Utah Science Vol. 46 No. 3, Fall 1985

UTAH SCIENCE

UTAH AGRICULTURAL EXPERIMENT STATION FALL 1985 VOLUME 46 NUMBER 3

Developing Hybrid Wheat

FALL 1985 VOLUME 46 NUMBER 3

UTAH SCIENCE

UTAH AGRICULTURAL EXPERIMENT STATION

Cover embossing by Trade Engraving Co., Salt Lake City, Utah.

Biotechnology for Utah Agriculture

Few scientific breakthroughs have attracted as much attention as biotechnology—and for good reason. Genetic engineering. Recombinant DNA. Cloning. Gene transfer and splicing. These and similar biotech terms have slipped into our vocabulary with an ease that belies the extraordinarily complex science behind the headlines.

Basically, biotechnology uses living organisms in agricultural and other processes. It may involve modifying the genetic material of living organisms, either to create a new organism which performs better, or to have the organism itself create new products. A variety of biotechnological techniques have given scientists a remarkable ability to control the inheritance of desirable traits.

Many of these techniques are relatively new, and much needs to be learned. Yet biotechnology represents a tremendous advance in the ability to improve plants, animals and microorganisms useful in agriculture.

What It Means for Agriculture

The productivity of American agriculture is due in large part to farmers' enthusiasm for innovation. For the first time, it appears that biotechnology could give farmers the upper hand against such age-old adversaries as diseases and pests. Here's some of what may be in store: Biotechnology may make plants and animals grow faster and yield more with no extra fertilizer or chemicals (for plants) or feed (for livestock). Embryo manipulation and cloning promise remarkable increases in the pace of genetic improvement.

Biotechnology promises to reduce chemical use in agriculture, significantly reducing production costs and the threat of groundwater contamination. New organisms may partially replace current pest-control methods, thus reducing insecticide use. Genetically engineered special "bugs" may be developed for special tasks, such as destroying chemicals in the soil, degrading toxic wastes, or even producing insecticides within plants. A better understanding of genes will let biotechnologists develop better vaccines. And plants can be tailored to specific conditions, such as salinity and drought. Nonlegumes might even be able to produce their own nitrogen.

Phenomenal improvements in agricultural productivity are possible that could dramatically improve the economic position of producers, agribusinesses and consumers,

In short, phenomenal improvements in agricultural productivity are possible through biotechnology, gains which could dramatically improve the economic position of producers and related industries. Consumers would also reap substantial benefits.

Biotechnology requires laborious, painstaking—and expensive—research. Some of these benefits can be reaped after years of research, while others are already in use or close to application. The potential gains clearly outweigh the costs. Some experts estimate that similar discoveries are likely to occur well into the 21st century.

There are costs associated with any research, and particularly for the new equipment and facilities required for biotechnology. Scientists must also master new techniques. Yet several studies have shown that few investments pay higher dividends than agricultural research; one recent study estimated that annual returns for agricultural research approach 50 percent, an extraordinarily high return. Biotechnology promises even higher returns.

Research To Help Utah Farmers

Utah agriculture is unique, and so is much of the research required to solve the state's agricultural problems and capitalize on new opportunities. The Utah Agricultural Experiment Station has focused on research to solve Utah's agricultural problems since it was founded in 1888. Biotechnology continues that tradition.

As the accompanying articles in this issue indicate, an innovative biotechnology program already exists at Utah State University, but more research is required if agriculture is to make best use of these opportunities.

Doyle Matthews, director of the Utah Agricultural Experiment Station, says biotechnology must accelerate at USU to effectively address the state's unusual or unique problems. "We will certainly utilize discoveries made elsewhere and will be

Harnessing the New Technology

—The Editor

selective in our research. We are not trying to address all the biotechnological problems in the world."

Biotechnology has also added new fuel to an old debate about "basic" versus "applied" research, a debate which Matthews feels often reflects semantic differences.

