elymus hirsutus*, Hultén 1968), as well as intergeneric crosses with the following: quackgrass (*Agropyron repens*, Komarov 1934), violet wheatgrass (*A. violaceum*, Polunin 1959), foxtail barley (*Hordeum jubatum*, Welsh 1974), and meadow barley (*H. brachyantherum*, Hodgson and Mitchell 1965).

Geographic Range and Habitat

The world range of beach wildrye (*E. mollis* + *E. arenarius*) is circumpolar, with most of its geographic range lying between 40° and 70° N. A recent discovery near 80°N on Ellesmere Island, about 600 miles north of its previously known northern limits in North America, may be a recent introduction (Porsild and Cody 1980).

The most unusual aspect of its geographic range is its peculiar affinity for seashores. In North America, it is found along most of the coastlines of Alaska and Canada. It also occurs commonly on coasts of the southern half of Greenland. The southernmost extent of its range on the Pacific coast is central California; on the Atlantic coast it extends south to New York (Hitchcock 1950). Beach wildrye occurs at inland locations only on the shorelines of the Great Lakes, Lake Athabasca, Great Slave Lake, and Great

Figure 2. Top: A planted field plot of beach wildrye that originally ended at the white string. In two growing seasons, vegetative spread by rhizomes to the right of the string has extended the plot two to three feet beyond its original limits. Photo 31 May. Lower: Close up view of robust rhizomes.

Bear Lake (Hultén 1968, Porsild and Cody 1980).

One of the common characteristics of such shorelines is their generally sandy nature, and beach wildrye typically grows in such sands. The Swedish botanist Linnaeus recognized this in applying the species name *arenarius* (pertaining to sand, growing in sand). Beach wildrye produces a vigorous growth of underground stems, called rhizomes (fig. 2); these and its fibrous roots bind coastal beach and dune sands, helping to stablilize them against disturbances by wind and water. The toughness of the heavily cutinized leaves and stems of beach wildrye undoubtedly serves to protect the plant from abrasive effects of blowing sand.

Reproduction

As with many other grasses, beach wildrye reproduces or spreads both vegetatively (by proliferation of underground stems) and sexually (by production of seeds).

The rhizomes of beach wildrye are large and vigorous, promoting the rapid spread of individual plants to cover sizeable areas (fig. 2). This action can be seen on numerous road shoulders in the Matanuska Valley, in the Turnagain Arm area, and on the Kenai Peninsula when plants of beach wildrye become established on road-fill. Dramatic evidence of the forceful growth of the sharp-pointed rhizomes is seen in Figure 3, in which are shown several that have penetrated up through a thick layer of hard asphalt road surfacing.

Figure 3. Examples of the growth force of beach wildrye rhizomes: (top) numerous tillers that have spread from a roadside stand of the grass and have emerged after growing up through dense, hard-packed asphalt road surface, and (bottom) close-up of a tiller that has emerged through asphalt. Photo 29 June.

Both the seeds and the seed heads or spikes of beach wildrye are relatively large (figs. 4, 5). However, this grass typically is not a heavy seed producer in Alaska because many of the potential seed sites (florets) often do not produce seed.

Natural Soil Stabilization

Beach wildrye's narrow, sinuous range along coastlines precludes the occurrence of great expanses of the grass as are found with inland species such as our Alaskan bluejoint or the prairie grasses of the West. Nonetheless, it has a useful role in the ecological niche it occupies. The natural deployment of beach wildrye in strand-plant communities causes it to be an important element in the vegetative cover in such coastal regions, interacting with other plant species. As the pioneering beach wildrye stabilizes coastal sands (fig. 6), other plants, including the nitrogen-fixing legume called beach pea (*Lathyrus maritimus*), are afforded protection and become part of the vegetative cover in expanding coastal plant communities.

Varied Uses

Beach wildrye has long history of use for livestock pasturage and as a harvested forage; additionally, however, humans have found a surprising number of other uses for this grass.

A recent survey of Viking legends and Norse folklore uncovered numerous references to the use of the seed of beach wildrye for human consumption (Anonymous 1983). Carbonized remains of the grass have been discovered in Viking archaeological sites and references have been found to a "nutritious, flavorful" bread made from the seed. It is believed that this grass was actually cultivated in Greenland during the Viking era.

Hitchcock (1950) states that seeds of *E. mollis* have been used for food by North American Indians, and Komarov (1934) records that "grains" of the closely related *E. arenarius* "may be used for food and they are sometimes gathered in the north of the U.S.S.R. for this purpose." Rita Blumenstein, who grew up on Nelson Island in southwest Alaska, reports that short sections of the fleshy rhizomes traditionally were cooked for food by Eskimos of that area (personal communication 1984[1]).

[1]Blumenstein, Rita (Eskimo name: Dunqiarh). 1984.

The strength of the linear fibers in leaves of beach wildrye suits the grass to a number of nonfood uses. Dried leaves are utilized in the weaving of baskets by Aleuts (Anderson 1959) and Eskimos (Aamodt and Savage 1949; Porsild and Cody 1980; Blumenstein, personal communication). Blumenstein, an authority on grass basketry, states that the leaf blades Eskimos collect at three distinct times of year (May, July, and Sept.-Oct.) differ in physical characteristics and therefore are best suited for different uses (basketry, cordage, etc.). Leaves collected in July are dyed with various agents to provide the colored patterns seen in grass baskets (fig. 7).

Komarov (1934) noted that, in the Soviet Union, "Gilyaks make ropes from the leaves of *E. mollis* Trin. and strings from the thin root fibers of this plant," and that "leaves of wildrye are used in weaving of mats." Porsild and Bowden. (1980) report that beach wildrye foliage has been used as an insole or insulating layer between the outer and inner native boots worn by Eskimos in Greenland. Aamodt and Savage (1949) stated that Eskimos have used beach wildrye for thatching of dwellings; as Evans (1897) noted, "at Kadiak (Kodiak) and elsewhere a tall-growing wild rye (undoubtedly *E. mollis*) is used to a considerable extent for thatching buildings."

Forage Uses

Some other wildrye species, both native and introduced, are valued for forage purposes. Chief among these are Russian wildrye (*E. junceus*), introduced to the U.S. from the Soviet Union in 1927, Altai wildrye (*E. angustus*), a more recent introduction from Mongolia, and Canada wildrye (*E. canadensis*), native in North America. Improved varieties within each of these three species have been developed and released in the U.S. and Canada.

These and other wildrye species of lesser importance for forage use are discussed by Klebesadel (1969) and Schwendiman and Hawk (1973).

Beach wildrye was rated as having little forage value by Schwendiman and Hawk (1973); moreover, no improved varieties of this species have been developed. Nonetheless, beach wildrye has a long history of use as a forage crop in Alaska, even though that use was quite minor in extent

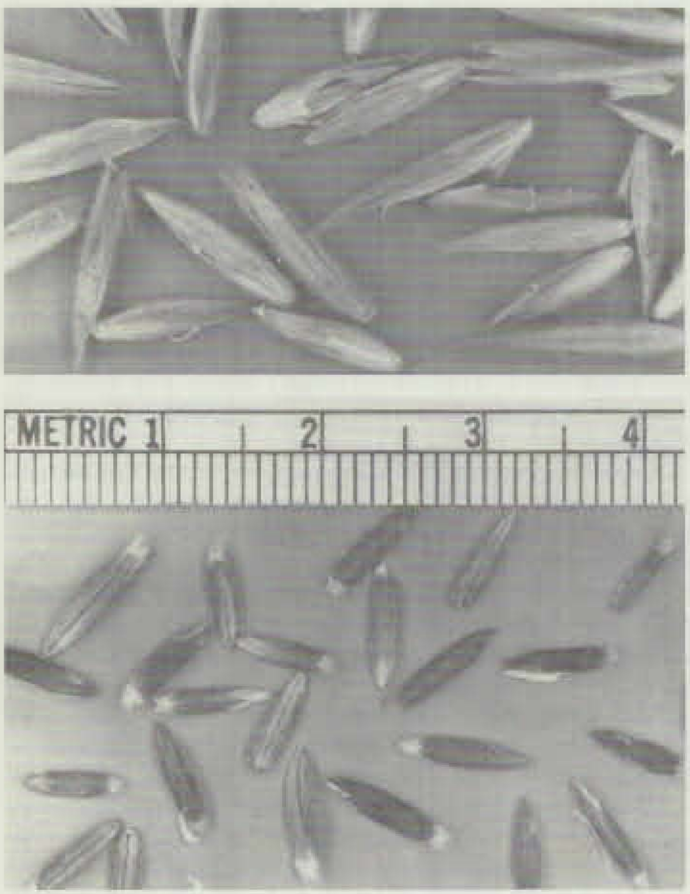

Figure 4. Seeds of beach wildrye showing examples of (top) some enclosed in seed covering called lemma and palea, and (bottom) naked seeds (caryopses) with coverings removed; it is in this form the seeds were used for human food. Numbered lines on scale are one centimeter apart (Note: 1 cm = .3937 in).

Figure 5. Typical seed heads (spikes) of beach wildrye. The pair on the right are at flowering stage with pollen-bearing anthers showing.

Figure 6. Edivence of the on-going "battle" between sea-waves, tides, wind, and beach wildrye for coastal sands. Top: Beach wildrye spreading over sandy beach. Middle: Partially washed-away dunes exposing formerly subterranean network of rhizomes and roots that bind the sands. Both photos taken 24 August near Port Moller on the Alaska Peninsula. Lower: Intermixed associations of beach wildrye and the nitrogen-fixing legume called beach pea along gulf coast near Cape Yakataga. Photo 26 June.

Figure 7. Beach wildrye has a long history of use by Alaskan natives in the manufacture of intricately crafted, assorted styles, of baskets. Examples of one type are shown above.

and occurred only in certain areas where there were significant, accessible stands of the grass near settlements where livestock was raised.

The earliest attempts to preserve harvested beach wildrye as silage for winter feeding of livestock in Alaska apparently were made at the Sitka Experiment Station about 1900 (Snodgrass 1908). It is probable, but not certain, that Evans (1897) was referring to even earlier utilization of beach wildrye when he reported that silos had been built and filled with "marsh hay from the tide flats" at a farm near Wrangell. On the basis of the success at Sitka, the practice was adopted on a larger scale for the herd at the Kodiak Experiment Station. Silage was made there from beach wildrye for all the years that station was operational, with the exception of 1912 and 1913 when a massive ash fall from the June 1912 eruption of nearby Mt. Katmai blanketed Kodiak Island and interrupted station operations (table 1). Frye Ranch, nearby, preceded the Kodiak Station in ensiling this grass; as early as 1907 that ranch put up 500 tons of beach wildrye silage annually.

M.D. Snodgrass (1907-1916), superintendent of the Kodiak station for several years, provided annual reports of operations involving silage made of beach wildrye there. Stands of the grass along tidewater and at the heads of bays were cleared of driftwood to permit horse-drawn mower travel (fig. 8). Fresh-cut beach wildrye was then loaded onto a launch-towed skiff and taken by water to the station's silos at Kalsin Bay. A tall sedge, *Carex cryptocarpa*, often occurred intermixed in the harvested stands of beach wildrye.

Experimental Evaluation

Alaskan beach wildrye was grown in experimental plots at the Matanuska Research Farm and compared for forage production with three other winterhardy cropland forage grasses: 'Polar' bromegrass, 'Engmo' timothy, and 'Garrison' creeping foxtail. The beach wildrye was frown from seed gathered from native stands occuring on tide flats along Knik Arm.

Commercial fertilizer disked into the Knik silt loam seedbed supplied N, P, and K at 32, 56, and 53 lb/A, respectively. All were planted 8 June 1972 in broadcast-seeded plots 5 × 18 ft in size with three replications, without companion crops. A pre-emergence application of dinoseb was applied uniformly over the seedbed shortly after planting to control weeds.

Seedling-year growth was harvested in mid-October, and two harvests were taken during each of the subsequent growing seasons (table 2).

In early spring of each year after the year of planting, while grasses were dormant, plots were top-dressed to supply N, P, and K at 126, 96, and 48 lb/A, respectively. A midseason topdressing of ammonium nitrate, applied

Table 1. Silage preserved at the Kodiak Livestock and Breeding Station for a term of years following start of operations there in 1907 (Snodgrass 1907-1916).

Year	Tons	Grasses Utilized
1908	65	Mostly beach wildrye
1909	100	Mostly beach wildrye
1910	150	Mostly beach wildrye
1911	170	Mostly beach wildrye
1912 1913		June 1912 eruption of Mt. Katmai deposited a layer of thick, volcanic ash; cattle removed; silage-making impossible
1914	100	Mostly bluejoint grass
1915	170	115 tons bluejoint + fireweed + 36 tons beach wildrye + 18 tons oats
1916	175	165 tons beach wildrye + 10 tons oats

Table 2. Forage yields of beach wildrye compared with three cropland forage grasses in broadcast-seeded field plots during four years at the Matanuska Research Farm. Experiment planted 8 June 1972.

	1972	1973		1974		1975		
Grasses	13 Oct	11 July	10 Sep	1 July	18 Sep	26 June	25 Sep	Total
	(Tons dry matter/acre)							
Beach wildrye	.20	1.01	.58	.66	.44	[1]	[1]	2.89
Polar bromegrass	.82	2.43	1.00	2.01	.22	2.43	1.86	10.77
Engmo timothy	.85	2.03	.89	2.22	.48	1.71	2.18	10.36
Garrison creeping foxtail	.89	2.42	1.01	2.11	.32	2.61	1.25	10.61

[1] Plots too weedy for meaningful yield data.

Figure 8. Cutting a stand of beach wildrye with team and mower on Kodiak Island. (Photo: Alaska Agr. Exp. Sta. Annual Report. 1916)

shortly after the first cutting each year after the year of planting, supplied N at 80 lb/A. After the final harvest each year, all plots were trimmed uniformly to a 2-in stubble to prevent uneven snow retention on plots over winter.

Beach wildrye was markedly inferior in forage yields to the three other grasses compared in all years of this study (table 2.) The stands of beach wildrye were relatively open, having a lower density of culms per unit of area than the other grasses compared. This contributed to lower forage yields and permitted a greater invasion of weeds in the beach wildrye plots. Although the other higher-producing grasses were harvested twice in 1975, no attempt was made to harvest the excessively weedy plots of beach wildrye 1975.

