ENERGY FROM CATTAILS

TABLE OF CONTENTS

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INTRODUCTION

The State of Minnesota has particular reasons to be interested in biomass produced in wetlands as a source of renewable energy. The state has no traditional fossil fuel resources within its boundaries[1] and hence must import them. On the other hand, the state has millions of acres of moist peatland and other marginal wetlands that could be used for biomass production. Biomass as an energy source has some significant advantages in that it is renewable, relatively non-polluting and does not add to the CO_2 burden of the environment.

Earlier reports by the Minnesota Energy Agency indicate the energy potential in cattails is a significant proportion of Minnesota's total energy demand. However, potential figures are only indicative of a significant resource base. The amount of traditional fuel displaced per acre is probably a better basis for comparison. Recent estimates indicate a yield of 17 dry tons per acre from natural stands. This figure is roughly equivalent to the productivity of corn with high fertilization rates. Most vegetation has a calorific value of 4100 cal/g (7480 Btu/ #), so cattail mass can be assumed to fall in this same range. Direct burning of this mass could displace traditional fuels creating an implied value of $188.00/acre,

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[1] Peat, of which Minnesota has substantial deposits, is regarded by some as a fossil fuel and by others as a very long term renewable resource.

replacing Western coal at $13.50/ton, or $724.00/acre, replacing #6 fuel oil at $.43/gallon.

Clearly, many acres would have to be used in order to create a significant displacement of traditional fuels. Estimates of the number of acres required to supply various needs are very speculative, but back-of-the-envelope calculations show approximately 200,000 acres of cattails could supply the process heat needs of the taconite industry on a continuous basis.

Recent research at the University of Minnesota has demonstrated that the common cattail (Typha spp.) can be grown in managed paddies and in natural sites with considerable success (Andrews and Pratt, 1978; Bonnewell and Pratt, 1978a; Moss et al., unpublished; Pratt, 1978a). The studies confirm earlier reports (Boyd, 1971; Bray et al., 1959; Dykyjova, 1971; Pearsall et al., 1956; Westlake, 1963) of the high productivity of cattails, known technically as emergent macrophytes, and suggest this genus as a promising candidate for wetlands biomass production. In contrast to many other proposed sources of biomass, cattails and related species are highly productive under conditions unsuitable for the growth of traditional food crops.

Cattails grow well in water from a few inches to three feet in depth. They also can grow hydroponically, floating on the surface. Hydroponically growing cattails are sometimes a nuisance when great rafts of them break away from established stands and are blown to distant shores by the wind.

The greatest potential for growing emergent macrophytes lies in the extensive peat bogs in the northern part of the state. Peat covers about seven million acres in the state. This vast area generally is unsuited to the production of food crops. Attempts to drain Minnesota bogs to create agricultural lands in the early part of this century were unsuccessful.

One Minnesota utility has proposed that peat be collected in northern Minnesota for use as a feed stock to a gasification plant. However, concern has been expressed about ecological and hydrological effects of such activities. Cattails already grow on some of this land, and our research leads us to believe that much more extensive stands could be established with less environmental damage than would result from peat mining. This would result in a renewable use rather than mining of peat. Cattails might also be grown hydroponically, extracting nutrients directly from the water, in shallow eutrophying lakes.

Support is requested through this proposal for a comprehensive study of the potential of Minnesota wetlands for plant biomass production. Included is a request for support to continue the study of the productive potential of cattails and to initiate studies of biochemical processing, land use, equipment parameters and other issues related to biomass energy development.

The harvesting of cattail material is a unique challenge when compared to the harvest of typical agricultural crops. Some of the characteristics which make this a unique challenge are: growth in submerged soils, high moisture content of the plant material, desire for harvest of the total plant, interwoven random root matrix and trafficability of the soils. The primary purpose of the harvesting portion of this study will be the development of a harvesting system for cattail plant material. A harvesting process will include unit operations of separation, in-field processing and transport. The separation operation will involve the detachment of the leaf-stem system from the rhizome system, and separation of the rhizome matrix from the soil. Operations concerned with in-field processing will include those activities necessary to ready the plant material for materials handling (conveyance), transport to processing plant and out-of-field processing. The transport operation will involve moving plant material to the edge of the field for transport to processing.

More knowledge of harvesting-related characteristics of cattail plant material and soil in cattail stands will be necessary for the development of a harvesting system. Some examples of the characteristics to be evaluated are mechanical strength of plant material components and soils, rhizome size, density and distribution and soil retention ability of rhizomes. These characteristics will be used in developing the concepts of unit operations, and the design criteria for the most promising concepts.

Plant materials are composed of polymers of several different kinds. A number of these polymers can be converted, usually by hydrolysis, to simpler compounds. These simpler compounds in turn can be converted to chemicals which are: (1) the same as, or closely similar to, the basic biochemicals obtained in ensilation (silage, haylage, herbage), (2) convertible to liquid fuels such as alcohol, and (3) the same as, or closely related to, those obtained from petroleum.

The conversion processes to be studied in this research are the biochemical and fermentation technologies. In nature, biochemical and fermentative conversion processes occur continuously, on a huge scale through decomposition of plant material. However, it is seldom straightforward to transfer nature's processes into chemical production facilities which are readily controlled, reasonably simple and energy efficient. The ability to use biochemical and fermentation technology depends on the process, the feedstock and the products desired from the raw biomass.

People generally understand the very large potential of biomass, but do not understand the potential process, and ease or difficulty with which different forms of biomass can be converted. There is a rather common impression that cellulosic biomass (plants) can easily be converted to alcohol (generally meaning ethyl alcohol), that the technology is at hand or nearly so and that the remaining problems are simply growing, harvesting and transporting the biomass.

Indeed cellulose can be converted to alcohol via hydrolysis of cellulose to glucose and oligosaccharides of glucose, followed by fermentation. However, the whole process is not simple; celluloses from different sources are not all the same. Hemicelluloses may be vastly different from one another in critical ways, such as in their solubility. Each feedstock needs separate evaluation, particularly if the aim is to obtain liquid fuels and alcohols. For each biomass feedstock, the nature of the cellulose, hemicelluloses and other polymers such as polymannans, pectins, cutins, starches and so on, will have to be carefully evaluated. If the polymers are to be stripped out of the biomass in a satisfactory way, myriad hydrolysis and conversion steps will have to be understood. It may be helpful or necessary to develop new processes. At a minimum, the enzymes and the microorganisms needed to produce those enzymes must be found and grown in production-sized batches. Current developments in the isolation of improved fermenting organisms will be followed closely.

It is necessary to distinguish between the technologies which support the bioconversion of starch and similar polysaccharides, and the technologies required in the use of biomass feedstocks other than starches. For example, the cattail rootstock contains starches (amyloses and amylopectins) which are readily hydrolyzed and probably quite fermentable. However, the tops or stems comprise 25 to 50 percent of the total biomass. Undoubtedly, they are of much different and perhaps a more troublesome composition. It would be desirable to obtain useful chemicals from the tops, but this is likely to require a bioconversion technology quite different from bioconversion of rhizome starches.

This study will also investigate economic means for removing phenolics from plant materials. Phenolic compounds are inhibitors of cellulose enzymes. Their removal, together with the removal of tannins and alkaloids, is likely to be advantageous, so that the rest of the biomass can then be ensiled or bioconverted to alcohols.

Choices will have to be made as to whether to bioconvert toward fatty acids (as in ensilation), or toward alcohols, ketones and other petroleum related compounds, with processes related to older technologies such as brewing. Even with older technologies, energy balances are uncertain, since the engineering and thermochemical data necessary to obtain the energy balances have not been determined. Biochemical and fermentative processes using thermophilic enzymes and organisms are of particular interest. If these can be harnessed to the processes, there are three major advantages: (1) "scrap heat" (low temperature waste heat, of which we often have a large surplus) can be used to help drive the reactions, saving energy now wasted, (2) the reactions are likely to go considerably more rapidly at high temperatures than at lower temperatures, and (3) the more rapidly reactions can be driven, the smaller the capital costs; the reactors, fermenters, etc., can be made smaller. These circumstances should make it feasible to site biochemical facilities close to power sources using the waste heat from electrical generation (cogeneration).

A comparison will have to be made with alternate processes which can also produce some of the desired fuels and chemicals. For example, controlled pyrolysis could be used to obtain hydrocarbons, such as ethylene and ethane. Conversion of certain feedstocks to methanol is also possible. Gasification and anaerobic fermentation to produce methane are, perhaps, viable possibilities. The scale on which the various processes are carried out also needs careful evaluation. Often large scale conversion processes are more efficient than small scale processes, but the reverse may be true for certain feedstocks. It is critical to determine whether the scale of operation can be kept small enough, and simple enough, to make local bioconversion processes feasible and profitable.

Assessing the potential of wetland plants as a renewable energy source for Minnesota requires a determination of what land in the state is suitable for growing the crops. The potential will depend, on a large part, on whether there is enough suitable land in the state, and whether using that land for biomass production will conflict or compete with other uses of the land.

The land use inventory portion of this project will complete a comprehensive inventory of land in the state to determine what areas are suitable for growing and harvesting wetland crops, and to then determine any conflicting uses of that land.

SCOPE OF WORK

Overall Research Program

Work on the growth and productivity of wetland plants began at the University of Minnesota in 1976. Professor Dale Moss of the College of Agriculture received a small grant from the Energy Agency to study the potential of cattails as an "energy" crop. The funds for this project were appropriated by the Legislative Commission on Minnesota Resources as part of its support for the development of alternative sources of energy.

The work was passed to Professor Douglas Pratt, who has continued and expanded the research. For the last 2½ years, the College of Biological Sciences has studied the growth and productivity of cattail species in research paddies, and in natural stands. The results of this have shown that cattails are highly productive on a tons of mass per acre basis, and have an interesting chemical composition, i.e., large percentages of sugar and starch.

The development of cattails as an agricultural product will most likely take many years and the work of many different specialists. Our knowledge of growth, productivity, chemical composition and response to fertilizer is limited, and our knowledge of diseases, pests, seeding and harvesting is practically zero. Cattails could become a completely new cash crop grown on areas that are not now used for the production of either crops or timber.

A balanced research program is needed which will determine the potential of this crop, and estimate the environmental and social impacts. It is now time to expand the research to include other University departments, state agencies and the private sector. This proposal contains a two year research program from the following University departments:

(1) Cattail Growth, Productivity and Ecology -- College of Biological Sciences, Botany Department, Ecology and Behavioral Biology;

(2) Cattail Chemistry -- College of Biological Sciences, Biochemistry Department;

(3) Cattail Harvesting -- College of Agriculture, Department of Agricultural Engineering; and

(4) Land Use Inventory -- Center for Urban and Rural Affairs.

The proposed work will be coordinated with the work of various state agencies, e.g., Department of Natural Resources, Energy Agency, Department of Economic Development, etc. However, even two years is too short a time span. There is no assurance that cattails are the optimum crop, the social benefits will outweigh the environmental impacts or that the crop can be economically processed into a useful form. It's likely that this research will expand in the future to encompass other plant species. It is also likely that large scale development will encounter some resistance, and that the work of many different types of specialists will be required.

The University is now evaluating the idea of investing a significant amount of its resources into biomass research. The establishment of a research institute seems to be a likely step if the work on cattails continues to show promising results. Such a step will require significant appropriations by the Legislature, and a commitment by the University. However, the plans are still very tentative, and much discussion is necessary before the final plan is presented to the 1981 Legislature. This proposal is aimed at obtaining the information required for the next step in developing cattails as a state resource. It is designed to build on the current work, and provide a solid base of technical knowledge to support the creation of a Minnesota Biomass Institute.

Proposed Work and Research Methods

The following section contains short descriptions of the research goals, and the methods which will be used to achieve those goals. The work has been coordinated within the University and with the state so that it represents the most important "next steps."

College of Biological Sciences
Botany Department
Ecology and Behavioral Biology Department

The research proposed by these departments is aimed at the following four objectives:

(1) The establishment of new stands in northern peatland;

(2) The manipulation of existing stands to increase productivity;

(3) Preliminary screening program to select for high productivity;

(4) A screening program to identify other promising wetland species for biomass production.

Establishment of New Stands

Preliminary experiments are now underway at the Carlos Avery Wildlife Area attempting to establish cattail stands through seeding and rhizome planting. These small scale experiments involve establishing stands near areas where cattails already grow highly successfully. We now propose to establish more extensive stands on peat soils where cattails are not growing at the Iron Range Resources Rehabilitation Board's (IRRRB) farm in St. Louis county. It has been proposed that cattails might be grown in natural peatlands, or after the peat is partially removed. To establish just how viable this approach might be, we propose to plant cattails at the site to determine which, if any, environmental parameters must be altered to achieve most favorable growth. Variables to be tested include soil pH, nutrient status, water level and planting techniques. Growth will be monitored throughout two growing seasons.