"On the one hand, learning the fundamental principles of science invariably lead to useful applications. On the other hand, those working with practical applications soon encounter problems that lead back to basic science. You simply can't neatly divide basic and applied science, and we are going to be concerned with both types of research.

"That doesn't mean, however, that we expect one researcher to address all aspects of a problem. That's why we have teams of researchers," Matthews says.

The following brief synopsis of some research already supported by the Experiment Station illustrates what is at stake.

Healthier Animals

Livestock diseases continue to cause staggering losses, and their toll is particularly accute in Utah where about three-quarters of farm income is derived from livestock. It's estimated that livestock diseases reduce production by about 20%; reduced reproductive efficiency reduces potential production by an additional 14 to 20%. Biotechnology can substantially reduce these losses.

Experiment Station researchers have used biotechnolgical techniques to develop an experimental vaccine against ram epididymitis, a reproductive disorder that causes infertility and sterility. In Utah, estimated annual losses due to the disorder total more than $1,000,000.

Other research is addressing remarkable new vaccines against diseases such as bluetongue, and avian coccidiosis, a disease which also affects sheep, pigs, and horses. Estimated annual losses in the United States due to coccidiosis approach $100 million.

In addition to vaccines to prevent diseases, biotechnology is useful in disease diagnosis and treatment. Many more applications are likely.

Ultimately, biotechnology is an investment in the future of agriculture, and in future generations.

Better Foods

Problems of particular concern to Utah's dairy industry are the undesirable flavors and losses often caused by variations in starter cultures used in cheesemaking. These losses probably amount to about $300,000 per year in a typical, medium-sized Cheddar cheese plant.

As noted elsewhere in this issue, a USU dairy microbiologist is using genetic engineering techniques to improve starters so they resist infection by other organisms, a leading cause of starter failure. Moreover, the genetic techniques don't add any "foreign" genes or microorganisms to food; they simply make better use of selection processes which microorganisms naturally undergo.

Scientists no longer have to use the "trial and error" method of selecting beneficial microorganisms—they can now design microorganisms to control spoilage, stabilize flavor and modify foods.

Biotechnology is essential in maintaining USU's reputation as one of the nation's leading dairy-research centers. In addition to improved organisms, research concerning processes such as cheesemaking also involves new processing methods, equipment, and chemical and physical processes. USU currently has nationally recognized experts in these areas.

Improved Plants

Identification and transfer of the genes for asexual seed production to wheat from a related species could result in dramatic yield increases similar to those obtained with hybrid corn. The techniques will also be useful in transferring desirable characteristics among different species of plants, perhaps helping wheat and grasses thrive on arid or marginal farmland, and increasing diseases resistance.

USU researchers are studying remarkable new ways of harnessing microorganisms, modifying them to protect plants, control pathogens, and perhaps even getting them to "manufacture" substances such as insecticides or to act as selective biological herbicides. Scientists are also trying to decipher photosynthesis and the molecular basis of plant diseases, findings which could signal a new generation of genetic engineering.

Biotechnology: A New Era for Agriculture

Healthier livestock that gain more weight on less feed. High-yielding hybrid wheat. Grasses which grow on arid lands, and which fix their own nitrogen or crops that contain bacteria that manufacture insecticides. More cheese from milk, and cheese flavors that attract new customers. These are only a few of the possible gains from biotechnology.

Biotechnology, as with other research supported by the Experiment Station, will have far-reaching effects. Farmers certainly benefit. Ultimately, the research is an investment in the future of agriculture in the state, one which could have a dramatic impact on the state's economic growth. And Matthews notes that biotechnology helps maintain excellence in instruction and research; in some respects it is an investment in future generations.

Experimental Sheep Vaccine Developed

USU veterinary scientist Mark C. Healey has already applied biotechnology techniques to develop an experimental vaccine against ram epididymitis, a reproductive disease that can ruin young purebred breeding rams worth $2,000-$5,000 each and increase infertility in commercial flocks. The vaccine was field tested this summer in the flock of B. B. Burroughs, Adrian, Oregon.

