UTAH SCIENCE

UTAH AGRICULTURAL EXPERIMENT STATION SPRING 1984 VOLUME 45 NUMBER 1

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UTAH AGRICULTURAL EXPERIMENT STATION

ABOUT THE COVER

The fields, arrayed with new varieties of Utah grains, resemble a patchwork quilt.

BASIC RESEARCH IN PHOTO-SYNTHESIS

J. Y. TAKEMOTO

Among the processes of life, few or none can match photosynthesis in scope and importance. Consider the vast acres of land devoted to producing crops, the many highly vegetated forests, and not least our finely manicured lawns and gardens. Photosynthesis is the critical process working in all these cases. It supplies the nutrients and oxygen that sustain most non-plant life forms, including us, by using light energy derived from the sun.

Signaling its importance is the support given by virtually every major university in the United States to research on some aspect of photosynthesis. At Utah State University, funds for such research programs are often supplied by the Utah Agricultural Experiment Station. These studies cross the borders of the traditional sciences: biology, physics, and chemistry, because a full understanding of photosynthesis will require information from all of these basic disciplines.

Despite substantial past efforts, there are still large gaps in what we know about the mechanisms of photosynthesis. For instance, as yet we do not have the basic working knowledge to intelligently manipulate or engineer photosynthesis in plants to our benefit, for example, to increase the yield of crops.

Photosynthesis in Plants and Algae

Photosynthesis by plants and algae involves the conversion of carbon dioxide (CO_2) of the atmosphere to sugar:

$$6\,CO_2 + 6\,H_2O \xrightarrow{\text{light}} \underset{\text{(sugar)}}{C_6H_{12}O_6} + 6\,O_2$$

This requires a substantial input of energy, all of which comes from the sun. To accomplish the process, plants have evolved efficient systems that capture the sun's light energy, transform it into chemical energy, and thereby drive the chemical conversion of CO_2 to sugar.

The light-capture and energy-transformation systems are housed in discrete structures of plant cells known as chloroplasts (Figure 1). The molecules needed to collect and transform light energy are located in an intricate network of membranes within the chloroplast. These molecules are specifically arranged to form two kinds of complexes. These are called: 1) *reaction centers,* which convert the light energy to chemical energy, and 2) *light harvesters*, which gather light energy and funnel it to the reaction centers (Figure 2). The reaction centers and light-harvesting complexes are mostly composed of chlorophyll and protein.

Two major tasks in photosynthesis research are to determine the structure of these complexes and to learn precisely how the chlorophyll and protein molecules are arranged in the complexes and membrane. This kind of information will contribute greatly to our understanding of how the molecules work and operate at the molecular level to carry out their functions in photosynthesis.

Bacterial Photosynthesis

Doing photosynthesis is not the exclusive privilege of plants and algae. A number of bacteria are also capable of harvesting and converting light into chemical energy. The mechanisms for light capture and conversion in bacterial closely resemble those of plants. Unlike plants, however, these bacteria do not contain chloroplasts. They instead house their reaction center and light-harvesting complexes in an extensive network of internal membranes that are connected to the outer surface membrane of the cell (Figure 3).

We have chosen to study these bacterial photosynthetic membranes and their complexes because they offer several advantages to researchers. Foremost is their amenability to having large amounts of membranes extracted free of other cell constituents. These purified membrane preparations are called chromatophores. Secondly, it is possible to obtain very pure preparations of the reaction center and light-harvesting complexes themselves. These two give us the tools we need to attack the problems determining structure and molecular arrangement in the photosynthetic membrane.

How Reaction Center Molecules Are Arranged in the Membrane

We have recently made several significant observations about the arrangement of molecules in the bacterial photosynthetic membrane. One of these findings is mainly concerned with the disposition of the proteins of the reaction center.

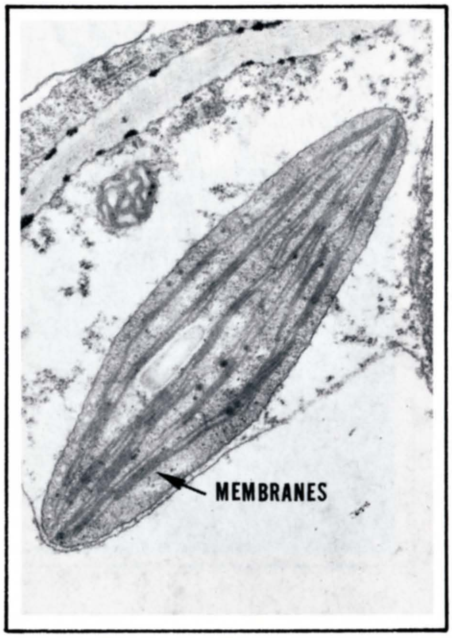

FIGURE 1. Electron micrograph of a thin-section of an alfalfa leaf showing the chloroplast (magnification × 8,320). Photo courtesy of Dr. William F. Campbell, USU Plant Science Department.

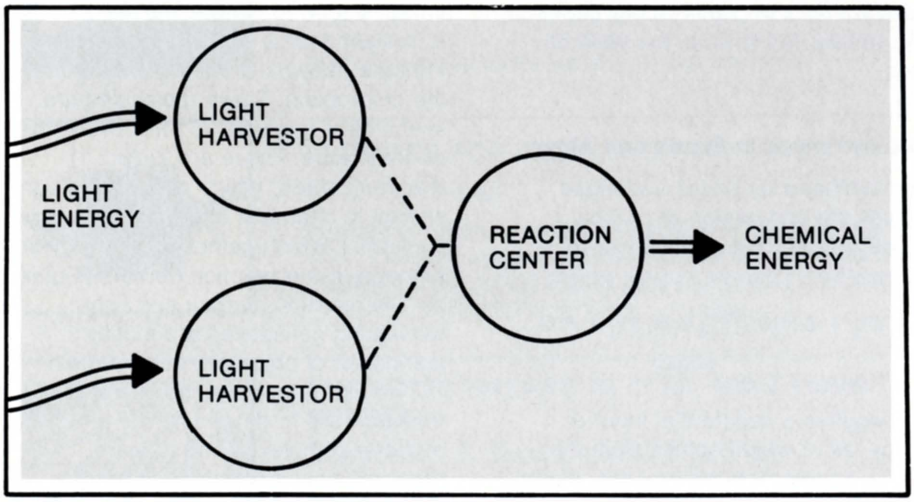

FIGURE 2. Light-harvesting complexes gather and funnel energy from light to reaction centers for conversion to chemical energy.

From very pure preparations of reaction centers, it has been learned that three separate proteins, designated H, M, and L (for heavy, medium, and light sizes) occur in this complex. Together, these proteins compose well over 90% of the total weight of the reaction center. H, M, and L can be readily identified after the chromatophores have been dissected and separated in an electric field on a clear, elastic material known as a polyacrylamide gel (Figure 4). To learn about the arrangement of the proteins, the chromatophores can be treated or labeled in some way before analyzing the proteins on the polyacrylamide gel. For example, when the chromatophores are labeled with radioactive iodine using a reagent that does not penetrate the membrane, only molecules that are exposed on the membrane surface are labeled. After dissociation and separation on the polyacrylamide gel, any labeled proteins are presumed to be ones normally exposed on the surface (Figure 5).

In this way, we have discovered that all three proteins (H, M, and L) are exposed on the chromatophore surface. Even further, by first labeling only one side of the membrane in one experiment and then the other side in another but parallel experiment, we have demonstrated that all three proteins are exposed on both sides. In other words, they all extend completely through the membrane. Additional proteins are also exposed on both sides of the membrane while others are exposed on only one side. For example, some of the proteins of the light-harvesting complex appear to also traverse the membrane completely.

Functional Significance

When these findings about reaction center arrangement are combined with other information on the function of this complex, a picture of how the reaction center may work in the membrane begins to emerge (Figure 6). Since the reaction center is exposed on both sides of the membrane, it is now believed that light energy causes a vectorial movement of electrons across the membrane through the reaction center. The electrons are donated to the reaction center on one side of the membrane by a molecule called cytochrome C_2, and the electrons are received by another molecule called ubiquinone on the other side. Such an electronic movement creates an electrical potential across the membrane that is then used to produce high energy chemical compounds. We are guessing that reaction centers in plant and algal chloroplasts work much the same way. Because all three bacterial proteins (H, M, and L) traverse the membrane, we do not yet know which particular protein serves as the "electron channel."

These experiments illustrate the kinds of basic research being done to probe the molecular structure and function of the photosynthetic machinery. Once a clear understanding of the molecular processes of photosynthesis is achieved, we will be able to manipulate photosynthesis in an intelligent and beneficial way.

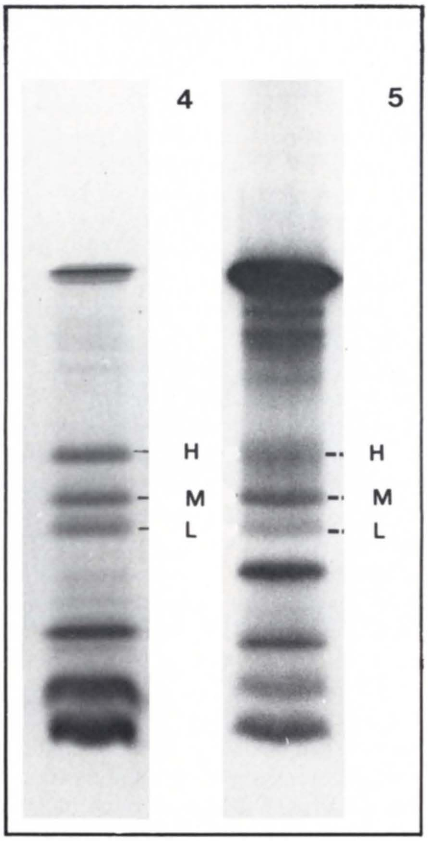

FIGURE 4. A polyacrylamide gel containing proteins of chromatophores isolated from ***Rhodopseudomonas sphaeroides****. The reaction center proteins H, M, and L were separated in an electric field, negative charge at the top and positive charge at the bottom of the gel. The gel was stained with Coomasie blue dye to reveal the proteins.*

FIGURE 5. A polyacrylamide gel showing proteins which are radioactively labeled on the surface of the chromatophore membrane. Reaction center proteins H, M, and L are exposed on the surface and therefore labeled. Shown is an x-ray film which was exposed to the gel to reveal the proteins which are radioactive.

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Clayton, R. K. 1971. Light and living matter: A guide to the study of photobiology. Volume 2: The biological part. McGraw-Hill Co., New York.

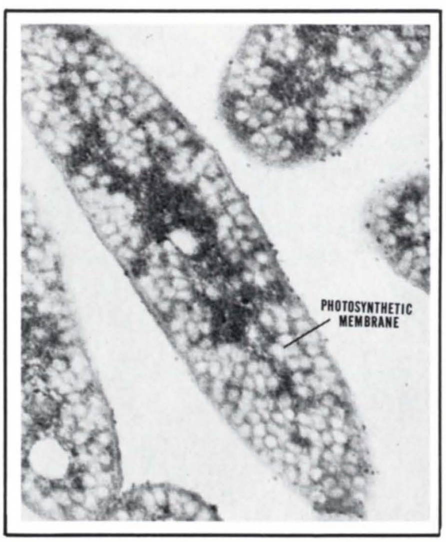

FIGURE 3. Electron micrograph of a thin-section of the photosynthetic bacterium, ***Rhodopseudomonas sphaeroides****. The round vesicular structures are membranes which house the photosynthetic apparatus. Photograph prepared by Patricia Trostle, Department of Biology and USU Electron Microscope Facility. (Magnification × 31,000).*

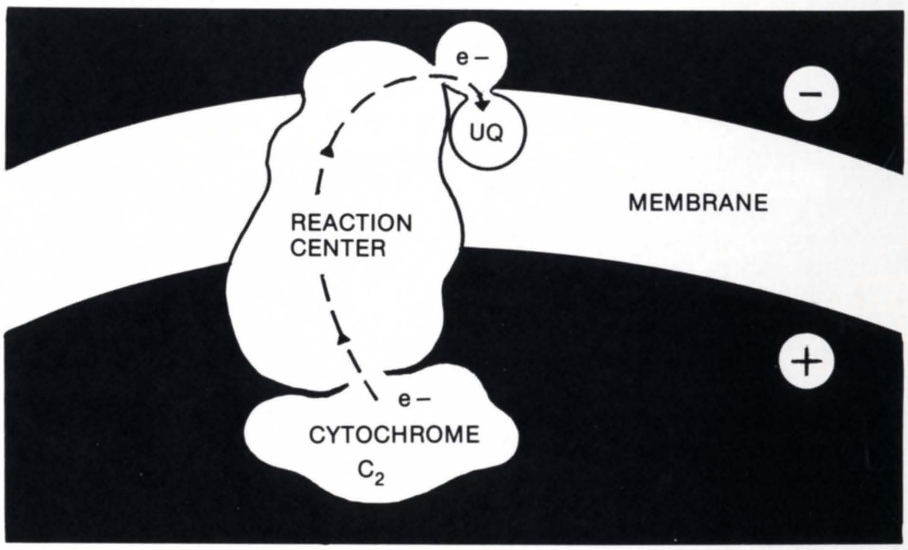

FIGURE 6. Model of the arrangement of the reaction center in the membrane. With light, electrons (e-) from cytochrome C_2 move through the reaction center and across the membrane to ubiquinone (UQ). An electric potential difference is created across the membrane and used to generate high energy chemical compounds.

ABOUT THE AUTHOR

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H. M. DEER

Pesticide Programs at USU

Should you be a certified pesticide applicator? What should you do if you need a pesticide or animal drug for a particular purpose but there is none currently registered? Do pesticide risks exceed benefits? What are the impacts of pesticide use? How are these impacts determined?

These questions and their answers are of interest to the public and to personnel at Utah State University who actively participate in several USDA pesticide programs. To understand the programs and how they affect your life, you should know something about a few federal acts and the agencies responsible for their passage and enforcement.

The National Scene

In 1970, the Environmental Protection Agency (EPA) was formed and assigned the responsibility of enforcing the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). EPA also was given the authority to establish tolerances for pesticide residues in edible foods, feeds, and their packaging materials. The Food and Drug Administrations (FDA) was charged with enforcing those tolerances through testing these items for chemical residues.

In 1972, the most detailed and comprehensive pesticide legislation in history was passed, the Federal Environmental Pesticide Control Act (FEPCA). The act recognized the need to protect the general public and environment from the potentially harmful effects of pesticides. The core of FEPCA was the requirement that the EPA deny registration to a pesticide unless it could determine that "when used in accordance with widespread and commonly accepted practices it will not cause unreasonable adverse effects on the environment," Section 3(c) (5). The unreasonable adverse effects are further defined as "any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of any pesticide," Section 2(bb).