The IRRRB farm is the site of a good deal of on-going agricultural research, and the cooperative attitude of personnel there should provide a valuable assist in launching biomass research. Because of the continuing research programs at the farm, a considerable amount is already known about the hydrology and the pH and nutrient status of the soils, although additional testing will precede the beginning of experimental work.

Manipulation of Existing Stands

Studies of existing cattail stands will be directed toward increasing the productivity of monodominant stands, and manipulating mixed stands to encourage the development of monodominant stands. Most of the information needed to formulate management schemes can be obtained most easily from studies of natural mixed and monodominant stands.

Approximately 70 stands will be sampled over a two year period, 35 mixed stands and 35 monodominant stands. Sampling sites will be selected using the information gathered by the Land Use Inventory (Part IV, this document), and recent DNR studies of peatlands and peatland vegetation.

We will also study the effects of adding fertilizer to natural stands, and of lowering the water level (drawdowns) on productivity. These studies will be carried out at the Carlos Avery Wildlife Management Area.

Preliminary Screening Program and Growth Studies

Before an extensive plant breeding program can be established, those characters which contribute most to overall yield must be identified. Clonal material from the most productive natural stands will be grown in paddies on the St. Paul campus. Detailed analyses of canopy architecture, including leaf width, length, angle and number, will be carried out during the second year of the study.

Cattails sometimes grow on floating mats, a condition that could facilitate harvesting the rhizome system. *Typha latifolia*, *T. angustifolia* and the hybrid *T. x glauca* differ in their tolerances to water depth and fluctuation. It is not known which of these is most likely to form floating mats, and under what conditions floating mats develop. We will sample floating mats in natural stands, and attempt to establish small scale floating mats. Comparative anatomical studies of rhizomes may reveal structural differences between mat forming and rooted varieties.

Our recent studies have confirmed reports of a high degree of variability in the relative amounts of above and below ground biomass produced, even in paddy experiments (Moss *et al.*, 1977; Pratt, 1978a). Because of the striking anatomical and biochemical differences in these two components of the plant, it is important to understand what factors are responsible for this variability, and whether by manipulating environmental conditions, one might maximize the production of one component or the other. We will attempt to correlate differences in the ratio of above and below ground biomass with environmental and biological variables.

Understanding the factors affecting flowering and seed production is very important. Flowering and seedset require large energy expenditures by the plant, and may need to be minimized. However, if seeding becomes the method of choice for establishing new stands, increasing seed production will also be important. We propose to investigate the extent of the variability in the degree of flowering in natural stands, and to correlate differences in the degree of flowering with environmental parameters, such as soil fertility and pH, soil type, plant species, geographic location, growth habit (rooted or floating), levels of specific nutrients and water level. Studies of seed viability of the two cattail species found in Minnesota and their hybrids will be conducted for samples collected from different locations and grown under different conditions.

Screening Program for Wetland Plants

The cattail is only one of an array of promising and productive wetland plants. We should direct our attention to other possibilities. We propose to include other productive wetland plants in our studies: *Phragmites communis* (a common reed) (Dykyjova and Hradecha, 1976); *Carex* spp. (sedge) (Gorham and Bernard, 1975); *Scirpus* spp. (bulrush) (Auclair *et al.*, 1976); *Phalaris arundinacea* (reed-canary grass); *Agropyron repens* (quack grass).

With equipment similar to that used in our earlier work with cattails on the St. Paul campus, we hope to investigate the productivity of several wetlands plants in carefully managed paddies. In parallel with this effort, we will estimate productivity in natural stands for comparison with already published estimates. Those plants that show the most promise for productivity and ease of management will be selected for further, more detailed studies in subsequent years for optimal fertilizer levels and formulations, optimal soil pH, alternative planting techniques and planting rates and the effect of mineral versus organic soils.

College of Biological Sciences
Biochemistry Department

Answers to questions about chemical content and bioconversion rates have to be in place before the processes can be brought out of the laboratory and into pilot plant or production stages. The proposed research program should answer the questions relating to:

(1) Analysis of chemical and biochemical content of cattail plant material;

(2) Microorganism and enzyme conversion processes;

(3) Production and isolation of the requisite enzymes;

(4) Chemical preconversion processes;

(5) Analysis of biochemical conversion processes.

Analysis of Chemical and Biochemical Content of Cattail Plant Material

The proposed research includes lipid and fiber determination, the amounts of fermentable carbohydrate and the amounts of polymers present which can be hydrolyzed into fermentable or feedable lower carbohydrates. The amounts of phenolics, proteins, troublesome compounds, such as certain alkaloids and substances which may be toxic, also shall be determined. For certain agricultural processes, the burden of pollutants (BOD, COD), ejected as unwanted materials, will have to be evaluated. Herbaceous plants vary a good deal in composition, so that analyses on individual species are necessary. Analyses will start with cattails and proceed to other species as the research by other departments progresses.

Microorganism and Enzyme Conversion Processes

The various microorganisms needed to produce those enzymes which can convert biomass polymers to simpler substances will be found, cultured and made available. In some cases, they will be induced to grow on the plant material under study, but mostly they will be grown in accepted nutrient solutions. New genetic variants in some fermentation processes may spell success versus economic disadvantage.

Production and Isolation of the Requisite Enzyme

In processes which use more than one enzyme treatment in a sequence, it may be necessary to use the isolated enzymes instead of the whole organisms. This circumstance sometimes occurs because the enzyme producer organism may have quite different requirements in terms of oxygen level, pH, temperature, etc. What is optimum for one organism may be quite disadvantageous for another. To accomplish this, isolation and immobilization of the enzymes is required, and the practical aspects of their storage and retention of activity must be determined.

There have also been some interesting developments in immobilized whole cell techniques which may enable us to use the short cut of mixed cultures methods. These and other developments in bioconversion technology will be followed closely.

Chemical Preconversion Processes

In some materials, e.g., wood, a chemical treatment, such as delignification, is of advantage. However, the need for such treatments varies from plant to plant. Even if the main polymers to be obtained are cellulose-related, hemicelluloses have varying rates of hydrolysis, and may require separation prior to fermentation. Before large scale production is useful, possible chemical preconversion processes should be carefully investigated because there may be substantial advantages and/or disadvantages, depending on the material being treated.

Analysis of Biochemical Conversion Processes

Practically all conversion processes produce a number of different products simultaneously. This is particularly the case in fermentation, which yields alcohols, aldehydes, lower fatty acids, etc. The nature of the products can change drastically, depending on the conditions, e.g., anaerobic versus aerobic conditions. Therefore, the proceses require continuous monitoring and careful control. Thermochemical balances and energy requirements are needed to understand and predict the economics of such processes. Measurements on reaction kinetics, heats of combustion of the various products and energy balances will be carried out as part of this research.

College of Agriculture
Agricultural Engineering Department

The engineering work necessary to develop cattails as an agricultural crop will extend over many years. The long range objectives are:

(1) To evaluate the harvesting-related characteristics of cattail plant material and soils in natural cattail stands;

(2) To develop and evaluate concepts for the unit operations in harvesting cattail plant material;

(3) To develop design criteria for the promising unit operations concepts;

(4) To integrate the better concepts into a harvesting system which readies plant material for transport to processing.

During the first two years, most of the effort will be concentrated on objectives 1, 2 and 3, and will relate to gathering basic data, such as material strength, compressibility, distribution of plant material and soil, etc. The preliminary nature of this work makes it difficult to list precisely the tasks which will be completed. However, two classes of work are anticipated:

(1) Field studies on plant and soil material using a mobil research platform;

(2) Conceptual design of equipment which could handle the various harvesting unit operations, e.g., collection, separation, transport, etc.

At the conclusion of the two year period, sufficient data will have been collected so that the research can progress to the building of prototypes. Although the harvesting objectives emphasize work on cattails, the methods, instrumentation and equipment developed during the first two years will be applicable to harvesting other wetland plants.

Center for Urban and Regional Affairs

The land use inventory work will achieve the following four objectives:

(1) Determination of the location and extent of land suitable for producing wetlands crops;

(2) Determination of the availability of those lands designated as suitable, based on local zoning ordinances, transportation networks, land use and ownership patterns;

(3) Assessment of any existing or potential conflicting uses;

(4) Investigate the social and economic impacts of biomass production on local and regional communities.

The project will first determine what Minnesota land is actually suitable for growing wetland crops. This land is often referred to as "marginal land," i.e., is land which is not used for agricultural production but which might be suitable for growing such energy crops as cattails, common reeds, bulrush, canary grass and quack grass.

The second step, once the suitable areas in the state have been listed, is determining ownership of the land. Is the land owned by the federal or state government, or is it owned by private individuals, corporations or Indian nations?

The third step, and a critical one, involves conflicting uses of the suitable land. The study will determine if the land is presently being used, or planned to be used, for other purposes, such as forestry production, agricultural production, wildlife habitat, wilderness areas, historical preservation or residential development. This portion of the study will also examine the necessary buffer zones required between the biomass production areas and neighboring lands which have competing or conflicting uses.

The final objective of this project is to define the potential social and economic impacts of producing wetland crops. CURA will sponsor a seminar consisting of four or five University of Minnesota faculty members having expertise in the relevant disciplines. These people will identify the important economic and social parameters of biomass production and prepare a report describing those issues requiring thorough examination.

The results from the study outlined above will be documented in a report containing a written manuscript, tables and maps--both work maps and a final wall map. The written manuscript will contain an assessment of the data that is derived from the study, and will be a joint effort of the principal investigator, project manager, technical consultants and project consultants.

At the end of the project, a workshop will be conducted by CURA in order to examine the results of the study and to discuss the public policy implications related to the land use issues of biomass utilization and the possible conflicts with other uses of the land. The workshop will include those who participated directly in the project, representatives from the University, the Minnesota Energy Agency, other appropriate state agencies and legislators. A person involved with comparable biomass and land use studies in Scandinavia, specifically Sweden or Finland, will be brought over for the seminar to discuss the Scandinavian experience.

TASK LISTS

Productivity and Ecology

Task List by Objectives

Objective 1 (Establishment of New Stands in Northern Peatland)

A. Field Tests

1. Collection and cleaning of seeds -- fall and winter 1979.
2. Collection and preparation of rhizomes for planting -- spring 1980.
3. Preparation of growing sites, chemical testing -- spring 1980.
4. Seeding and planting -- spring 1980.
5. Observation and recording of growth, pest problems, response to chemical treatments -- spring, summer, fall 1980.
6. Determination of productivity and shoot density -- fall 1980.
7. Additional seeding and planting operations as required -- fall 1980.
8. Submission of interim report -- December 1980.
9. Observation and recording of growth, etc. -- spring, summer, fall 1981.
10. Determination of productivity, etc. -- fall 1981.

B. Preparation of final report -- winter 1982.

C. Submission of final report -- March 1982.

Objective 2 (Manipulation of Existing Stands to Increase Productivity)

A. Selection of 70 cattail stands (35 mixed stands and 35 monodominant stands) -- spring 1980.

B. Initial measurements -- 1980.

1. Standing crop weight - wet and dry.
2. Plant density.
3. Species frequency and contribution to total biomass.
4. Measurement of leaf area index (LAI).
5. Plant height.
6. Water table depth and yearly fluctuation.
7. Water analysis.
8. Soil analysis.
9. Plant tissue analysis.

C. Sampling of floating mats -- summer 1980-1981.

D. Fertilization tests -- summer 1981.

E. Water level control tests -- summer 1981.

F. Preparation of final report -- spring 1982.

Objective 3 (Preliminary Screening Program to Select for High Productivity)

A. Field studies

1. Selection of sampling sites -- spring 1980.
2. Study of flowering and correlation with environmental parameters -- summer 1980, summer 1981.

3. Study of variation in proportion of above and below grown biomass -- fall 1980, fall 1981.

B. Paddy experiments

1. Gathering of materials for planting -- spring, summer 1980.
2. Preparation of paddies, St. Paul campus -- spring 1980.
3. Planting of various species -- spring, summer 1980.
4. Care and maintenance of paddies, observations of growth and pest problems -- spring, summer, fall 1980.
5. Determination of productivities -- fall 1980.
6. Additional paddy experiments with most promising species -- spring, summer, fall 1981.
7. Analysis of canopy architecture, selection of clonal material -- fall 1980.
8. Analysis of canopy architecture, experimental plots -- spring, summer, fall 1981.