Hazards

The toughness of the dried grass, which contributes to its value as a raw material for basketry, mats, thatching, and other such uses, may also be largely responsible for causing impaction of the digestive tract in livestock. Snodgrass (1907 through 1916) reported several cattle deaths from impaction when hungry animals consumed excessive amounts of dried, weathered grass in early spring on Kodiak beaches before new spring growth became available. This problem is not unique to beach wildrye, however; impaction can also occur with excessive consumption of other grasses in an indigestible state. When beach wildrye on Kodiak was cut and preserved at a nutritious stage of growth, no feeding problems were reported, and animals thrived on silage (Snodgrass 1907 through 1916).

Some seeds of beach wildrye occasionally are replaced by a fungus called ergot (*Claviceps purpurea*). When this occurs, the ergot is identifiable in the seed head as a purplish-black, seed-shaped object somewhat larger than a normal seed. Ergot occasionally occurs in many of the cereal crops and in other species of grass as well. Although ergot is used in some drug preparations, it can be poisonous if consumed by animals or humans and must be avoided.

Conclusions

Mankind has found many uses for beach wildrye around the world. However, results of the study reported here suggest that this grass should not be considered as a potential cropland forage species in southcental Alaska where other, more productive grasses grow well. Naturally occurring beach wildrye stands can be grazed or harvested for forage where large stands occur, and records show that was the case on Kodiak Island and in other coastal locations.

Although seeds of the grass have provided human food on a subsistence basis in earlier times, the relatively meager production of seed heads per unit area by beach wildrye, contrasted with the major cereal crops, precludes economical use of the grass for this purpose.

A logical use for beach wildrye may be as a soil-stabilizing species in coastal or inland sandy situations. The species could be planted with seed harvested from native stands or from fields planted for seed production. Artificial selection might identify lines more productive of seed than the general population. Beach wildrye could also be propagated vegetatively with transplants or rhizome segments in a process called sprigging.

Beach wildrye will probably continue to be used for the manufacture of baskets by Alaska natives. This utilization, which began largely for utilitarian purposes, now finds a valuable outlet in sales to urban Alaskans and tourists.☐

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Figure 1. Lobelia is a popular bedding plant commonly used in hanging baskets and garden borders.

Alternaria Seedling Blight of Lobelia

By

Roseann Hartke Leiner* and Donald E. Carling**

Lobelia (*Lobelia erinus* L.) is a popular bedding plant in Alaska and other regions with cool growing seasons. Lobelia plants are often used in hanging baskets (fig. 1), alone or in combination with other flowers, and as border plantings in mixed flower gardens. Lobelia plants are typically started from seed in the greenhouse, where seeds are sown at very high rates in flats of artificial media. When seedlings reach a height of approximately .4 inches, they are transplanted in clumps of five to ten plants into larger containers.

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Lobelia, like many other bedding plants, are subject to damping off and seedling blight when produced in this manner. Warm temperatures and high humidity that prevail in a greenhouse environment favor the development of many microorganisms that can be responsible for seedling blight.

Such was the case in 1983 when a commercial nurseryman in Alaska reported large losses on his spring lobelia crop. Many seedling flats were total losses, while other flats produced apparently healthy seedlings which later withered and died soon after transplanting. The nurseryman explained that most seedling blight occurred in flats sown with lobelia variety (var.) Sapphire, while less serious blighting occurred in var. White Lady and other varieties. *Alternaria* spores were found on diseased lobelia seedlings, and a recent report of research done in England describes the

Figure 2. To test seed infection, lobelia seeds were placed on MEA petri plates. From twenty-five seeds of 1984 var. Sapphire on this plate, one produced an Alternaria fungus colony, and three produced colonies of unidentified bacteria.

Figure 3. Alternaria alternata spore chain viewed under a microscope (200x). Species identification is based on spore size and shape.

fungus *Alternaria alternata* (Fr.) Kiessler as a seed-borne pathogen of lobelia (Hall and Taylor 1983). Studies were initiated to find out if *A. alternata* was present on the lobelia seed lots and, if so, whether *A. alternata* could produce the seedling blight symptoms seen on lobelia.

Seed Infection

Blighted seedlings and samples of seed from which the seedlings were produced were delivered to the Agricultural Experiment Station's Palmer Research Center for examination. Lobelia seed lots were tested for *A. alternata* contamination by placing ten to twenty seeds on petri plates of malt extract agar (MEA). Two-hundred seeds of each lot were tested. Plates were incubated at room temperature in darkness for two days and then incubated in room light for five more days (Hall and Taylor 1983). Seeds contaminated with *A. alternata* produced a dark green fungus colony on the agar surface (fig. 2), and copious numbers of spores were collected from these colonies. The spores were characteristically dark in color and multicellular with longitudinal, oblique, and transverse crosswalls (Ellis 1971). Based on microscopic examination of these spores (fig. 3), the fungal colonies were identified as A. *alternata* (Calvert, personal communication*).

A. alternata is a cosmopolitan fungus that commonly lives on plant debris and in soil. Under some conditions, *A. alternata* will parasitize plants causing such diseases as seedling blight on lobelia and black pit disease on potato tubers (Droby et al. 1984). More often, *A. alternata* grows as a saprophyte on plant tissue that has already died from such other kinds of stress as poor nutrition, insects, or other disease (Agrios 1978). When conditions favor fungal growth, *A. alternata* produces large numbers of spores which may be carried by air currents and water splashes to nearby plants. Lobelia seed may be contaminated when *A. alternata* spores land on the seed coat before the seed is harvested from the fields, if *A. alternata* is growing on plant debris in or near the field.

Ten per cent of the 1984 var. Sapphire seeds were contaminated with *A. alternata* (see table). An additional 28 per cent were contaminated with unidentified bacteria that produced yellow mucoid colonies around the seed on MEA. It is not known what effect, if any, this bacteria may have on seed germination or seedling disease. The second seed lot, 1983 var. Sapphire, was that associated with the seedling-blight problem at the commercial greenhouse mentioned above. Following the seedling-blight epidemic, the nurseryman treated leftover seed with PCNB (terrachlor), hoping to solve the problem. PCNB was applied as a dust to the seed packages and as a drench over the planted seedling flats. Although none of the 1983 var. Sapphire seed was available for testing before PCNB seed treatment, a high level of *A. alternata* contamination is assumed, based on the very high incidence of seedling blight on this variety in the greenhouse. The PCNB seed treatment apparently

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Table. Seedling blight symptom development on inoculated and noninoculated lobelia seedlings from different seed lots.

Seed lot	*A. alternata* seed contamination (%)	Inoculation with *A. alternata* None	At planting	At emergence
1984 var. White Lady (untreated)	0	0	+ +	+ +
1984 var. Sapphire (untreated)	10	+	+ + +	+ + +
1983 Sapphire (treated with PCNB)	0	0	+ +	no data

Symptom expression: 0 = no symptoms, + = light, + + = medium, + + + = heavy.

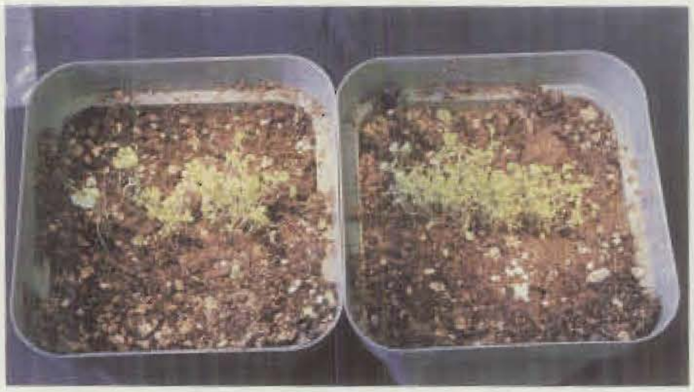

Figure 4. Comparison of healthy lobelia seedlings (right) with seedlings exhibiting light seedling blight symptoms (left). The same quantity of seeds were sown in each pot, but the plant stand is thinner in the blighted pot, indicating that some seedlings died after exhibiting symptoms of leaf wilting, stem discoloration, and collapse.

Figure 5. Comparison of healthy seedlings (right) with a heavily blighted planting (left). Again, the same quantity of seeds were sown in each pot, but the difference in plant stands is obvious and remnants of dead seedlings remain in the blighted planting.

was effective; in this survey, 1983 var. Sapphire had no *A. alternata* contamination and only 4 per cent of the seeds were contaminated with bacteria. Neither *A. alternata* nor bacterial contamination was detected on the 1984 var. White Lady seed lot.

Inoculation Studies

Development of symptoms of seedling blight and the comparative value of inoculum source and time of inoculation were observed in the following studies. Pots were planted with seed from each of the three lobelia seed lots tested for *A. alternata* contamination: 1984 var. White Lady with no *A. alternata* contamination, 1984 var. Sapphire with 10 per cent *A. alternata* contamination, and 1983 var. Sapphire with no *A. alternata* contamination after PCNB seed treatment. Pots of each lobelia seed lot were inoculated with *A. alternata*, either at planting or shortly after seedling emergence, by placing small pieces of *A. alternata* colonized MEA on the soil. The purpose of introducing laboratory-produced inoculum was to compare its disease-producing capacity with that of seed-borne inoculum. One pot of each seed lot was not inoculated. After one month of growth, the seedlings in each pot were graded according to the amount of seedling blight symptoms present.

Noninoculated seed lots known to be contaminated with *A. alternata*, 1984 var. Sapphire, displayed slight seedling blight symptoms while the noncontaminated seed lots, 1984 var. White Lady and 1983 var. Sapphire treated with PCNB, produced no symptoms of seedling blight (see table). As expected, all pots inoculated with *A. alternata*, regardless of seed source, developed symptoms of seedling blight (figs. 4 and 5) including wilting of leaves and brown discoloration of the lower stem. A small amount of *A. alternata* decreased seedling vigor, while heavy infection caused death. Pots acquiring A. *alternata* inoculum via seed contamination and inoculation showed more seedling death than pots receiving only one source of inoculum. The time of inoculation, either at planting or post-emergence, had no quantitative effect on seedling blight development by the time the experiment was terminated. However, symptoms of seedling blight appeared earlier when inoculation occurred at planting. A. *alternata* spores were consistently recovered from pots showing seedling blight symptoms.

A second experiment was done to confirm that *A. alternata* was the primary pathogen involved in lobelia seedling blight. Inoculation treatments were replicated on two seed sources, 1984 var. Sapphire and 1983 var. Sapphire. The 1983 seed source had been treated with PCNB. Five pots of each combination were planted for a total of twenty pots. Two weeks after planting, treatments were inoculated by putting one milliliter of an A. alternata spore suspension, produced according to the method of Shahin and Shepard (1979), directly on the soil. This inoculum dose contained approximately one billion *A. alternata* spores. The pots were covered with plastic to ensure that a high humidity was maintained, and after 34 days each pot was examined for blighted seedlings. Several seedlings from each pot were placed on MEA petri plates to confirm the presence of *A. alternata*.

The noninoculated 1983 var. Sapphire treated with PCNB developed no symptoms of seedling blight, indicating no inoculum present. No *A. alternata* spores were recovered from these pots. The 1984 var. Sapphire seed with no inoculation developed symptoms of seedling blight, due to the presence of seed-borne inoculum. All inoculated pots of both seed lots displayed symptoms of seedling blight, and A. *alternata* spores were reisolated from all pots with such symptoms.

Discussion

Alternaria alternata, generally regarded as a weak pathogen, can cause seedling blight of lobelia from seed-borne inoculum. In England, seedling blight has been reported to cause serious losses of lobelia bedding plants in some years (Hall and Taylor 1983). A survey by Hall (1978) found *A. alternata* contamination on 71 per cent of fifty-one lobelia seed lots, with an average of 27 per cent contamination on seed produced in England, 10 per cent contamination on seed produced in Canada, and 1.7 per cent contamination on seed produced in the United States. The lobelia seed produced in the United States had little *A. alternata* contamination with one exception: 1974 var. Sapphire seed had 15 per cent contamination (although 1973 var. Sapphire produced in the United States has 0 per cent contamination).

For lobelia seed lots contaminated with *A. alternata*, several effective seed treatments have been described. Aerated-steam seed treatment is recommended by Hall and Taylor (1983) for effective control of seed-borne *A. alternata* on lobelia. Aerated-steam seed treatment requires a specialized apparatus to apply aerated steam at 125°F for 15-20 minutes to lobelia seed lots. This treatment causes a slight delay in seed germination. Lobelia seed treatment with 0.2 per cent thiram suspension was also tested, but thiram seed treatment seriously delayed germination and did not consistently reduce *A. alternata* contamination (Hall and Taylor 1983). Iprodione (Rovral, manufactured by Rhone-Poulenc Inc.) fungicide is recommended for use against Alternaria sp. and is commonly used in England for treatment of lobelia seed before sowing (Taylor, personal communication*). PCNB (terrachlor) has been used for lobelia seed treatment in Alaska with apparent effectiveness, but no studies have been reported on the efficacy of PCNB seed treatment for control of *A. alternata* on lobelia.

Seedling blight of lobelia has been reported in Alaska in one incident in 1983 when seedling blight caused substantial loss of lobelia bedding plants, resulting in financial loss for lobelia production in that commercial greenhouse operation. Since many seed lots are not contaminated with seed-borne *A. alternata*, seed treatment of all lobelia seed is not necessary, though it is routinely done in England where seed-borne contamination is higher (Taylor 1984). Seed lots suspected of *A. alternata* contamination should be treated before sowing. If symptoms of seedling blight occur on lobelia seedlings, the affected flats should be removed from the greenhouse because *Alternaria* spores can spread to surrounding flats via air currents and water splashes. Lobelia seedings infected after emergence by spores produced on nearby plants may succumb to seedling blight under the stress of transplanting. If further use of a lobelia seed lot that produced seedling blight symptoms is planned, the remainder of the seed lot should be treated before sowing to reduce the effect of seed-borne *A. alternata*.

*Taylor, G.S. Professor, Department of Biology, University of Manchester, U.K. 1984.

Summary

Seedling blight caused by *A. alternata* is capable of destroying lobelia seedlings in the greenhouse. The best solution to the problem is to avoid the use of seed lots contaminated with *A. alternata*. Many lobelia seed lots have no *Alternaria* contamination, but contaminated seed lots can be treated effectively with iprodione or aerated steam before sowing. If lobelia seedlings show symptoms of *A. alternata* seedling blight, the affected flats should be removed from the greenhouse to prevent secondary infection of surrounding lobelia seedlings by *A. alternata* spores produced on the infected seedlings.□

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Intensive development along the lower Kenai River has spawned the need for recreation planning.