This definition essentially required the EPA to conduct risk versus benefit analyses for all pesticide uses. Congress recognized that pesticides will inherently cause some risks because they are biologically active chemicals. The risks, however, were to be balanced against the benefits derived from the pesticides' use.

Amendments to FEPCA in 1975 reemphasized the need for EPA to give consideration to the beneficial aspects of pesticide use. They also strengthened the role of USDA in the decision-making process regarding pesticide classifications and withdrawal from the market. EPA also was required to take into consideration what effects cancelling or suspending the use of a pesticide might have on the production and prices of relevant agricultural products. Additionally, the EPA would have to prepare an economic impact statement for any cancellation order. The EPA and USDA are concerned with pesticides that vary in type (Table 1) and formulation (Table 2). About 1,600 different, biologically active chemicals can be pesticides, and about 48,000 pesticide products are available for sale and use in this country. All of these pesticides are registered with the EPA by about 8,000 different companies representing basic manufacturers and pesticide formulators. Many common household products are actually pesticides (Photo 1).

Pesticide Applicator Training Program

Pesticides that, when applied in accordance with widespread and commonly recognized practices, may cause unreasonable adverse effects on the environment, including injury to the applicator, are classified as "restricted use" products (Table 3). The application of restricted-use pesticides is limited to applicators who have been certified as qualified to use or supervise their use.

In Utah, a Pesticide Applicator Training Program is available to individuals who want to become certified applicators of restricted-use pesticides. Certification is for a period of five years, then recertification is required if the applicator wants to continue to be able to use restricted-use pesticides (Table 4). Utah State University is charged with the training of pesticide applicators. The Utah Department of Agriculture does the certifying on the basis of an examination, or the completion of a self-study program, or graduation from an approved training course.

Training courses are held on an annual basis in various Utah counties. Specialists in pesticide regulation, entomology, weed science, plant pathology, and occupational health conduct these courses as needed and are always available for additional informational needs. Applicators become certified according to their category of pesticide use, but they can certify themselves in any or all categories (Table 5). EPA sets the standards by which applicators must be certified, but each state, usually through its State Department of Agriculture, conducts the certification process by way of an EPA approved plan.

Utah Pesticide-Impact Assessment Program

To satisfy the 1972 amendments to FIFRA, the EPA began to collect risk information on pesticides that had already been registered and were in use. EPA conducted literature searches, sought unpublished data, and requested information from any likely source in an attempt to determine if unreasonable risks existed in association with a pesticide's uses. If the EPA determined that such risks were present, the pesticide in question was formally brought into a regulatory process known as RPAR (Table 6).

The USDA subsequently formed the National Agricultural Pesticide Impact Assessment Program to collect information on the usage, benefits of use, and exposure. For each EPA-designated RPAR pesticide, the USDA formed an assessment (of risks/benefits) team composed of scientists and others knowledgeable about the pesticide in

1. Many common household products are actually pesticides.

2. Pesticides are used in the home, the garden, and on the lawn.

3. During mixing and loading, protective clothing reduces exposure to pesticide concentrates.

4. To avoid crop damage from ground application equipment, aerial application is often necessary.

5. Protective clothing protects applicators of pesticides.

6. Protective clothing should be washed after each use.

7. Additional pesticide products are needed for effective control of lice on sheep.

8. Control of powdery mildew in tomatoes with sulfur is a minor pesticide use.

9. Pesticide applicators receive training so that they may become certified to use restricted use pesticides.

question. The USDA asked that each state gather the needed information on a statewide basis and submit it to the USDA assessment team. The ultimate result was a biological and economic report on each RPAR pesticide that was sent to the EPA for their consideration in reaching a regulatory decision on the future availability and status for that pesticide. In Utah, an advisory committee (representing the concerned departments in USU's colleges of agriculture and science) was formed to help collect pesticide usage data for the state.

EPA's final decisions frequently require that risks be reduced through a variety of methods: labels may be amended; formulations changed; uses reduced; and/or classifications changed to restricted use. Negotiations with the pesticide manufacturing company are utilized in an attempt to avoid costly legal processes.

The USDA also provided a research fund to be drawn upon by cooperating land grant universities. The research was to assist the EPA in analyzing pesticide risks/benefits. Utah State University researchers have had several projects qualify for funding (Table 7).

Minor-use Pesticide and Animal Drug Registration Program

Under the law, any use of a pesticide or drug in a way other than stated on the label or allowed for by regulation is a "misuse," and the misuser can be fined. Each label instruction must be registered with the EPA (pesticides) or the FDA (drugs). The registration procedure requires proof that the pesticide or drug poses no undue hazard when used as instructed. Research and development costs for the registration of most pesticide and drug uses are paid by the pesticide and drug manufacturers, who expect enough sales to return a profit. Many pesticides and drugs are used on such a small scale, however, that their research and development costs greatly exceed possible returns to the manufacturer. In some cases, such a use is essential for efficient crop or animal production. Even these small or minor uses require registration to protect the user from a possible fine.

The IR-4 program is a nationwide effort of the USDA, the EPA, the FDA, the separate state agricultural experiment stations, and manufacturers, producers and growers. The national headquarters is at Rutgers University in New Brunswick, New Jersey, with five regional offices, one each for state agricultural experiment stations in the eastern, southern, western, and northern regions, and a special USDA Agricultural Research Service (ARS) unit. All are equipped with laboratories for residue analyses.

An IR-4 research project begins when a state liaison representative (one per each state agricultural experiment station) recognizes or is alerted to a need for minor-use registration of a pesticide or drug. A "minor-use need" must meet the following criteria:

1. That losses are occurring because there is no registered pesticide or drug.
2. That registered pesticides or drugs are not effective or acceptable for some reason.
3. That the use is so limited that commercial development would be unprofitable.

IR-4 projects can involve changes in amounts, timing, and types of applications of registered pesticide or drug uses, as well as the addition of new crops or animals or pests or diseases to existing labels. Each request for a project goes through the regional office to the national headquarters, where a check is made to see if an effective pesticide or drug is already registered for that use. If not, a manufacturer or patent holder is approached to obtain their support for the proposed registration. Only with such support do personnel of the national headquarters, in cooperation with the manufacturer and EPA or FDA begin to work up a tentative protocol for efficacy testing, and, when needed, residue sampling. The final result is a registration that will enable growers and producers to solve particular pest or disease problems. USU researchers have conducted and are doing various IR-4 studies (Table 8).

ABOUT THE AUTHOR

Howard M. Deer is Coordinator for Pesticide and Toxic Substances Programs at Utah State University. He also holds an appointment as Extension Pesticide Specialist and is a faculty member of the Department of Animal, Dairy and Veterinary Sciences and the Interdepartmental Program in Toxicology. His area of research is reducing occupational exposure to pesticides and specifically the exposures associated with the fumigation of stored grain. He has degrees from the University of Wisconsin and University of Minnesota.

TABLE 1. Types of pesticides.

Acaricides—mites, ticks
Algicides—algae
Attractants—animals
Avicides—birds
Bactericides—bacteria
Dessicants—water removal
Defoliants—foliage removal
Disinfectants—microorganisms
Fumigants—insects, rodents
Fungicides—plant pathogens
Germicides—germs
Growth Regulators—plants
Herbicides—weeds
Hormones—disrupt life cycles
Insecticides—insects
Miticides—mites
Molluscicides—mollusks
Nematicides—nematodes
Ovicides—eggs
Pediculicides—lice
Pheromones—interrupt mating
Pisicides—fish
Repellents—animals
Rodenticides—rates, mice
Sanitizers—microorganisms
Slimicides—microorganisms
Sterilants—microorganisms
Wood Preservatives—mold, fungi, insects

TABLE 2. Pesticide formulations.

Emulsifiable Concentrates
High- and Low-Concentrate Solutions
Ready-to-use Solutions
Dry Flowables
Aerosols
Pressurized Gases and Liquids
Microencapsulations
Soluble and Wettable Powders
Granules
Dusts
Baits
Volatile Liquids and Solids
Pellets
Tablets

TABLE 4. Utah's certified applicators.

Commercial	1,142
Noncommercial	1,517
Private	5,625

TABLE 5. Utah's categories for certification of applicators.

Agricultural
Forest
Ornamental and Turf
Seed Treatment
Aquatic
Right-of-Way
Industrial, Institutional, Structural and Health Related
Public Health
Regulatory
Demonstration and Research
Aerial

TABLE 3. Pesticides that have some or all uses restricted in Utah.

Active Ingredient	Trade Name	Type
Aldicarb	Temik	Insecticide
Aluminum phosphide	Phostoxin, Fumitoxin	Fumigant
Amitraz	Baam	Insecticide, Miticide
Azinphos methyl	Guthion	Insecticide
Calcium cyanide	Cyanogas	Fumigant
Carbofuran	Furadan	Insecticide
Chlorobenzilate	Acaraben	Miticide
Chlorophacinone	Rozol	Rodenticide
Chloropicrin	Larvacide	Fumigant
Cycloheximide	Actidione	Fungicide
Demeton	Systox	Insecticide
Diclofop methyl	Hoelon	Herbicide
Dicrotophos	Bidrin	Insecticide
Disulfoton	Di-syston	Insecticide, Acaricide
EPN	EPN	Insecticide, Acaricide
Endrin	Several trade names	Insecticide
Ethoprop	Mo-Cap	Insecticide, Nematicide
Ethyl parathion	Several trade names	Insecticide
Fenamiphos	Nemacur	Nematicide
Fensulfothion	Dasanit	Insecticide, Nematicide
Fenvalerate	Pydrin	Insecticide
Fonofos	Dyfonate	Insecticide
Magnesium phosphide	Fumi-Cel	Insecticide
Methamidophos	Monitor	Insecticide
Methidathion	Supracide	Insecticide, Acaricide
Methomyl	Lannate, Nudrin	Insecticide
Methyl bromide	Several trade names	Fumigant
Methyl parathion	Several trade names	Insecticide
Mevinphos	Phosdrin	Insecticide
Milban	Milban	Fungicide
Monocrotophos	Azodrin	Insecticide, Acaricide
Nicotine alkaloid	Several trade names	Insecticide
Nitrofen	Tok	Herbicide
Paraquat	Paraquat CL, Gramoxone	Herbicide
Permethrin	Ambush, Pounce	Insecticide
Phorate	Thimet	Insecticide
Picloram	Tordon	Herbicide
Phosphamidon	Dimecron	Insecticide
Pronamide	Kerb	Herbicide
Sodium fluoroacetate	Compound 1080	Rodenticide
Strychnine	Several trade names	Rodenticide
Zinc phosphide	Several trade names	Rodenticide

TABLE 6. Rebuttable presumption against registration (RPAR) pesticides.

Chemicals	Date of RPAR Issue	Current Status
Amitraz (BAAM)	4/06/77	Completed
Benomyl (Benlate)	12/06/77	Completed
BHC	10/19/76	Converted to Lindane
Cadmium	10/26/83	Undergoing study
Captan	8/18/80	Undergoing study
Carbon tetrachloride	10/15/80	Undergoing study
Chlordecone (Kepone)	3/25/76	Completed
Chlorobenzilate	5/26/76	Completed
Chloroform	4/06/76	Completed
Coal tar	10/18/78	Undergoing study
Cresote	10/18/78	See coal tar
DBCP (Fumazone, Nemagon)	9/22/77	Completed
Diallate (Avadex)	5/31/77	Completed
Dimethoate (Cygon)	9/22/77	Completed
EDBC's (Mancozeb, maneb, metiram, nabam, zineb)	8/10/77	Completed
Endrin	7/27/76	Completed
EPN	9/19/79	Completed
Ethylene dibromide (EDB)	12/14/77	Completed
Ethylene oxide (ETO)	1/27/78	Undergoing study
Fluoroacetamide (1081)	12/01/76	Completed
Inorganic arsenicals	10/18/78	Undergoing study
Lindane	2/17/77	Completed
Maleic hydrazide (MH)	10/28/77	Completed
Oxyfluorfen (Goal)	4/27/81	Completed
PCNB (Terraclor)	10/27/77	Completed
Pentachlorophenol (PCP)	10/18/78	Undergoing study
Pronamide (Kerb)	5/20/77	Completed
Ronnel		Undergoing study
Sodium fluoroacetate (1080)	12/01/76	In agency review
Strychnine/strychnine sulfate	12/01/76	Completed
2,4,5-T/Silvex	4/21/78	Completed
Thiophanate methyl (Topsin M)	12/07/77	Completed
Toxaphene	5/25/77	Completed
2,4,5-Trichlorophenol	8/28/78	Undergoing study
Trifluralin (Treflan)	8/30/79	Completed

TABLE 7. USU pesticide impact assessment projects.

1. Comparing the Efficacy of Carbaryl, Trichlorfon, and Malathion on Alfalfa in Utah, Donald W. Davis, William A. Brindley, and Terrence F. Glover.
2. The Quantification of Pronamide Benefits in Alfalfa Hay and Seed Crops, John O. Evans, Robert W. Gunnell, and Richard D. Gibson.
3. Importance of Paraquat and Dinoseb in Orchard Management Systems, J. Lamar Anderson and Richard Gibson.
4. Quantification of Benefits in Fruit Quality from Daminozide Treatment of Apple and Tart Cherry Orchards, J. Lamar Anderson and Ronald H. Walder.
5. Evaluation of the Economic Importance of Fungicides for Early Blight Control of Tomato, Sherman V. Thomson and Harold Linsay.
6. A Technique to Identify Insecticide Cost-Benefit Ratios in Individual Fields, William A. Brindley.
7. Management and Possible Correction of an Assessed Insecticide Resistance Problem, William A. Brindley and Craig S. Baird.

TABLE 8. USU's IR-4 projects.

1. Use of the Pesticide Napromide (Devinrol) to Control Annual Grasses in Perennial Ornamentals, William A. Varga.
2. Use of the Pesticide Chlorothalonil to Control Leaf Spot on Aspen, Sherman V. Thomson
3. Use of the Pesticide Endosulfan (Thiodan) to Control Cane Girdler on Raspberries, Donald W. Davis.
4. Use of the Pesticide Sulfur to Control Powdery Mildew on Tomatoes, Sherman V. Thomson.
5. Use of the Pesticide Fenthion to Control Nose Bots and Lice on Sheep, Clell V. Bagley
6. Use of the Pesticide Deltamethrin to Control Lice and Keds on Sheep, Clell V. Bagley.
7. Use of the Pesticide Aldicarb (Temik) to Control Sucking Insects and Chalcid Wasps on Native Nursery Shrubs and Forbs, B. Austin Haws.
8. Analysis of Vetch for Residues of the Pesticide 2,4-DB, Raghubir P. Sharma
9. Analysis of Sheep for Residues of the Pesticide Diazinon, Raghubir P. Sharma.