Objective 4 (Screening Program to Identify Other Promising Wetlands Species for Biomass Production)

A. Field studies

1. Selection of sampling sites -- spring 1980.
2. Study of flowering and correlation with environmental parameters -- summer 1980,

summer 1981.

3. Study of variation in proportion of above and below grown biomass -- fall 1980, fall 1981.

B. Paddy experiments

1. Gathering of materials for planting -- spring, summer 1980.
2. Preparation of paddies, St. Paul campus -- spring 1980.
3. Planting of various species -- spring, summer 1980.

Biochemical Conversion of Plant Biomass

Task List by Objectives

Objective 1 (Analysis of Chemical and Biochemical Content of Cattail Plant Material)

A. Chemical assays

1. Lipid determination.
2. Fiber determination (AOAC procedures).
3. Protein determination (Hartree-Lowry total nitrogen by Kjeldahl).
4. Possible toxic substances.
   a. phenolic determination
   b. alkaloid determination

B. Characterization of carbohydrates

1. Sugars
2. Starches

3. Cellulose
4. Lignins
5. Other polymers
6. Total carbohydrates

Objective 2 (Analysis of Microorganisms and Enzyme Conversion Processes)

A. Classification growth of microorganisms which can use the material of interest to produce exocellular enzymes.
B. Study of microorganism genetic variants.
C. Isolation of microorganism exocellular enzymes.
D. Enzyme production dependence on microorganisms.
E. Enzyme production dependence on nitrogen source.

Objective 3 (Production and Isolation of the Requisite Enzyme)

A. Production and storage of hydrolose enzymes.
   1. Isolation
   2. Immobilization
   3. Storage means
   4. Activity retention
B. Use and value of spent organisms.
   1. Protein content
   2. Protein extractability
C. Stripping of noxious chemicals, e.g., phenolics and alkaloids.

Objective 4 (Chemical Preconversion Processes)

A. Non-enzymatic hydroysis.

B. Deliquification requirements.

C. Chemical modification of polymers.

Objective 5 (Analysis of Biochemical Conversion Processes)

A. Extractability of polymers used by microorganisms and affected by enzymes.

B. Raw material (feedstock) requirements.

1. Composition
2. Size

C. Operating parameters for future pilot plant tests.

1. Oxygen levels
2. Optimal pH
3. Temperature
4. Rates of mixing

D. Rates of conversion for hydroysis and fermentation.

1. Determination of products.
2. Combustion calorimetry.
3. Thermochemical balances.
4. Energy requirements.

Timetable

The analytical procedures will be set up first, and the tasks under Objective 1 will be completed in six months. The tasks under Objective 2 and 3 will be completed by the end of the first nine months. Objective 4 will be completed by the end of six months, and Objective 5 tasks will be completed by the end of the second year. The second year of the project will be used to perform the same analyses on different plant species.

Cattail Harvesting

Task List by Objectives

Objective 1 (To Evaluate the Harvesting-Related Characteristics of Cattail Plant Material and Soils in Natural Cattail Stands)

A. Obtain instrumentation (transducers and recorders) and fabricate fixtures for quantifying the following harvesting-related characteristics:
   1. Vertical distribution of plant material and soil.
   2. Plant material strength, such as tension, shear and torsion.
   3. Magnitude of force required to separate plant material (rhizome matrix) from soil.
   4. Compressibility of rhizome matrix.
   5. Bulk and specific density of plant material.
   6. Cutting resistance of plant material.
   7. Soil trafficability in cattail fields.

B. Obtain and prepare mobile research platform for field studies.

C. Obtain data for the above characteristics.

D. Evaluate data for the above characteristics.

Objective 2 (To Develop and Evaluate Concepts for the Unit Operations in Harvesting Cattail Plant Material)

A. Develop a list of alternatives for the harvesting unit operations as described in the introduction. Some concepts to be considered are vibrating knife, rotary cutter, auger flightings, potato (rod or bar) chain and centrifuge.

B. Develop working prototypes of the most promising alternatives.

C. Laboratory test the working prototypes.

D. Field evaluate the working prototypes.

E. Select concepts for Objective 3.

Objective 3 (To Develop Design Criteria for the Promising Unit Operations Concepts)

A. Conduct extensive field studies to determine optimum design parameters.

B. Specify design parameters for those successful concepts for unit operations.

Objective 4 (To Integrate the Better Concepts into a Harvesting System Which Readies Plant Material for Transport to Processing)

Tasks under this objective will not occur until much later in the research, therefore, a specific task list is not practical at this time.

Timetable

The tasks will be carried out in the order given above. During the first year, the major effort will be devoted to Objective 1, evaluation of physical characteristics. The data should be obtained near the end of the growing season, such that field conditions match those expected at harvest time. Some initial development on the mobile research platform will also be done during the first year. During the first year, preliminary work will be completed on Objective 2, develop and evaluate concepts for unit operations. One or two promising concepts may be laboratory and field tested.

During the second year, the major emphasis will be placed on developing and evaluating harvesting machine concepts. Continued work on evaluating harvesting-related characteristics may be carried on depending on the need. Also during the second year, work will begin on developing design criteria for the promising unit operation concepts.

All the field work during the first and second years must be conducted using a research platform capable of carrying instrumentation, working models for unit operations and researchers through cattail fields. More investigation is needed to explore available equipment and determine the requirements of the mobile research platform.

Completion of work on Objectives 2 and 3 will require an additional two years. Objective 4, to integrate optimum concepts into a harvesting system, will be completed during the fifth year. However, it is likely that data collected during the first two years will modify our current thinking about the development schedule so that future proposals may reflect significantly changed work scopes and budgets.

Land Use Inventory

Task List by Objectives

Objective 1 (Determination of the Location and Extent of Lands Capable of Producing Wetland Crops)

A. The Minnesota Land Management Information System (MLMIS) will be used to identify potential biomass production areas. The following factors will be addressed in making this assessment:

   1. Soil type (organic and mineral)
   2. Climate
   3. Hydrologic setting
   4. Current vegetative cover

B. Results of MLMIS data analysis will be compared against other records, i.e., low and high aerial photos, soil maps, land use records, etc.

C. Examination of other MLMIS data variables will permit the availability of the above lands for biomass production to be determined. Factors to be considered include:

1. Current and projected land use.
2. Ownership patterns.
3. State and local controls, i.e., zoning.
4. Transportation networks.

D. Findings of this investigation will be presented in a preliminary report, including required maps and tables.

Objective 2 (Refinement of the Above Analysis Based on Findings from Related Biomass Research Efforts)

A. Review of MLMIS analysis and other biomass research to determine necessary revisions to land selection model.

B. Select new data elements required for proper update and code these into MLMIS.

C. Run final analysis to determine land suited for producing wetland crops.

D. Present findings in final report, including necessary maps and tabulations.

Objective 3 (Examination of Potential Use Conflicts of Lands Suited for Biomass Production)

A. Review of current and projected land use plans for areas suited for wetland crops.

B. Determination of potential conflicts between competing uses and biomass production. Of the uses listed below, those presenting the greatest conflicts will be addressed.

1. Agriculture
2. Forest production
3. Wildlife production
4. Wetland preservation
5. Peat harvesting
6. Recreation
7. Urban development

C. Evaluation of potential impact of the above uses on biomass production (and vice versa) to be made from available suitability studies and related investigations.

D. Determination of necessary buffer zones between biomass production areas and competing uses.

E. Findings will be presented in a report, including maps and tables.

Objective 4 (Investigation of the Potential Social and Economic Impact of Biomass Production)

A. University of Minnesota faculty seminar to identify and discuss social and economic issues of biomass production and impact on local and regional communities.

B. Report compiled by seminar to enunicate those parameters requiring thorough investigation.

Timetable

It is anticipated that the projects outlined above will require two years to complete, and the included budget figures are based on this schedule. The tasks will be carried out in the order discussed above. Work during the first year will be devoted to completing Objective 1. It is hoped that some of the groundwork for Objective 2 will be laid during this year as well. Objectives 2-4 will be addressed and completed in the second year of the study. Preparation of published wall maps could extend the two year framework. Factors beyond the control of the investigators may also alter this proposed schedule.

PROJECT ORGANIZATION

This project will be organized through the University of Minnesota College of Biological Sciences with Dr. D.C. Pratt as Project Director and Principal Investigator. Co-Principal Investigators will include:

Mr. W. Craig, Center for Urban and Regional Affairs

Dr. E. Gorham, Ecology and Behavioral Biology

Dr. R. Lovrien, Biochemistry

Dr. D.C. Pratt, Botany

Dr. C. Schertz, Agricultural Engineering

Dr. R. Schuler, Agricultural Engineering

The Director will call for meetings of all Principal Investigators quarterly, or whenever necessary, to help coordinate efforts among departments and assess progress. An interim report will be submitted December 1, 1980, and a final report March 1, 1982.

Subcontracts and Consultants

The Center for Urban and Regional Affairs (CURA) at the University of Minnesota will contract with the Land Management Information Center (LMIC) at the Minnesota State Planning Agency to use its computer mapping services in order to determine the lands in the state suitable for growing wetland crops, the availability of these lands for such use and any potential conflicting uses of the land.

The LMIC houses the Minnesota Land Management Information System (MLMIS) which is a system used to centralize and analyze data on Minnesota's resources. MLMIS was developed as a cooperative project of CURA and the State Planning Agency, and is both a depository of geographically-based information and a computer analysis system. MLMIS data includes cultural, resource and political boundary information. Information is stored on computer files by 40 acre parcel for every land parcel in the state. It is organized by region, county and township, and can be accessed for mapping or statistical analysis. In addition, a package of computer software has also been developed to use and manipulate the data. Information can be compiled in tabular, statistical, map or computer file form. This software is called the Environmental Planning and Programming Language (EPPL), and is available at the Center for use on MLMIS data or any compatible data.

CURA will select technical consultants from the University of Minnesota community to assist in the development of this project. These people will draw from their professional endeavors to provide substantive input for the study. These consultants will also serve on an advisory panel which will review the selected research methods and analyze the final products of the investigation. This panel will include Dr. John Borchert (Professor, Geography); Dr. Phil Raup (Professor, Agricultural and Applied Economics); and Dr. Phil Gersmehl (Professor, Geography).

During the course of the project, several consultants will assist in the technical and administrative coordination of the study. They will also organize a public policy seminar to discuss the results of the study. Those consultants include Thomas Scott, Director, CURA; Thomas Anding, Associate Director, CURA; Dean Abrahamson, Professor, Humphrey Institute of Public Affairs, and Co-Chairman, All-University Council on Environmental Quality. Their time will be donated by CURA. CURA will also donate secretarial services for the project.

ENVIRONMENTAL CONSIDERATIONS

Minnesota's peatlands are a valuable and precious asset. As the world's energy problems intensify, pressures to utilize any and all energy resources, including peat, will grow, and the environmental consequences must be carefully considered. All energy production technologies have environmental drawbacks, although they are not all equally disruptive. It seems more desirable, for instance, to use peat as a substrate for the production of a renewable energy crop rather than as a consumable commodity which, if heavily exploited, would not last long. If a decision is made to harvest some of the state's peat resource as energy, cattails might serve as a tool for the reclamation of lands from which peat has been removed. The reclaimed areas might be managed so as to provide excellent habitat for birds and other wildlife, and a renewable energy source at the same time. The energy crops produced in this reclamation effort would serve as an alternative to the harvesting of peat for energy, and might eventually make the continued exploitation of peatlands unnecessary.

Minnesota peatlands cover a vast area, and it is known that they vary in their floristic and vegetative characteristics, as well as in their hydrology and water chemistry. Eventually, a detailed survey of the peatlands will be needed to ascertain those most suitable for growing wetland energy crops, and what modifications would be required in these and other areas for optimum production. Work of this type is being proposed in this document for one site in northern Minnesota. The peat areas of the state have already been mapped in some detail by teams from the University of Minnesota and the Minnesota Department of Natural Resources. These studies will provide a ready base of information for determining the areas with the best potential for energy production. The extent of Minnesota's non-peat wetland has not been adequately assessed, and we propose to make a preliminary study of the extent of those areas (much of which is in the southern half of the state) that are suitable for wetland energy crop production.

If, after further study, large scale exploitation of wetland plants for energy seems to be feasible, extensive environmental impact studies of the effects of agricultural activities in wetland areas will be needed. It also will be necessary to consider the effects of facilities needed for transporting and processing biomass for energy or chemical feedstocks. The proposed work will provide a basis for consideration of potential impacts, and is necessary before any sensible evaluation of alternatives can occur.