River Recreation Management Research

A Decision-Making Framework Applied to the Kenai River

By

Lee Westenburg* and Alan Jubenville**

Introduction

In 1983, in response to concerns about recreational demands that were being placed on the Kenai River, the Alaska Legislature mandated that a comprehensive management plan be developed for the Kenai River Special Management Area (KRSMA). In response, the University of Alaska-Fairbanks (UAF) School of Agriculture and Land Resources Management (SALRM) initiated a study of management strategies for the river, funded by its Agricultural Experiment Station. The purpose of the Kenai River Recreation Management Study (KRRMS) at UAF was to examine the perceptions the current river users have of potential management strategies.

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Background of Problem

The Kenai River system is exceptional, even by Alaska standards. It is characterized by superb biological and visual resources. The river's clear, turquoise water hosts eight runs of four Pacific salmon species as well as trophy rainbow trout and Dolly Varden. The Kenai mountains surrounding the upper river as well as the lowlands along the lower river support abundant wildlife, including bald eagles, migrating waterfowl, moose, caribou, wolves, furbearers, and other wildlife.

The Kenai River system is the most heavily used freshwater fishery in Alaska. The Kenai and its tributaries represent almost 16 per cent of the state's total recreational fishing effort, about 170,000 angler-days (Mills 1983). One out of every six anglers in Alaska fishes the Kenai drainage. Because of its accessibility and proximity to the port of Anchorage, the Kenai attracts visitors from all over the state, the nation, and the world. The Kenai River king salmon is the major attraction. The Kenai River king salmon sport fishery is the largest single-species sport fishery in the state, and use of this sport fishery has increased over 400 per cent in the past 10 years (Logan and Hammarstrom 1984). The Kenai River coho and Russian River red salmon sport fisheries are also major recreational attractions within KRSMA.

Recreational use of Alaska's rivers in general has intensified at a startling pace over recent years. The fundamental guidelines for policy and decision making for these waters have not been adequately formulated. The pressures that users impose on Alaska's river recreation resources are likely to continue to increase, emphasizing the immediate need for river recreation research to address policy and planning issues. If Alaska is to continue to provide the unique recreational opportunities for which it is renowned, a framework for addressing the management decisions spurred by this increased use is needed. This paper presents a general management framework and integrates this framework into the study of the Kenai River recreationists.

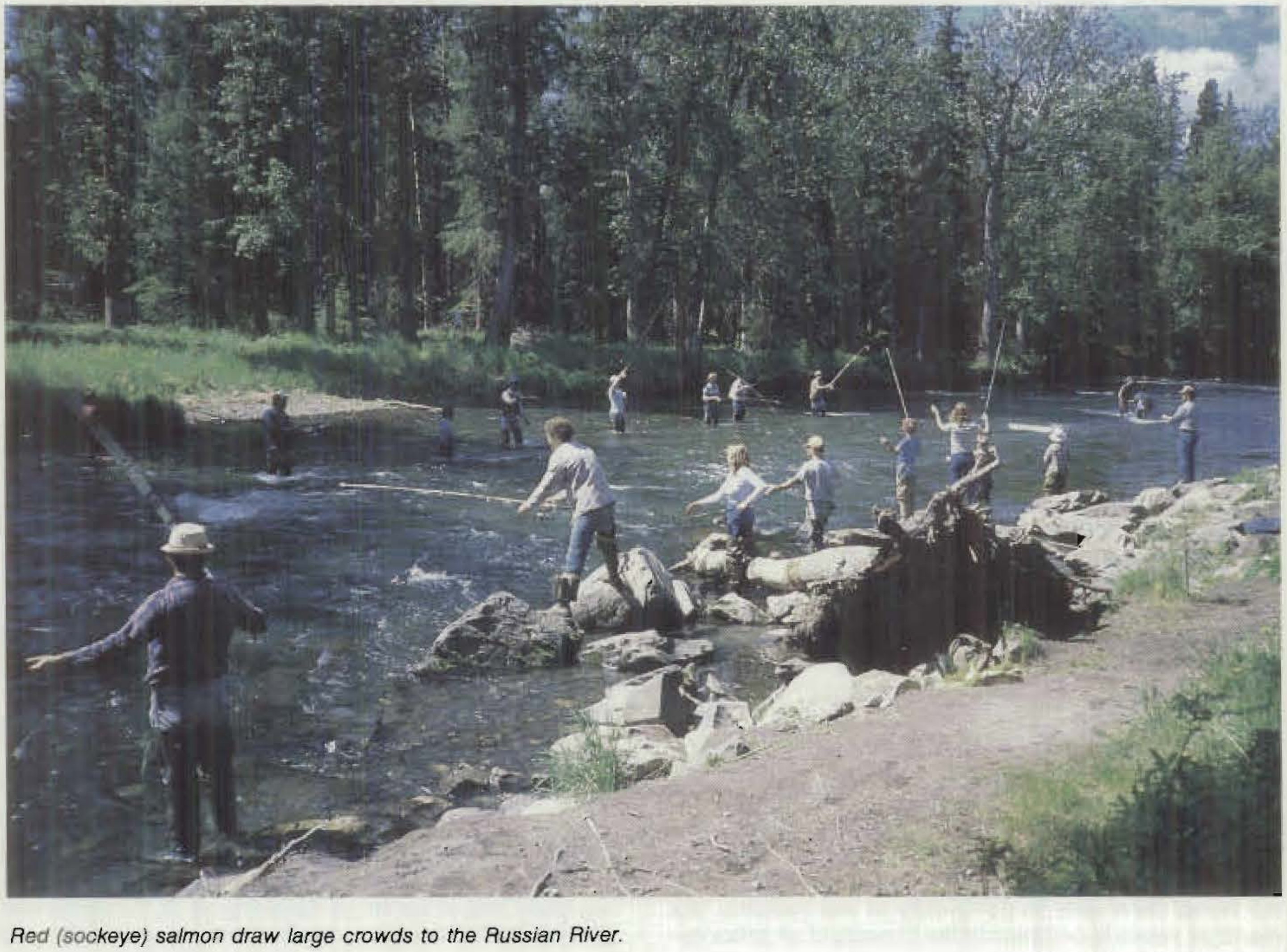
Canoeing, kayaking, and rafting are common activities on the upper Kenai River.

Research Response on Other Rivers

Intensive use of a river system is not a problem unique to the Kenai. There are many examples of controversies concerning river use throughout the Lower 48. The management approach for these waters has been, almost without exception, to stabilize levels of use at some number determined to be the "social carrying capacity" (Becker et al. 1984). Although this goal of protecting the resource is admirable, these limits and actions taken to implement them may differentially affect various subgroups of users and subsequently alter the aggregate user population. It is important that the manager understand the potential effects on the various subgroups of users before choosing a particular policy direction. It is not the aggregate population, but specific subgroups, which provide the important response to any proposed management action. Without disaggregation of the population and representative sampling within subgroups, the research results will often be of little value to the manager in his policy decision making.

The typical research design used to study these types of problems has been the one-shot case study—usually a survey of a given sample size of the aggregate user population (e.g. Schreyer and Roggenback 1978). The disaggregation of users for sampling purposes that has taken place has been based on the motivations of the individual, e.g. those who float rivers for nostalgic reasons (reminiscent of early explorations) versus those who do so for the sense of achievement. Graefe et al. (1984), in summarizing the previous twenty years of motivational research, concludes that motives for participation have not been shown to be linked to a given activity, environmental setting, or even to decision choices of the individual over time.

From a policy perspective, KRRMS attempts to overcome the deficiencies of other studies by trying to discern perceptual differences between various user subgroups. The research design developed in this paper should improve the managerial decision making because it is linked to the decision-making framework. It is the linkage of research to that framework that provides the focus of this paper. The novelty of river recreation management in the state of



Red (sockeye) salmon draw large crowds to the Russian River.

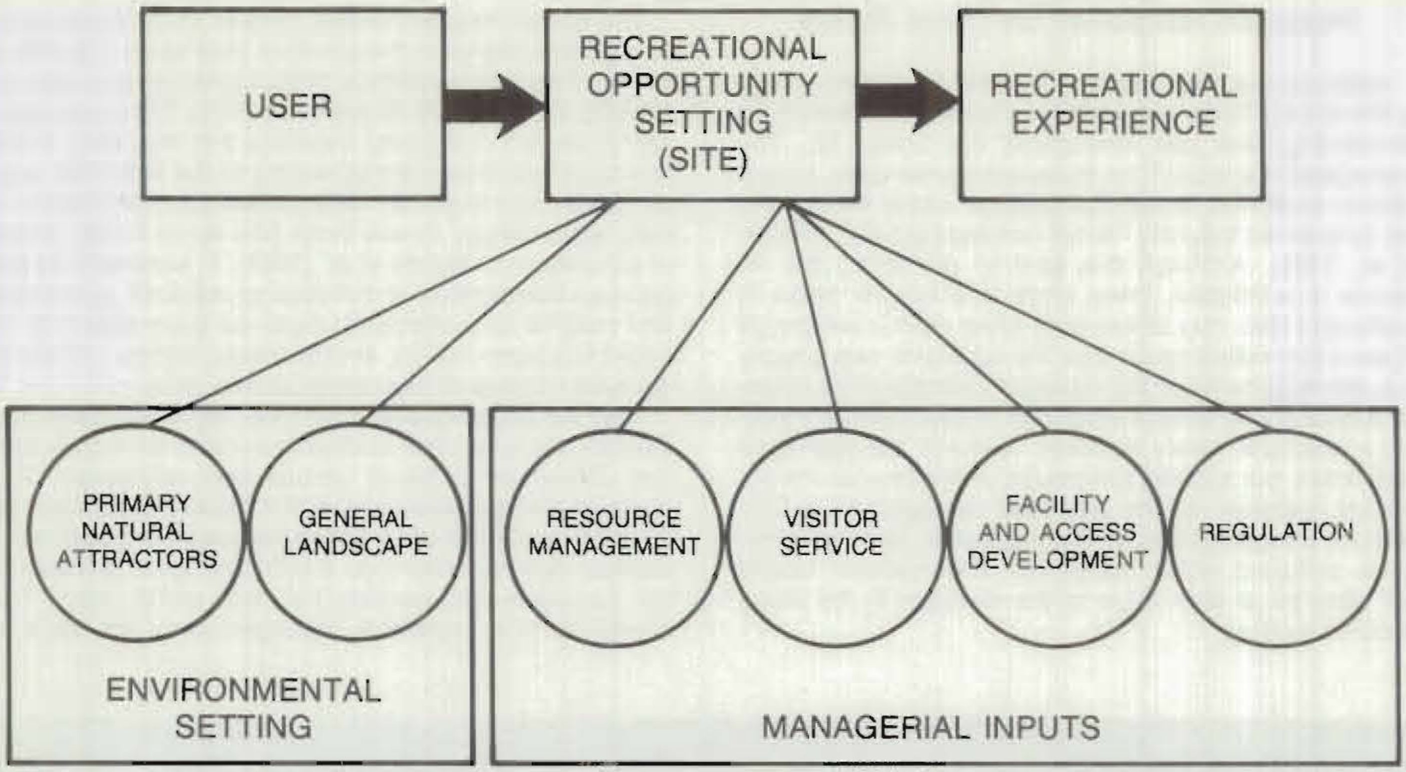


Figure 1. Recreation Management Model (Jubenville and Becker 1983).

Alaska and the precedents that will be set on the Kenai River make an understanding of the linkage between management action and user response even more pressing. This is especially true in light of recently proposed legislation that would expand management responsibility through the establishment of a State Recreational River System.

Decision-Making Framework

The decision-making framework is summarized in the following five steps:

1. Identify managerial inputs into the recreation site
2. Identify user subgroups on the Kenai River
3. Determine user response to management inputs by subgroup
4. Project effects of the various management policy options on the subgroups within population
5. Choose and implement policy option.

These five steps are a conceptualization of the process a manager goes through in choosing a given course of action. Depending on the relative significance of the particular problem or such constraints as a limited budget, the manager may not actually collect new data to assist him through the steps. However, for significant resources like the Kenai River with its complexity of use patterns, the manager needs to understand the impacts of all policy options. It is the researcher's role to measure empirically user response to potential management action and predict the impacts of the options. It is the manager's role to weigh the relative impacts and choose a course of action. The research design should incorporate the first four steps in order to be of assistance to the manager. These steps and the research methodology applied to each are presented in more detail below.

Identification of Inputs

A theoretical model identifying the inputs into a recreational setting is proposed by Jubenville and Becker (1983). This model, shown in Figure 1, presents two major sets of inputs. The first is the environmental setting. The primary natural attractors and general landscape characteristics determine the type of recreational setting that exists. The second set of inputs are managerial and are divided into four categories: resource-management programs, visitor services, facility and access developments, and regulations. On any river, the environmental inputs are considered as constants, therefore the only variable inputs that can affect the type of recreational opportunity offered to recreational users are the managerial inputs.