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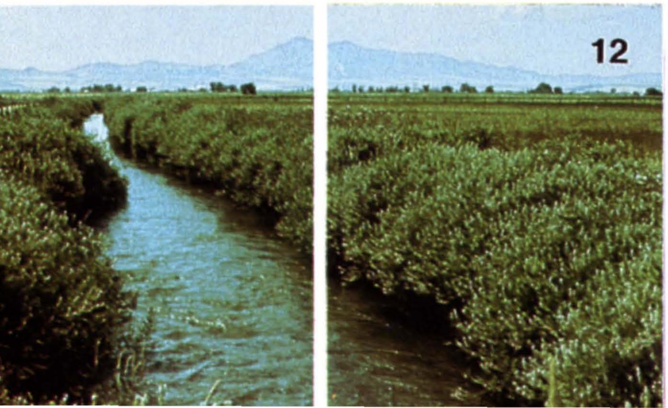
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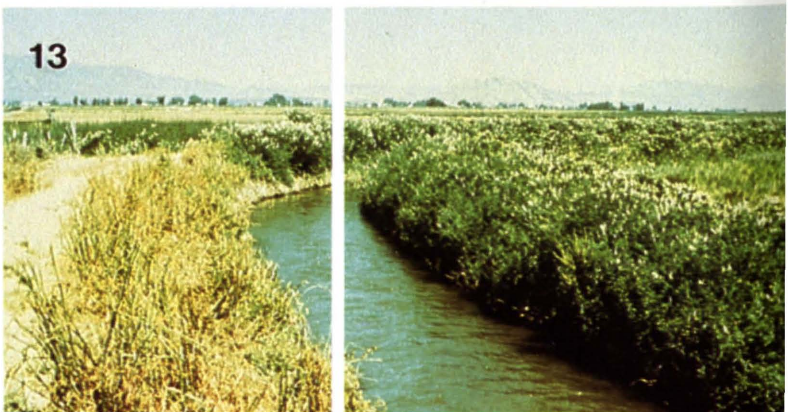
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PHOTO CAPTIONS

1. Goatsrue is a perennial legume which at maturity is typically 3 to 6 feet high.

2. The seeds are bean-shaped, a dull yellow and 2.5 times larger than alfalfa. A mature plant can produce as many as 25,000 seeds annually.

3. Each blossom produces a narrow, straight pod containing an average of 6 seeds.

4. The leaves of goatsrue are odd-pinnate with 5-8 pairs of leaflets.

5. Since goatsrue is avoided by livestock, overgrazed pastures provide an ideal environment for goatsrue to become dominant.

6. Flowers are blue and white and are born in terminal or auxillary racemes.

7. Goatsrue responds well to a mixture of 2,4-D and dicamba applied twice per season for two consecutive years.

8. Mature goatsrue plants 8 days after spraying.

9. Mechanically disturbing goatsrue is not an effective control measure. The plant is often able to re-grow within one week.

10. Most domestic animals avoid goatsrue due to its unpalatability and moderate toxicity.

11. Goatsrue, though not often found in grain fields, will invade cropland if a population of the weed is well-established in the area.

12. A goatsrue infestation of a canal near the Logan Airport typifies the spread of the weed by the valley's irrigation systems.

13. Reducing the seed source by treating the canal banks is an important step in the eradication process.

J. O. EVANS

Goatsrue Eradication

A REALISTIC GOAL

The scientific and popular agricultural literature contains numerous articles concerning eradication of one weed species or another. In reality, eradication of any of our serious weeds is practically impossible, no matter how desirable that goal may seem. Most of these same weeds have very benign beginnings and *could* have been eradicated at one time with a single stroke of a shovel, scythe, or hoe. Our predecessors must be blamed for letting such potential pests get out of hand. The majority of our noxious plants were either deliberately brought into this country for an anticipated value, or inadvertently introduced in one manner or another. In addition to goatsrue, other troublesome weed species presently found in Utah are puncturevine (*Tribulus terrestris* L.), bur buttercup (*Ranunculus testiculatus* L.), snow speedwell (*Veronica campylopoda* L.), kochia (*Kochia scoparia* L.), and quackgrass (*Elytriga repens* (L.) Nevsiki) to mention just a few.

The general public is quite unaware of how significantly weeds can reduce crop yields and quality, lower the grazing potential of the public and private rangeland and pastures, and detract from the natural beauty of the countryside. Today, many individuals have thriving businesses that involve their transporting weedy plant species throughout the country because of purported potentials as beneficial crops or for ornamental uses. These practices add to the difficulty of controlling, much less eradicating, certain weedy types.

To our knowledge, no species, once identified as weeds, have been eliminated from cropland. Instead, the weed populations simply increase or decrease in relation to the effort exerted to control them. In this article we describe what may be a unique opportunity to eradicate a potentially serious weed.

Goatsrue (*Galega officinalis* L.), a weed that exists only in Cache County, Utah, probably can be eliminated if any weed can. Goatsrue is a deep-rooted perennial legume introduced from Europe as a potential forage crop. It propagates only by large, heavy seeds that are effectively disseminated by water. It is not very competitive but flourishes in noncropped areas such as ditchbanks, fencelines, and uncut pastures, causing these areas to be very unproductive and unsightly. Since the plant is rigorously avoided by animals, it quickly takes over uncultivated crops and pastures. Because goatsrue's heavy seeds are readily moved by irrigation systems, plants are found in nearly all fields downstream from original infestations.

The plant was tested as a forage by the Utah Agricultural Experiment Station for a three-year period beginning in 1891. It was quickly categorized as an inferior forage because the young plants, though leafy and succulent, proved to be very unpalatable to livestock. Somewhat later, the plants were shown to contain a poisonous alkaloid known as galegine (2-methyl-2-butenylguanidine). The mature plants and seeds have killed sheep in feeding trials, but there has been little concern about the dangers of goatsrue as a poisonous plant since it is avoided by animals. Unfortunately, this avoidance allows the plants to reproduce and spread and, in many cases, completely "take over" pastures and eliminate grazing. Over-grazing on uninfested areas hastens the spread of the goatsrue.

In 86 years goatsrue has spread slowly over an area of about sixty square miles in Utah's Cache County, primarily between the highline canals and the drainage systems on the valley floor. Due to its mildly aggressive behavior it was not considered a weed problem until 1974, when local citizens placed the species on the state list of noxious weeds in hopes of preventing its spread north toward Idaho or into other Utah valleys or adjoining states.

Goatsrue can be controlled quite easily be cultivation or spraying. The weed is not commonly observed in annual crops such as corn, small grains, or sugarbeets, which are customarily planted into prepared seedbeds. Occasionally, it is encountered in small grain plantings near areas of heavy goatsrue infestations. Goatsrue is observed in established alfalfa fields, but mowing limits its spread since seeds are not produced.

Herbicides can be used to control goatsrue in pastures (Table 1) whereas mowing is not an effective means of controlling the weed. Repeated mowing will prevent seed production by goatsrue and reduces the plant's vigor to about half that of uncut plants. Further reductions are observed if mowing is continued faithfully for a number of years. Mowing, however, does not bring goatsrue under control as effectively as other strategies, such as herbicides. Clipping the initial growth when it is about 24 inches tall, followed by spraying the regrowth when approximately the same height is the most effective treatment.

Various herbicides can reduce a thriving stand of goatsrue by 90 percent or more in one year. The plants are especially sensitive to dicama or 2,4-D and their combinations (Table 1), but other herbicides are also effective. Mixtures of 1/2 lb/A 2,4-D and 1/4 lb/A dicamba will reduce goatsrue stands very well if applied twice per season for two consecutive seasons.

In the fall of 1976, a program was initiated to control or eradicate goatsrue in Utah's Cache County. Infested areas were carefully mapped and most of the landowners having goatsrue infestations volunteered their support and cooperation. Isolated instances of a potential need for regulatory action may disapper when the success of the project surfaces.

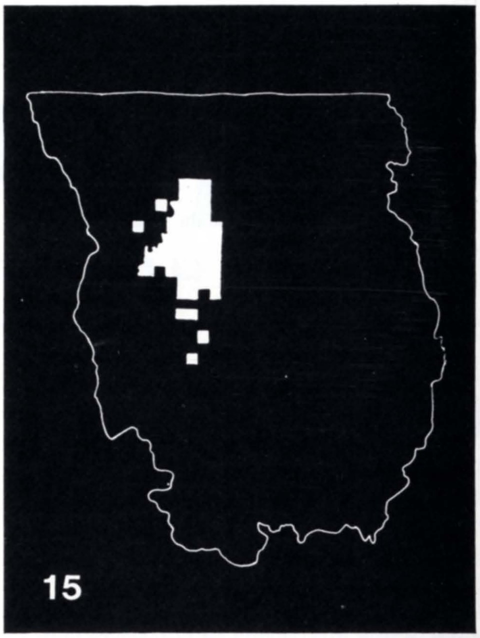
One major obstacle to weed control programs is the need to educate the public about the benefits of such efforts. Another universal problem lies in providing adequate follow-up to prevent reinfestation. For the goatsrue program, that means three to five years of concerted effort followed by an observation interval. Any lesser investment of time would jeopardize success since goatsrue seed remains viable in soil for at least four years.

In 1980 the Animal Plant Health Inspective Service (APHIS) selected goatsrue as a candidate weed to be removed from the United States. At this time a major effort to eliminate the weed is in progress, combining the teamwork of APHIS, Utah Department of Agriculture, Cache County Weed District, local landowners, and Utah State University. A section of the original weed infestation was chosen to demonstrate goatsrue eradication. It was intensively surveyed, treated and monitored for four consecutive years, the fourth being 1983, in which excessive seedlings appeared. However, it is still very likely the eradication schedule will be realized within a reasonable time frame. Repeated visits to eliminate successive crops of new seedlings were necessary to prevent any juvenile plants from going to seed. Well established mature plants now represent a very small percentage of the goatsrue encountered in this area. Current estimates are that 85 percent or more of the older plants are gone and the remaining ones are weakened to such an extent that they will soon disappear.

The unique character of the weed (with respect to its dissemination, the limited area of the present infestation, and the ease with which it can be controlled at nearly all stages of growth) seems to present a unique opportunity to eradicate a weed before it becomes a problem of major proportions. So, when it comes to weeds, the time to act is now.

ABOUT THE AUTHOR

John O. Evans is an associate professor of the Plant Science Department. He is weed control specialist devoting full time to the impact of weeds on field crop production. His research effort encompasses weed biology, herbicide technology and investigations of practical and economic problems involved in developing weed control methods.



14. Usually left undisturbed by cropping and harvesting practices, goatsrue thrives along ditch banks.

15. Goatsrue, found only in Cache Valley, infests an area of 60 square miles.

16. An infested Smithfield waterway north of Hyde Park prior to herbicide treatment.

17. The same waterway after herbicide treatment.

18. The flowers and leaves of goatsrue resemble other legumes and are often mistaken for alfalfa.

TABLE 1. A comparison of the effects of control methods on goatsrue (Galega officinalis L.) in terms of plant injury and forage production one year after treatment.

		Goatsrue Response		
Treatment	**Rate lb/A**	**Treatment Year Injury Index (0-10) 21 Days After Treatment**	**Year After Treatment Fresh weight lb/A First Cutting**	**Injury Index (0-10) 21 Days After Treatment**
Control[1]	——	0	4629[2]	0
1 clipping	——	0	3627	0.8
2 clippings	——	0	2620	1.6
3 clippings	——	0	2415	1.9
2,4-D (amine)	1.50	6.3[3]	1261	3.2
dicamba	0.75	7.9	314	5.7
2,4-D +	1.00			
dicamba	0.50	9.3	218	6.2
1 clipping + 2,4-D[4]	1.50	9.3	116	6.0
1 clipping + dicamba	0.75	9.0	102	7.3
1 clipping + 2,4-D +	1.00			
dicamba	0.50	9.0	172	7.9

[1]Average of 11 control plots in treatment year was 4418 lb/A N.S.
[2]Only first clipping was weighed.
[3]Injury index ratings taken 21 days after spraying. (0 = no effect on the plant, 1-9 = gradations of increasing damage, 10 = kill)
[4]Where herbicides were combined with clipping, spraying took place 21 days after 1st clipping.

CROWNVETCH

a possible problem weed in utah

Crownvetch is that new "miracle" ground cover that you find advertised in most current nursery and seed catalogs. Photographs show hillsides blanketed with a floral pink. Captions advertise an instantaneous solution to problem slopes, and a quick "cover-up" for the local eyesore. As is often the case in this age of aggressive advertising, you are given little factual information about this plant. What is this new wonder plant?

In fact, there is nothing new about crownvetch. It was given its scientific name, *Coronilla varia*, in 1753 by Carolus Linnaeus (the "father" of scientific nomenclature). Its generic name is the Latin diminutive of *corona*, meaning crown, in allusion to the dense crown-like cluster of flowers. The plant is a member of the pea, or legume family (Fabaceae), thus its similarity to clover as well as our common vetch is no mere coincidence. Its homeland is Europe, where it is widespread in the Mediterranean region.

What, then, is crownvetch doing in Utah? It has not arrived by natural means. All Utah records may be traced to plantings by man, either for ornament, fodder, or as revegetation for disturbed areas (roadsides, mines, dumps, etc.). Crownvetch was first reported from benches east of Provo in 1970, and has since been collected in Salt Lake, Cache, and Sevier Counties.

The first Cache County record was reported in the summer of 1983, when Alice Johnston of the Veterinary Science Department brought a plant to the Intermountain Herbarium for identification. Returning to the mouth of Logan Canyon, where Alice had made her find, I discovered a number of plants growing along an irrigation canal as well as on dry hillsides of a new housing development. In all likelihood, the plants were seeded to stabilize slopes in the housing development. There is every indication, however, that the plants are spreading naturally onto surrounding hillsides.

Like many Eurasian plants, crownvetch has the potential to become a widespread and common weed in Utah. Climatically, Utah is very similar to the steppes of western Asia. When plants are introduced from that part of the world, they find an amenable habitat here, but do not have their natural predators or competitors to keep them under control. Dyer's woad (*Isatis tinctoria*) and Russian thistle (*Salsola* spp.) are just two examples of Eurasian plants that promise to be problem weeds forever in Utah.