Three years ago, the Department of Animal, Dairy, and Veterinary Sciences expanded their laboratory research concerning ram epididymitis, prompted in part by results of field research by USU Extension veterinarian Clell V. Bagley which indicated that the disease was far more prevalent than many had thought and was caused by several types of bacteria, not just the bacterium *Brucella ovis*.

The vaccine avoids the negative side-effects often associated with traditional bacterins.

Healey produced monoclonal antibodies against the disease-causing bacteria by "fusing" antibody-producing cells with cancer cells. (Monoclonal antibodies are targeted against specific antigens.) The resulting antibody-producing cells (hybridoma cells) are grown in test tubes, and are essentially immortal.

He used these monoclonal antibodies to identify the bacterial strains which caused epididymitis. "We now think epididymitis is two distinctly different diseases having the same clinical signs," Healey says. One form, which is caused by *Brucella ovis*, is found almost exclusively in range sheep, while six or seven types of gram-negative pleomorphic rods were found in young purebred rams. The two most common gram-negative bacteria were *Actinobacillus seminis* and *Histophilus ovis*.

"As it turns out, *Brucella ovis* is a primary pathogen but, for some reason, the gram-negative bacteria, which normally are found in most sheep, can also cause the disease. These other bacteria may become involved when testicles are bruised, or due to nutritional or hormonal changes, or other factors. Viruses may also be involved," Healey explains.

Commercial vaccines for *Brucella ovis* are of no value in combatting the type of epididymitis that primarily afflicts young virgin lambs in purebred flocks.

Healey developed a vaccine against *Actinobacillus* sp. by selectively extracting surface antigens from bacterial cells. Such vaccines aren't as precise as single-antigen (subunit) vaccines, but are far less expensive to produce. If field tests indicate that the vaccine is effective, it should eventually be possible to produce a commercial vaccine for about $1.25 per dose. "The method seems to be economically feasible, and that's important since the market for sheep vaccines probably doesn't warrant the expense of developing single-antigen vaccines."

The vaccine should avoid the negative side-effects often associated with traditional bacterins, which are based on whole bacterial cells that are either weakened or killed, and then injected to trigger the production of antibodies.

The ram epididymitis research is partially funded by the Utah Department of Agriculture, and involves researchers with the Caldwell Veterinary Teaching Center, Caldwell, Idaho.

Healey and biologist Nabil N. Youssef are also using monoclonal antibodies to characterize antigens associated with avian coccidiosis, findings which might eventually lead to a vaccine against that disease. (See related article in this issue).

Molecular Sleuthing to Design New Vaccines

"Manufactured" synthetic vaccines which trigger the production of specific antibodies promise dramatic improvements in human and livestock health.

Joseph Li, USU molecular biologist, is attempting to produce such a synthetic, subunit vaccine against bluetongue viruses. According to U.S.D.A. estimates, losses attributable to bluetonge viruses, which primarily afflict sheep and goats, total about $40-$50 million annually in the U.S. Li thinks his molecular sleuthing could result in an experimental vaccine in about 5 years.

The genetic material of the bluetongue viruses is segmented double-stranded RNA instead of DNA, a factor that makes research more difficult in many respects. But the small differences among various serotypes of the virus should enable Li to track down the molecular origin of specific viral proteins, particularly those which trigger antibody production There are 21 to 22 serotypes of bluetongue viruses, each of which has 10 genes.

Li and his research staff have begun the painstaking task of isolating individual genes from five serotypes. Li plans to determine exactly how each gene and its encoded gene product contribute to the replication and production of the infectious bluetongue virus.

Once he's learned that, he can start to fabricate and design an extremely precise—and effective—vaccine against the virus.

"One potential problem with most inactivated vaccines is that they aren't always 100 percent inactivated, and there's the risk of actually infecting an animal. The chemicals used to inactivate a virus may also be harmful if injected into an animal," Li says.