In terms of the environmental setting, the Kenai River originates in the eastern Kenai Peninsula of southcentral Alaska and flows westerly approximately 83 miles, entering Cook Inlet at the city of Kenai (figure 2). As mentioned previously, the Kenai River system is the most heavily used

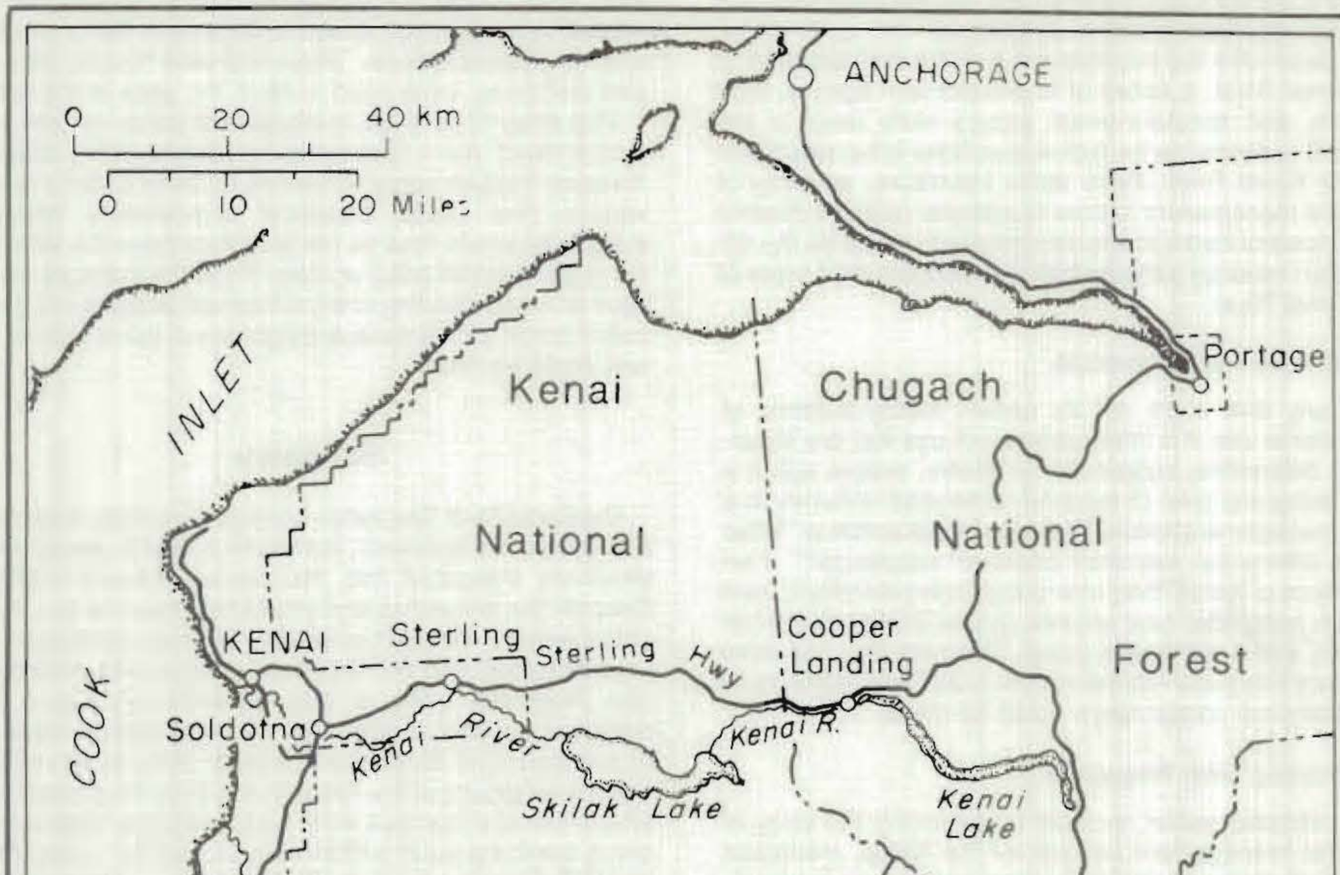


Figure 2. The Kenai River Study area.

freshwater fishery in Alaska, and the king salmon is the major attraction. The Kenai River silver and Russian River (a major tributary to the Kenai) red salmon sport fisheries are also major recreational attractions.

To determine the possible input to the management of the Kenai River, a series of interviews with agency, land owners, and special-interest groups were used in the KRRMS to determine the technical options to be considered for the Kenai River. From these interviews, an array of possible management actions to address various concerns were incorporated into a questionnaire to measure the differential response patterns between subgroups of users of the Kenai River.

Identification of Subgroups

On any river there will be certain macro patterns of recreational use; it is these patterns of use that are important in delineating subgroups. In theory, people within a given subgroup tend to respond somewhat uniformly to a given management action. The important question is "What is the differential response between subgroups?" Five subgroups of Kenai River user groups were identified: bank anglers, nonguided boat anglers, guided boat anglers, river floaters, and a composite group. The sampling was done to ensure adequate representation of all five subgroups so that statistical comparisons could be made.

Determining User Response

As indicated earlier, in order to determine the array of potential management actions for the Kenai, managers from all agencies having some responsibility for the lands and waters of the Kenai River system were interviewed to determine their concerns and possible options to address those concerns. Assuming that those options were based on real concerns, the aggregate responses should represent the array of management options for the Kenai River. Also, land owners and representatives of special interest groups were also interviewed to determine their concerns and considered options. These interview results, plus expert testimony, were used to fill in the gaps in the array.

This array of potential management policy options was incorporated into a questionnaire using a rating scale to measure the perceptual response to these options by the various river users. Statistical comparisons between subgroups would then be made to determine the differential response to all policy options. Thus, the manager would have an understanding of the differential impacts of a given policy option on the various subgroups of users prior to actual implementation.

Summary

The Kenai River Recreation Management study developed a new research approach, the results of which can be more effectively integrated into managerial decision making. Basically the research design incorporated the first four steps of the decision-making framework. The managerial options were identified, and the response by the various subgroups was measured using a mail questionnaire. Once the statistical analysis is done, the manager should have an understanding of the effects of a given policy option on the various subgroups of the Kenai River users. Weighing these effects on the subgroups while addressing the original concerns, the manager should be able to chart the future of the Kenai River more effectively. Furthermore, we think that this integration of research and management into a common framework should be considered in future recreation planning efforts within the state.□

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Predicting the Growth and Yield Of Interior Alaska Forests

By

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Introduction

Timber management in Alaska's interior, that area in which spruce-mixed hardwoods form the dominant forest vegetation, is in its infancy. Within this region are found three native conifers: white spruce (*Picea glauca* [Moench] Voss), black spruce (*Picea mariana* [Mill.] B.S.P.), and eastern larch (*Larix laricina* [Du Roi] K. Koch); eastern larch is also known as tamarack. The hardwood component of this region consists of four species: paper birch (*Betula papyrifera* Marsh.), quaking aspen (*Populus tremuloides* Michx.), balsam poplar (*Populus balsamifera* L.), and western black cottonwood (*Populus trichocarpa* Torr. and Gray). The last is found only south of the Alaska Range. Thus, there are seven native species which could be managed for fiber or energy production.

Often, it is suggested that nonnative species (exotics) should be managed. Successful introductions for fiber production are quickly identified elsewhere. Examples include: Monterey pine (*Pinus radiata* D. Don) from California to New Zealand, Caribbean pine (*Pinus caribaea* Mor.) to Brazil, and European larch (*Larix decidua* Mill.) to eastern North America. The failures are usually ignored, but include: Scot's pine (*Pinus sylvestris* L.) to eastern North America; Austrian pine (*Pinus nigra* Arnold) to eastern North America and the Pacific Northwest; Norway spruce (*Picea abies* [L.] Karst.) to the eastern United States; and eucalyptus (*Eucalyptus* spp.) to northern California, the Pacific Northwest, and southern British Columbia. Streets's (1962) monumental effort, *Exotic Forest Trees in the British Commonwealth*, describes the failures and successes of exotics. With this in mind, two species which are candidates for testing have a high probability for success in interior Alaska: lodgepole pine (*Pinus contorta* Dougl.), which grows in Yukon and does best on the coarser soils, and Siberian larch (*Larix sibirica* L.) from western Siberia and eastern Russia.

Comparing species options for timber production requires much thought. The quality and quantity of timber produced and made available for use are major considerations. In a previous paper (Packee 1984b), the five stages of forest production were identified along with many of the potential commercial products of each species native to interior Alaska.

The timber manager can use end-product information to select the species for management. However, he does not know what the future value of today's end products will be; for example, spruce siding may have been replaced by aspen waferboard siding. A second alternate is to grow those species which have the most options for end products.

Neither of the above alternatives has taken into consideration the growing capacity of the land. Commercial forest land is land capable of producing a minimum of 20 cu. ft. of wood per acre per year. There are 22.5 million

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acres of potential commercial forest land in interior Alaska, a large portion of which is not available for commercial timber harvest (Hutchison 1967). Only Georgia and Oregon have a commercial forest land base larger than that of interior Alaska (USDA For. Serv. 1982); their commercial forest land bases are 24.8 and 24.2 million acres respectively.

The actual capacity of the land to produce timber in interior Alaska is unknown. Limited growth and yield data are available for three species: white spruce, paper birch, and quaking aspen. These data are inadequate if one accepts the goal of timber management, "Produce maximum, practicable per acre yield of usable wood fiber."

Growth and Yield Program For Interior Alaska

In 1984, a growth and yield program was initiated for interior Alaska through the Agricultural Experiment Station, School of Agriculture and Land Resources Management, University of Alaska-Fairbanks (Packee 1984a). The objectives of the program are designed to meet the land manager's requirements to practice good timber management by utilizing all species available to him.

The program is ambitious. It has been broken into discrete project units aimed at providing answers for specific needs. Some may consider the size of the program staggering; however, the discrete units permit the orderly production of results for early use by land managers.

The goals of this program are to quantify the timber productivity of interior Alaska forest lands and to provide forest managers with appropriate equations, tables, and graphs essential for making decisions for basic, state-of-the-art timber management.

Specific project units and objectives are:

1. Years to Reach Breast Height: Determine the number of years required for each tree species to reach breast height for appropriate ecosystems and stand conditions.
2. Site Index: Develop appropriate polymorphic site index curves for each tree species using a standard index age at breast height.
3. Levels of Growing Stock: Initiate levels of growing stock studies for yield analyses for each tree species for a) plantation establishment, b) precommercial thinning, and c) commercial thinning.
4. Energy Values: Determine "correct" energy values for each species for representative Alaskan material.
5. Volume Tables: Test available, individual, tree-volume tables and/or develop individual tree-volume tables for each species.
6. Yield Tables: Develop natural and managed stand-yield tables for pure (80 per cent or more of one species) stands of appropriate species.
7. Growth and Yield Models: Assess growth and yield prediction models (equations) for use with Alaskan species and select the most promising for adaptation.

Years to Reach Breast Height

Breast height on a tree is accepted as 4.5 feet above the point of germination. Breast height represents the height at which most species have passed through the initial period of establishment and adjustment to a site, and most species do not exhibit their characteristic growth capability until they have reached at least breast height (Husch 1956). Breast height also represents a height at which trees have gained dominance over most competing understory herbaceous and woody vegetation.

Breast height is a standard height for diameter measurement and age determination in North America. In Alaska, Farr (1967) used breast height for his white spruce site index curves because early height growth is slow, total age (at ground line) is physically difficult to determine, and decay at or near ground level often eliminates core wood. Years to reach breast height may vary from stand to stand, due to differences in stand history (King 1966); for example, one stand might have had serious brush competition, another stand might have had none.

A major disadvantage of using breast height age is in determining the total age for the calculation of rotation age (the age at which the stand is ready to be harvested) and harvest scheduling. For successful plantations, knowing the planting date essentially eliminates the problem. In natural stands, age-correction factors must be used.

Determination of years to reach breast height provides information on the early competitive ability of each species, the average number of years to add to age at breast height in order to obtain total age, for matching species to site and identifying vegetation-management needs. Few data on years to breast height exist for most species in interior Alaska.

During the summer of 1984, young stands, generally under 15 feet tall, were selected throughout interior Alaska for sampling. On each site, environmental data were collected so as to relate growth to site conditions. Environmental factors considered include latitude, elevation, aspect, slope, landform, presence of permafrost, and vegetation.

At each site, ten saplings of each species present were cut at 6 inches above the point of germination. A stump height of 6 inches was chosen to represent the height of an established seedling, planted or wild; emphasis is on the concept that the seedling can grow freely. The lower 4-foot section was then cut from the sapling. These sample sections were then taken back to the laboratory for ring counting. The number of years to breast height is determined by subtracting the number of years at breast height (the top end) from the number of years at the butt end.

Preliminary results suggest that black spruce grows more slowly than white spruce and white spruce grows more slowly than tamarack. The hardwoods grow faster than the two spruces. This last observation suggests serious competition problems for white spruce where hardwoods are present.

Site Index

Site index, the height of a stand at a predetermined age, is still considered to be one of the best approaches for evaluating site productivity or site quality (Hagglund 1981). A typical set of site index curves is presented in Figure 1. The higher the site index, the more ideally suited is that site for production of that species.

Site index has general use in determining growth potential, land values, and practices employed in timber management. Site index commonly provides access to standard growth and yield tables (stocking, basal area, yield). Hence, accuracy of the site index curves determines their adequacy for management decision making.

Clutter et al. (1983) state:

The proper measurement and interpretation of site quality are important tasks for almost all forest managers. Product sizes and values at various ages are largely controlled by site quality and stand density. Certain investments that are fully justified on good sites constitute economic folly on less productive sites. Responses to certain cultural measures often differ dramatically among areas of unequal site quality. (p. 31).

Site index curves have been developed for white spruce (Farr 1967) and paper birch and quaking aspen (Gregory and Haack 1964a). Index age is different for each: breast height age 100 for white spruce, breast height age 50 for paper birch, and total age 50 for quaking aspen. These curves have not been tested independently. The sample size is small: 100 to 120 trees for white spruce, an undetermined number of trees for paper birch, and 43 trees for quaking aspen. By comparison, Carmean (1978) used 721 trees for sugar maple (*Acer saccharum* Marsh.), 483 for basswood (*Tilia americana* L.), 93 for paper birch, and 42 for aspen. He (1979a, b) recommends much larger samples for paper birch and aspen. Carmean's site index curves

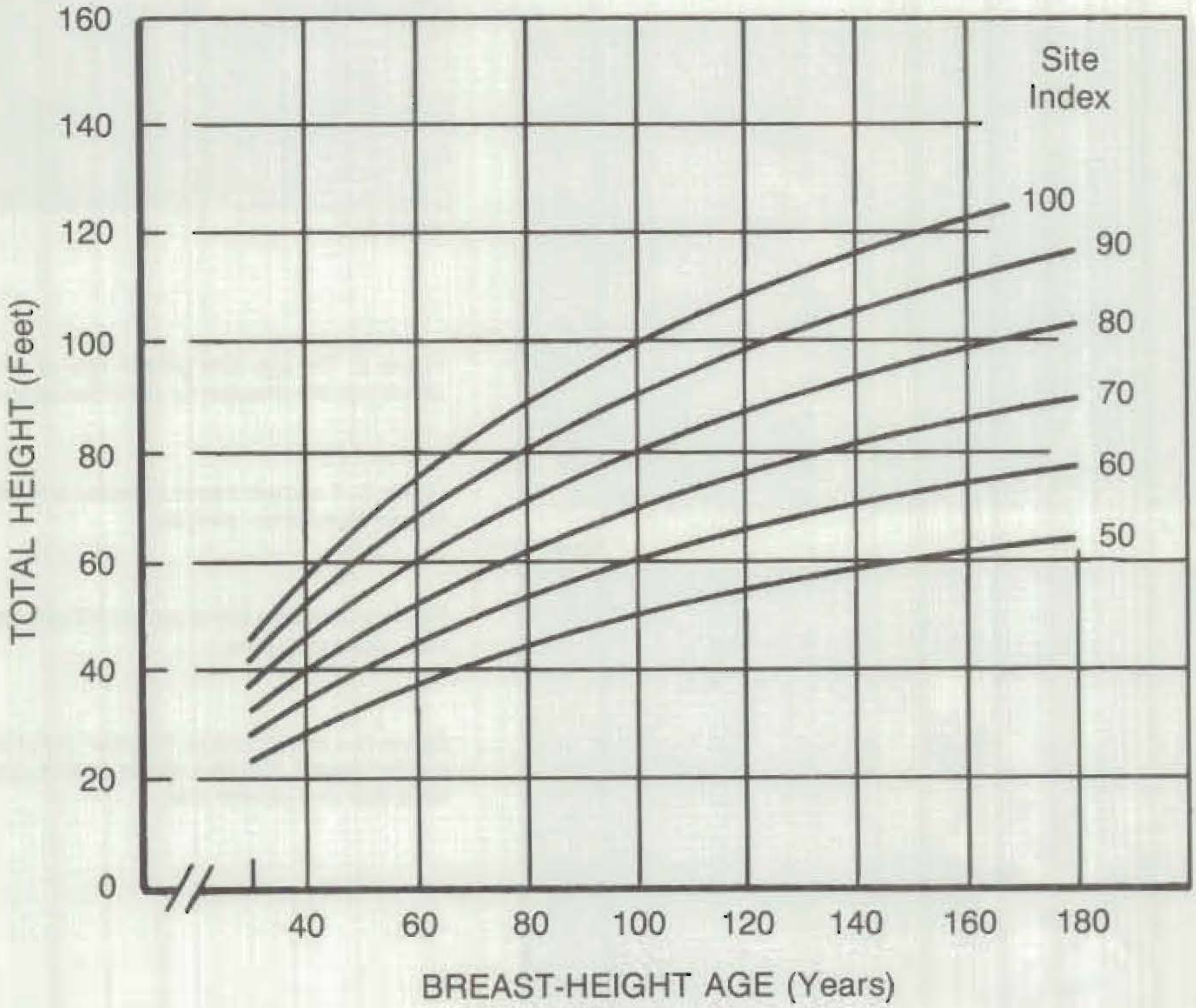

Figure 1. An example of site index curves; this set of curves is based on the curves of Farr (1967).