Crownvetch is not only potentially an aggressive invader of rangelands and agricultural croplands; it may also be poisonous to livestock. M. Colburn Williams, Adjunct Professor of Biology and a researcher in the USDA Poisonous Plants Laboratory, reports 3-nitropropionic acid in samples of *Coronilla varia* (Williams, 1981). Dr. Williams has sampled crownvetch-infested fields in the Midwest and found toxic, aliphatic-nitro-compounds in all sampled specimens of crownvetch. Crownvetch has been used to experimentally induce nitro-poisoning in swine, meadow voles, and chicks (Shenk et al., 1976). Farmers and ranchers in the Midwest report, however, that cattle are attracted to the crownvetch and graze it without harmful consequence (M. C. Williams, pers. comm). An explanation might be that in the central plains states there is a good mix of grasses and forage available for grazing animals. In our drier western ranges, with less forage, the effect of toxic compounds may be amplified.

Records of crownvetch should be reported to local county agents or to Dr. Richard Chase (USU's Extension Weed Specialist). Records should be in the form of a pressed specimen accompanied by collection information. These specimens will then become a part of the public record when deposited in the Utah State University herbarium. By way of this permanent record, we can trace the spread of this plant. A welcome accompaniment to the record would be a note stating that all the plants were eradicated with the collection. With an informed public, perhaps we will never need to add crownvetch to the growing list of Utah's noxious weeds.

LEILA M. SHULTZ

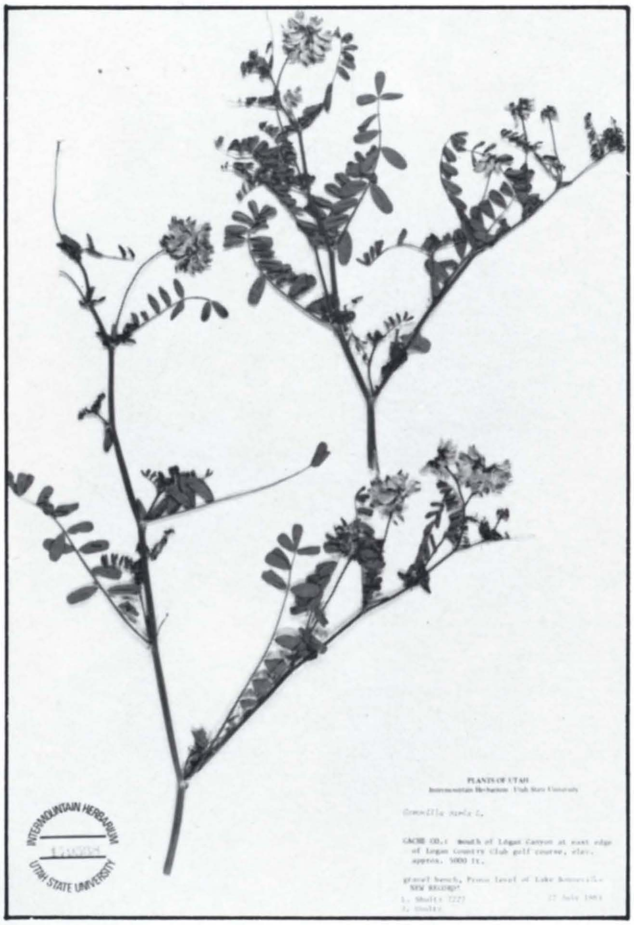


PHOTO CAPTION

*Crownvetch (**Antennaria alphina** (L.) Gaertn.) a new weed located in Cache County at the mouth of Logan Canyon at the east edge of Logan Country Club Golf Course, elevation approximately 5,000 feet on the gravel bench, Provo level of Lake Bonneville.*

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ABOUT THE AUTHORS

Leila M. Shultz is the Curator of the Intermountain Herbarium which is part of the Department of Biology in the College of Science. The Utah State University Herbarium is the major research collection of plants of the Intermountain Region. Dr. Shultz is contributing to an *Atlas of Utah Plants* and is a specialist on the taxonomy of Sagebrushes (*Artemisia* spp.).

NEW GRAIN VARIETIES FOR UTAH

WYNNE

A NEW, HARD RED, SEMI-DWARF, SPRING WHEAT

R. S. ALBRECHTSEN

Seed of a new semi-dwarf, hard red spring wheat variety is now available to Utah growers. The new variety was named 'Wynne' in honor of the late Dr. D. Wynne Thorne, who served for many years as a faculty member and administrator in the Utah Agricultural Experiment Station and as Vice President for Research at Utah State University. The new wheat was developed by Utah Agricultural Experiment Station personnel in cooperation with members of the U.S. Department of Agriculture. Local commercial flour mills assisted with milling and baking quality evaluations.

Origin and History

Wynne originated as a single plant selected from the cross, Roque 66 × Fremont, made at Logan in 1969. Roque 66 is a semi-dwarf variety from Mexico; Fremont was developed at the Utah Agricultural Experiment Station. First-generation plants were grown in the greenhouse during the winter of 1969-70. Succeeding segregating generations were grown in the field during 1970-73, during which time desirable plants were selected and the plants progressed

A PATCHWORK OF GRAIN CROPS

1. Wynne Wheat, a new hard red spring variety.
2. Barley heads
3. A barley varietal trial.
4. Wheat and oat yield trials.
5. Experimental plot combine.
6. Foundation field of the new hard red winter, semi-dwarf wheat, Ute.


3
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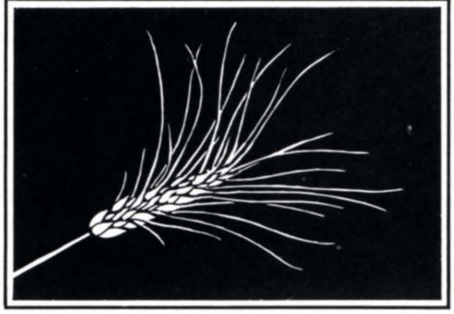
WHEAT



toward genetic homozygosity (true breeding). Single heads were selected from the F_5 generation of the cross in 1973 (approximately 1/10 ounce per head), and the seed from these heads was used to plant one 5-foot head row of each selection. Wynne was selected from these rows, and the one pound of seed harvested in 1974 was used to begin a detailed testing program throughout which the selection was designated as Ut. 74S25-776.

Wynne was evaluated for yield and other agronomic, pathologic and quality characteristics in Utah tests for 6 years and throughout the western U.S. and Canada for 3 years prior to its release. Breeder seed was produced at Yuma, Arizona, during the winter of 1980. Foundation seed was produced in 1981 and was released to growers in the spring of 1982.

Agronomic Performance

Wynne has outyielded Fremont, Borah and Powell (other hard-red spring wheats with which it has been compared) by an average of 3.8, 4.9, and 1.1 bushels per acre, respectively, in 34 irrigated tests conducted in Utah over 8 years, 1976-83 (Table 1). In the same tests, it yielded 2.5 bushels less than the soft-white, semi-dwarf variety, Fielder, but 2.5 bushels more than Twin, and 14.8 bushels above the standard tall variety, Lemhi 66.

Other Agronomic Characteristics

Wynne is a white-chaffed, semi-dwarf, spring wheat with flaring beards. It heads 1-2 days later than Fremont and Borah, but roughly 3-5 days earlier than Powell and the soft-white varieties with which it was compared (Table 2). The height of Wynne is comparable to that of Fremont, Powell, and Twin; it is roughly 2 inches taller than Borah, and 2 and 10 inches shorter than Fielder and Lemhi 66, respectively. Wynne was lowest in percent lodging of the six varieties with which it was compared. In test weight, it was higher than Powell, Twin, and Lemhi 66, but slightly lower than Fremont, Borah, and Fielder.

Pathologic Characteristics

Wynne is moderately resistant to the prevalent races of stripe rust in Utah and the Intermountain Region. This disease does not occur regularly in Utah, but it can be destructive when a source of infection and favorable environmental conditions are present. Wynne appears to have adequate resistance to other spring wheat diseases that prevail in Utah and the surrounding area.

Quality Characteristics

Wynne is a bread wheat with generally good milling and baking properties. Table 3 compares major quality characteristics of Wynne with those of other hard-red spring wheats grown in the same tests at various locations over a 7-year period. All evaluations were made in the quality control laboratories of two commercial flour mills in the Ogden area. Most of the comparisons made were between Wynne and one of its parents, Fremont. Wynne was usually slightly lower in percent protein than other varieties with which it was compared. This is not surprising, since increased yield is often accompanied by decreased protein level. Stability values, which are a measure of dough mixing strength, were generally satisfactory. Loaf volume, loaf score, and baking ratings were nearly always equal to those of other varieties with which Wynne was compared.

Adaptation

Wynne has a combination of characteristics that should make it a popular choice among spring-wheat varieties available to producers. Performance of any crop, however, depends not only upon selection and utilization of the best available variety or hybrid, but also upon providing an optimum environment in which the crop can be produced. This favorable environment is particularly important if the full potential of high-yielding, semi-dwarf varieties is to be realized. Wynne is no exception to this rule. Without favorable moisture, fertilizer, planting date, weed control, and other environmental factors, its high genetic yield potential cannot be fulfilled. Wynne is recommended for production under irrigation and conditions of high soil fertility. It likely is not well adapted for dryland production or other stress conditions.

Seed Availability

Registered seed was produced in 1982 and Certified was produced in 1983. Seed should be available for commercial production in 1984. Inquiries about Foundation seed or information on commercial seed sources should be directed to the Utah Crop Improvement Association, Utah State University, Logan, Utah 84322; telephone: (801) 750-2082.

ABOUT THE AUTHOR

Rulon S. Albrechtsen is Professor of Agronomy in the Plant Science Department. His major area of research is in breeding and testing improved varieties of barley, spring wheat and oats. He also works on other methods of improving small grain production in Utah. Dr. Albrechtsen teaches courses in Grain Crops and Plant Breeding at Utah State University.

TABLE 1. Comparative yields of Wynne and six other spring wheat varieties in irrigated yield tests grown throughout Utah, 1976-83.

		Bushels per acre								
		5-nurs. avg.	3-nurs. avg.	4-nurs. avg.	5-nursery average			3-nurs. avg.	4-nurs. avg.	
Variety	Class	1976	1977	1978	1979	1980	1981	1982	1983	8-yr. avg.
Wynne	a	87.2	85.1	89.2	94.1	88.6	74.0	76.3	57.8	81.5
Fremont	a	75.2	81.1	86.0	94.4	83.2	73.9	73.8	53.7	77.7
Borah	a	74.9	78.5	84.1	91.6	83.5	73.5	74.6	52.4	76.6
Powell	a	79.7	85.4	88.4	94.6	88.2	73.4	75.8	57.4	80.4
Twin	b	83.1	78.8	85.1	95.4	80.4	67.7	75.1	66.1	79.0
Fielder	b	82.8	87.6	91.7	99.2	92.0	76.7	84.4	57.5	84.0
Lemhi 66	b	68.2	71.0	67.7	87.7	70.9	47.2	65.9	55.3	66.7

a = hard red spring
b = soft white spring

Wynne has a favorable combination of agronomic, pathologic and quality characteristics

TABLE 2. Heading date, plant height, percent lodging, and test weight data for Wynne and six other spring wheat varieties with which it was compared, 1976-83.

Variety	Heading date (June)	Plant height (inches)	Lodging (percent)	Test weight (lbs/bu)
Wynne	23	32.3	3	59.2
Fremont	22	32.6	8	59.9
Borah	21	30.5	20	59.9
Powell	26	32.3	11	58.3
Twin	28	32.6	14	57.0
Fielder	27	34.2	5	60.2
Lemhi 66	27	42.4	24	58.2

TABLE 3. Quality characteristics of Wynne and other hard-red spring wheats with which it was compared, 1976-83.

Variety	Year	Location grown	Protein* (percent)	Stability (minutes)	Loaf volume (**)	Loaf score***	Baking rating
Wynne	1976	Farmington	14.60	13.5	900	82	Good
Fremont	1976	Farmington	15.00	14.0	875	82	Good
Wynne	1977	Farmington	14.00	11.2	875	84	Good
Fremont	1977	Farmington	14.25	9.8	775	78	Good
Wynne	1978	Logan	13.00	8.2	750	69	Good–
Fremont	1978	Logan	13.20	5.0	700	49	Fair–
Wynne	1978	Morgan	14.50	8.2	850	78	Good
Fremont	1978	Morgan	15.10	8.5	750	63	Fair
Wynne	1979	Logan	13.10	6.5	800	82	Good
Fremont	1979	Logan	14.15	7.5	775	65	Good–
Wynne	1980	Logan	11.80	5.0	850	85	Good +
Fremont	1980	Logan	13.15	4.5	700	49	Fair–
Wynne	1980	Farmington	13.55	6.8	850	82	Good
Powell	1980	Farmington	11.65	8.0	825	79	Good
Wynne	1980	Morgan	12.70	7.5	850	79	Good
Fremont	1980	Morgan	13.80	4.8	800	72	Good–
Wynne	1981	Palmyra	14.75	6.5	45.00	8 7 7	
Fremont	1981	Palmyra	13.50	4.0	44.50	8 7 7	
Wynne	1983	Logan	13.15	12.0	47.50	8 6 7	Good–
Borah	1983	Logan	12.50	11.5	48.50	8 7 8	Good
Wynne	1983	Palmyra	14.70	17.6	46.50	7 7 7	Fair–
Fremont	1983	Palmyra	15.95	23.5	46.50	8 7 7	Fair

*Percent protein is based on 14% moisture content of grain.
**Three-digit numbers are expressed in cc's; 4-digit numbers are in inches.
***Loaf score is a composite of volume, grain, and external appearance; 100 points are possible for 2-digit numbers; 10 points are possible for each digit in the 3-digit numbers.

UTE

A NEW, SHORT, IRRIGATED BREADWHEAT

W. G. DEWEY

Seed of the first winter wheat variety developed specifically for irrigated lands in Utah was released by the Utah Agricultural Experiment Station in limited quantities to commercial seedsmen in the fall of 1983. The new variety, named Ute, was bred in response to an expressed interest on the part of irrigated winter wheat growers for a hard-red alternative to the soft-white types they are presently growing. Utah is predominantly a hard-red breadwheat producing area, and the bulk of our dryland acreage is planted to hard-red wheats, which commonly command a price premium over the soft-white non-breadwheat types. Our dryland varieties, however, have generally not been well suited to irrigated conditions because of their relatively tall straw, which is usually desirable under dryland conditions but poses lodging problems under irrigation.

Until now the only short-strawed, lodging-resistant winter wheat varieties adapted to high yielding irrigated conditions in this area have been soft-white semi-dwarfs from the Pacific Northwest, such as Nugaines, Stephens, McDermid, and Daws. Although these varieties have done, and will likely continue to do, an excellent job for irrigated winter wheat growers in Utah, Ute should provide a viable option for those who want to grow a hard-red type.