BUDGETS

Budget, Botany and Ecology and Behavioral Biology

First Year

	Requested Funds	Funds Donated by CBS
A. Personnel - Salaries and Wages		
1. Project Coordinator and Principal Investigator ¼ time, 1 year	$10,950	$ 7,300
2. Co-Principal Investigator 1 month	3,162	3,162
3. Assistant Scientist 1 year, full time	15,000	
4. 3 Project Assistants 1 year, ½ time	21,000	
5. 2 Undergraduate Assistants 1 year, ½ time	8,400	
6. Secretarial Help ¼ time	2,500	2,500
Total Wages	$61,012	$12,962
B. Staff Benefits		
1. Academic	$ 2,964	$ 2,197
2. Civil Service	3,675	525
Total Benefits	$ 6,639	$ 2,722
C. Equipment and Expendable Supplies		
1. Leaf Area Meter	$ 4,800	
2. Portable pH Meter	600	
3. Chemicals and Glassware	500	
4. Fertilizers, Lime, Biocides	600	
5. Miscellaneous Expenses (tools, boots, etc.)	400	
Total Supplies	$ 6,900	

	Requested Funds	Funds Donated by CBS
D. Chemical Testing		
1. Soils, Water, Plant Material	$ 7,000	
E. Field Preparative Work		
1. Harvesting Rhizomes for Planting	800	
2. Excavation of Shallow Ponds in Peat Soil	6,000	
3. Preparation of Paddies (St. Paul campus)	4,000	
Total Field Preparation	$10,800	
F. Computer Time	$ 500	
G. Travel		
1. Travel to Field Sites	$ 3,000	
2. Travel to Meetings (2)	800	
3. Personal Expenses	2,000	
Total Travel	$ 4,800	
Grand Total, First Year	$90,651	$15,865

Second Year

	Requested Funds	Funds Donated by CBS
A. Personnel - Salaries and Wages		
1. Project Coordinator and Principal Investigator ¼ time	$11,830	$ 7,887
2. Co-Principal Investigator	3,384	3,384
3. Assistant Scientist 1 year	16,200	
4. 3 Research Assistants 1 year, ½ time	22,500	
5. 2 Undergraduate Assistants 1 year, ¼ time	9,000	
6. Secretarial Help	2,700	2,700
Total Wages	$65,614	$13,971
B. Staff Benefits		
1. Academic	$ 3,271	$ 2,423
2. Civil Service	4,158	594
Total Benefits	$ 7,429	$ 3,017
C. Equipment and Expendable Supplies		
1. Chemicals and Glassware	$ 500	
2. Fertilizers, Lime, Biocides	400	
Total Supplies	$ 900	
D. Chemical Testing	$ 7,500	
E. Computer Time	$ 600	
F. Travel		
1. Travel to Field Sites	$ 3,500	
2. Travel to Meetings (1)	500	
3. Personal Expenses	2,200	

Total Travel	$ 5,200	
Grand Total, Second Year	$87,243	$16,988

Proposed Budget, Biochemistry

First Year

	Requested Funds	Funds Donated by CBS
A. Personnel - Salaries and Wages		
1. Principal Investigator 1 month	$ 2,500	$ 7,500
2. Technician 1 year	13,600	
3. Research Assistant 50%, 1 year	6,300	
4. Secretarial Help 5%	500	
Total Personnel	$22,900	$ 7,500
B. Staff Benefits		
1. Academic	$ 525	$ 1,575
2. Civil Service	2,856	
Total Benefits	$ 3,381	$ 1,575
C. Equipment and Supplies		
1. Hewlett-Packard High Pressure Liquid Chromatography System, with the minimal number of add-ons.[1]	$23,500	

[1] The analytical work is the most demanding in time required, and need for repeated, routine measurements is very large number. Large portions of the proposed work can be much more efficiently handled by means of HPLC (High Pressure Liquid Chromatography). This major instrumentation is requested especially for assay of dilute carbohydrates in water. They afford many of the principal questions around which fermentability and enzyme conversion reactions depend. Without HPLC, the proposed work will be far more ardous and demanding. The HPLC system should be interfaced to a computer, but we probably can use our existing HP 9810 system for that. We also request updating our spectrophotometer power supply, which is nearly 20 years old.

	Requested Funds	Funds Donated by CBS
2. Update instrument power supply for updating Beckman DV-2 spectrophotometer	$ 1,750	
3. Equipment Modification, Microcalorimeter		$ 3,500
4. Miscellaneous, disposable supplies, chemicals, gases, glassware, reagents, biologicals, chart paper, growth media	6,000	
5. Shop work, equipment repairs	2,000	
6. Communication and publication costs	900	
Total Supplies	$34,150	$ 3,500
D. Travel		
1. Travel to College Material	$ 200	
2. Travel (2 meetings in the U.S. on fermentation and conversion technology)	800	
Total Travel	$ 1,000	
Grand Total, First Year	$61,431	$12,575

Second Year

	Requested Funds	Funds Donated by CBS
A. Personnel - Salaries and Wages		
1. Principal Investigator 1 month	$ 2,700	$ 8,100
2. Technician 1 year	14,700	
3. Research Assistant 50%, 1 year	6,800	
4. Secretarial Help 5%	540	
Total Personnel	$24,740	$ 8,100
B. Staff Benefits		
1. Academic	$ 580	$ 1,742
2. Civil Service	3,234	
Total Benefits	$ 3,814	$ 1,742
C. Equipment and Supplies		
1. Miscellaneous, disposable supplies, chemicals		
2. Gases, glassware, growth media	$ 8,000	
3. Shop work, equipment repairs	3,000	
4. Communication and publication costs	950	
Total Supplies	$11,950	
D. Travel		
1. Travel to Meetings (1)	$ 450	
2. Travel to Collect Material	100	
Total Travel	$ 550	
Grand Total, Second Year	$41,054	$ 9,842

Budget, Agricultural Engineering

First Year

	Requested Funds	Experiment Station Contribution
A. Personnel - Salaries and Wages		
1. Principal Investigator 2 months	$ 5,000	$11,000
2. Research Fellow	9,000	
3. Technician	15,000	7,500
4. Student Labor	5,000	
5. Secretarial Help	4,000	
6. Drafting	3,000	
Total Personnel	$41,000	$18,500
B. Staff Benefits		
1. Academic	$ 2,940	$ 2,310
2. Civil Service	3,150	1,575
Total Benefits	$ 6,090	$ 3,885
C. Field Vehicle		
1. Mobile Research Platform	$14,000	
D. Travel		
1. Vehicle Costs:		
a. To research site	$ 1,600	
b. Other travel	500	
c. Hauling equipment	800	
2. Personal Expenses	2,400	
Total Travel	$ 5,300	

	Requested Funds	Experiment Station Contribution
E. Instrumentation		
1. Transducers and Recorders	$18,000	
2. Fixtures	7,000	
Total Instrumentation	$25,000	
F. Machinery and Machine Components for Test Equipment	$19,000	
G. Shop and Laboratory Facilities		$ 7,000
Grand Total, First Year	$110,390	$29,385

Second Year

	Requested Funds	Experiment Station Contribution
A. Personnel - Salaries and Wages		
1. Principal Investigator 2 months	$ 5,400	$11,880
2. Research Fellow	9,720	
3. Technician	16,200	8,100
4. Student Labor	5,400	
5. Secretarial Help	4,320	
6. Drafting	3,240	
Total Personnel	$44,280	$19,980
B. Staff Benefits		
1. Academic	$ 3,251	$ 2,554
2. Civil Service	3,564	1,782
Total Benefits	$ 6,815	$ 4,336
C. Field Vehicle		
1. Mobile Research Platform	$14,000	
D. Travel		
1. Vehicle Costs		
a. To research site	$ 2,000	
b. Other	1,000	
c. Hauling equipment	2,000	
2. Personal Expenses	2,600	
Total Travel	$ 7,600	
E. Instrumentation		
1. Transducers and Recorders	$ 5,000	

	Requested Funds	Experiment Station Contribution
2. Fixtures	$ 2,000	
Total Instrumentation	$ 7,000	
F. Machinery and Machine Components for Test Equipment	$25,000	
G. Shop and Laboratory Facilities		$ 7,560
Grand Total, Second Year	$104,695	$31,876

Budget, CURA

First Year

	Requested Funds	Funds Donated by CURA
A. Personnel - Salaries and Wages		
1. Principal Investigator (W. Craig) 10%, 9 months	$ 2,100	
2. Research Fellow (J. Anderson) 80%, 9 months	14,000	
3. Graduate Assistants 200 hours	1,200	
4. Technical Consultants U of M faculty at $500 each	2,500	
5. Secretarial Help 25% time equivalent		$ 2,025
6. Project Consultants		
a. T. Anding 10%, 9 months		3,010
b. D. Abrahamson 5%, 9 months		1,575
c. T. Scott 5%, 9 months		1,600
Total Personnel	$19,800	$ 8,210
B. Staff Benefits		
1. Academic	$ 3,220	$ 1,235
2. Civil Service		405
Total Benefits	$ 3,220	$ 1,640
C. Services		
1. Land Management Information Center computer costs and map production	$ 5,000	

	Requested Funds	Funds Donated by CURA
2. Cartographic Costs	$ 750	
3. Travel for Site Visits	1,000	
Total Services	$ 6,750	
Grand Total, First Year	$29,770	$ 9,850

Second Year

	Requested Funds	Funds Donated by CURA
A. Personnel - Salaries and Wages		
1. Principal Investigator (W. Craig) 10%, 9 months	$ 2,400	
2. Research Fellow (J. Anderson) 80%, 9 months	16,000	
3. Graduate Assistants 400 hours	2,800	
4. Technical Assistants U of M faculty at $1000 each	4,000	
5. Secretarial Help 25% equivalent		$ 2,300
6. Project Consultants		
a. T. Anding 10%, 9 months		3,300
b. D. Abrahamson 5%, 9 months		1,750
c. T. Scott 5%, 9 months		1,800
Total Personnel	$25,200	$ 9,150
B. Staff Benefits		
1. Academic	$ 3,680	$ 1,370
2. Civil Service		460
Total Benefits	$ 3,680	$ 1,830
C. Services		
1. Land Management Information System, computer costs and map production	$ 5,000	
2. Cartographic Costs	1,000	

	Requested Funds	Funds Donated by CURA
3. Travel for Site Visits	$ 1,000	
4. Public Policy Seminar on Production of Wetland Crops in Minnesota		$ 2,000
5. Cost to Bring Biomass Expert from Scandinavia to Seminar	$ 1,500	
Total Services	$ 8,500	$ 2,000
Grand Total, Second Year	$37,380	$12,980

Total Project Costs

First Year

	Requested Funds	Funds Donated by U of M
Botany and Ecology and Behavioral Biology	$ 90,651	$ 15,865
Biochemistry	61,431	12,575
Agricultural Engineering	110,390	29,385
CURA	29,770	9,850
Total, First Year	$292,242	$ 67,675

Second Year

	Requested Funds	Funds Donated by U of M
Botany and Ecology and Behavioral Biology	$ 87,243	$ 16,988
Biochemistry	41,054	9,842
Agricultural Engineering	104,695	31,876
CURA	37,380	12,980
Total, Second Year	$270,372	$ 71,686
Grand Total	$562,614	$139,361

PAST RESEARCH AND LITERATURE SURVEYS

The Productive Potential of Cattails and Other Wetland Plants

During recent years, several workers at the University of Minnesota have been engaged on a limited scale in research on biomass sources and properties. This work was funded by the Legislative Commission on Minnesota Resources and the University of Minnesota. Several promising areas of research emerged from these endeavors, and they have provided the impetus for this proposal.

The work undertaken on biomass in previous years has dealt with specific aspects such as the utilization of crop residues, mapping of the areas of the State of Minnesota where crop residues could likely be removed from the soil without harm to agricultural productivity, and a cropping system that might increase residue supply while maintaining full food production. Agricultural residues offer an attractive source of energy, and development of the technology to utilize biomass could well result in these residues becoming an important source of energy in Minnesota and elsewhere.[1]

During the course of research on cropping systems and the potential of crop residues as energy sources, it was decided to compare photosynthetic productivity on agricultural lands (where it is known that water deficits are often a limiting factor for plant production) with a system where

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[1] Tri-College study on sunflower stalks in Red River Valley, Dennis Mathiason, MSU.

water is nearly always in ample supply. The so-called emergent macrophytes (those which occupy the water's edge in ponds, lakes and swamps) are some of nature's most highly productive species. Many emergent aquatic species are native to Minnesota where millions of acres of wetland provide an abundance of habitat. We have focused our attention on the genus Typha whose leaf structure and the nature of its foliar canopy make it a very effective solar collector (Dykyjova, 1971). The cattail consist of the above ground canopy and an extensive underground stem or rhizome system with attached roots where much of the biomass is stored. Two species of Typha, T. latifolia and T. angustifolia, are common in our region. A natural hybrid of these two species, Typha X glauca, is also very abundant and has served as a basis for most of our experimental work.