Figure 2

Figure 3

Figure 4

Figure 5

Figure 2. The age and growth rate of a candidate tree are checked for site index sampling.

Figure 3. A sample tree is selected and felled for site index stem analysis.

Figure 4. A sample tree is out into 4-foot lengths; note measuring tape.

Figure 5. A typical disk or "cookie" is cut from a 4-foot length. The disk will be used to determine age and growth rate.

were constructed for an area much smaller and environmentally more uniform than interior Alaska.

There are no local site index curves for the other species. At the present time, I know of no curves for balsam poplar and the only set of curves of which I am aware for tamarack are for Minnesota and are more than 25 years old (Gevorkiantz 1957) and of questionable methodology.

Sampling requirements for site index are more rigid than are those for sampling for years to breast height. A stand suitable for site index sampling must be even-aged for the species being considered, must have adequate stocking, must be relatively free of damage, and the candidate sample trees must be free-growing (that is, show no evidence of greatly reduced growth from competing vegetation). Figure 2 shows a member of the growth and yield crew checking the age of a candidate tree. Four acceptable dominant trees are located on a ± 0.1-acre plot, the site then is characterized environmentally.

The sample trees are felled (fig. 3) and sectioned into 4-foot lengths beginning with the 0.5-foot stump (fig. 4). A disk is cut from each section, (fig. 5) for age and diameter growth rate determinations. All disks from a single tree are taped together (fig. 6) and taken to the laboratory for accurate ring counts and diameter measurements. This procedure is referred to as stem analysis.

Figure 7 shows two disks; the larger is a 77-year-old white spruce that is 19 inches in diameter and the smaller is a 48-year-old tamarack, 9.5 inches in diameter. The white spruce is from a warm, upland loess site in the Rosie Creek area; the tamarack is from a permafrost, lowland muck site near Fairbanks.

The height of each section is plotted on graph paper to develop a height-over-age curve for each tree. Analysis of these curves identifies which ones can be grouped together; average curves for each group are then prepared. These are then smoothed to form the site index curves.

During 1984, our primary effort has been to obtain enough trees to develop site index curves for tamarack; preliminary curves should be available in late 1985.

Levels of Growing Stock

The level of growing stock is the number of trees evenly distributed on an acre. Volume of wood per acre and growth per acre are influenced by the available growing space utilized by the individual trees making up the stand. Within reasonable limits, the greater the amount of space available to a tree, the faster the tree will grow (Clutter et al. 1983).

The timber manager can control the growth of individual trees of a stand by manipulating the number of and distance between trees on an acre. Through such manipulation, the manager can alter total yield, tree size, thinning activities, and roatation age of a stand. Economic implications are substantial.

Table 1 provides an illustration of yield implications for white spruce in Ontario, Canada. Note that merchantable volume per acre decreases as the mean diameter at breast height (dbh) increases. Also, note that tree size and, hence, piece (log) size decreases with increasing number of trees planted per acre. Large piece size at harvest and low investment cost at time of planting may be highly desirable for a company involved only in sawmills; on the other hand, an integrated company which produces lumber and pulp may prefer the 6×6 or 7×7 spacing in order to obtain optimum per-acre yields to meet its fiber demands.

Stand density (stems per acre or basal area per acre) can affect height growth, diameter growth, and stem form. These factors control individual tree volume. Ultimately, stand density affects stand yield; however, this relationship is complex. Stand density can be manipulated at time of planting, at time of crown closure through a precommer-

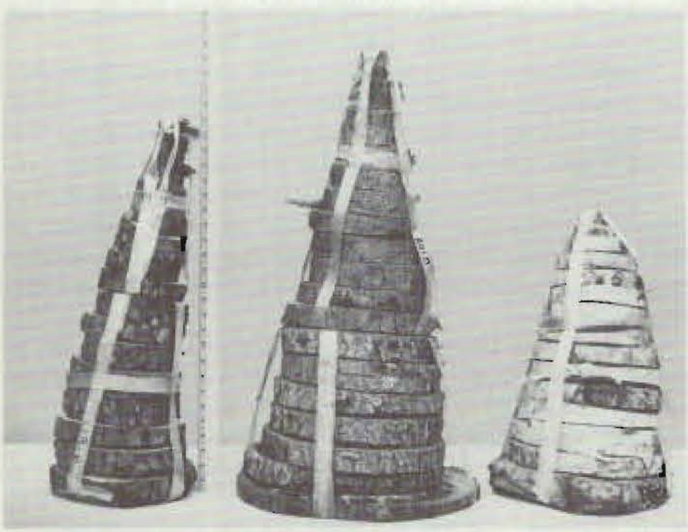

Figure 6. All "cookies" from each of three single trees taped together in sequence; the species shown here are: white spruce, paper birch, and tamarack.

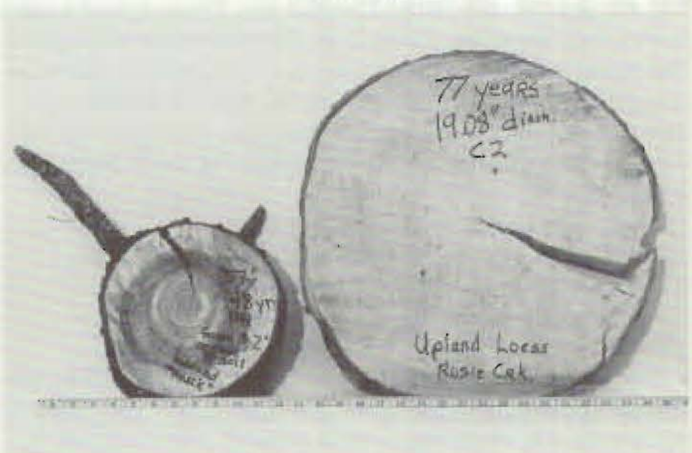

Figure 7. The larger of these two "cookies" is a white spruce, 19 inches in diameter and only 77 years old, from a highly productive site; the smaller is a tamarack, 9.5 inches in diameter and 48 years old, from a permafrost site considered to be "nonproductive forest land." Both cookies are from breast height.

Table 1. Yield table for 50-year-old, unmanaged, white spruce plantations (site index at 50-year breast height = 60) at Petawawa Forest Experiment Station, Chalk River, Ontario (Stiell 1976).

Spacing	No. planted		Yield: at 50 years			
					Volume	
	Stems/ acre	Stems/ acre	Mean dbh	Basal area	Total	Merchan-table
(ft)			(in)	(ft²/acre)	(ft³/acre)	
4×4	2733	1680	4.8	308	3942	3272
5×5	1742	1250	5.2	187	3560	3097
6×6	1210	980	5.7	172	3273	2880
7×7	889	790	6.1	160	3037	2703
8×8	681	650	6.5	149	2840	2556
10×10	436	436	7.4	128	2470	2223

cial thinning, and during later stages of stand development through commercial thinnings.

Priorities for levels of growing stock studies begun in 1984 and continuing through 1986 are emphasizing plantation establishment. Future studies will include manipulation of the growing stock of established stands including precommercial and commercial thinnings.

In the autumn of 1983, white spruce seed was collected by the public, a large amount of which is being used to reforest the Rosie Creek burn. An appropriate seedlot was selected for the first plantations of levels of growing stock. Tamarack seed was collected from a high-quality stand in the Standard Creek drainage by SALRM personnel. Seed was sown in early 1984 by Alaska Department of Natural Resources Division of Forestry's personnel at the state nursery in Eagle River. The seedlings will be ready for outplanting in spring of 1986.

Two sites were selected for these installations of levels of growing stock: the tamarack will be planted in the Rosie Creek area near the burn. The white spruce will be planted within the Bonanza Creek Experimental Forest on a broad, flat ridge within the Rosie Creek burn. The long-term plan is to establish at least twenty-one installations throughout the state: four for white spruce, four for tamarack, three for paper birch, two for balsam poplar, two for black cottonwood, two for quaking aspen, and four for black spruce. Five stocking levels will be compared at each plantation installation:

1) 4' × 4' = 2,723 trees per acre
2) 6' × 6' = 1,210 trees per acre
3) 8' × 8' = 681 trees per acre
4) 10' × 10' = 436 trees per acre
5) 12' × 12' = 302 trees per acre

Each installation requires a minimum area of 7.5 acres. Seedlings succumbing to early mortality will be replaced to ensure full stocking at each desired stocking level.

Plantations will be assessed for survival rates and height, and diameter measurements will be taken when seedlings are large enough. Such assessments will be made annually for the first five years and thereafter at five-year intervals. The collected data will be similar to that obtained by stem analysis without having to cut down the trees.

Table 2. Heat values for a standard cord for Alaska tree species; note the disagreement in BTU content and hence, ranking due to data source.

Species	Source[1]		Source[2]		Source[3]	
	BTU[2]	Rank[3]	BTU[2]	Rank[3]	BTU[2]	Rank[3]
Tamarack	24.00	103	23.87	89	25.30	96
Paper Birch	23.40	100	26.73	100	26.25	100
Black Spruce	19.10	82	20.53	77	19.09	73
Quaking Aspen	17.70	76	19.09	71	18.14	69
Balsam Poplar	17.20	74	19.57	73	16.32	62
White Spruce	16.20	69	17.66	66	19.09	73
Black Cottonwood	15.50	66	18.62	70	16.71	64

[1] Source: 1) Greaves and Schwartz (1951) citing Hale (1933) given for air-dry cord. 2) Greaves and Schwartz (1951) calculated from specific gravity. 3) Forest Products Laboratory (1974) calculated from specific gravity.
[2] BTUs expressed as 100 thousands.
[3] Rank = % of energy with paper birch = 100.

Energy Values

Although wood is an important energy source for Alaskans, the concept of energy yield per acre is frequently ignored by forest managers. Energy yield per acre is an important consideration in Alaska where annual harvests of wood for fuel are estimated to exceed 5 million cubic feet (60-70 thousand cords).

Commercially cut, stove-length firewood in the Fairbanks area typically sells for $65 to $115 per delivered cord. The price range reflects moisture content, prejudice against or preference for a particular species, length, and whether the wood is split or round. The consumer seldom considers accurate heat values of wood. Hence, paper birch frequently sells at the same price as spruce and occasionally spruce sells at a premium over paper birch. Ironically, white spruce has considerably fewer BTUs per cord than does paper birch.

Adding to the confusion is the lack of standard, reasonably accurate, energy values for each tree species. Canadian sources provide different energy values for the species than do those in the United States.

Regardless of stove efficiency and wood moisture content, the public should know energy values either in BTUs per pound or ton or per standard cord or per 100 cubic feet of solid wood of various species before purchasing.

The price of firewood should be comparable to that of other fuels based on BTUs per unit, i.e. cords, gallons, or tons. Similarly, the landowner or timber manager should be able to set the price for fuelwood stumpage on the basis of quality.

Table 2 provides relative, calculated heating values of the seven native tree species of interior Alaska. The relative values are based on a value of 1.00 for paper birch.

A preliminary search of the literature suggests the ranking: tamarack = paper birch > black spruce > quaking aspen = white spruce > balsam poplar = black cottonwood. However, once below black spruce, the rankings vary greatly.

If a more detailed search of the literature provides no additional information, then analyses to determine specific gravity and direct energy will be conducted. The latter procedure will use a calorimeter.

Once per-acre volumes for each species are predictable and the BTU value per unit for each species is available, the land manager can manage for energy production. Such information could affect drastically the level of growing stock for which he manages and increase the return on his investment.

Volume Tables

Individual tree volumes are basic to forest management activities. Stand volume is the sum of the volumes of the individual trees that comprise the stand (Cutter et al. 1983). Thus, yield tables, growth and yield prediction models, and simple comparisons of treatment affects require individual tree volume.

There are three common units of volume currently used in interior Alaska: board foot, cord, and cubic foot. The first two imply conversions to end products; the last is based on direct volumetric measurement of the merchantable or total stem.

Board-foot measure attempts to estimate the final yield of sawn lumber from a round, uncut log; at best it is a crude estimate which is not sufficiently accurate for industrial purposes (Young 1967). More importantly, the board-foot yield of an individual tree is highly dependent on how the tree is manufactured into logs, efficiency of the sawmill equipment, skill of sawmill crew (especially the sawyer), and market conditions (good markets encourage greater use of small pieces; demand for large timbers results in less sawdust).