Development

The cross that produced Ute was made in 1972. One of its parents is Cardon, a relatively tall, hard-red dryland winter wheat variety. The other parent was an F_1 hybrid with a rather complicated ancestry involving Bannock, a medium-height spring wheat, and a semi-dwarf winter wheat breeding line. The actual pedigree is Hussar/Turkey//Ridit/3/Oro/Ridit/4/Norin 10/Brevor/5/Delmar/6/Columbia/7/Bannock/8/Cardon. Ute derives its short straw from Norin 10 and its breadmaking qualities largely from Cardon and Bannock. It was selected as a single F_5 plant in 1977. During its testing period, Ute was identified as breeding selection 1195-152.

Description

Ute is a bearded, bronze-chaffed wheat with a winter growth habit. Kernels are hard-red, medium in size, and about average in test weight, i.e., approximately 60 pounds per bushel. Relative to other hard-red winter wheats presently being grown in this area, Ute's most distinguishing characteristic is its reduced height. It is usually 12-18 inches shorter than most standard-height varieties and 4-6 inches shorter than such semi-dwarf varieties as Nugaines and Stephens. Table 1 contains height, lodging, and heading date data for Ute and a number of winter wheat varieties commonly grown under irrigation in Utah. Ute's straw is short but not particularly stiff or heavy. It has a nodding head at maturity and feeds well into a combine. We have rarely observed lodging in Ute, even under high levels of fertilization and irrigation. It is early-to-intermediate in heading and maturity, similar to Stephens and Manning.

Yield Performance

Most of the hard-red, semi-dwarf breeding lines we have tested over the years have failed to yield as well as the soft-white semi-dwarf check varieties. Ute has been an exception. In 4 years of yield testing under irrigation at Logan, its yields have been comparable to those of the best soft-white types (Table 2). Ute has consistently outyielded Manning and Neeley, the only hard-red winter wheats presently grown to any extent under irrigation in this area. Its yield advantage over these latter varieties is due in large part to its superior lodging resistance.

Quality Considerations

Good breadmaking quality is usually more difficult to achieve under irrigation than under dryland conditions, primarily

TABLE 1. Height, lodging and heading date data for several winter wheat varieties grown under irrigation at Logan (1980-1983 4-year average).

Variety	Height (inches)	Lodging*	Heading Date
Neeley	48	M-S	June 11
Manning	44	M-S	June 8
Daws	39	N-SL	June 12
McDermid	39	SL	June 7
Stephens	38	N	June 8
Nugaines	37	N	June 12
Ute	33	N	June 9

*N = None; SL = Slight; M = Moderate; S = Severe

TABLE 2. Yields of irrigated winter wheat varities grown at Logan, Utah, over the 4-year period 1980-1983.

	Bushels per Acre				
Variety*	1980	1981	1982	1983	4-yr. avg.
Stephens	157.7	131.5	123.9	132.3	136.1
Ute	154.8	135.4	123.7	129.9	136.0
Nugaines	151.0	136.0	120.6	128.4	134.0
McDermid	151.6	129.0	122.4	126.5	132.4
Daws	151.9	121.9	116.0	120.4	127.6
Manning	141.2	118.8	114.2	125.5	124.9
Neeley	128.8	101.8	111.3	112.4	113.6

*Ranked in order of 4-year average yields.

Due to superior lodging resistance, Ute outyields other hard red winter wheats under irrigation

because of the yield differential and the inverse relationship that commonly exists between yield and grain protein. As a general rule, the higher the yield the lower the protein, particularly if soil nitrogen is limiting. Since grain protein is laid down relatively late in the plant's growth cycle, yield gets first call on nitrogen supplies, and whatever is left is available for grain protein. Consequently, a few extra bushels per acre will frequently result in a significant reduction in protein percentage. This is not a problem in the soft-white varieties, where low protein is considered desirable for most of their end-product uses, e.g., cookie and cake flours. Relatively high protein is a must, however, for breadwheats. Maintaining the necessary protein levels at yields in excess of 120 bushels per acre, which are attainable under irrigation, is much more difficult than at the 30-35 bushel yield that is typical of our drylands.

The key to combining high yields and high protein lies in providing adequate nitrogen to supply both needs. To accomplish this, a farmer who plans to grow high-yielding, quality breadwheat under irrigation may have to manage his fertilization practices, particularly the amount and timing of his N application, more carefully than he has been accustomed to with the soft-white varieties. Split applications, with part of the N going on after vegetative growth has largely ceased and kernel formation has begun, can help to keep protein levels up. With the increasingly popular practice of applying part of the fertilizer via irrigation systems, this "late feeding" with N is becoming more feasible.

In milling and baking tests conducted by commercial mills at Ogden (Con Agra and Pillsbury), Ute exhibited satisfactory breadmaking quality, in spite of our letting protein levels slip into the marginal range (Table 3).

Disease Characteristics

Ute has shown fair resistance to both dwarf and common bunt in our artificially inoculated test plots. It also appears to be moderately resistant to the naturally occurring races of stripe rust in this area and moderately susceptible to mildew.

Recommended Use and Seed Availability

Ute will probably find its best use under high-producing irrigated conditions, particularly in those situations where farmers may prefer to grow a hard-red breadwheat over a soft-white type. Its short straw and lodging resistance should make it especially suitable to sprinkle irrigation. Those wanting to try Ute and planning to market it as a breadwheat would be well advised to provide adequate N fertilizer to supply both the yield and protein needs of the crop. Split, late application of N may be particularly helpful in maintaining protein at acceptable levels.

Approximately 10,000 pounds of Foundation seed was produced in 1983 and distributed to certified seed growers through the Utah Crop Improvement Association. This was planted on about 100 acres in the fall of 1983 and should provide several thousand bushels for fall seeding in 1984. Inquiries as to specific seed sources can be directed to the Utah Crop Improvement Association at Utah State University, Logan, Utah 84322.

ABOUT THE AUTHOR

Wade Dewey is a professor in the Plant Science Department, with a teaching and research assignment in the area of plant breeding. His primary responsibility has been the winter wheat breeding program at USU, which he has directed over the past 27 years. Ute is the latest in a series of varieties that have resulted from this program.

TABLE 3. Quality characteristics of Ute and several standard breadwheat varieties (data from Con Agra Mills at Ogden, Utah).

	Test Wt. (lbs/bu)		Protein %		Mixing Stability (min)		Loaf Volume (in)		Baking Rating	
Variety	**1981**	**1982**	**1981**	**1982**	**1981**	**1982**	**1981**	**1982**	**1981**	**1982**
Dryland:										
Cache	60.6	62.6	11.1	13.1	6.6	12.6	750	700	G–	F
Hansel	60.1	62.4	11.0	12.6	18.8	21.1	800	800	G	G
Manning	59.5	62.5	10.3	12.4	6.5	18.3	775	800	G	G
Jeff	61.2	63.4	11.0	12.7	10.6	13.7	775	775	G	G
Weston	61.6	62.8	11.3	13.1	14.5	17.6	800	725	G	G–
Irrigated:										
Manning	62.7	63.1	11.0	11.2	4.5	20.9	700	800	G–	G
Neeley	62.8	62.2	12.4	11.6	7.2	17.8	750	750	G	G–
Ute	61.2	60.6	11.0	10.6	5.0	12.0	775	750	G	G

Dryland samples were from a composite of county yield trials.
Irrigated samples were from irrigated yield trials grown at Logan.

BRACKEN

A SPRING FEED BARLEY

R. S. ALBRECHTSEN

Bracken is not the final answer as a feed barley for Utah, but it does possess a favorable combination of yield and other agronomic, pathologic, and quality characteristics that should make it a popular choice among barley producers. Developed and released by Utah Agricultural Experiment Station personnel, the variety was named in honor of the late Aaron F. Bracken, Professor of Agronomy at Utah State University and long-time Superintendent of the Nephi Dryland Field Station. The U.S. Department of Agriculture cooperated in evaluating the variety prior to its release.

Parentage and History

Bracken originated as a single F_5 plant selected from the cross, Woodvale 2X Primus × S.D. 67-297. Woodvale is a locally adapted 6-row feed barley developed at the Utah Agricultural Experiment Station; Primus and S.D. 67-297 were both developed at the South Dakota Agricultural Experiment Station. Bracken was identified as Ut. B1-1399 throughout the 7 years that lapsed between its selection as a breeding line in 1973 and its eventual naming and release as a new variety in 1980. It was evaluated for yield and other agronomic, pathologic, and quality characteristics in tests in the major barley producing areas of Utah and the western United States. The release process was hastened one year by the production of Breeder seed at Yuma, Arizona, during the winter of 1978. This enabled Foundation seed to be produced at Logan in 1979, and the release to growers to occur in the spring of 1980.

Yield Performance

Irrigated yield tests conducted in Utah over a 7-year period have shown Bracken to yield at a level equal to that of Steptoe, presently the most widely grown barley variety in Utah and the Intermountain Region (Table 1). These two varieties have consistently been among the top-yielding entries in performance trials. Average yield of Bracken exceeded that of four other varieties with which it was compared by 12.4 to 24.3 bushels per acre. Bracken likely is not as widely adapted as is Steptoe; however, yields of the two varieties were quite comparable in federally coordinated, regional barley tests throughout the western U.S. and parts of Canada.

Other Agronomic Properties

Bracken is a 6-row, white aleurone, smooth-awned, spring feed barley. It has a rather compact head, with a glossy appearance prior to maturity, similar to that of Woodvale. Heading date for Bracken is similar to that of Steptoe and Trebi. It heads about 3 to 6 days earlier than Woodvale and Lud, respectively, and 4 days later than Gem (Table 2). Bracken is also comparable to Steptoe and Trebi in plant height. It averaged, however, only 12 percent lodging compared to values of 20, 26, 29, and 60 percent for Steptoe, Woodvale, Gem, and Trebi, respectively. Test weight of Bracken is equal to that of Steptoe, and slightly higher than those of the other 6-row varieties, Woodvale, Gem, and Trebi. The 2-row varieties such as Lud are consistently higher in test weight than are the 6-row types.

Pathologic Characteristics

Bracken has consistently shown a lower level of susceptibility to loose smut than has Steptoe. (Loose smut is generally the most serious disease of barley in Utah.) Loose-smut infected heads are occasionally seen in Bracken, but the level of infection is generally very low or absent. Bracken appears to have satisfactory resistance to other barley diseases common to Utah and the Intermountain Region.

Quality Factors

Historically, quality has not been monitored as closely in feed barley as it has been in wheat and malting barley. Criticism of the widely grown variety, Steptoe, however, which cites its many reported cases of low protein content and consequently inferior feed value in some animal rations, has prompted a closer look at this quality characteristic. Table 3 shows comparative percent protein values for Bracken and Steptoe produced in the same nurseries at five locations over 4 years, 1980-83. Bracken exceeded Steptoe in percent protein in each of the 20 comparisons made. Differences ranged from as little as 0.4 to as much as 4.3 percentage points. Four-year (20-comparison) average values for Bracken and Steptoe were 12.5 and 10.6, respectively, on an "as is" basis and 13.8 vs. 11.7 on an "oven dry" basis; average differences between the two varieties were 1.9 and 2.1 percentage points on an "as is" and "oven dry" basis, respectively.

Summary

Bracken barley has a favorable combination of high yield and good protein content, accompanied by satisfactory plant height, lodging resistance, test weight, maturity date, and disease resistance. The significantly superior protein content of Bracken over that of Steptoe, even though the two are essentially equal in yield, gives Bracken a distinct advantage in protein production per acre. This difference will be of particular value to producers who either feed the barley they produce (in rations where they benefit from the higher protein) or market it on the basis of protein content.

Regardless of how many virtues a variety may have, it almost always will have some weaknesses as well. Bracken is no exception to this rule. Although it has strong, stiff straw throughout most of its developmental stages, Bracken plants develop a somewhat brittle head and stem upon maturity. As a result, shattering and loss of seed may occur during the harvest operation if the crop is allowed to become over-ripe prior to harvest. This need not be a problem if harvesting is accomplished as soon as the crop is mature. Those who plan to produce caution.

Like other varieties with a high genetic yield potential, Bracken must be provided a proper environment in order for this high potential to be realized. Bracken is best adapted for production under irrigation and conditions of good soil fertility. It does reasonably well under dryland conditions, but is not likely to give the superior performance there that it does in a more favorable environment.

Seed Availability

Bracken seed is generally available through commercial seed channels. Inquiries about Foundation seed or information on commercial seed sources should be directed to the Utah Crop Improvement Association, Utah State University, Logan, Utah 84322; telephone: (801) 750-2082.

TABLE 1. Comparative yields of Bracken and five other spring barley varieties in irrigated yield tests grown throughout Utah, 1976-83.

	Bushels per acre									
	2-nurs. avg.	3-nurs. avg.	4-nurs. avg.	5-nursery average				4-nurs. avg.		
Variety	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**7-yr. avg.**	**8-yr. avg.**
Bracken	110.4	130.3	122.0	142.9	110.4	118.2	101.8	82.8	113.8	114.9
Steptoe	106.0	126.2	*	141.9	113.6	121.4	102.8	83.2	113.6	*
Lud	96.2	114.2	104.4	129.6	103.0	105.4	89.1	72.4	98.6	99.0
Woodvale	102.0	107.6	101.7	128.9	103.7	97.2	85.9	65.1	95.9	96.4
Gem	99.6	109.6	99.7	125.3	98.8	97.1	81.0	59.9	101.4	101.8
Trebi	96.4	93.2	89.1	118.0	90.7	91.0	84.0	62.7	90.9	90.6

*Steptoe was not in the 1978 tests due to an error in seed source; consequently, it is not included in the 8-year average yields.

TABLE 2. Heading date, plant height, percent lodging, and test weight of Bracken and five other spring barley varieties with which it was compared, 1976-83.

Variety	Heading date (June)	Plant height (inches)	Lodging (percent)	Test weight (lbs/bu)
Bracken	19	32.7	12	48.7
Steptoe	19	32.4	20	48.5
Lud	25	30.7	12	51.4
Woodvale	22	30.1	26	47.1
Gem	15	33.0	29	47.5
Trebi	20	32.9	60	47.6

ABOUT THE AUTHOR

Rulon S. Albrechtsen is Professor of Agronomy in the Plant Science Department. His major area of research is in breeding and testing improved varieties of barley, spring wheat and oats. He also works on other methods of improving small grain production in Utah. Dr. Albrechtsen teaches courses in Grain Crops and Plant Breeding at Utah State University.

TABLE 3. Percent protein of Bracken and Steptoe barley, 1980-83.