Summary of Previous Work

Growth of Cattails in Mineral Soil

The productivity of most native species of plants can be greatly enhanced by careful management, and it was assumed that this might be true of cattails as well. Unfortunately, little was known about managing cattails as a crop. For initial tests, the plants were grown in 1.5 m^2 paddies constructed of plywood lined with polyethylene film. The paddies were filled with a soil mixture of four parts field soil, two parts manure and one part sand (Moss et al., 1977). The soil depth in the paddies was 30 cm, and the water level was maintained 10 cm above the surface of the soil. The individual paddies were grouped tightly together, and a border was provided to eliminate edge effects which might otherwise result in erroneously high estimates of productivity.

The rhizome pieces used to plant the paddies were small segments of root-rhizome with small attached roots. The paddies were fertilized at a rate of 36, 4 and 8 kg/ha of N, P and K respectively, much as one might treat a productive corn field (Moss et al., 1977).

The biomass productivity of the cattails grown as described was compared with normal corn fields grown nearby and with a densely planted, highly fertilized "energy crop" of winter rye (for early spring growth), followed (in the same season) by densely planted corn or sorghum. The cattail paddies yielded 40 metric tons of dry matter per hectare, which compared favorably with 25 tons/hectare obtained from the high yielding (150 bu/A) corn, and 34 tons/hectare yielded by the double cropping system (Moss, personal communication).

Growth of Cattails in Organic Soil

Most of the actual and potential habitat for cattails in the State of Minnesota exists in regions with organic or peat soils as opposed to the agricultural mineral soils used in the initial stages of the study. To permit a more accurate assessment of the potential of cattails in sites actually available, paddy experiments were initiated in 1977 using natural peat soils obtained from a bog in the Forest Lake area. These experiments have been described in a recent paper (Andrews and Pratt, 1978), and will be summarized only briefly here.

The yields from plants grown in managed paddies on peat were generally 20-30 percent lower than those reported by Moss et al. (unpublished), but were still very impressive. The effects of differing rates of fertilizer application and different planting rates were also assessed. A study of the seasonal growth rate confirmed earlier reports in that the maximum accumulation of above ground biomass occurred in mid-August, and values decreased thereafter as materials were delivered to the rhizomes and roots for over winter storage. The growth rate of the roots and rhizomes increased progressively until the experiment was terminated in mid-October following a late season frost. In a related study, Bonnewell and Pratt (1978), reported on the effects of nutrients on productivity and morphology of hybrid cattails. They reported that reduced nitrogen concentrations increased root growth by as much as 75 percent over plants grown in normal concentrations.

Establishing a cattail crop in potential wetland areas might be greatly facilitated if it were possible to use seeds as opposed to the rhizome pieces used in the first several years of the University of Minnesota study. Rhizome pieces require a greater sacrifice of materials from the previous year's harvest, would be more difficult to plant and would have to be refrigerated if stored over winter for spring planting. With this in mind, procedures have been developed for isolating the seed from contaminating materials in the spike, so that seeds could be dispersed more easily and accurately (Bonnewell, in preparation). Because little was known of conditions favoring germination of the seed, a laboratory and field study was initiated. In 1978, cattails were successfully grown from seed in peat filled paddies on the St. Paul campus, and although seeding did not occur until relatively late in the season (June 27), yields of 8 tons/hectare were obtained (Bonnewell, in preparation). Encouraged by this success, efforts are underway to establish cattail stands from seed in the Carlos Avery Wildlife Area twenty miles north of the Twin Cities. Obviously, it is premature to preduct how successful this effort will be, although initially at least the venture appears to be quite successful.

Other aspects of our cattail research during the past two growing seasons have dealt with growth requirements which must be understood before cropping efforts can be successful (Pratt, 1978; Bonnewell, in preparation). Included among these are the following: optimum soil pH for cattail growth, optimum fertility levels and optimum levels of individual nutrients, need for minor elements and the light requirement for seed germination. Parameters related to field culture and harvesting have also been investigated, including the following: optimum planting rates for seeds and seed pieces, depth and distribution of roots and rhizomes in peat and mineral soils and techniques for establishing floating mats of hydroponically nourished cattails. Biochemical features of the cattail are also under investigation, including a determination of the moisture, protein, fat, ash, crude fiber and carbohydrate concentration of rhizomes and leaves, and the relative amounts of starch and cellulose in various parts of the plant (Glass, 1978, 1979).

The Basis for the Cattail's High Seasonal Productivity

The rate of cattail biomass accumulation is greatest, and almost constant, between June 15 and September 15 (Moss *et al*., 1977). Thus, the decreasing day length through July and August appears to be compensated for by increased photosynthetic capacity as the foliage canopy develops. Growth rates during the period of maximum production average about 40 g/m^2 day in agricultural soils, and about 30 g/m^2 in peat soils (Andrews and Pratt, 1978; Pratt, 1978a). Loomis and Gerakis (1975) cite record high growth rates for agricultural crops of near 50 g/m^2 day for C_4 species like corn, and 35 g/m^2 day for C_3 species like soybeans achieveable, normally, for only relatively short periods of 2 or 3 weeks. A growth rate of 30-40 g/m^2 day for a two month period is remarkable in that it is sustained for an unusually long period of time. The solar radiation capture efficiency increases as the season progresses, and as the foliage canopy develops more fully, reaching its highest value of 3.1 percent in August (Moss et al., 1977). These values are well below the 4.5 percent values reported for both C_3 and C_4 crop species during their period of most rapid growth (Loomis and Gerakis, 1975); and thus the high seasonal yields of cattails are due more to a sustained moderate level of growth than to an unusually high spurt of photosynthetic activity.

The high productivity of cattails can be rationalized in a number of ways. Its peculiar leaf anatomy can be described as two appressed leaves separated by a reflective barrier, and this structure appears to increase the efficiency with which directly incident and reflected sunlight can be utilized in photosynthesis. The leaf area index in cattail stands can reach values of 8 or 10, while the usual maize field will maintain an index of only 4 to 5 (Moss et al., 1977); and in the foliage canopy, because of the upright leaf angle, a greater proportion of the leaf area is exposed to direct sunlight. In contrast with most crop plants, cattails begin growth early in the spring and remain active until the leaves are killed by frost in the fall. Because of their adaptability to a wide range of temperatures, they are able to remain active through a greater proportion of the growing season. Each of these factors undoubtedly contributes to the cattail's success as solar energy collector, but the relative importance of each has not as yet been carefully assessed.

Some Structural and Biochemical Aspects of Cattails

The above and below ground portion of cattail biomass take two distinctly different forms, structurally and biochemically. The above ground green leafy material consists largely of cellulose and hemicellulose, with a lignin content appreciably lower than typical wood tissues (Ladisch, M.R., personal communication), which is significant when considering the extraction and utilization of the cellulose since lignin is a major impediment to such efforts. The portions of the leaves above the water level dry down following a killing frost to a moisture level approaching 20 percent, at which point they are easily combustible. By the end of the season, about 40 percent of the total biomass normally consists of leaf material, although values from 25 to 50 percent have been observed (Pratt, 1978a). The reasons for this high degree of variability have not been established. The below ground portion of the cattail plant consists primarily of whitish, spongy rhizomes with attached roots. From 90 to 95 percent of the rhizome biomass is located in the top eight inches of soil, and as much as 70 percent of its dry weight consists of edible starch (amylose and amylopectin) and sugar (sucrose, glucose and fructose) (Glass, R., personal communication). The rhizomes might be used as food for animals or humans, although this possibility has not been adequately studied. The relative simplicity of processing starches and sugars as opposed to lignin and cellulose makes the rhizome particularly valuable.

Experiments in the Carlos Avery Wildlife Area

Mention was made earlier of seeding experiments presently underway in the Carlos Avery area. We are now in the second year of other experiments in the same area designed to contribute helpful information for managing cattail crops. Some of the parameters under investigation are the following: the effect of cutting and harvesting shoots on productivity, regeneration and over-wintering; the effect of fertilization and pH control on productivity in natural stands; the feasibility of establishing cattail stands by seeding and planting of rhizome pieces; and the effects of harvesting shoots, roots and rhizomes on regeneration and productivity. Progress reports are issued periodically on this research (Pratt, 1978b, 1979a, 1979b), but definitive results will not be available until the final report is prepared in December of this year.

Harvesting Literature Related to Wetland Plants

The harvesting of cattail plant material provides a new opportunity for harvesting machine design. No other harvesting system known is fully capable of harvesting cattail plant material. However, many ideas may be obtained from studying harvesting systems for aquatic plants and root crops. Many of the aquatic plant harvesting systems are designed to harvest floating surface plants such as water hyacinth, water-borne plants such as algae, emergent plants such as reeds and rushes, and submerged rooted plants.

Existing harvesting systems deal only with above-ground plant material, but it may be that cattail harvesting must include collection of both the above and below ground portions. If the harvesting of cattail plant material involves two stages, i.e., harvesting above-soil plant material and below-soil plant material, then the existing aquatic harvesting equipment has direct application for the first stage only (Koegel et al., 1978).

The basic steps for harvesting aquatic plants are: (a) cut the vegetation below the water surface at a convenient depth to free a large part of the plant material but leave the root system intact, (b) collect the cut portions of the plants and remove them from the water, and (c) transport, process and dispose or utilize the plant material as feasible (Livermore and Koegel, 1978).

Some aquatic harvesting systems, referred to as single stage, combine the first two steps. Components of such a system include a horizontal reciprocating mower bar mounted directly ahead of the lower end of an inclined, porous elevating conveyor which extends the full width of the cutter. On some systems, vertical cutters are utilized to provide a clean cut through dense beds. The elevating conveyor moves plant material to a holding bin (Livermore and Koegel, 1978).

Another aquatic plant harvesting system separates the first two steps. The plant material is cut by a machine below the water and permitted to float. A second machine, sometime later, collects the floating material which may have moved some distance from the cutting site (Livermore and Koegel, 1978).

The major problem to be solved in harvesting the cattail plant material is collecting the material below the soil surface. Several tuber and root harvesting systems do exist for potatoes, sugar beets and other vegetables. However, these systems deal with plants which are in rows and not partially submerged. This facilitates harvesting. The roots of cattails appear to form a large dense matrix of intercrossing roots, thus causing the vegetable harvesting equipment to be unsatisfactory for direct application to harvesting cattail rhizomes.

The harvesting of taro, an edible aroid, may provide some insight into how to harvest a wetland root crop. The taro plants are grown in rows, therefore provide a different situation compared to harvesting cattail. Taro harvesting utilizes auger flighting for digging and plant breakage prior to lifting the root material from the soil. This auger operates at a depth of 6 inches (Smith, 1975).

Sod cutting is another harvesting method which may provide some direction. In this system, a vibrating knife is used to separate the sod from the soil, so the same concept may provide a means for separating rhizome matrix from the soil.

The literature does not give any clear direction to the best type of harvesting system. Therefore, a long research process is anticipated during which many types of equipment will be tested under actual conditions. This type of research will be very expensive because of the need to design and build one of kind units.

Summary of Previous Work on Land Use

Extensive work regarding land use and land use suitability has taken place in Minnesota. Much of that work has been facilitated by an environmental information system developed by CURA and now operating in the State Planning Agency--the Minnesota Land Management Information System (MLMIS). MLMIS contains three features relevant to this study:

(1) A rich geographic data base of environmental and cultural information, e.g., land use, forest cover type, soil, ownership, etc.

(2) The ability to interpret and overlay this data.

(3) Tabular and map output.

By using this tool, many relevant studies have been completed.

The location of peat deposits and their characteristics are of direct concern to this study. Three major peat concentrations in northern Minnesota were studied and mapped for energy content of the peat: Koochiching county, the Arrowhead region and the Northern Headwaters region (CURA, 1976a, b and c). Public ownership of these lands was mapped and tabulated in three separate reports which were aimed at aiding in the development of public policy with regard to the mining of peat. Anderson (1978), who had worked on these reports for MLMIS, expanded the scope of this investigation in his study of the peat resources of Koochiching county. Here potential conflicting uses of the peat lands were studied in detail.