Cords are a common measure for firewood, pulpwood, chemical wood, and material going into waferboard. Normally, timber is not measured in cords, but the volume is converted into cords. A standard cord occupies a space of 128 cubic feet, however, the solid wood volume in a cord is highly variable and can range from less than 80 to more than 90 cubic feet. Variability of the solid wood volume in a cord is due to diameter, length, straightness, and limbiness of bolts as well as care in stacking.

Cubic-foot volume is an attempt to estimate the amount of fiber in a tree available for conversion into end products. Cubic-foot volume has long been considered the best method of volume measurement; but Young (1967) warns that the magnitude of the errors that are possible by measuring volume in cubic feet can be large if proper care is not taken.

Inasmuch as the current trend in forest measurement is toward decreasing use of end-product units (board feet, cords) as measures of stem volume, the increase in weight scaling, and the increase in manufacturing for multiple products, cubic-foot volume appears to be the most utilitarian approach for volume tables.

Cubic-foot volume tables exist for white spruce, paper birch, quaking aspen, western black cottonwood (Gregory and Haack 1964b), and balsam poplar (Haack 1963). No tables are available for tamarack or black spruce. None of the tables have been adequately tested. There are concerns that the tables do not apply to a particular region. In comparing four sets of volume tables (Gregory 1960, Haack 1963, Gregory and Haack 1964a, Dippold and Farr 1971) for paper birch, one finds that differences of more than 500 cubic feet per acre, depending on tree size and number per acre, can occur. Table 3 provides a portion of a cubic-foot volume as an example of volume table.

The trees sampled for the site index unit of the growth and yield progam will be used as the initial data base. These data will be used to test existing volume tables and/or develop new tables.

The width of each annual ring will be measured to the nearest 0.01 inch on each disk from a tree. Measuring is done with a Bannister Incremental Measuring Machine under a low-power microscope. By adding together the width of rings for selected periods of growth, e.g. 0 to 5 years, 5 to 10 years, etc., the diameter of the tree is calculated for each period.

Volume of the tree is determined for a particular period by adding together the volume of each 4-foot bolt. The volume content of the bolt is calculated using Smalian's formula:

$$V = \tfrac{1}{2}\,(A_u + A_l)\,L.$$

Where:

V = bolt volume in cubic feet
A_u = upper end, cross-sectional area in square feet
A_l = lower end, cross-sectional area in square feet
L = bolt length, in feet

Using this method, tree volume to any specified top diameter, i.e. 6-inch, 4-inch, or tip can be determined accurately.

Using these derived volumes, currently accepted or available volume tables can be tested. The volume of the sample tree is simply compared to the volume presented in the table for a tree of the same size. Variations are statistically analyzed to determine the accuracy of the tables.

If no volume table exists or a new table is required, the sample size must be increased to provide adequate trees in all cells of the volume table (a cell being a particular diameter and height, e.g., in Table 3, a 10-inch dbh and a 70-foot height). Ideally there should be a minimum of at least five trees per cell for the typical range of tree diameters and height. This does not suggest that the sample size per

Table 3. Portion of a cubic-foot volume table for white spruce in the Kuskokwim River valley, Alaska (extracted from Dippold and Farr 1971).

DBH	Total height in feet				
(inches)	40	50	60	70	80
	(cu. ft.)				
6	2.6	3.4	4.2	—	—
8	5.0	6.4	7.7	9.1	—
10	8.1	10.2	12.3	14.4	16.5
12	11.8	14.9	17.9	21.0	24.0
14	16.2	20.4	24.5	28.7	32.8

cell is only five. Chapman (1921) states that, for a species: *"ten trees in each separate diameter and height class will suffice. This would call for a total of 500 to 2500 trees."*

In the case of tamarack, using height classes of 4 feet and diameter classes of 1 inch and assuming a height range of 40 to 80 feet and a diameter range of 4 to 12 inches, 250 to 400 trees will be required for accurate volume tables. However, using the preferred stem-analysis approach described above required sample size could be reduced to less than 200 trees without sacrificing accuracy and tables could be developed that are more precise.

Volume tables are the basis for timber inventories, yield tables, and growth and yield models. The more exacting the individual tree volume tables and associated equations, the more accurate are inventories and yield tables. Most large forest products companies have developed precise volume tables. For example, Weyerhaeuser Company (Wiley et al. 1978) developed volume tables for western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) using height classes of 1 foot for a height range of 20 to 190 feet and diameter classes of .1 inch for a diameter range of 2 to 40 inches. They have some of the most sophisticated and accurate yield tables and growth and yield models in North America.

Yield Tables

Yield tables provide expected volumes of wood per acre. They use stand characteristics which are easily measurable. Commonly, these variables include site index, stems per acre, age, diameters, and heights of sample trees.

Yield tables can be grouped into natural (even-aged and uneven-aged) and plantation (thinned and unthinned). Table 1 provides an example of part of a larger table showing variable density plantation yields. The part illustrated here is for site index 60: 50-year-old, unthinned, white spruce. Variable density refers to the number of stems per acre or basal area; there are six density levels in Table 1.

Construction of yield tables requires a large number of permanent sample plots; these plots are remeasured at regular intervals. The procedure will be discussed in a later issue of *Agroborealis*.

Growth and Yield Models

Models for predicting growth and yield are mathematical equations or systems of equations that provide total volume or value estimates per acre based on the level of inputs. The use of such models permits economic analysis, generates decisions concerning the optimum age at which to harvest, and provides estimates of response to certain treatments or combinations of treatments and the optimum timing of those treatments.

The only activity planned at this time is to determine what models exist and are most practical for interior Alaska. Along with this review, data requirements will be identified for inclusion in the permanent program showing sample plots.

Cooperation

The growth and yield program described above is truly cooperative in nature. It could not be done without a cooperative effort. Cooperators include USDA Forest Service Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry; the Alaska Department of Natural Resources Division of Forestry; the USDI Bureau of Land Management; the Fairbanks North Star Borough; the Matanuska-Susitna Borough; the USDD Fort Wainwright; the Toghotthele Corporation; Doyon, Limited; Alaska Gold Company; and several other small corporations and individuals. As the program develops, we anticipate that more cooperators will join the effort. The number is small because we have limited our contacts during the first season to those organizations and/or individuals whose land is readily accessible.

In the future we hope to increase the number of cooperators. The benefit to cooperators is the applicability of data and results to their lands.

Funding for the program includes University of Alaska appropriations, McIntire Stennis funds, and Alaska Division of Forestry. In addition, various organizations and individuals have volunteered their time. Present available funding will permit the accomplishment of 55 per cent of planned goals on schedule. Additional funding source are being investigated.

Summary

The program for studying growth and yield at the Agricultural and Forestry Experiment Station of the University of Alaska is designed to provide basic quantitative data for decision-making by timber managers in interior Alaska. It consists of seven units or projects. Whenever appropriate, data gathered for one unit will be utilized in other units. This will result in lower costs, shorter time periods required to acheive goals of some units, and a more comprehensive database.

Where appropriate, field data are being tied to obvious environmental characteristics. Hence ecological impacts on growth and yield can be described and incorporated into tables and models for growth and yield.□

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Mycorrhizae

A Review of the Importance of Fungi From High-Latitude Forests of Alaska

By

Gary A. Laursen*

Introduction

Virtually all cone-bearing trees of the boreal forest that extend into many parts of Alaska, including interior forests, (fig. 1) demonstrate the delicate and often poorly understood fungus (mykes)-plant root (rhiza) relationships termed *mycorrhizae*. Documentation of these relationships between fungi and plants has only been made for Sitka and white spruce in Alaska (Shaw et al. 1982). However, in my work I have demonstrated their presence in seven ericoid (heath) species that include the alpine azalea (*Loiseleuria procumbens*), bearberry (*Arctostaphylos alpina* and *A. uvi-ursi*), Labrador tea (*Ledum decumbens* and *L. groenlandicum*), the bog blueberry (*Vaccinium uliginosum*), and the lowbush cranberry (*V. vitis-idaea*).

Of course, consideration only of conifers and ericaceous plants excludes a whole group of other plant species to be found in Alaska's interior. It is inferred from the literature that 90 per cent of these other Alaskan species participate in vesicular-arbuscular mycorrhizae, which contribute significally to nutrient absorption, storage, and release within the host's roots (Kendrick 1984). This belief extends to the world's more than 300,000 plants as well.

In this paper, we will focus primarily on the inferred relationships most surely demonstrated by some larger (macro) fungi found in high-latitude Alaskan forests.

The higher fungi consist primarily of many species comprising two major groups (classes): the mushrooms and toadstools (Basidiomycotina) and the cup fungi (Ascomycotina). Both groups of fungi are represented in forest, muskeg, alpine, and Arctic tundra habitats of Alaska's huge interior. It is reasonable to estimate that there are about 750 higher fungi to be found in Alaska's boreal forest. These are approximately the same species found

Figure 1. A mature white spruce forest ecosystem (Bonanza Creek Experiment Forest) in the Alaskan interior where many species of epigeous and hypogeous macrofungi fruit and are in mycorrhizal association with over- and understory plants, 25 miles south of Fairbanks, Alaska. (Photo by R.A. Mowrey)

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typically in similar forest environments across Canada and the northern United States. It is also suspected that several new species of fungi from Alaska will be found and are yet to be described. However, many of the fungi are commonly associated with the vascular plant species that also constitute components of the boreal forest found in Alaska.

Hultén (1968) describes 1,974 taxonomically distinct vascular plants belonging to 1,559 species, 412 genera, and 89 families from Alaska and Yukon, many of which are to be found in Alaska's interior. Most, if not all, of these plants have become hosts with which the higher fungi (mycobionts) are associated.

Fungi-vascular plant associations are usually divided into four categories, also common in forests of interior Alaska. This first article in a series of four deals only with the mycorrhizal (Greek:mykes = *fungus*, + rhizae = *root*) association. Those to be discussed in subsequent issues of *Agroborealis* are: *parasitic* fungus associations, in which the host vascular plant is typically harmed by the fungus; *saprophytic* fungus associations, in which the fungal mycelium (the fungus plant body) consists of a mass of tubes (hyphae) of microscopic proportions that permeate a substrate by producing degrading enzymes that digest organic litter and other substances in, on, or above the soil with which the mycelium comes in contact; and *pathogenic* fungus associations, a group which coincides with members of parasitic groups but which usually kill their hosts (Laursen and Chmielewski 1982).

Mycorrhizal Association

Background

The concept of mycorrhizae was initially suggested by Vittadini (1842) who first considered the idea ten years earlier. It wasn't until Frank (1885) coined the term 'mycorrhiza' that this symbiosis became a widely known concept. Much later, Hacskaylo (1972) termed this association 'reciprocal parasitism.' Biologically, the newly described phenomenon dates back some 400 million years to the Devonian period of the Paleozoic era. Fungal hyphae have been found in fossil roots and root-like rhizoids of several plants (Trappe and Fogel 1977).

Researchers have argued over what constitutes the mycorrhizal association in relation to host-fungus interactions. Some researchers argue that such associations are mutual, while others argue for parasitism (Marks and Foster 1973). Still others differ as to whether or not these associations are obligate or facultative. One essential fact remains: Mycorrhizae are part of a desirable and necessary biological water- and nutrient-gathering relationship for a wide variety of vascular plants (Marks and Foster 1973).

It has been reported that, of the flowering plants that form mycorrhizal associations, all but two families are represented. Some lycopods, ferns, and mosses also demonstrate these associations. Flowering plants of some importance that do not host mycorrhizae are the 7 genera and 223 Alaskan taxa of sedges (Hultén 1968) that are frequently found growing in standing water or in wet soils. Species of the mustard family, many of which are economically important vegetables in Alaska and include the cole plants, typically do not have mycorrhizal associations. Fungi which form mycorrhizae are aerobic organisms which, therefore, could not survive in association with root-soil systems which are continually inundated or embedded in anaerobic soils; hence, such fungi are not found in association with most sedges; neither are they found in the rapidly growing and often central tap and storage root systems of species in the cole plants, which fact raises some question.

It has been suggested that fast root growth may inhibit infection. Further, it is not known whether the aquatic flowering plants in Alaska, such as cattails, burr weeds, and pond weeds, demonstrate mycorrhizae. These plants feed oxygen to their roots by means of specialized air cells; hence, fungi could survive. But Alaskan species have simply not been examined critically for infections. Other plants, such as Alaska cedar, Western red cedar, and juniper that are found on wet, mesic to dry sites, all have mycorrhizae. In contrast to herbaceous plants, virtually all woody plants require mycorrhizal fungi for survival.

Generally, soils exposed to high or prolonged light intensities and which possess low nutrient status favor the development of mycorrhizae. The conditions of prolonged light and low soil nutrients are found in the Alaskan interior during the spring and fall, the times when mycorrhizae are forming.

In forest soils of interior Alaskan birch/aspen forests, as in most other soil and litter types, there exists a resident biomass of living fungal hyphae that form masses of microscopic tubes that permeate virtually all upper substrates within the soil profile (Moore 1985). Fungal hyphae release enzymes, such as chitinase, peroxidase, cellulase, and protease, which allow them to digest and penetrate substrates. These secretions aid the chemical breakdown of tough organic substances that, once chemically decomposed, are absorbed and used by the fungus and/or host plant as energy and nutrient sources for growth and reproduction. Once absorbed by the fungi into single-celled filaments or into multicelled tubular hyphae called rhizomorphs, the nutrients are transported for use elsewhere or stored (Melin and Nilsson 1958). Thus, the fungi become important contributors to the degradation and decomposition of organic substances. The result is the translocation of those absorbed nutrients to sites of storage and utilization.

Any one plant may be infected by many species of mycorrhizal fungi. Further, a particular fungus may infect many plant species. It has been speculated that fungi may connect a series of trees of similar or different species to one or more nutrient sources. Fungi do absorb soil nutrients in solution to be translocated, a vital and necessary function for survival, particularly in nutrient- and climate-stressed environments.