Li plans to apply recombinant DNA techniques (with his own modifications) to insert each bluetongue virus gene into the plasmids of laboratory-reared bacterium to produce virus-specific proteins. To increase production, he'll increase the number of plasmids per bacterium from 1 or 2 to 50 or more.

> It may be possible to fabricate and design extremely precise and effective vaccines.

"We now know a great deal about two of the larger genes—the L2 and L3 genes—that produce very specific proteins which solicit neutralizing antibody production in an animal," Li explains. Careful comparisons of the differences in the gene sequences among the five serotypes will help him decipher and piece together the amino acid sequences of each gene product. With the aid of six computer programs, he will then try to predict which domain—area of the gene product—causes the production of antibody. Eventually, he'll know enough to make an effective subunit synthetic peptide vaccine.

Similar techniques have been used to develop experimental synthetic peptide vaccines against foot-and-mouth disease and hepatitis B.

Li also plans to produce monoclonal antibodies against each viral protein, especially the protein that triggers neutralization antibody production. These monospecific antibodies will help identify animals infected with the bluetongue virus. Passive immunity when these monoclonal antibodies are injected might also help infected animals combat the bluetongue virus infection. Li and his research associates also hope to develop a bluetongue anti-idiotype vaccine, one which utilizes antibodies to stimulate the body's defenses.

Designer Genes for Different Microorganisms

Molecular biologist Dennis Welker is just setting up his lab to start developing the genetic engineering techniques to manufacture products such as hormones and other proteins.

The techniques may not be unusual, but the microorganism he will be using is different. His research involves *Dictyostelium discoideum,* a single-celled organism which lives in the soil. Since *D. discoideum* is more closely related to mammals and other higher animals than bacteria, it should be more feasible to engineer it to "manufacture" materials needed to produce livestock vaccines and other animal health care products.

"Essentially, I'll be trying to do what has been done with the bacterium *E. coli,* but with a system more in common with animals. With luck we will get a better product than can be made with bacteria," Welker says.

Welker will first characterize the plasmids, small circular molecules of DNA, in the microorganism and will later produce the vectors needed to transfer foreign genes into the microorganism from these plasmids.

He has already verified the existence of the plasmids, and now needs to characterize them and locate restriction enzyme sites, the locations where genes can be inserted. That phase may take several years, although the pace of progress depends in large part on funding and personnel.

"A realistic short-term goal is to determine the location of these sites and where *D. discoideum* genes are located in relation to them. With this knowledge, we might be able to insert and express a foreign gene," Welker explains.