Other conflicting land uses have also been studied. Minnesota lands most suited to cropping have been determined and mapped by the State Planning Agency (EPD, 1978). Studies of drought and irrigation potential are currently underway to supplement that work. A model for determining lands most suited to commercial forestry has been developed and has been used to map these lands in the Arrowhead region. The amount of new land in Minnesota required for these and a dozen different land uses in 1990 has been studied and reported by the State Planning Agency (EPD, 1978).

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Pratt, D.C. 1978b, 1979a, 1979b. Progress reports 1, 2 and 3 to Minnesota Energy Agency on project entitled "Potential of Cattails as an Energy Source." 3 pages, 10 pages and 3 pages respectively.

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Westlake, D.F. 1963. Comparisons of plant productivity. Biol. Rev. 38: 385-425.

CURRICULUM VITAE

July 1979

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AGE:	31
MARITAL STATUS:	Married

EDUCATION:

Dates	Colleges	Major	Degree
Sept. 1966--June 1970	St. Olaf College Northfield, MN	Biology History	B.A.
Sept. 1971--Sept. 1974	Univ. of Minnesota Minneapolis, MN	Soil Science	
Sept. 1974--Sept. 1977	Univ. of Minnesota Minneapolis, MN	Geography	M.A.

M.A. Thesis: "An Inventory and Evaluation of the Peat Resources in Koochiching County, Minnesota."

PROFESSIONAL EXPERIENCE: (10/76 - present) Land use planning consultant to the Minnesota State Planning Agency, Division of Environmental Planning, St. Paul, Minnesota, 55101.

Description of Tasks:

(10/76 - 6/79) I developed a cropland suitability study for the State of Minnesota. Using the Minnesota Soil Atlas, state climatic data, and the MLMIS computer system, I constructed a model which evaluated the capability of all soils in Minnesota to produce the commonly grown agricultural crops. Land use and ownership factors which place limitations on the availability of land for agricultural purposes, were also considered. The published report, Minnesota Cropland Resources, provides maps and manuscripts describing the analysis process.

(9/78 - 6/79) I coordinated a study which modeled the occurrence of agricultural drought in four west-central Minnesota counties. Using data on crop water demands, soil types, and records of temperature and precipitation, the probabilty and duration of drought was predicted. The MLMIS computer system was employed to map the drought prone soils and the subsequent water requirements should irrigation be used. The results of this investigation will provide vaulable information concerning potential demand on groundwater resources. This study is documented in a report submitted to the contracting agency.

(1/79 - 7/79) I developed a system of evaluating the soils of the Minnesota Soil Atlas according to their physical and chemical properties. About thirty characteristics of each soil type were considered. Among these were erosion factor (K) shrink-swell, hydrologic grouping and permeability. Over one thousand separate soil types have been rated and this information is now stored on the MLMIS computer system. This data is currently being used by several state agencies in land use investigations.

(7/78 - present) Research Fellow (part time), Center for Urban and Regional Affairs, University of Minnesota.

Description of Tasks:

I have provided technical assistance on land use change studies conducted by the Center on Olmsted, Wright and Clay Counties. Duties have included data collection, interpretation, and design of research methods. I have also provided liaison services between the Center and governmental agencies (State and Federal) on a number of land use concerns.

(3/73 - 9/76) Graduate research assistant and contract employee, Minnesota Land Management Information System, (MLMIS), Center for Urban and Regional Affairs, University of Minnesota.

Description of Tasks:

The MLMIS is a resource inventory and management system that was developed at the University of Minnesota and is now administered by the Land Management Information Center at the Minnesota State Planning Agency. The primary objective of the MLMIS is to provide information to public officials in making land and water management decisions. Personal duties included the development of state and regional models for forestry, peat mining and agriculture. I was also responsible for development and interpretation of all soil data used in resource studies conducted by the project.

(4/74) Consultant to EDAW Inc., Environmental Planners, Minneapolis, Minnesota.

Description of Tasks:

I was responsible for developing a statewide rating of Minnesota lands for forest production. The prepared map and text were used in a power plant siting report prepared by the above planning corporation.

PUBLICATIONS AND REPORTS:

Minnesota Cropland Resources, Division of Environmental Planning, Minnesota State Planning Agency, 1979.

"Agricultural Drought and Irrigation Needs in West Central Minnesota" (project report), Division of Environmental Planning, Minnesota State Planning Agency, 1979.

"Interpretations for the Soils of the Minnesota Soil Atlas" (project report), Division of Environmental Planning, Minnesota State Planning Agency, 1979.

"Koochiching County Peat Resources - A Planning Demonstration", Center for Urban and Regional Affairs, Map Series No. 4, University of Minnesota, Minneapolis, MN., April 1975. (With Alan Robinette and Don Yaeger)

"Soil Information and Interpretive Procedures", Center for Urban and Regional Affairs, Report No. 4004, University of Minnesota, Minneapolis, MN., January 1976.

"Forestry Demonstration Case Using the Minnesota Land Management Information System," Center for Urban and Regional Affairs, Report No. 4003, University of Minnesota, Minneapolis, MN., November 1974. (With Kenneth Kozar and Jack Shea)

"Peat Mining Suitability Study," Technical study on Arrowhead Region for Minnesota State Planning Agency, Center for Urban and Regional Affairs, University of Minnesota, Minneapolis, MN., March 1976. (With Alan Robinette)

Curriculum Vitae - Nancy J. Andrews

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Present Position: Assistant Scientist, University of Minnesota, Botany Department

Education:

1969-73 B.A. Carleton College, Northfield, MN, Biology major.

1973-75 M.A. University of South Dakota, Vermillion, SD, Plant Ecology. Thesis: Epiphytic Cryptogams and the Effects of Air Pollution in North-eastern South Dakota.

1975-77 Ph.D. Program, Washington University, St. Louis, MO. Plant Biology.

1977-present Ph.D. Program, University of Minnesota, St. Paul, MN. Botany.

Professional Organizations

American Society of Plant Physiologists
Ecological Society of America

Honors

Phi Sigma (elected 1974)
Phi Kappa Phi (elected 1979)

Employment

1979- Assistant Scientist, Univ. of Minn. Botany Department.
1977-79 Research Assistant, Univ. of Minn. Botany Department (part time).
1975-77 Research Fellow, Washington University, St. Louis, MO (part time).
1973-75 Research Assistant and Teaching Assistant, Univ. of South Dakota, Vermillion, NSF.

Publications

Andrews, N. J. 1975. Lichens: Natural Indicators of Air Quality. In: Sulfur in the Environment, Missouri Botanical Gardens.

Andrews, N. J. and D. C. Pratt. 1978. The Potential of Cattails (*Typha* spp.) as an Energy Source: Productivity in Managed Stands. Abstracts, 46th Annual Spring Meeting, Minn. Acad. Sci.

Andrews, N. J. and D. C. Pratt. 1978. Energy Potential of Cattails and Productivity in Managed Stands. J. Minn. Acad. Sci. 44(2).

Pratt, D. C. and N. J. Andrews. 1980 (in preparation). Cattails as an Energy Source. Symposium Papers, Institute of Gas Technology, 1980.

CURRICULUM VITAE

January 1979

NAME:	William James Craig
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TELEPHONE:	Office: (612) 373-7833 Home: (612) 377-8888
BIRTH:	July 13, 1942, Minneapolis
MARITAL STATUS:	Married
CHILDREN:	Joshua, born February 24, 1974, and Jessica, born July 1, 1976
EDUCATION:	B.A. 1965 University of Minnesota, Minneapolis Major: Mathematics Minor: Geography M.A. 1972 University of Minnesota, Minneapolis Major: Geography Supporting fields: Economics and Statistics M.A. Research Paper Topics: "Paired Schools: Selecting a Partner for Kenwood Elementary School by Minimizing Physical and Social Distances," and "The Demographic Potential Model: Its Theory and Value in Historical Analysis"
MILITARY EXPERIENCE:	None
POSITIONS HELD:	(9/70 - present) Assistant Director of the Center for Urban and Regional Affairs (CURA) at the University of Minnesota. CURA was established in 1967 to increase University involvement with the community. My job involves providing liaison between the faculty and students at the University and public and private officials in the community. In addition, I provide technical support to both these groups. Specific projects include: -- Minnesota Land Management Information System (MLMIS). I have both directed this project and been its information system director. I did much of the technical design work and wrote most of the data entry software. MLMIS is now an operational service of the Minnesota State Planning Agency.

-- Land Records and Computer Assisted Assessment. This project was funded by the state of Minnesota through its Intergovernmental Information Systems Advisory Council (IISAC). I directed this project and did most of the research. Phase one produced a conceptualization report defining what further work should be done. This report was based on a review of the literature, statute, and county operating environments. Phase two produced a request-for-proposals, which will be issued and funded by the state, for the development of a transferable computer assisted appraisal system.

-- Other Land Based Research. I have been involved with various committees and headed research projects dealing with land. State Committees have included committees on parcel identification and geocoding standards for IISAC, the State Planning Agency committee on defining and mapping prime agricultural lands, the Department of Transportation's committee on land use and development issues of the state transportation plan, and the MLMIS advisory committee. Research projects have included studying consistency of air photo interpretation, the possibility of using building permits to monitor changes in land use, the conversion of prime agricultural land to urban uses, and many more. See publications below.

-- Numerous others which involved project evaluation (e.g. St. Paul USAC project), extensive use of Census data, survey research, computer assisted cartography, systems analysis and design, computer programming, and spatial analysis.

(9/68 - 8/70) Director of the Social Sciences Research Facilities Center (SSRFC) at the University of Minnesota. This Center provides technical consulting and programming services for Social Science students and faculty. In addition to directly servicing this clientele, I was responsible for managing the staff and equipment of the center.

PUBLICATIONS AND REPORTS:

"Accessibility Measurement and Use in Land Use Planning," paper prepared for 14th Annual Conference of the Urban and Regional Information Systems Association, August 1976.

"Analysis of the Interstate Commerce Commission's Proposed Expansion of the Minneapolis-St. Paul Commercial Zone and Alternative Proposals," for MacKall, Crounse and Moore, of Council, March 3, 1976.

"An Analysis of the Racial Disparities in the Juror Selection Procedures in the Western Division of the South Dakota Federal District Court," paper prepared for the Wounded Knee Defense Committee, September 14, 1973.

"Computers and Public Service," special topic issue of CURA Reporter, Center for Urban and Regional Affairs, University of Minnesota, Vol. V No. 1, February/March 1975.

"Land Records and Computer Assisted Assessment," Proceedings of the 15th Annual Conference of the Urban and Regional Information Systems Association, 1977, Vol. 3, pp. 389-395.

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"MLMIS Data Entry Software System Documentation," Minnesota Land Management Information System, Center for Urban and Regional Affairs, University of Minnesota, January 1977, 168 pages.

"MLMIS Geocoding Procedures," Minnesota Land Management Information System, publication # 4005, Center for Urban and Regional Affairs, University of Minnesota, July 1976.

Perspective on Minnesota Land Use - 1974, with John R. Borchert, et. al., Minnesota Land Management Information System report #6, Center for Urban & Regional Affairs, University of Minnesota, 1974.

"Projected 1970-80 Population Changes," SPA/CURA Wall Map Series, Map 4, Center for Urban and Regional Affairs, University of Minnesota, October 1977.

"Reapportionment and the Computer," Law and Computer Technology, Vol. 6, No. 2, March/April 1973, pp. 50-56.

"Redistricting," Commentary in Annals, of the Association of American Geographers, Vol. 67 (1977), pp. 641-43.

"Residential Heating Fuel Type, 1970," SPA/CURA Wall Map Series, Map 5, Center for Urban and Regional Affairs, University of Minnesota, March 1978.

"University of Minnesota Final Project Evaluation Report," with T.L. Anding, J.E. Jernberg, R.S. Johnson, and S.J. Kahn, Human Resources Development Subsystem HUD contract No. H-1214, document No. ST0018, March 1972.

"A Useful Computer Function to Measure Distances," The Professional Geographer, Vol. 23, 1971, pp. 157-159.

PROFESSIONAL ORGANIZATIONS

Association of American Geographers (since 1967)

Urban and Regional Information Systems Association (since 1970)

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Education

B.Sc. with diploma of Distinction in botany and zoology, Dalhousie University, Halifax, Nova Scotia, Canada, 1945

M.Sc. in experimental zoology, Dalhousie University, 1947

Ph.D. in plant ecology, University College, London, 1951

Research fellowship, State Forest Research Institute, Stockholm, and Institute of Plant Ecology, Uppsala, Sweden, 1950-51

Professional employment

1943 Summer Assistant, Dalhousie University Herbarium.

1944 Summer Assistant, Dominion Experimental Station, Kentville, N.S.

1945 Summer Assistant, Dominion Dept. of Agriculture, vegetation survey of the Maritime Provinces of Canada.

1946 Demonstrator in elementary zoology, Dalhousie University.
Summer Assistant, Inland Fisheries Survey of Nova Scotia.

1947 Demonstrator in experimental zoology, Dalhousie University.
Summer Assistant, Inland Fisheries Survey of Nova Scotia.