		As is basis					Oven dry basis				
Location	**Variety**	**1980**	**1981**	**1982**	**1983**	**4-yr. avg.**	**1980**	**1981**	**1982**	**1983**	**4-yr. avg.**
Logan	Bracken	12.6	12.6	10.5	10.5	11.6	13.5	14.2	11.7	11.5	12.7
Logan	Steptoe	11.1	10.9	10.1	9.1	10.3	12.0	12.0	11.2	10.0	11.3
Farmington	Bracken	12.3	11.9	15.4	16.4	14.0	13.2	13.0	17.3	18.1	15.4
Farmington	Steptoe	9.8	10.6	11.9	12.6	11.2	10.6	11.6	13.4	13.8	12.4
Riverside	Bracken	11.4	13.6	11.7	13.2	12.5	12.2	14.9	13.1	14.5	13.7
Riverside	Steptoe	9.1	10.8	10.4	11.2	10.4	9.8	11.9	11.7	12.4	11.4
Morgan	Bracken	9.8	13.9	11.6	14.2	12.4	10.5	15.4	13.0	15.6	13.6
Morgan	Steptoe	9.4	11.3	9.9	13.1	10.9	10.1	12.5	11.2	14.5	12.1
Palmyra	Bracken	12.5	12.9	11.6	11.9	12.2	13.4	14.1	12.9	12.9	13.3
Palmyra	Steptoe	10.1	11.0	9.9	10.4	10.4	10.8	12.1	11.0	11.3	11.3
Averages	Bracken	11.7	13.0	12.2	13.2	12.5	12.6	14.3	13.6	14.5	13.8
Averages	Steptoe	9.9	10.9	10.4	11.3	10.6	10.7	12.0	11.7	12.4	11.7
Differences		1.8	2.1	1.8	1.9	1.9	1.9	2.3	1.9	2.1	2.1

Legumes For Wildland Plantings

M. D. RUMBAUGH

The inclusion of adapted legumes in wildland plantings produces many benefits. Improvements in forage yield, quality, and seasonal distribution increase an area's carrying capacity for livestock and game animals.

When selecting species to be used in wildlands, five primary criteria should be applied: (1) availability of plants or seeds, and *Rhizobium* inoculum, (2) ease of establishment (vigor and competitiveness), (3) forage quality (nutrients and toxicity), (4) compatibility with associated species, and (5) persistence (or reseeding potential). Secondary criteria include: (a) nitrogen fixation activity, (b) lateral spread by stolons, rhizomes, or roots, (c) seasonal distribution of forage, and (d) suitability for soil conservation, stabilization, or reclamation.

Alfalfa (*Medicago sativa* and *M. falcata*) and biennial sweetclover (*Melilotus alba* and *M. officinalis*) have been used in wildland plantings more often than other legumes. Many other species, however, should be considered for certain sites and purposes.

In this article the less publicized candidates are evaluated along with the traditional "reliables."

Variation and Adaptation of Legumes

The legume family (Leguminosae) contains more species than any other plant family except for the grasses (Gramineae) and the orchids (Orchidaceae). There are at least 500 genera of legumes, with approximately 15,000 species distributed world-wide. Certain genera such as *Astragalus*, contains numerous and extremely diverse species. There are 849 species of that genus native to the Soviet Union, while nearly 550 occur in North America and 174 in Utah. Morphological variation within the Leguminosae ranges from large perennial trees (e.g., *Gleditsia triacanthus*—Honeylocust) to shrubs (e.g., *Prosopis glandulosa*—mesquite) and annual herbs (e.g., *Crotolaria spectabilis*—rattlebox). Adaptation varies from tropical jungles to deserts and arctic mountains. Only the grasses exceed legumes in economic importance, and there is no shortage of genetic diversity within the Leguminosae. Suitable species exist for all types of wildland plantings.

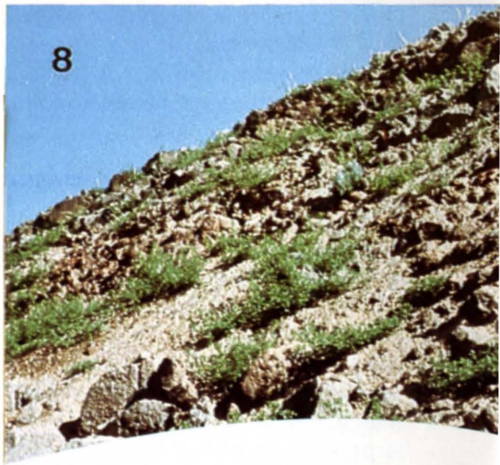
Nitrogen Fixation

Although the nitrogen fixation activity of legumes is of less importance than some of their other attributes, it is a unique process and will be considered prior to discussing individual species. Many plants other than legumes possess mechanisms for nitrogen fixation, but the quantity of nitrogen they fix is much less than that fixed by the legume host-*Rhizobium* symbiotic mechanism.

Inadequate supplies of plant-available nitrogen frequently limit forage production on western rangelands. Nitrogen deficiency has been estimated to reduce plant growth on 178 million acres (72 million hectares) of rangeland in the Northern Great Plains alone. Nitrogen fertilization increased herbage yields 32 to 114 percent in average or near average precipitation years and 218 percent during above-average precipitation years when evaluated over a 10-year period. These yield increases occurred without major species compositional changes in the native vegetation. Increased yields and better herbage quality resulted from nitrogen fertilization of other arid rangelands in the Great Basin even in a year when soil moisture was exceptionally low. However, application of fertilizer to rangelands is expensive. Once established, an adapted legume species under proper management can continue to add fixed atmospheric nitrogen to the range site on a sustained basis without the recurring cost of annual fertilization.

Native legumes often actively fix nitrogen when present on rangelands. In a study of central North American grasslands, native species of *Amorpha, Cassia, Lespedeza, Psoralea,* and *Schrankia* actively fixed atmospheric nitrogen. Species that occupied niches in pioneer through late seral stages of succession had a greater nitrogen-fixing capacity than species that were more limited to the climax stage. Symbiotic fixation in grasslands at the Jornada (desert grassland in southern New Mexico), Pawnee (shortgrass prairie in northeastern Colorado), Cottonwood (mixed prairie of western South Dakota), Pantex (shortgrass prairie of northern Texas), and Osage (tallgrass prairie in central Oklahoma) research sites has been shown to be small. Yet, several lupine species actively fixed nitrogen in northern Utah, and legumes growing in annual grasslands of California added significant amounts of nitrogen to the soil-plant system. *Astragalus lentiginosus, Dalea fremontii,* and *Lupinus argenteus* fixed nitrogen in the desert of southern Nevada. Even in the Colorado desert near Palm Desert, California, native legumes of the genera *Astragalus, Dalea, Lotus, Lupinus,* and *Prosopis* have been found to be nodulated and to fix nitrogen.

The preponderance of evidence indicates that native legumes are capable of nitrogen fixation during at least a part of their growing season. Where they have been eliminated by overgrazing, the range site is not receiving the benefit of the nitrogen that could be added by the legume-mediated fixation process. Reintroducing the native species or replacing them with improved strains or other adapted legumes should help restore the site to full productivity.



*1. A native legume (**Lupinus caudatus**) growing on a range site in the Raft River Mountains of Northern Utah (Park Valley).*

*2. A native legume peavine (**Lathyrus brachycalyx**), flowering profusely on a foothills range site east of Santaquin, Utah.*

*3. Alfalfa (**Medicago sativa**) seeded prior to 1908 on a Montana range site and grazed since 12" of precipitation/year still has an excellent and productive stand of alfalfa.*

*4. Alfalfa (**Medicago sativa**) seeded on a Pinyon-Juniper range site near Manilla, Utah, after chaining.*

*5. Purple flowered alfalfa (**Medicago sativa**) and yellow flowered birdsfoot trefoil (**Lotus cornitulatus**) growing on a mountain grassland range site in Cache County, Utah.*

*6 & 7. Foxtail clover (**Trifolium rubens**) has recently been introduced from the Balkan Mountains of Europe and is being bred for use on high elevation rangelands of the western states.*

*8. Sweetclover (**Melilotus officinalis**) pioneering on a rocky slope near Snowville, Utah.*

Alfalfa

Alfalfa (*Medicago sativa* and *M. falcata*) has been included in more range-seeding projects in North America than any other legume. The genus *Medicago* is not native to the western hemisphere. It evolved in the Mediterranean region, but the perennial forms of most interest for wildland use arose in western and central Asia. The potential value of alfalfa for rangeland improvement in North America was first expressed by a horticulturist, Dr. N. E. Hansen of South Dakota. In an address delivered in 1911 to the State Conservation and Development and Dry Farming Congress held at Pierre, South Dakota, Hansen said, "If we could clothe our naked hillsides with these wild Siberian alfalfas we could increase their present carrying capacity for stock seven to eight times." Hansen's concepts were more sharply defined by 1913 when he wrote, "These alfalfas and clovers may be used in two ways (1) As a cultivated crop for hay and pasture, and (2) to introduce as wild plants into the native ranges of the Prairie Northwest, where they will probably be able to hold their own with any plant now found there."

Experimental attempts to establish alfalfa in existing grass stands by sod seeding were initiated at Highmore, South Dakota, as early as 1909. It was also at Highmore that Samuel Garver discovered plants in one of Hansen's Russian introductions that had extensive, spreading lateral root systems. That characteristic has since been incorporated through breeding into a number of range and pasture alfalfa cultivars. Canadian scientists assumed an early and commanding lead in the breeding and use of alfalfa for grazing. A few ranchers also realized its potential and pioneered methods to establish alfalfa in native vegetation.

Despite the risk of stand failure in adverse environments, range managers recommend the use of alfalfa for range improvement projects more frequently than any other legume. Alfalfa is known to persist well once it is established. It is also capable of reproduction and self-perpetuation through natural reseeding on sites with as little as 11 inches (28 cm) annual precipitation. Preliminary data indicate that alfalfa can fix nitrogen during periods of drought stress when other legume species are not nodulated or are not active. When alfalfa is well established in game ranges, it effectively keeps game animals on those ranges and helps prevent their invading cultivated fields. The introduction of the dryland cultivar 'Nomad' proved to be one of the most successful techniques used to improve antelope (*Antilocapra americana*) ranges in southeastern Oregon. After 36 separate aerial seedings on more than 56,000 acres (22,000 ha), alfalfa constituted 10 percent of the vegetation present for 6 years or longer. More antelope does with fawns were observed on these seedings than on adjacent shrub-dominated rangelands.

Gains in forage yield that can be realized as a result of establishing legumes depend on site characteristics, precipitation, the legume species, interactions with associated species, and relative stand densities. Fourteen-year-old stands of alfalfa that were sod-seeded into a 35-cm annual precipitation shortgrass range in Harding County, South Dakota produced 253 percent as much total forage as untreated check plots. In a more complex experiment involving grass, shrub, and legume components growing at Nephi, Utah, significant increases in forage yields were attained through the use of alfalfa and other legumes. Crested wheatgrass (*Agropyron cristatum*) produced 183 percent as much grass foliage when grown with legumes, as when it was grown without legumes. In addition, the alfalfa plants contributed directly in a major way to a higher total forage yield.

Protein concentrations of grasses also increase when they are grown in association with legumes. In the experiment at Nephi previously cited, transect segments containing only grass had forage with 5.5 percent protein when averaged over four harvests. Segments in which both grass and alfalfa were growing produced grass forage that averaged 6.2 percent protein. In addition, the alfalfa foliage had twice the protein concentration of the grass on each of the four sampling dates. Both the quantity and the quality of the grass improved because of its association with alfalfa. The legume also appeared to cause the crested wheatgrass to recover more rapidly after clipping. Grass grown with alfalfa produced twice as much forage per year after it was first harvested as did grass grown without alfalfa. Again, the alfalfa also contributed directly and importantly to total regrowth forage.

Alfalfa was easily established on Idaho fescue (*Festuca idahoensis*), bluebunch wheatgrass (*Agropyron spicatum*), western wheatgrass (*A. smithii*), and junegrass (*Koeleria cristata*) range by a combination of close grazing and tillage or by close grazing and broadcasting seed into frost cracks. The alfalfa thrived and established colonies of plants on dry, wind-swept sites at a 2,000-f (1,500-m) elevation where soils contained sufficient lime. A short period of intense grazing during May and June was considered more favorable management for alfalfa than a long period of summer grazing.

Sweetclover

Sweetclover occurs sporadically throughout the United States as a pioneer plant on disturbed sites. The two species most frequently encountered are *Melilotus alba* (white-flowered) and *M. officinalis* (yellow-flowered). There are annual and biennial forms of each, but most populations are biennial. Both species grow rapidly, are deep-rooted, are excellent seed producers, and fix nitrogen very well when properly inoculated with suitable *Rhizobium* bacteria. Heavy stands are common along roadsides and in gullies where a supply of seed has accumulated in the soil and moisture has collected.

Sweetclover ranks next to alfalfa in frequency of use for improvement of perennial ranges. There is less information, however, about its value. Yellow-blossom sweetclover seeded with *A. desertorum* in Montana produced more forage than either the grass or legume seeded alone. The crude protein content of sweetclover forage in that study exceeded the content in alfalfa. Protein content of grass grown with either legume species was higher than that of grass grown in a pure stand. Sweetclover also performed very well on a dense-clay range in western South Dakota that had been severely depleted by drought and overgrazing. After being seeded in 1962 without seedbed preparation, yellow-blossom sweetclover reseeded naturally and remained a compatible associate with the native vegetation during a 5-year study. Combined grass and sweetclover forage production averaged 1,804 lb/acre (2,022 kg/ha) annually compared to 750 lb/acre (840 kg/ha) for the control treatment. The grass component was increased by 373 lb/acre (418 kg/ha) as a result of legume-supplied nitrogen. Western wheatgrass (*Agropyron smithii*) vigor and protein content were also improved. Native perennial grasses were not reduced in abundance by sweetclover competition.

Volunteer yellow-blossom sweetclover produced more than 450 lb/acre (500 kg/ha) of seed on a Montana rangeland receiving an average of 20 inches (50 cm) annual precipitation and located at 4,700 to 7,000 feet (1,400 to 2,100 m) elevation. Stand maintenance on south-facing slopes was not a problem once the sweetclover was well established. On north-facing slopes it grew but, because of undetermined factors, did not reseed. The most effective method of introduction was to broadcast seed after the limber pine (*Pinus flexilis*) and big sagebrush (*Artemisia tridentata*) had been burned. Without site preparation, the few plants that were established produced little seed because of close grazing by deer. The large amount of sweetclover that resulted from seeding after burning gave the deer more legume growth than they could keep from going to seed. Second-year sweetclover was highly competitive to sweetclover seedlings. To obtain the best forage utilization and seed production, pasturing was initiated prior to bloom stage and stopped when the plants had been grazed to a 10-inch (25-cm) stubble. The sweetclover then regrew and produced an abundance of seed. The same management procedure probably could be used elsewhere with other adapted range legumes.