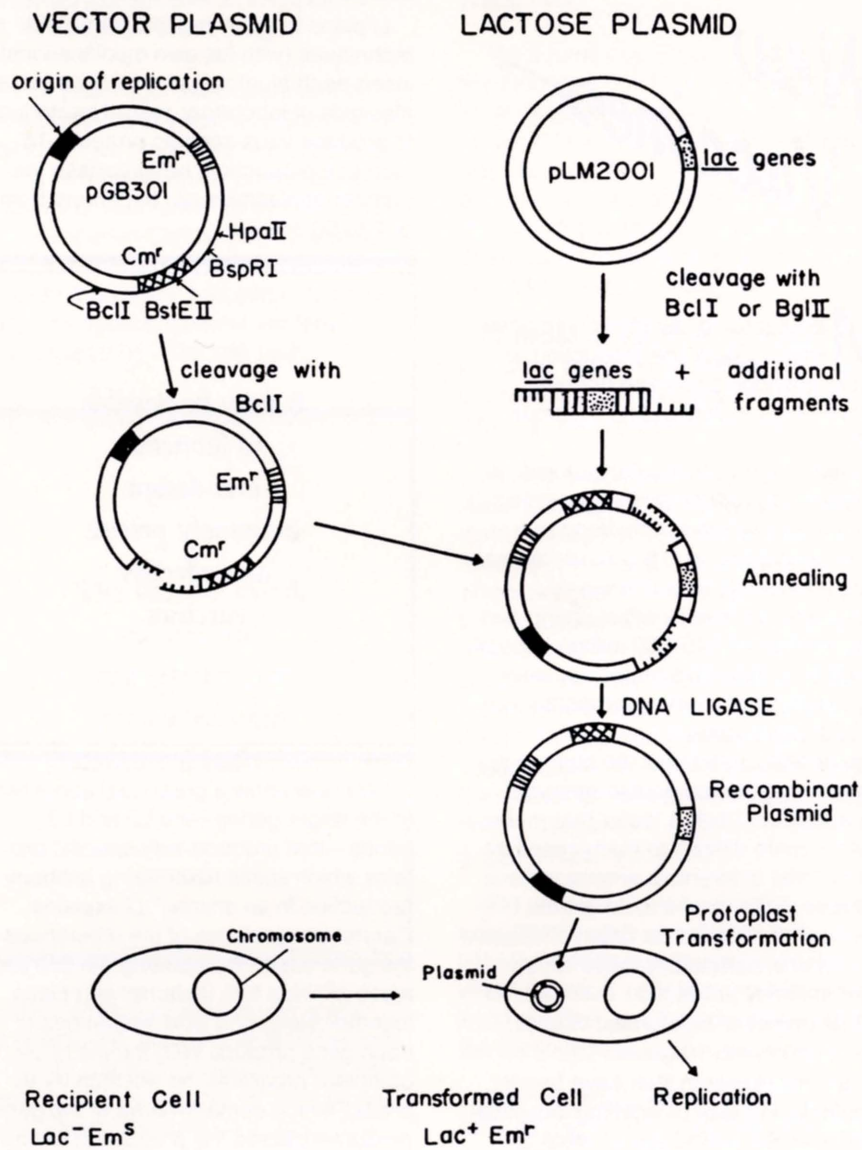
D. discoideum could eventually be used to manufacture products to combat viruses, and protozoan and fungal diseases.

Improved Microorganisms for Better Dairy Products

Food production and preservation often involve microorganisms—some good, some bad. Food-processing biotechnology promises to help researchers improve the beneficial organisms and decrease losses by the harmful ones.

Dairy microbiologist Jeffery Kondo is developing genetic engineering techniques to improve dairy starter cultures. Potential savings to the dairy industry

MOLECULAR CLONING OF LACTOSE METABOLISM IN *S. lactis*



could total millions of dollars annually.

First, however, Kondo must develop the appropriate gene cloning and genetic transfer systems for the group *N streptococci,* the starter bacteria strains often used to produce cheese and other fermented milk products. These bacteria produce lactic acid when they grow, essential in the production of fermented milk products.

The milk-fermenting ability of group *N streptococci* often varies, however. Many strains sometimes produce off-flavors, and most are susceptible to attack by bacterial viruses which can destroy the starter bacteria. As a result, there are relatively few strains suitable for use in dairy fermentation.

Kondo says genetically engineered strains might be able to increase the shelf-life of perishable fermented milk products by inhibiting spoilage bacteria. Strains might also be developed that resist bacterial viruses, and decrease cheesemaking and ripening times while enhancing yields and flavor.

The group *N streptococci* contain from 2 to 13 plasmids. Plasmids, circular DNA molecules which exist independently of the main genetic machinery of the cell, the chromosomal DNA, are found in most species of bacteria. Under normal circumstances, a particular plasmid is dispensible, but some may contain genes which are essential or advantageous to cells in certain environments. Many important milk-fermenting properties of starter bacteria are controlled by plasmids.

Plasmids are usually unstable and, if lost, the traits associated with them are also lost. This loss of plasmid DNA is referred to as plasmid curing, and is responsible for the failures of many starter cultures.

Kondo has developed methods to perform recombinant DNA techniques in group *N streptococci,* and has been able to clone the genes responsible for lactose utilization, an important property which enables the bacteria to grow in milk. By using gene-cloning techniques, Kondo will better understand the group *N streptococci,* which will in turn help him develop improved bacterial strains for the production of fermented dairy products.