1950 Lecturer in Botany (Grade IIc), University College, London, England.

1952 Lecturer in Botany (Grade IIa), University College, London, England.

1954 Ecologist, Freshwater Biological Association, Ambleside, England (Senior Scientific Officer).

1958 Lecturer in Botany, University of Toronto, Ontario, Canada.

1959 Assistant Professor of Botany, University of Toronto.
Research Worker (summer), Ontario Dept. of Lands and Forests.

1960 Research Worker (summer), Ontario Dept. of Lands and Forests.

1961 Associate Specialist (summer), Dept. of Soils and Plant Nutrition, University of California, Berkeley.

1962 Associate Professor of Botany, University of Minnesota.

1965 Professor and Head, Dept. of Biology, University of Calgary, Alberta, Canada.

1966-74 Professor of Botany, University of Minnesota.

1967-71 Head, Dept. of Botany, University of Minnesota (elected by Dept. faculty).

1975- Professor of Ecology, University of Minnesota.

Membership in professional organizations

Present

American Association of University Professors (Vice-pres., University of Minnesota (Twin Cities) Chapter, 1967-68, President, 1968-1969, Executive Board Member also in 1964-65, 1969-71, 1979).

American Society of Limnology and Oceanography (member Editorial board, 1970-72).

British Freshwater Biological Association.

Ecological Society of America (member Editorial Board 1965-67).

International Association of Pure and Applied Limnology.

Scientists' Institute for Public Information (elected as member, 1971, fellow 1972).

Past

American Association for the Advancement of Science.

American Geophysical Union (member, Committee on Geochemistry of Water, 1965-67),

American Institute of Biological Sciences.

British Society of Soil Science.

British Ecological Society.

Federation of American Scientists.

International Commission on Atmospheric Chemistry and Radioactivity, Association of Meteorology and Atmospheric Physics (member for Canada, 1959-62).

Minnesota Academy of Science.

Minnesota Committee for Environmental Information (Charter member and board member 1968-70).

Nature Conservancy of America.

New York Academy of Science.

Nova Scotia Institute of Science.

Relevant publications (out of a total of approximately 100)

1949 Some chemical aspects of a peat profile. Journal of Ecology 37: 24-27.

1950 Variation in some chemical conditions along the borders of a Carex lasiocarpa fen community. Oikos 2: 217-40.

1951 The iron and manganese content of some plants present in the natural vegetation of the English Lake District. Annals of Botany 15: 247-63. (A.M. Mayer and E. Gorham).

1953 A note on the acidity and base status of raised and blanket bogs. Journal of Ecology 41: 153-56.

1953 Some early ideas concerning the nature, origin and development of peat lands. Journal of Ecology 41: 257-74. (review).

1953 Chemical studies on the soils and vegetation of some waterlogged habitats in the English Lake District. Journal of Ecology 41: 345-60.

1955 On the acidity and salinity of rain. Geochimica Cosmochimica Acta 7: 231-39.

1956 Acidity and specific conductivity measurements in some plant communities of the New Forest valley bogs. Journal of Ecology 44: 118-28. (P.J. Newbould and E. Gorham).

1956 Acidity, specific conductivity, and calcium content of some bog and fen waters in northern Britain. Journal of Ecology 44: 129-141. (E. Gorham and W.H. Pearsall).

1956 The ionic composition of some bog and fen waters in the English Lake District. Journal of Ecology 44: 142-52.

1956 On the chemical composition of some waters from the Moor House nature reserve. Journal of Ecology 44: 377-84.

1956 Production ecology I. Standing crops of natural vegetation. Oikos 7: 193-201. (W.H. Pearsall and E. Gorham).

1957 The development of peat lands. Quarterly Review of Biology 32: 145-66 (review).

1958 The influence and importance of daily weather conditions in the supply of chloride, sulphate and other ions to fresh waters from atmospheric precipitation. Philosophical Transactions of the Royal Society of London, B, 241: 147-78.

1958 Free acid in British soils. Nature 181: 106.

1958 Accumulation of radioactive fallout by plants in the English Lake district. Nature 181: 152-54.

1959 A comparison of lower and higher plants as accumulators of radioactive fallout. Canadian Journal of Botany 37: 327-29.

1960 The chemical composition of some bog waters from the Falkland Islands. Journal of Ecology 48: 175-81. (E. Gorham and J.B. Cragg).

1961 Factors influencing supply of major ions to inland waters, with special reference to the atmosphere. Bulletin of the Geological Society of America 72: 795-840 (review).

1961 Water, ash, nitrogen and acidity of some bog peats and other organic soils. Journal of Ecology 49: 104-6.

1961 The ionic composition of waters from three Polish bogs. Journal of Ecology 49: 127-33. (S. Tolpa and E. Gorham).

1967 Some chemical aspects of wetland ecology. Proceedings of the 12th Annual Muskeg Research Conference, Calgary, Canada, 1966. Technical Memoirs of the National Research Council of Canada, Associate Committee on Geotechnical Research, No. 90: 20-38 (review).

1967 Caloric values of organic matter in woodland, swamp, and lake soils. Ecology 48: 492-94. (E. Gorham and J. Sanger).

1971 The penetration of bog peats and lake sediments by tritium from atmospheric fallout. Ecology 52: 898-902. (E. Gorham and R.H. Hofstetter).

1973 A comparison of the abundance and diversity of fossil pigments in wetland peats and woodland humus layers. Ecology 54: 605-11. (J.E. Sanger and E. Gorham).

1974 Distribution of purple photosynthetic bacteria in wetland and woodland habitats of central and northern Minnesota. Journal of Bacteriology 117: 826-33. (M.E. Burke, E. Gorham and D.C. Pratt).

1974 The relationship between standing crop in sedge meadows and summer temperature. Journal of Ecology 62: 517-521.

1976 Acid precipitation and its influence upon aquatic ecosystems — an overview. Proceedings, First International Symposium on Acid Precipitation and the Forest Ecosystem, Ohio State University, 1975 (review), pp. 425-458. Also in Journal of Water, Air and Soil Pollution 6: 457-481 (review).

1978 Life history aspects of primary production in sedge wetlands. Pp. 39-51 in Freshwater Wetlands, ed. R.E. Good, D.F. Whigham and R.L. Simpson, Academic Press. (J.M. Bernard and E. Gorham).

1978 Ecological aspects of the chemistry of atmospheric precipitation. Pp. 265-296 in Multidisciplinary Research Related to Atmospheric Sciences, ed. M.H. Glantz, H. van Loon and E. Armstrong, National Center for Atmospheric Research, Boulder, Colorado (review).

1978 The mineral content of Sphagnum fuscum as affected by human settlement. Canadian Journal of Botany 56: 2755-2759. (E. Gorham and D.L. Tilton).

CURRICULUM VITAE

NAME:	Rex Lovrien
BIRTHDATE:	January 25, 1928, Eagle Grove, Iowa
U.S. CITIZEN:	Male
EDUCATION:	B.A. Univ. of Minnesota, 1953 Ph.D. Univ. of Iowa, 1958 (Physical Chemistry)
POSTDOCTORAL POSITIONS:	NSF Postdoctoral, Yale University, 1958-1959. NSF Postdoctoral, Yale University, 1960-1961. NIH Postdoctoral, Univ. of Indiana, 1961-1962. Research Associate, Univ. of Minnesota, 1962-1964.
HONORS, PROF. SOCIETIES:	Bausch and Lomb Awardee Phi Lambda Upsilon Award Elected member, Am. Soc. of Biol. Chemists Sigma Si, Biophys. Soc., Am. Chem. Soc., Am. Assoc. Adv. of Sci.
POSITIONS:	Prof. in Biochemistry, 1977 to date. Assoc. Prof. in Biochemistry, Coll. Biol. Sciences, 1969 to 1977. Assoc. Prof. in Bioengineering Program, 1973 to date. Assis. Prof. in Biochemistry, 1965 to 1969.
RESEARCH INTERESTS (Biochemistry and bioengineering):	Enzymology and fermentation, conversion of cellulose, thermophilic enzymes. Thermochemistry of chemical and biochemical reactions, bacterial heat production. Analytical biochemistry, the human red cell, and hydrocarbon solubility. Separation of enzymes, and inhibition and control of enzymes.
TRAINEES AND POSTDOCTORAL FELLOWS COMPLETED:	Four Ph.D. trainees Four M.S. trainees
PUBLICATIONS:	Kurtti, T., Brooks, M., Wensman, C. and Lovrien, R. Direct Microcalorimetry of Heat Generation by Individual Insects. _J. Thermal Biol._ _4_, 129-136 (1979). Anderson, P.C. and Lovrien, R. A Flow Calorimeter for Assay of Hormone and Metabolite Induced Changes in Steady State Heat Production by Tissue. (In press) _Analytical Biochemistry_ 1979.

Anderson, P.C. and Lovrien, R. Energetics of the Response of Coleptile Tissue to Indoleacetic Acid. Characterization by Flow Calorimetry as a Function of Time, IAA Concentration and pH. (Accepted) Planta (1979).

Anderson, K.J., Hart, G. and Lovrien, R. Quantitative Aspects of Phenyl Substituted Alcohol and Ether Bacteriostatic Interaction with Escherichia coll B/5. Microbios. 26 (1978) 153-172.

Anderson, P.C. and Lovrien, R. Human Red Cell Hemolysis Rates in the Subsecond to Seconds Range. An Analysis. Biophys. J. 20, 181-191 (1977).

Pesheck, P.S. and Lovrien, R. Cosolvent Control of Substrate Inhibition in Cosolvent Stimulation of β-Glucuronidase Activity. Biochem. and Biophys. Res. Comm. 79, 417-421 (1977).

Gawtry, R. and Lovrien, R. Thermoelectric Design Considerations in Biological Microcalorimeters. Calorim. Conf. 30, 47-49 (1975).

Lovrien, R., Tisel, W. and Pesheck, P. Stoichiometry of Compounds Bound to Human Erythrocytes in Relation to Morphology. J. Biol. Chem. 250, 3136-41 (1975).

Hedlund, B. and Lovrien, R. Thermodynamics of 2,3-Diphosphoglycerate Association with Human Oxy- and Deoxyhemoglobin. Biochem. Biophys. Res. Commun. 61, 859-867 (1975).

Turner, R., Liener, I.E. and Lovrien, R. Equilibria of Bowman-Birk Inhibitor or Association with Trypsin and α-Chymotrypsin. Biochemistry 14, 275-282 (1974).

Lovrien, R., Pesheck, P. and Tisel, W. Protein and Hydrogen Ion Control of Photochromism in Aminoazobenzene Compounds. J. Am. Chem. Soc. 96, 244 (1974).

Lovrien, R. Thermochemical measurements of trypsin association with Inhibitors. Bulletin of Thermodynamics and Thermochemistry, 15th Ann. edition, p. 73 (1974).

Tan, K. and Lovrien, R. Enzymology in Aqueous-Organic Cosolvent Binary Mixtures. J. Biol. Chem. 247, 3278-3285 (1973).

Hedlund, B., Danielson, C. and Lovrien R. Equilibria of Organic Phosphates with Horse Oxyhemoglobin. Biochemistry 11, 4660-68 (1973).

MANUSCRIPTS SUBMITTED: Four new manuscripts submitted in 1979, for J. Cell Biol., Biotech. and Bioeng., Biochemistry, and Science.