As a wildland species in the Intermountain area, sweetclover maintains itself best on favorable sites of the mountain brush and pinyon-juniper zones, but its contribution to forage yield has not been documented. In addition to being a valuable forage plant, sweetclovers are important species for honey production and their seeds are of some value to upland gamebirds. Dwarf forms are known and the merit of breeding rapidly growing and early maturing cultivars of short stature for droughty sites should be explored.

Clovers

True clovers belong to the genus *Trifolium*. Most species require an annual precipitation in excess of 20 inches (50 cm) in order to do well, and no species native to North America has been used extensively throughout the United States. More research has been conducted with *Trifolium* species on California rangelands than elsewhere and the use of clover has been very successful there. The seeding of adapted species and phosphate fertilization accompanied by appropriate management increased the grazing capacity three-fold in one experiment lasting five years. A mixture of annual clovers of varying growth habits allowed a much greater latitude in adjustment of stock use than was possible with a single species. Clovers most often used for improvement of these annual rangelands are rose clover (*T. hirtum*), crimson clover (*T. incarnatum*), and subterranean clover (*T. subterraneum*).

In the southeastern United States, rangelands that have white clover (*T. repens*) growing with any of the five major perennial forage grasses record increases in the protein concentrations of the resulting forage all season long. Grass forages grown with the clover averaged as high or higher in protein than monospecific grass forage fertilized at nitrogen rates up to 300 lb/acre (336 kg/ha). The inclusion of clover also significantly increased the calcium concentration of the forage compared to that of the grass alone. Biologically, growing a legume such as white clover on southern ranges probably offers more opportunity to increase the nutritional yield and quality of the forage than does any other practice generally available. This also may be true of high elevation western ranges receiving sufficient precipitation to support growth of *Trifolium* species.

Three relatively unknown clovers merit attention as candidates for potential use on higher elevation western rangelands. These are *T. amabile, T. ambiguum,* and *T. rubens*. All have certain deficiencies such as poor seedling vigor, but it may be possible to overcome these through breeding or management. *Trifolium amabile* is indigenous to Andean rangelands at elevations between 9,500 and 12,800 feet (2,900 and 3,900 m). It is a more vigorous and productive perennial than many of our native, high-elevation clovers such as the *T. beckwithii* of the Intermountain Region. Little research has been done with this species, and only a few germplasm accessions are available to plant breeders. It grows well at Logan, Utah, however, at an elevation of 4,500 feet (1,400 m), and its value for mountain meadow and mountain grassland seeding should be tested.

Kura clover (*T. ambiguum*) has been investigated previously in the United States but has not achieved prominence as a forage crop. It is a cold-hardy, drought tolerant, rhizomatous perennial that is resistent to several virus diseases that attack other clovers. In early work with this species, however, stands failed because of weak seedlings and a lack of nodulation. Until quite recently, only a few germplasm accessions were available in the United States, and sufficient genetic diversity was not present to permit plant breeders to correct these problems.

As a consequence of recent plant collections in the Soviet Union by D. R. Dewey and A. P. Plummer, United States breeders now have access to an adequate representation of the genetic diversity of *T. ambiguum* to successfully develop improved populations for wildland use. Four-year-old plants of that collection growing in a spaced-plant nursery at Logan, Utah, had an average crown diameter of 30 inches (73.4 cm), were 12 inches (30.5 cm) in height, and had 49 heads per square foot (530 heads per m^2). Superior clones of this species were selected and progeny trials initiated.

The Dewey and Plummer collection also contained one accession of *T. rubens*. Only one prior introduction of this species, sometimes called foxtail clover, has been available in the United States. I know of no current agronomic research with *T. rubens*, yet in many ways it is an attractive clover. Plants grown at Logan, Utah, were perennial, winter-hardy, tall, erect, and productive of both forage and seed. Individual plants yielded as much as 1.2 ounces (33 g) of seed. Since *T. rubens* evolved in the submontane xerothermic areas of submediterranean middle Europe, it may possess attributes of hardiness and drought resistance of value to the wildlands of the Intermountain Region. Despite the lack of seedling vigor and the restricted germplasm base available, we have initiated a selection and evaluation program with this species.

Sweetvetch

One species of sweetvetch, *Hedysarum coronarium*, has achieved prominence as a forage crop in countries bordering the Mediterranean and in parts of Australia. Known as sulla or sulla sweetvetch, *H. coronarium* is fed either as fresh forage or as hay, or is used as a green manure crop to improve soil fertility and tilth. Sulla is reported to tolerate annual precipitation of 18 to 93 inches (46 to 236 cm), annual temperatures of 42 to 83 F (5.7 to 29.9 C), and to range from the Boreal Moist through the Tropical Forest Life Zones.

*9. An introduced milkvetch (**Astragalus cicer**) growing with crested wheatgrass (**Agropyron cristatum**) near Nephi, Utah.*

*10. A native legume, Northern Sweetvetch (**Hedysarum boreale**), and an introduced legume, yellow-blossom sweetclover (**Melilotus officinalis**), growing together on a range site in the Wasatch National Forest, Utah.*

*11. A native legume, northern sweetvetch (**Hedysarum boreale**) growing with crested wheatgrass (**Agropyron cristatum**) near Nephi, Utah.*

*12. A native milkvetch (**Astragalus** sp.) in Central Utah.*

H. mongolicum and *H. scoparium* have received some attention in China as species suited for range improvement and for stabilization of sand dunes. Seeds of these two species have been available to scientists in the United States only within the last two years. Seed increase efforts and research with them and with *H. coronarium* has been initiated in Utah and Montana.

The native Utah sweetvetch, *H. boreale*, is regarded as a valuable wildland legume. Sweetvetch starts growth early in the spring, produces abundant forage, and some basal leaves remain green throughout the winter. The foliage is highly palatable to big game and livestock. The species is a good seed producer and is well suited to cultivation for that purpose. *H. boreale* also may be vegetatively propagated and transplanted to sites where direct seeding is not possible or is not desirable. Sweetvetch strains differ in rhizome development, plant size, seedling vigor, disease resistance, and seed yield. Utah sweetvetch and all other *Hedysarum* species tested, contained condensed tannins and therefore are thought to be bloat-safe legumes.

Milkvetch

The genus *Astragalus*, to which the milkvetches belong, is an extremely diverse and interesting group of plants. It also is a group that presents many problems for ranchers. More than 500 species are native to North America. These can be divided into classes according to their effects on animals: (1) those that are acutely toxic, (2) those that are chronically toxic, (3) those that cause the locoweed syndrome, (4) those that are toxic due to their selenium content, and (5) a class that is nontoxic. None of the 500 species have been exploited for range improvement work. Two introduced Asiatic species have been used in wildland plantings.

Astragalus falcatus, sicklepod milkvetch, is a very productive legume from the Soviet Union and is well adapted to favorable areas of the pinyon-juniper and big sagebrush ranges. It is a large plant that often protrudes above the snow to provide winter feed. The inclusion of sicklepod milkvetch with crested wheatgrass in a planting at Nephi, Utah, increased both the forage and protein yields of the grass. This species has the additional advantage that it is easier to establish than several other legumes with which it has been compared. Unfortunately, *A. falcatus* foliage contains high levels of nitro compounds and should be classified as a poisonous plant. Therefore, this species should not be introduced into additional wildland sites unless strains are discovered which are not toxic to animals.

Astragalus cicer, cicer milkvetch, is entirely safe for grazing and has been used more extensively in North America than any other member of this genus. Breeding work with cicer is underway in Colorado and Alberta, and several improved cultivars have been released. Relatively low seedling vigor has restricted the use of this species as a forage plant. Cicer is bloat safe and is known to be better adapted to sandy soil than to loam soil. It does best at locations receiving more than 15 inches (40 cm) annual precipitation. On a droughty site in Utah, cicer had lower forage and protein yields than either sicklepod milkvetch or alfalfa. More information about this species should be obtained from longer term and larger plantings. Its use in wildland improvement projects should be encouraged.

Sainfoin

Sainfoin, *Onobrychis viciifolia*, is an attractive legume with many characteristics desirable for wildland use. It is nonbloating, relatively easy to establish, and productive of forage and seed. Sainfoin is a deep-rooted perennial with a tap root that can extend to a depth of 3 to 30 feet (1 to 10 m). It also is reported to be winter-hardy, drought resistant, and long-lived, although significant losses of sainfoin stands have been observed during 4- and 5-year test periods in Colorado and in central Montana.

Sainfoin performed better where it was seeded alone in range scalping and interseeding studies in Montana than where it was seeded with a grass. However, none of the stands were considered satisfactory. The competitive ability of the sainfoin seedlings was considered to be questionable under range conditions although the species seemed able to maintain itself and to spread into a mixed vegetational cover once it was established. The researchers suggested that information on the following points was needed before wide use of sainfoin on rangeland could be recommended.

1. Performance (productivity and longevity) in large scale interseedings.
2. Comparison with other legumes under range conditions.
3. Performance under seasonal grazing on range.
4. Animal response to sainfoin-interseeded range.
5. Methods of controlling undesirable plants in established sainfoin interseedings.
6. Watershed and wildlife relationships of sainfoin in range interseedings.
7. Overall effects on multiple-use management of private and public lands.

Few of these problems have been addressed in a significant way since the list was formulated in 1968. One important study took place in Turkey during 1969-1975. A replicated grazing experiment with sheep was conducted on five-hectare plots. Hay yields of native range, alfalfa plus grass, and sainfoin plus grass treatments were 0.93, 2.02, and 1.82 t/acre (1.047, 2.264, and 2.040 t/ha). The resulting live weight gains of sheep were 21.0, 56.3, and 51.8 lb/acre (23.5, 63.1, and 58.1 kg/ha) for native range, alfalfa plus grass, and sainfoin plus grass plots. After an appropriate economic analysis, profits from each of the legume treatments exceeded 300% of that for the untreated native range.

Other Legumes

Many species of herbaceous legumes other than those already discussed have been considered by plant scientists for wildland projects. These include native or introduced members of the following genera: *Amorpha, Baptisia, Chamaecrista, Coronilla, Dalea, Desmanthus, Indigofera, Lathyrus, Lespedeza, Lotus, Lupinus, Medicago, Petalostemum, Shrankia, Sphaerophysa, Strophostyles, Tephrosia,* and *Vicia*. Undoubtedly, there are others not listed here. Most often these species have not been used extensively because they lack seedling vigor and consequently are difficult to establish, or they are poor seed producers. In some instances, suitable *Rhizobium* cultures have not been available. More rarely, research with a vigorous species was halted because of fear that the legume would prove to be a weedy pest.

Conclusion

The world plant community has provided several herbaceous legumes of proven value for wildland plantings. Their use should be extended by range managers in a position to do so. These species frequently improve the quantity, quality, and seasonal distribution of forage, thereby increasing the carrying capacity and profitability of rangelands. They fix significant quantities of atmospheric nitrogen, which ultimately is used by associated grasses. Most legumes benefit wildlife as well as livestock. Some excel in lesser ways as effective species for soil conservation, mine soil reclamation, honey production, and site beautification.

Lesser known species are being improved by plant breeders. As this germplasm becomes available, range scientists are encouraged to evaluate it, document its advantages and disadvantages, and appraise the originators of their findings. Through cooperative efforts, more legumes will find a home on western wildlands.

ABOUT THE AUTHORS

Melvin D. Rumbaugh is a research geneticist employed by USDA-ARS. He is a collaborator with the Plant Science Department specializing in the development of legumes and forbs for rangeland improvement.

THE SODIC HAZARD IN COAL MINE OVERBURDEN

C. AMRHEIN, A. BROWN and J. J. JURINAK

Salt accumulation on surface of planting beds under furrow irrigation.

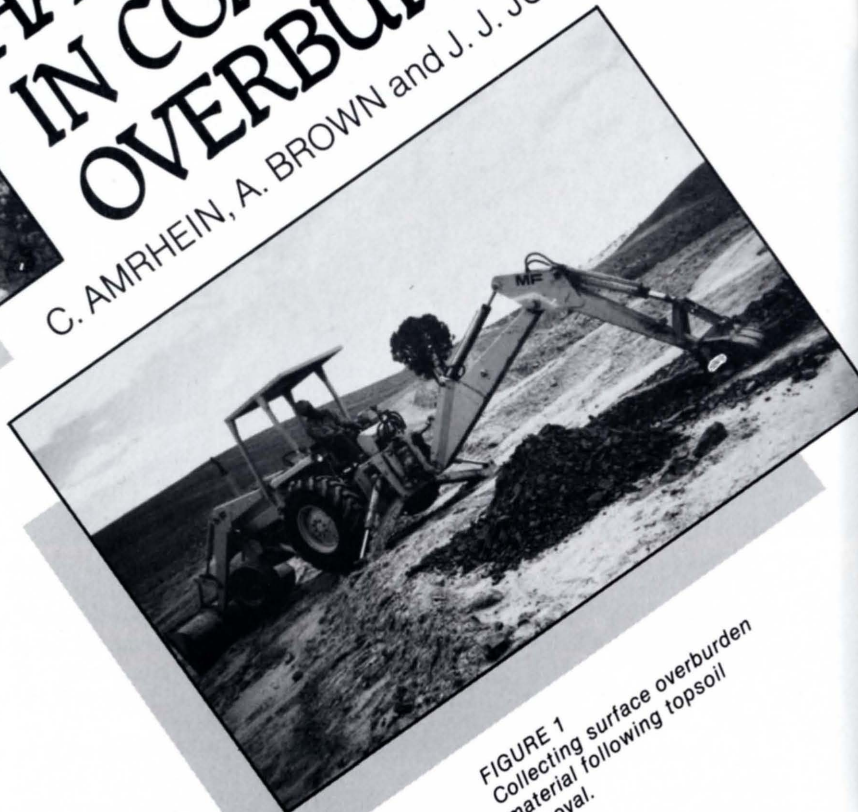


FIGURE 1
Collecting surface overburden material following topsoil removal.

Salt affected soils are a common feature of arid and semi-arid climatic regions. These soils are characterized by their adverse effects on vegetation, commonly due to salinity interacting with plant metabolism. It is also possible that toxic elements (for example, boron) are associated with the saline soils. In some cases, the adverse effects are due to the deterioration of the soil structure and the resultant decrease in soil permeability caused by the presence of sodium salts. This situation is exemplified by sodic soils.