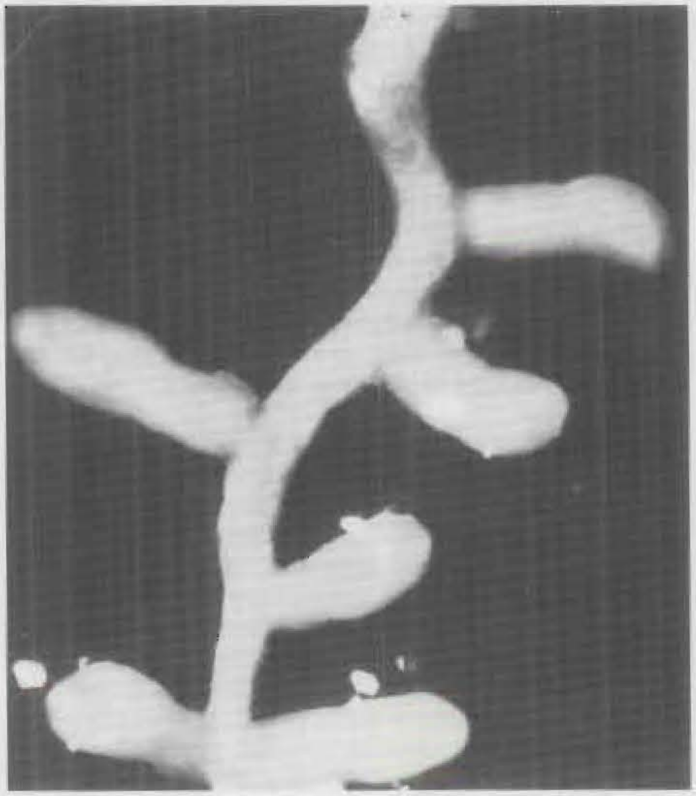

Figure 2. Pinnately branched ectomycorrhizal rootlets of the dwarf Arctic willow Salix pulchra, *Barrow, Alaska.*

Contributions of the Fungi to the Association

Until recently, mycorrhizae were thought to benefit the host only by improving the ability of the host to absorb added moisture and nutrients. However, many important functions of mycorrhizae are now recognized.

The associated fungus (mycobiont) extends the root system, often to great distances beyond the host plant. This increases the penetration of the root system into nutrient-holding substrates beyond nutrient-depleted soils nearer the actual roots of the host plant. In this way, the absorptive surface area of the roots of the host plant is increased tremendously. The fungus also increases the permeability for absorbtion by host root cells. Fungal hyphae absorb and translocate water, minerals, and nutrients contained within soil solutions. Most are in the form of positive or negative ions.

Of considerable importance are the fungi-produced enzymes, i.e., pectinase and cellulase. They are used to dissolve host plant glues and cellular components to allow fungal penetrations for nutrient injection into the host plant. Fungi-produced auxins and vitamins stimulate root growth, size, and longevity; cytokinins stimulate cellular division; and inhibitors, such as hydroxybenzyl alcohol, protect roots from secondary invasion by soil invertebrates, bacteria, actinomycetes, and other potentially harmful or competitive soil fungi.

Contributions of the Host Plant to the Association

The host plant produces an attracting agent referred to as the 'M' factor named for Professor Melin, a Swedish physiologist. He identified and demonstrated the agent produced by host-plant roots that chemotropically attracts soil-borne mycorrhizal-forming fungi. The plant contributes in other ways by providing vitamin B and photosynthetically produced carbohydrates directly to the fungus.

Types of Mycorrhizae

The existence of mycorrhizal fungi, both epigeous (above ground) and hypogeous (below ground), is well known and documented for many North American higher plant communities (Hacskaylo 1973, Hacskaylo and Thompkins 1973, Harley 1959, Marks and Kozlowski 1973, Schenck 1982).

Mycorrhizal form and function lead continually to questions that ultimately become focal points for exciting research. They exist as one or more of three basic forms, i.e., ectomycorrhizae, ectendomycorrhizae, and endomycorrhizae.

Ectomycorrhizal Associations

Ectomycorrhizal associations, as defined by Peyronel et al. (1969) include root-surface fungi that may involve saprophytes, potential parasites, and mycorrhizae formers. Truly ectomycorrhizal associations are characterized by having a prominent mantle (40-300 mm) of fungus hyphae covering the slow-growing, succulent, unsuberized vascular plant roots. These roots are pinnately (fig. 2) and dichotomously branched (fig. 3). Hyphae from the mantle

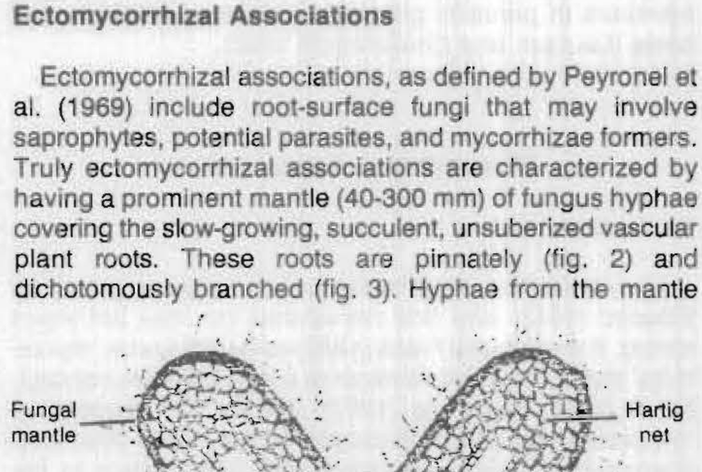

Figure 3. A typical, dichotomously branched schematic of an ectomycorrhizal rootlet demonstrating external hyphae, the fungus mantle (sheath), and the Hartig net. (Redrawn after F.F. Sanders)

Figure 4. An unsuberized rootlet of S. pulchra, *an Arctic willow, in cross section, demonstrating the thick, white fungus mantle.*

penetrate the root and pass between cortical cells by dissolving the middle lamella (figs. 4 and 5). Cortical cells typically are not penetrated and intercellular penetration into the host cortex proceeds to varying depths. Hyphae do not penetrate nor go beyond the endodermis and into the inner cylindar of the central root. This intercortical cell network of hyphae is termed the *Hartig net* (fig. 5).

The morphologies of ectomycorrhizally infected roots vary considerably (Marks and Foster 1973). Generally, the roots are thicker, more brittle, and differently colored than uninfected roots. Rootlets often exhibit characteristic branching that include pinnate, racemose, or dichotomous patterns. Thickness varies from a thin hyphal mass to a thick (100-300 μm) mantle. The mantle affects the soil fungus-root zone (geomycorrhizosphere); it is a rich site in, on, and around which bacteria, algae, and other fungi live. Thus, the surface of the mantle provides a complex ecological habitat for other soil-inhabiting organisms too.

Woody plants of Alaska that have ectomycorrhizal associations are alder and birch (Betulaceae); some heaths (Ericaceae); true fir, hemlock, larch, pine, and spruce (Pinaceae); and poplar and willow (Salicaceae). Ectomycorrhizal associations with these plants are known to exist throughout Alaska, including Alaska's Arctic (Laursen and Ammirati 1982).

Our investigations have shown that many species of mycorrhizal fungi form large fruiting bodies (mushrooms and toadstools) that are abundantly produced in forests of interior Alaska. They exist both above and below litter layers on the forest floor. Although most mycorrhizae-forming fungi are difficult to culture, some of the same or similar

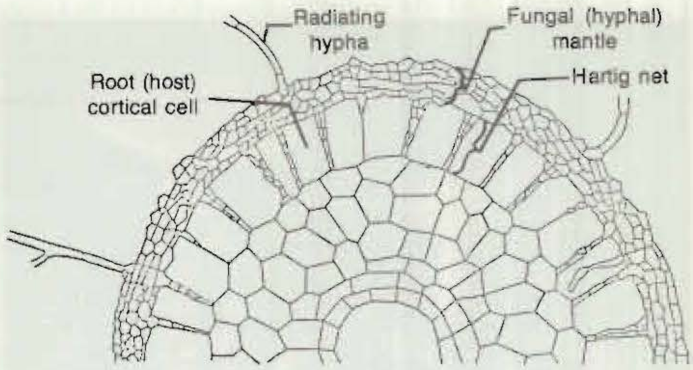

Figure 5. A cross-sectional schematic of an ectomycorrizal root showing external hyphae, the thick mantle, and intercellular Hartig net formation between cortical cells. (Redrawn after J.L. Harley, 1965)

species to those found in Alaska have been successfully isolated, cultured, and used for reestablishing mycorrhizal symbioses using *in vivo* techniques (Antibus 1980).

It is through mycorrhizae that many of the edible and poisonous mushrooms and/or toadstools make a significant contribution to interior Alaskan forests. Many species are ectomycorrhizal mycobionts. Those above ground typically belong to groups of fungi termed: agarics, those having gills (figs. 6 and 7), boletes or sponge mushrooms (figs. 8-10), puffballs or powder sacs (fig. 11); and the cup fungi (fig. 12). Those below ground constitute the false truffles (club fungi) (figs. 13-15), and true truffles (sac fungi) as shwon in Figures 16 and 17.

Ectendomycorrhizal Associations

These associations are characterized by having thin (10-40 mm) mantles, a loose weft (cotton-like), or single hyphal strands; a reduced Hartig net; a poor dichotomy in rootlet branching; and, ultimately, inter- and intracellular penetration and proliferation of fungal hyphae into and around cortical cells. At best, it is an association that is often difficult to demonstrate, even though somewhat common in taxa of the heath (Ericaceae) and pine families (Pinaceae).

Fungi of this group are very similar to those forming ectomycorrhizae in that certain species of agaric (*Amanita* and *Cortinarius*) and bolete (*Boletus*) fungi demonstrate this relationship.

Endomycorrhizal Assocations

Endomycorrihzae are found to penetrate cortical cells (figs 18 and 19). Root surface evidence of their presence may only mean the existence of a few hyphae along the root's surface. Typically, endomycorrhizae have been grouped into two basic forms: those that have septate hyphae and those whose hyphae are essentially without compartmentalizing septa (coenocytic).

Figure 6. A typical agaric Amanita (A. *muscaria*), *similar to those that may form "arbutoid" endomycorrhizae.*

Figure 7. A typical Cortinarius (C. subtorvus), *similar to the fungi that may also form 'arbutoid' endomycorrhizae. Driftwood, Alaska.*

Figure 8. A typical bolete, Boletus (B. edulis), *similar to the fungal group that may form "arbutoid" endomycorrhizae, Eagle Summit, Alaska. (Photo by O.K. Miller)*

Figure 9. The bolete Suillus grevillei, *an ectomycorrhizal associate found only with larch (tamarack)* Larix laricina *in interior Alaska. North Pole, Alaska.*

Figure 10. The bolete Leccinum scabrum, *an ectomycorrhizal associate found with dwarf birch* (Betula glandulosa *and* B. nana)*in Arctic and subarctic muskeg habitats. Driftwood, Alaska.*

Figure 11. An earthstar (puffball relative) Geastrum saccatum, *known for its ectomycorrhizal association with members of the Pinaceae. Blacksburg, Virginia.*

Figure 12. The cup fungus Helvella corium, *known to form ectomycorrhizae with the dwarf willow* Salix rotundifolia. *Barrow, Alaska.*

Figure 13. The false truffle (basidiomycete) Alpova diplophloeus *forms ectomycorrhizal associations with deciduous tree species in interior Alaska, Fairbanks. (Photo by T.A. Moore)*

Figure 14. Gautieria otthii, *a false truffle ectomycorrhizal mycobiont found in association with white spruce. Fairbanks, Alaska.*

Figure 15. Gautieria graveolens, *a false truffle that also forms ectomycorrhizae with white spruce in interior Alaska, Fairbanks.*

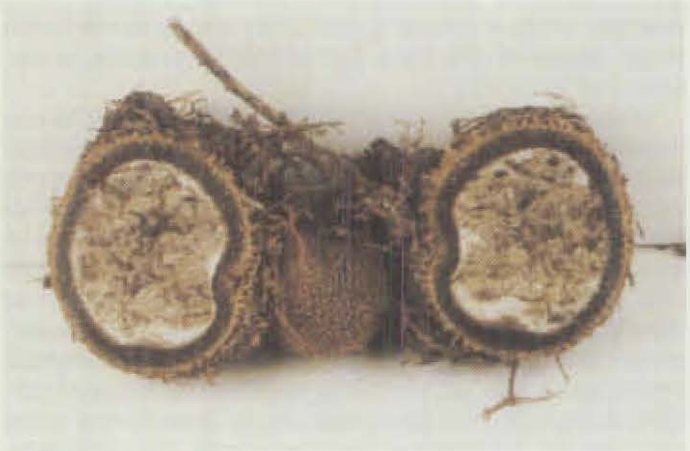

Figure 16. The true (nonedible) truffle, Elaphomyces muricatus, *that is found in association with black spruce. Fairbanks, Alaska.*

Figure 17. The edible true truffle, Geopora cooperii, *an ectomycorrhizal associate with paper birch* (Betula papyrifera). *Fairbanks, Alaska.*

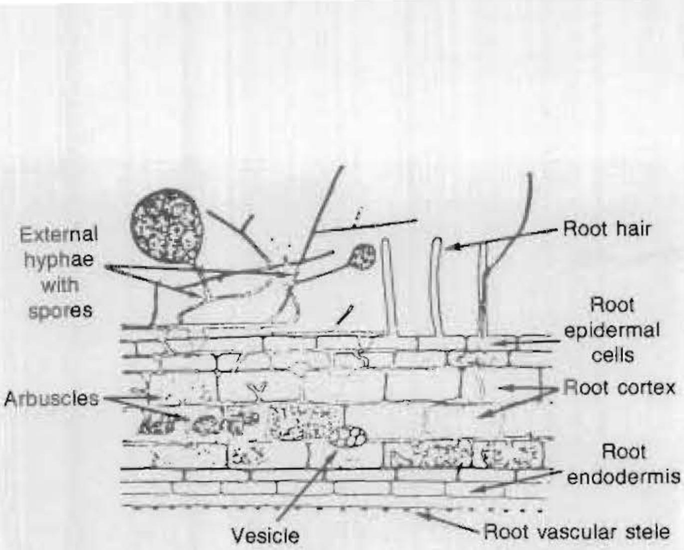

Figure 18. A schematic of typical endomycorrhizal infections that demonstrate arbuscules (branched dendritic haustoria), vesicles (swellings), and external hyphae and spores. (Redrawn after F.F. Sanders.)