CURRICULUM VITAE -- Douglas C. Pratt

BIRTH Minneapolis, Minn. 31 March 1931

SOCIAL SECURITY NUMBER 469-26-4755

FAMILY STATUS Married, seven children

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University of Minnesota, St. Paul,
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EDUCATION

B.S. with distinction, in natural science education
Univ. of Minn., Mpls. 1952

M.A. in botany (plant physiology)
Univ. of Minn., Mpls. 1959

PhD in botany (plant physiology)
Univ. of Minn., Mpls. 1960
thesis professor: A. W. Frenkel

POSTDOCTORAL EDUCATION

A.E.C. Post Doctoral Fellowship in Physical Chemistry (Photochemistry), Chemistry Dept., Univ. of Minn. 1960-62.
Supervisor: R. S. Livingston

PROFESSIONAL ORGANIZATIONS

<u>Present</u>

- AAAS
- Amer. Assn. Univ. Prof.
  - Vice-Pres., Univ. of Minn. (Twin Cities Chapter), 1972-73
  - President 1973-74
  - member of executive board for 7 years
- Amer. Soc. Photobiology
- Amer. Soc. of Plant Physiol.
- Minn. Acad. Science

<u>Past</u>

- Amer. Chem. Soc.
- Bot. Soc. Amer.
- Minn. Committee for Environ. Information
- Nature Conservancy
- Soc. of Gen. Physiologists

HONORS

- NROTC Scholarship 1948-52
- Kettering Foundation Fellowship 1955-59
- Sigma Xi (elected full member 1960)

EMPLOYMENT RECORD

1952-55 Supply Officer, U.S.N.
1960 Instructor, Botany Dept., Univ. of Minn.
1960 Research Scientist, Northrup King Seed Company.
1962-66 Asst. Prof., Carleton College, Northfield, MN.
1966-70 Assoc. Prof., Botany Dept., Univ. of Minn.
Director of Gen. Biology Program, 1966-69.
1970- Professor, Botany Dept., Univ. of Minn.
Chairman, Plant Physiol. Program 1973-75.
Head, Botany Dept., 1975- .

PUBLICATIONS

Pratt, D. C. and A. W. Frenkel. 1958. Nitrogen fixation and photosynthetic activity in Rhodospirillum rubrum. Bacteriological Proceedings: p. 45.

Pratt, D. C. and A. W. Frenkel. 1959. Studies on nitrogen fixation and photosynthesis of Rhodospirillum rubrum. Plant Physiol. 34: 333-337.

Dubach, P., D. C. Pratt, F. Smith and C. M. Steward. 1959. The possible role of glycerol in the winter-hardiness of insects. Nature 184: 288-289.

Pratt, D. C., D. D. Hickman and A. W. Frenkel. 1960. Formation of photochemically active chromatophores in dark grown cells of Rhodospirillum rubrum. Plant Physiol. 35: supplement x.

Pratt, D. C., A. W. Frenkel and D. D. Hickman. 1961. Observations on the formation of the photosynthetic apparatus in Rhodospirillum rubrum and some comments on light-induced chromatophore reactions. In: Biological Structure and Function, Goodwin and Lindbergh, ed., pp. 295-306. Academic Press, New York, New York.

Grellmann, K. H., R. Livingston and D. Pratt. 1962. A flash photolytic investigation of rhodopsin at low temperatures. Nature 193: 1258-1260.

Pratt, D. C., R. Livingston and K. H. Grellmann. 1964. Flash photolysis of rod particle suspensions. Photochem. and Photobiol. 3: 121-127.

Pratt, D. C. 1968. Photoreactions of isorhodopsin at low temperatures. Photochem. and Photobiol. 7: 319-324.

Pratt, D. C. and E. Gorham. 1970. Occurrence of Athiorhodaceae in woodland, swamp and pond soils. Ecology 51: 346-349.

Lam, P. B. and D. C. Pratt. 1970. A comparison of light-triggered spectral changes in rhodopsin and isorhodopsin. Photochem. and Photobiol. 12: 44-48.

Burke, M. J., A. Moscowitz and D. C. Pratt. 1971. 10 Cis Retinylidene in the visual pigments. Fed. Proc.

Burke, M. E., R. Eastman, E. Gorham and D. C. Pratt. 1971. Photosynthetic bacteria at two locations in Minnesota. Bact. Proceedings.

Pratt, D. C., P. L. Bergad, and G. E. Ham. 1971. Nitrogenase activity in a strain of Rhodopseudomona sp. containing bacteriochlorophyll b. Bact. Proceedings.

Gorham, E. and D. C. Pratt. 1972. Influence of soil acidity on the occurrence of Athiorhodaceae. Journal of the Minn. Acad. of Science 38: 2-4.

Burke, M. J., D. C. Pratt and A. Moscowitz. 1972. Low-temperature absorption and circular dichroism studies of phytochrome. Biochemistry 11: 4025-4031.

Burke, M. J., D. C. Pratt and A. Moscowitz. 1972. Low-temperature absorption and circular dichroism spectra of phytochrome. Plant Physiology. supplement.

Burke, M. J., D. C. Pratt, T. R. Faulkner, and A. Moscowitz. 1973. Analysis of the absorption and circular dichroism of some visual pigments. Experimental Eye Research 17: 557-572.

Burke, M. E., E. Gorham and D. C. Pratt. 1974. Distribution of purple photosynthetic bacteria in wetland and woodland habitats of central and northern Minnesota. Journal of Bacteriology 117: 826-833.

Andrews, N. J. and D. C. Pratt. 1978. The potential of cattails as an energy source: Productivity in managed stands. Abstracts, 46th Annual Spring Meeting, Minn. Acad. Sci.

Bonnewell, V. and D. C. Pratt. 1978. Effects of nutrients on Typha angustifolia x latifolia productivity and morphology. Abstracts, 46th Annual Spring Meeting, Minn. Acad. Sci.

Andrews, N. J. and D. C. Pratt. 1978. The potential of cattails (Typha spp.) as an energy source: Productivity in managed stands. Journal Minn. Acad. Sci. 44: 5-8.

Bonnewell, V. and D. C. Pratt. 1978. Effects of nutrients on Typha angustifolia x latifolia productivity and morphology. Journal Minn. Acad. Sci. 44: 18-20.

Gorham, E. and D. C. Pratt. 1978. Minnesota's wetlands -- the potential uses of peat bogs and cattail marshes. Ag. World 4(6): 1-5.

Pratt, D. C. 1978. Fuel for the future. In: Sun Day Minnesota. Special publication of Minnesota Environmental Education Board.

Bolton, G. and D. C. Pratt. 1979. A new method for the purification of phytochrome. Plant Physiol. (accepted for publication).

OTHER PROFESSIONAL ACTIVITIES

Reviewer of manuscripts for Plant Physiology

Reviewer of grant requests for NSF

Panelist, NSF Institutional Scientific Equipment Program (2 years)

Panelist, DOE Appropriate Energy Technology Grant Program

Lecturer. Numerous appearances over the past decade before state and local government bodies and public audiences in person and on radio and TV to discuss environmental problems and bioenergy potential. Several appearances before area high school groups to discuss careers in biology.

Lecturer in KTCA-TV series "Our Man Handled Environment".

Member of Resource Council for the Science and Technology Project of the Minnesota Legislature.

MAJOR UNIVERSITY SERVICE

University Senate (two 3 yr terms)
Senate Committee on Resources and Planning
University Planning Council
Policy Committee for Cross-Disciplinary Studies, College of Liberal Arts
Administrative Committee of the College of Biological Sciences
Lake Itasca Field Station - Curriculum Advisory Committee
Director of Graduate Studies - Botany (2 terms)
Director of Graduate Studies - Plant Physiology Program
Committee on University Sponsored Educational Materials
St. Paul Learning Resources Center - Planning Committee
Summer School Advisory Committee
Dean's Committee to investigate salaries in the College of Biological Sciences as compared with other units within and outside the Univ. of Minnesota (chairman).

GRANT SUPPORT

NSF, 1963-66, A Flash-Photolytic Investigation of Rhodopsin. $28,500
NSF, 1966-68, An Investigation of the Photochemical Properties of Rhodopsin. $10,500
NSF, 1968-71, A Study of Light-Initiated Changes in Visual Pigments and Related Substances. $21,200
NSF, 1971-74, Intermediates in Photoconversion of Rhodopsin and Phytochrome. $25,600
NSF, 1977-79, The Photoconversion of Phytochrome: A Spectroscopic Study. $50,000
Minnesota Energy Agency, 1977-78. $25,000
Minnesota Energy Agency, 1978-80. $30,000
University of Minnesota Graduate School
1966 - $16,525
1967 - 4,995
1968 - 2,780
1969 - 4,500
University of Minnesota, Limnological Research Center, 1968-70, Distribution and Abundance of Photosynthetic Bacteria in Wetlands and Lakes of Minnesota. $6,700

VITAE

Name: Cletus E. Schertz

Academic Rank: Professor - full time

Degrees:	B.S. Agricultural Science, University of Illinois	Jan	1954
	B.S. Agricultural Engineering, University of Illinois	June	1954
	Ph.D. Co-major: Ag Eng and T & M, Iowa State U, Ames	June	1962

Other Related Experience:

1962-1967 Assistant Professor, Department of Agricultural Engineering, University of California, Davis

1957-1958 Instructor, T & AM, Iowa State University, Ames

Principal Publications:

Equipment and procedures for combine separation studies on wild rice. Paper no. NCR78-1003 for presentation at NC Regional ASAE Meeting, Saskatoon, Saskatchewan, 1978. (With Boedicker and Chinsuwan)

Wild Rice Harvest - new challenge for grain combines. Proceedings of the International Grain and Forage Harvesting Conference. ASAE. 1978. (With Oelke, Skoe, and Barron)

Reel drive-ground or power. Paper no. NC72-401 for presentation at the Regional ASAE Meeting in Brookings, South Dakota. 1972. (With Nystrom, Stieger, Tang and Theis)

Reel and grain interactions. Paper no. 72-624 for presentation at the ASAE Meeting, Chicago, Illinois. 1972. (With Lindblom)

Floating draper-extension header for soybeans. Paper no. 75-1536 for presentation at the ASAE Meeting in Chicago, Illinois. 1975. (With Nordquist)

Some comments on 'IPI' - Individually Paced Instruction Toward Better Teaching. University of Minnesota, Colleges of Agriculture, Forestry, and Home Economics. 9(2)5-6, 1976.

Reduction of soybean gathering losses with floating draper extension. Paper no. 76-1553 for presentation at the ASAE Meeting, Chicago, Illinois. 1976. (With Nordquist, Petersen, Unterzuber and Bebernes)

Scientific and Professional Societies:

American Socitey of Agricultural Engineers

American Society for Engineering Education

National Institute of Farm Safety

Honors and Awards:

Alpha Epsilon

Tau Beta Pi

Alpha Zeta

Sigma Xi

VITAE

Name: Ronald T. Schuler

Academic Rank: Associate Professor - Full Time

Degrees:

B.S. Agriculture, U of Wisconsin (Madison)	Jan	1963
B.S. Mechanical Engineering, U of Wisconsin (Madison)	Oct	1963
M.S. Agricultural Engineering, U of Wisconsin (Madison)	June	1967
Ph.D. Agricultural Engineering, U of Wisconsin (Madison)	Jan	1972

Other Related Experience:

1970-1976	Assistant and Associate Professor, North Dakota State U
1969-1970	Instructor, University of Wisconsin (Madison)
1965-1969	Research Assistant, University of Wisconsin
1963-1965	Officer, U.S. Army, Battle Creek, Michigan
Summer '63	Engineer Trainee, Hamilton Manufacturing, Two Rivers, Wisconsin

Principal Publications:

Effect of air flow and temperature in mechanical dryers on wheat quality. Proceedings of the Ninth Symposium on Thermal Agriculture. March 8-9, 1973. (With Moilanen and Miller)

Effect on wheat quality of air flow and temperature in mechanical dryers. Farm Research Bulletin 30(6)15-19, 1973. (With Moilanen & Miller)

Effects of drying on sunflower-seed oil quantity and fatty acid composition. Transactions of ASAE 16(3)520-521, 1973. (With Zimmerman)

Structurally damped Timoshenko beam theory applied to vibrating tree limbs. Transactions of ASAE 16(5)886-889, 1973. (With Bruhn)

Sunflower harvesting. The National Sunflower Grower 1(7)10, 12, 1974.

Sunflower-seed drying. The National Sunflower Grower 1(8)6-8, 10, 1974.

Testing radial ply tractor tires. Farm Research Bulletin 32(2)22-23, 1975. With Kucera and Vogel)

Grain harvesting losses in North Dakota. Farm Research Bulletin 32(6)20-21, 1975. (With Radakowski and Kucera)

Displacement, velocity and acceleration. Instrumentation and Measurement for Environmental Sciences. ASAE, St. Joseph, Michigan. Chapter 3, 1st Edition. (With H. W. VanGerpen)

Small Grain Harvesting Loss Evaluation in North Dakota. International Grain and Forage Harvesting Conference. Ames, Iowa. 1977.

Harvesting, Handling, and Storage of Sunflower Seeds, Sunflower Monograph, Chapter 4, 1978. (With Hirning, Hofman, and Lundstrom)

Scientific and Professional Societies of Which a Member:

American Society of Agriculture Engineers

Sigma Xi

National Association of Colleges and Teachers of Agriculture

North Dakota Registered Professional Engineer

Honors and Awards:

Alpha Epsilon