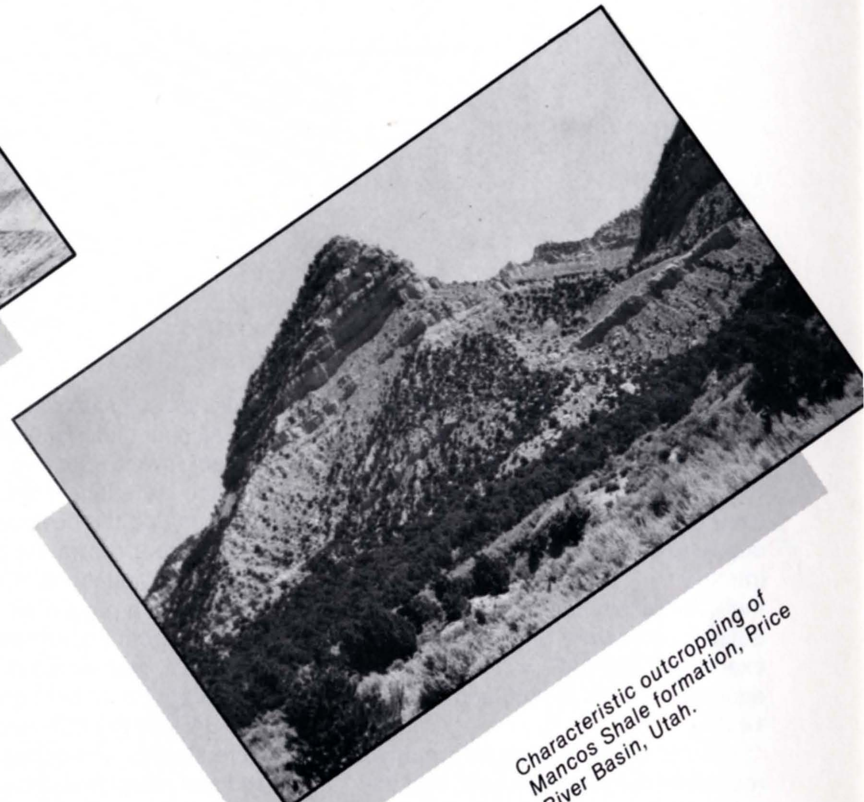
Not all soils in sub-humid regions are salt-affected. Salt-affected soils are always associated, however, with climatic regions that lack sufficient rainfall to leach away the salts that accumulate as rocks and geologic formations weather to form the soils' parent materials. Sedimentary rocks of marine origin are notorious as a source of salt. A prime example is the Mancos shale formation, which covers large areas of Utah, Colorado and Wyoming and is considered a major contributor to the salt load of the Colorado River.

Human activities can also add salt to the soil. One of the many possibilities is by applying irrigation water. Plants utilize essentially pure water, thereby leaving in the soil nearly all the salts that were added as constituents of the irrigation water. The use of good quality (low-salt) irrigation water and proper management can help reduce this potential problem.

An expanding problem that involves salt-affected soils in the Intermountain West is the large areas of land disturbed by the surface mining of coal and other energy related industries. Much of this land has sodic or saline soils or geologic material (overburden) that overlie(s) the coal seam. During the mining process the sodic or saline overburden is removed exposing the coal seam which is then mined. Following the coal removal, the overburden material is replaced. Stringent environmental legislation now requires the restoration and revegetation of these disturbed lands after mining has ended. The reclamation of these lands before native vegetation can be established presents a major economic and management problem to the mining industry.

The dilemma facing both the mining companies and the state and federal regulatory agencies, whose job it is to verify compliance with environmental statutes, is to determine which soil or overburden material is affected severely enough to warrant the expense of chemical reclamation. The project reported here addresses this problem and was designed to develop guidelines

FIGURE 2
Collecting deep overburden material at the 60 foot depth in a mining pit.



Characteristic outcropping of Mancos Shale formation, Price River Basin, Utah.

and procedures for the chemical diagnosis of the sodic problem in disturbed overburden materials, particulary those associated with the surface mining of coal.

The Sodic Hazard

Two principal diagnostic techniques are currently used to determine the sodic (sodium) problem in soils at the field level. One is based on the chemical analyses of a soil extract and is called the sodium adsorption ratio (SAR). It is empirically related to the amount of sodium absorbed on the clay mineral surfaces in a given soil, i.e., the exchangeable sodium ratio (ESR). The direct measurement of the ESR is the second and more accurate way to assess the sodic problem. It is, however, the much more difficult of the two techniques to accomplish in the laboratory. Earlier studies by personnel of the U.S. Salinity Laboratory, Riverside, California, using data from a total of 59 agricultural soils from western U.S. showed that a linear relationship existed between the ESR and SAR. This relationship can be written

$$ESR = k\ SAR \qquad (1)$$

where "k" is a proportionality constant also referred to as the Gapon selectivity coefficient. The SAR is defined as

$$SAR = [Na] / [Ca + Mg]^{1/2} \qquad (2)$$

where sodium (Na), calcium (Ca) and magnesium (Mg) are the total analytical concentrations expressed in millimoles per liter as measured in a saturation extract of the soil. The units for the SAR are $(mmol\ L^{-1})^{1/2}$. The ESR is defined as

$$ESR = NaX / (CEC - NaX) \qquad (3)$$

where NaX is the exchangeable sodium adsorbed by the clay minerals in milliequivalents per 100 grams of soil and CEC is the cation exchange capacity in milliequivalents per 100 grams of soil. The ESR measures the ratio of adsorbed Na to all other adsorbed cations. Another common way to express the amount of exchangeable Na is by the exchangeable sodium percentage (ESP), which is the percentage of the CEC occupied by exchangeable sodium, i.e. (NaX/CEC)100 = ESP. The The relationship between ESP and ESR is

$$\frac{ESP}{100\text{-}ESP} = ESR = k\ SAR \qquad (4)$$

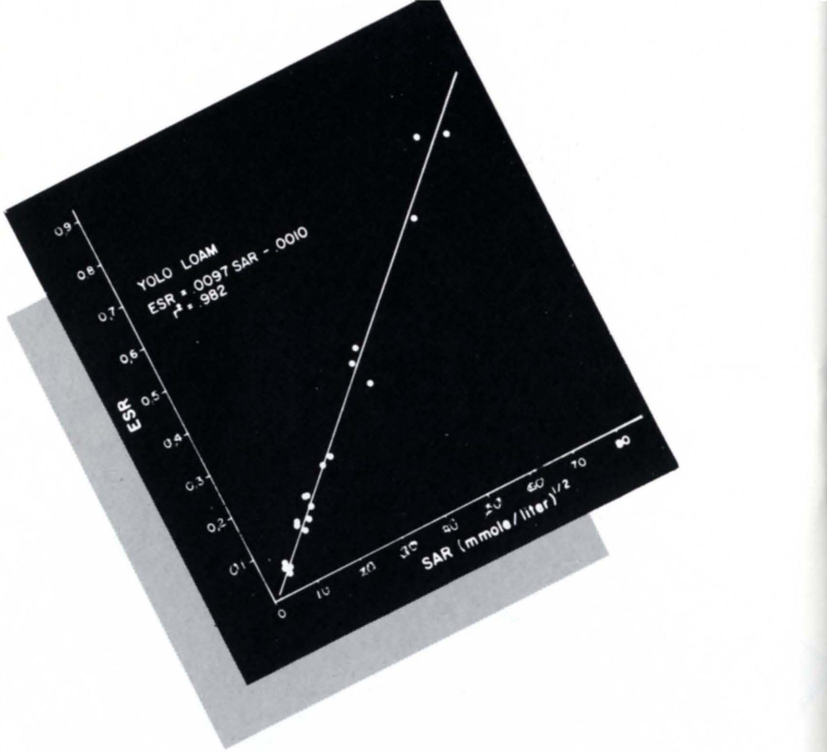


FIGURE 3
The ESR-SAR relationship for Yolo loam in the concentration range of 10 to 500 meq/liter.

The value of the selectivity constant "k" in equations 1 and 4 is important since multiplying the SAR by "k" gives the ESR or ESP. The value currently used by regulatory agencies and industry to convert SAR to ESR is 0.015 (mmol L^{-1}),$^{-1/2}$ which was determined at the U.S. Salinity Laboratory (U.S. Salinity Laboratory Staff, 1954). For example, if the SAR = 11, then using equation 4, ESR = .165 and ESP = 14.2%.

Unfortunately, studies by a number of researchers have suggested that the value of "k" is not a constant but varies with soil texture; total salinity and clay mineralogy of the soil; and the Ca/Mg ratio of the soil solution. Thus, its true value for any particular overburden or soil may be in question. If "k" is less than 0.015 (mmol L^{-1}),$^{-1/2}$ the amount of material classified as sodic will necessarily be less, thus reducing the amount of overburden requiring special handling and reclamation. The savings thereby accrued to the mining industry would ideally be passed on to the energy consumer. If the value of "k" is greater than the accepted value, more effort and cost will be required by the industry to prevent degradation of the environment relative to its original condition.

Measurement in Soils

We studied two overburden samples, designated surface and deep, obtained from the Spring Coal Mine, Decker, Montana. The "surface" overburden represents an area from which the non-sodic topsoil was removed exposing sodic subsoil material. Figure 1 shows the sample material being collected. The "deep" overburden represents subsurface material exposed at a 60-foot depth during the development of a mine pit. Figure 2 shows the sample site. To facilitate evaluations of treatment responses, a productive agricultural soil ("Yolo") from Sacramento Valley, California, was included in the study.

The effects of both solution salinity and SAR on the ESR and "k" values were studied by treating the overburden and soil samples with solutions of predetermined SAR and salinity. Treatment solutions were constructed from NaCl and $CaCl_2$ salts to give a concentration range of 10 to 500 milliequivalents per liter and SAR range of 5 to 80 (mmol L^{-1}).$^{1/2}$ All treatments were replicated 4 times.

Potential Sodic Problem is Site Specific

The ESR was measured and plotted against SAR as shown in Figures 3, 4, and 5. We found, as have other researchers, a strong linear relationship between SAR and ESR. Further, the selectivity coefficient "k", as measured by the slope of the line, was less than the value of 0.015 (mmole L^{-1})$^{-1/2}$ currently in use. There were differences among sample responses to treatment. The Yolo soil and "surface" overburden had "k" values of 0.0097 and 0.0087 (mmol L^{-1}),$^{-1/2}$ respectively, which were unaffected by increasing salinity (see Figures 3 and 4). In contrast, the "k" values for the "deep" overburden were a function of salinity; as the salinity increased, the value of "k" decreased (Figure 5). The "k" values for the "deep" overburden varied from 0.0138 (mmole L^{-1})$^{-1/2}$ at low salinities to 0.0047 (mmol L^{-1})$^{-1/2}$ at high salinities. The differences in treatment response are tentatively attributed to the difference in clay mineral composition. The Yolo and "surface" overburden contained mainly montmorillonite, kaolinite and illite minerals. The "deep" overburden contained only kaolinite and illite minerals. More research is required to clarify this point.

This study points out the importance of determining the potential for a sodic problem at each site in question.

We have verified that the linear relationship between ESR and SAR is independent of the salinity level but we have also found that the proportionality or Gapon's selectivity coefficient "k" varies with different soils or geologic materials.

The data also suggests that the sodic problem is reduced in the presence of kaolinite clay particularly at high salinities.

For the soils studied in this report, the value of "k" was found to be lower than the value commonly used to calculate the ESR. These data suggest the potential for a sodic soil problem may be less than previously thought.

This research suggests a method for a more accurate assessment of the chemistry of potentially sodic soils. The results will be reflected in more appropriate and cost-effective reclamation procedures for disturbed lands and salt-affected agricultural soils.

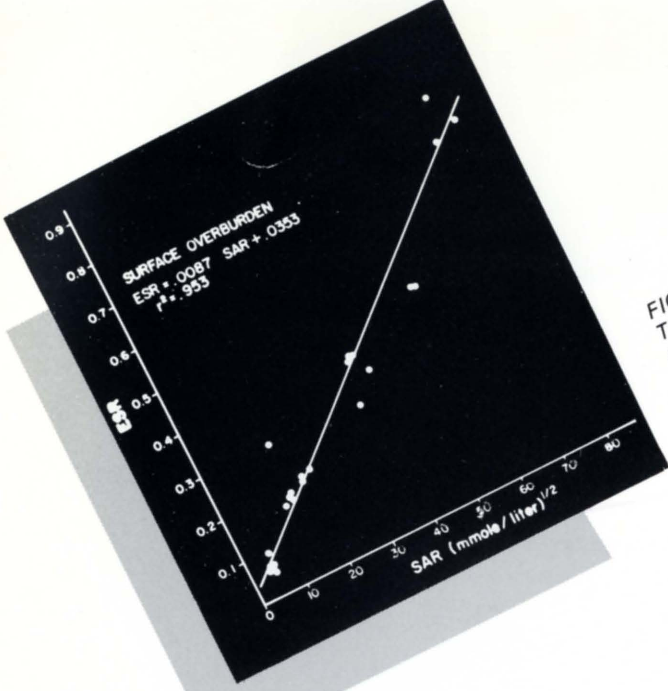


FIGURE 4
The ESR-SAR relationship for surface overburden in the concentration range of 10 to 500 meq/liter.

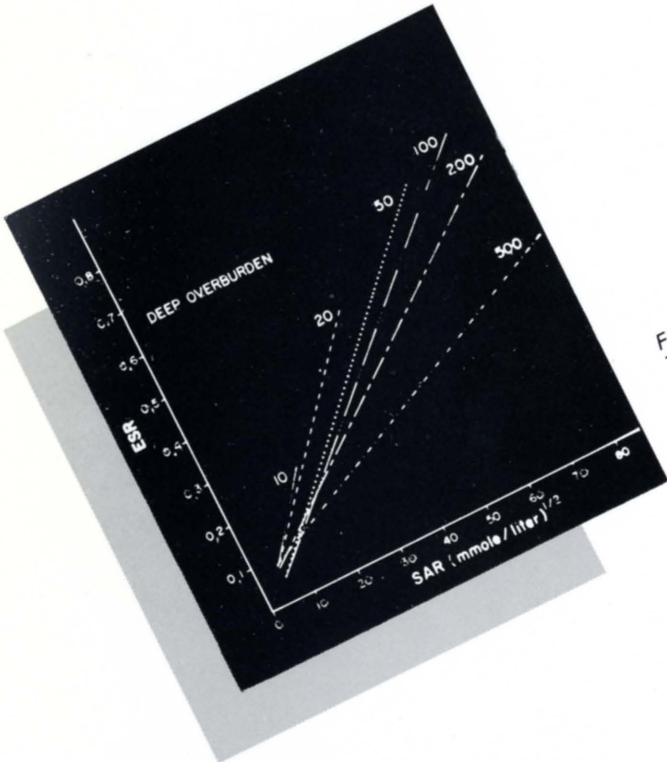


FIGURE 5
The ESR-SAR relationship for deep overburden at the designated salinity levels.

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