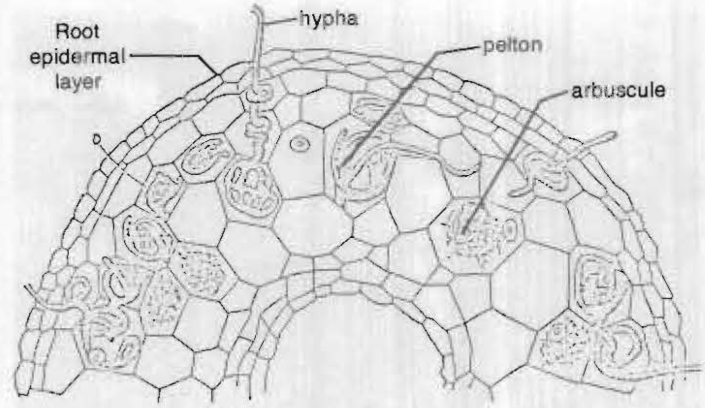

Figure 19. A schematic cross-section of an endomycorrhizal infection demonstrating fungal penetration into cortical cells, peltons (coils), and intracellular digestion of the hyphae. (Redrawn after J.L. Harley, 1965, Ecology of soil-borne plant pathogens-prelude to biological control. LA: UC Press.)

Septate endomycorrhizae are further subdivided into three types: the "arbutoid," "ericoid," and "orchid" forms. Some arbutoid and ericoid mycorrhizae are placed into ectendomycorrhizal or even into ectomycorrhizal groups by some authors. It is from our lack of knowledge and understanding that such confusion has resulted, and more study is needed. The relative but significant importance of ericoid mycorrhizae to ericaceous plants is essential to continued subsistence-gathering activities. Infected plants include the Alaskan, bog, dwarf, and early blueberries; the bog and mountain cranberries; and the huckleberries. The Labrador teas, rhododendrons, bearberries, azaleas, kalmias, bilberries, and heathers are also dependent on this type of mycorrhizal association.

Arbutoid: This endomycorrhizal type has been reported from work on a number of genera within the heath and closely related families, none of which are reported from Alaska. The only arbutoid host genera common to Alaska are blueberries (*Vaccinium*) and bearberries (*Arctostaphylos*). Reports of arbutoid mycorrhizae have not yet been made from Alaska in the open literature.

The arbutoid type is transitional between ecto- and endomycorrhizae. They are characterized by having: 1) a fungal mantle or sheath, however thin, surrounding the infected rootlets; 2) intracellular fungal penetration; 3) the development, in some cases, of an intracellular network of hyphae (not to be confused with the intercellular Hartig net of truly ectomycorrhizal types); and 4) root dimorphism that may or may not be present. Species of fungi known to form 'arbutoid' endomycorrhizae belong to fungi in genera containing some poisonous mushroom species such as *Amanita* (fig. 6), *Cortinarius* (fig. 7), and the edible *Boletus* (fig. 8) (Cox and Sanders 1974, Kinden and Brown 1975).

Ericoid: This mycorrhizal type occurs throughout the hairlike root system of members of the heath family. Hyphal strands or fungal wefts develop on or in close proximity to root surfaces. Epidermal and cortical cells are penetrated. The fungi ramify within cells to form coils or knots called peltons that fill much of the vacuolated lumen. But once again, the central vascular cylinder (stele) of the root is not invaded by the fungus. Only one form of ericoid endomycorrhizal fungus has been successfully isolated, grown, and fruited in culture (Pearson and Read 1973). This cup fungus was identified as *Pezizella ericae* Read sp. nov. (Read 1974).

Orchid: This type of mycorrhizae is found in symbiosis with members of the orchid family and have been identified as being the most complex. Fungi found in association with this group of plants belong to the form genus *Rhizoctonia* which belongs to the form order *Mycelia sterilia* because species have been observed to produce no asexual or sexual structures and spores, only vegetative hyphae. Cultural characters of their mycelium simplify recognition. Perfect (sexual) stages of other similar fungi have since been found. These fungi were found to belong to the jelly fungus genera *Ceratobasidium, Sebacina,*and *Tulasnella* (Hadley 1975, Warcup 1975). A jelly fungus of close affinity to the above three genera of jelly fungi, but of another species, is pictured in Figure 20.

True endomycorrhizae of the second type, those having nonseptate hyphae, often form swellings (vesicles), dichotomously branched trees of hyphae called haustoria (arbuscules) (fig. 18), or coiled single hyphal strands (peltons) (fig. 17). These hyphal structures are formed inside host cortical cells, root-hair cells, or epidermal cells of fine roots. The presence of vesicles and arbuscules has resulted in terming those infections vesicular arbuscular-mycorrhizae. It is interesting to note that all three internal hyphal cell types are ultimately digested by the host cell. Most flowering and many lower plants demonstrate these associations. Members of the heath family, the pea family, many grasses and their allies, Indian pipe, orchids, wintergreen, and the rose family that typically host this association are all found in Alaska. However, this associa-

Figure 20. A typical jelly fungus (Tramella) and a distant cousin to those forming "orchid" endomycorrhizae. Big Fork, Montana.

Figure 21. The agaric mushroom, Armillaria mellea, *that forms endomycorrhizal associations and also a virulent root rotter of conifers in interior Alaska. Blacksburg, Virginia.*

tion with the lower mycorrhizal fungi belonging to the phycomycetes and zygomycetes are still to be described from Alaskan plant roots: compressed leaf conifer family members, including red cedar, Alaska cedar, and junipers, also demonstrate this dependent relationship.

The agaric fungus *Armillaria* (fig. 21) and species of jelly fungi, *Ceratobasidium, Sebacina,* and *Tulasnella,* form the orchid-type associations with orchids. *Armillaria* is of economic interest because of its pathogenicity on conifers and the ability of its spores to survive Alaskan winters (Shaw 1981).

Importance to Agriculture and Forestry

Applied mycorrhizal investigations are needed for two significant reasons with regard to developing industries in Alaska. Mycorrhizae are crucial to many crops and forest timber species and to the management of renewable forest resources, to say nothing of their importance in maintaining dynamic nutrient balances in any ecosystem (fig. 1).

Many tests using mycorrhizal inoculation of grain crops have been made in pots, bins, or cans. Although these tests made in culture do not equate with natural soils, they have established that plant yield on an unsterilized, phosphorus-deficient soil can be increased by inoculation with vesicular-arbuscular mycorrhizae from the genus *Endogone* (Khan 1975). Mycorrhizae may even play a significant role in the acquisition of boron (BO^{-3}, $B_4O_7^{--}$) that has been shown by Wooding (personal communication*) to be important in the development of barley and potato farming within Alaska.

It is well documented that a number of fungi form ectomycorrhizae with coniferous species in Alaska; several fungi also form ecto-, ectendo-, and endomycorrhizae with principal hardwood species which are also common to Alaska. However, documentation of the formation of mycorrhizae by Alaskan material is needed. Of particular concern are those processes related to absorption, translocation, cycling, and the availability of nutrients.

Fungi-dependent and economically important tree species in the forest ecosystem of interior Alaska are assumed to develop mycorrhizae as seedlings. The fungi are already resident within organic substrates of most sites. Sexual reproduction by mushrooms through production of a fruiting body often results in the release of massive spore loads for the continued reinfection of substrates. Fungal spores are often dependent on some form of pregermination treatment or conditioning and/or aging within organic substrates, such as being processed through animal guts, before they will germinate.

When a habitat is disturbed (by clear cutting or fire, for example), substrates supporting the spore inoculum may also be destroyed. Reforestation, using preinoculated seedlings, may prove to be successful if plants re-enter the system already infected with mycorrhizae. For Sitka and white spruce, Shaw and Molina (1980) and Shaw et al. (1982) have demonstrated that containerized seedlings can be inoculated with ectomycorrhizal fungi. The ultimate test has yet to be made, that is, to recover the original fungal inoculum from an outplanted tree. Such results would help investigators answer questions about competitive exclusion, sustained survival, and growth and yield for both agricultural crops and timber products for a renewable-resource industry within Alaska.

The implications for reforestation are important for timber management, for watershed protection and improvement, for the improvement of food and habitat for wildlife, for outdoor recreation, hunting, subsistence food gatherers (i.e., berries, herbs, and fungi), and for developing an integrated pest-management program. Examining and defining mycor-

*Dr. Frank Wooding, Professor of Agronomy, Agricultural and Forestry Experiment Station, University of Alaska-Fairbanks.

rhizal associations and the culturing of fungi for resynthesis and testing of mycorrhizal infections have tremendous potential for reforestation through the outplanting of seedlings infected with a fungus genotype already conditioned to pre-existing interior Alaskan soil and climatic conditions. Alaskans must learn not to destroy the natural balance between the mycorrhizal fungi and plants having significant importance as food or fiber.☐

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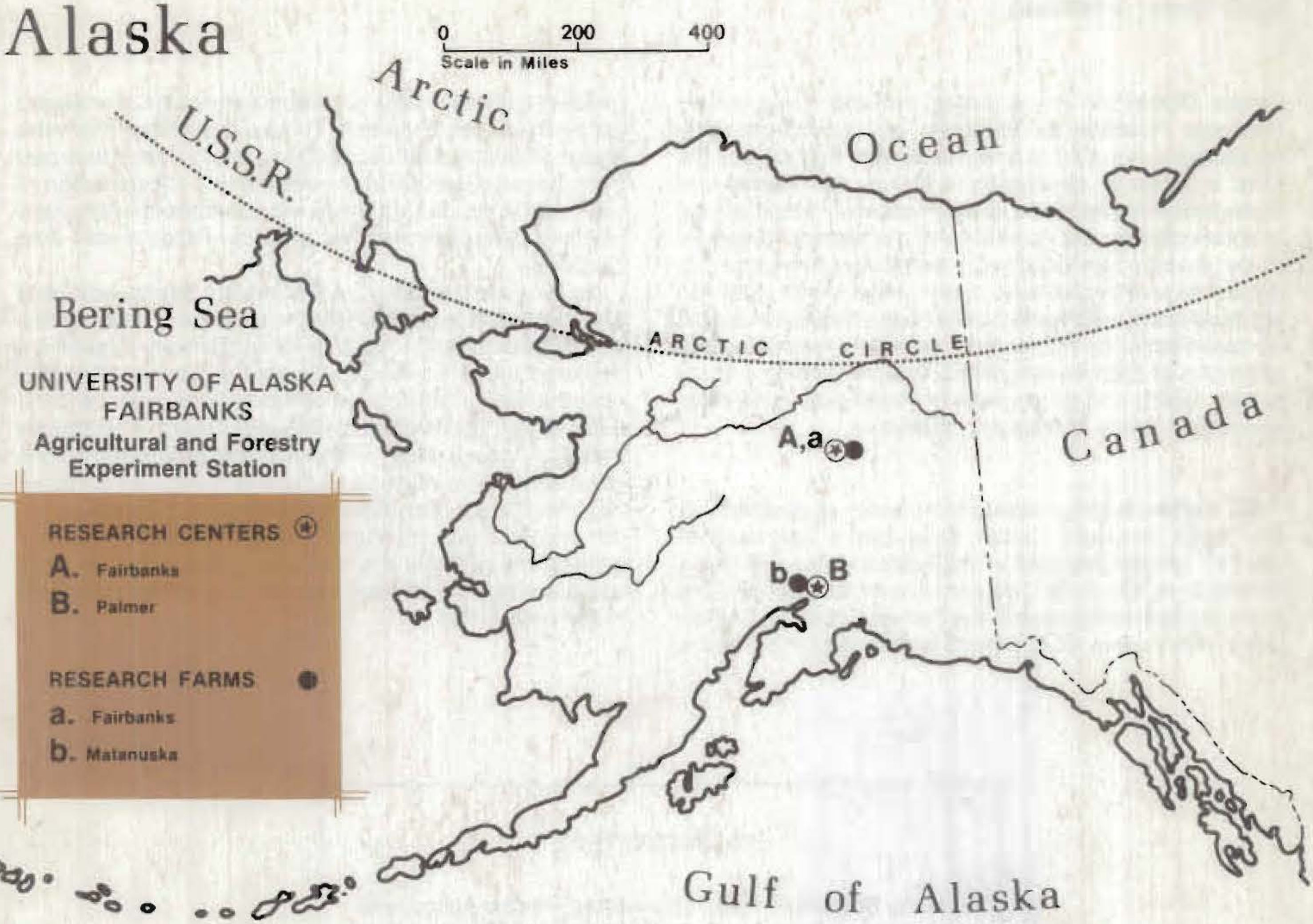
Grants Committee for a project entitled "Horticulture Research Priorities as Identified by Commercial Horticulturists in Alaska." In conjunction with that project, Dr. Kirts is currently developing a list of commercial horticulturists in Alaska and a survey instrument which will aid in accomplishing the objectives of the project. These include: providing an initial liason between commercial horticulturists and horticultural scientists in Alaska, identifying those areas which commercial horticulturists feel should be investigated by horticultural scientists, improving the relevance of such investigations, and developing a study pattern which can be applied to investigations in other agricultural areas in Alaska in the future.

Dr. Chien-Lu Ping, assistant professor of agronomy at the Palmer Research Center, conducted a field study of volcanic ash-derived soils in the Susitna Valley and Kenai Peninsula in late June. The participants included Dr. Dot Helm, a plant ecologist with the Palmer Research Center, Doug Van Patten, SCS project leader in Homer, and a group of Japanese soils scientists and one plant ecologist led by Dr. Sadao Skoji from Tohoku Univeristy. This work is part of an international study to classify soils developed from pyroclastic material or volcanic ash. Classification of such soils in Japan and Alaska would provide the data base of class definition of those soils developed under cold climates.

Dr. Ping also coordinated the first Soil Survey and Land Use Workshop in Alaska in May of this year. The workshop was sponsored by the Agricultural and Forestry Experiment Station, the U.S. Forest Service, the Soil Conservation Service, the Alaska Department of Natural Resources, and the Alaskan Soil and Water Conservation Board. Participants included Federal, state, and local governments and private consultants. The purpose of the workshop was to: serve as a mechanism of communication between the soil scientist and land-use planners, improve the quality of soil survey, and promote the wise use of soil survey in land-use planning. A workshop proceedings will be published in the near future.

In Memoriam

John Brooks III, research assistant with the Agricultural and Forestry Experiment Station's Applied Reindeer Program, died in Kotzebue, Alaska, in October 1984 of congenital heart failure. Mr. Brooks joined the experiment station staff in 1982, bringing with him a knowledge of range animal nutrition and experience as manager of a large, northern Minnesota farm/ranch. At the time of his death, Mr. Brooks's responsibilities in Kotzebue included conducting range science field studies and assisting animal science and animal health researchers in their work in western Alaska. He had also set up a microcomputer system for the range-science projects which facilitates data analysis, filing, and communications. He is survived by his wife, Wendy, and his son, Travis John, born in June 1985. A scholarship fund has been established in Mr. Brook's memory. All gifts are tax deductible and may be sent to John Brooks III Agricultural Scholarship Fund, David Erie, treasurer, Box 126, Gonvick, Minnesota 56644.



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