Unraveling the Secrets of Toxins and Photosynthesis

"We have a limited ability to manipulate the genes of plants because we simply don't know that much about the molecular biology of plants," says molecular biologist Jon Takemoto who is deciphering the molecular basis of some plant diseases and photosynthesis.

One of Takemoto's research projects concerns the lethal toxin, syringomycin, produced by *Pseudomonas syringae* bacteria that are found on the foliage of nearly all plants. The toxin causes extensive losses in crops such as corn and beans.

"Something, perhaps physical damage

to the plant, sends a chemical signal that lets bacteria colonize the plant and start producing toxin." Takemoto says the toxin apparently affects the outer membrane of plants cells through which nutrients and other materials must pass.

Even though the toxin is relatively easy to extract and is fairly stable, the chemical structure of syringomycin is not yet completely known. "Very low levels of the toxin drastically alter the function of the membrane. And it appears that the toxin alters the membrane by affecting an ATPase enzyme, which is essential in a variety of cell functions."

If the toxin does affect the ATPase, it may be a useful molecular probe to isolate and characterize the enzyme.

Takemoto is trying to learn the structure of the toxin, determine exactly what membrane(s) the toxin affects, and identify the molecular interactions involved. His research isn't directly motivated by the search for "practical" applications, but his findings might eventually be used to genetically engineer plants better able to resist toxins.

"Learning the molecular basis of plant-toxin interactions can help develop a strategy for genetically engineering plants, either by preventing unfavorable interactions or by promoting favorable interactions," Takemoto says.

Takemoto is also studying the molecular mechanisms by which photosynthetic organisms harvest light, findings which could also help genetically engineer plants, this time to become more-efficient light harvesters.

"We don't yet know enough to go in at will and engineer a plant to improve photosynthesis, even though there have been tremendous advances in our understanding during the last 5 years," Takemoto adds.

There are several potential strategies by which plants might be genetically engineered to improve their ability to harvest light. For example, light-harvesters could be oriented in the plant leaf for better access to sunlight, the number of light harvesters might be increased, or the structural relationship between the molecules of harvesters, chlorophyll, and protein might be altered. It might even be possible to modify light collectors to capture some of the more-abundant wavelengths.

Takemoto is now isolating the chlorophyll-protein complexes that harvest light and is learning how they are arranged in the cell. The molecules which harvest light are organized in such a way that they pass the light energy to neighboring molecules. This energy is converted into usable chemical energy when it reaches the reaction centers.

Healthier plants

Through Engineered Bacteria

It may be possible to improve crop yields by engineering certain microorganisms associated with plants.

Microbiologist Anne Anderson says biotechnology may eventually help plants capitalize on beneficial microbes and resist those that are pathogenic.

Anderson's research group is characterizing the compounds involved when bacteria or fungi initially colonize plants. "We think plants recognize certain surface structures of microbes, and may initiate defense mechanisms, just as the human body defends itself against microbes." Some of a plant's defense mechanisms, such as the epidermal layer which is similar to mammalian skin, are passive. A plant can also muster active defenses.

Studies involving two fungi, one a pathogen which causes anthracnose and the other a beneficial microbe which produces ectomycorrhizae on certain conifers, indicate that a plant's basic metabolism changes dramatically when it contacts surface components produced by the fungi. For example, plant cells produce more phenolics (aromatic compounds), which may form defensive barriers or act as antibiotics. These changes may be crucial in hindering the growth of invading organisms. Similar phenolic responses are initiated when a resistant plant is challenged by a microbe.

"The research on resistant mechanisms, initiated on the physiological level, has now progressed to chemical characterization. The next logical step would be to isolate the DNA in both the fungi and the plant that are responsible for these resistant responses," Anderson says.

Pedobiology, the biology of plant roots, is a relatively neglected research area that may hold tremendous potential for biotechnology. Several research groups have found that certain non-pathogenic bacteria can increase plant yields by as much as 20 percent.

Anderson has found that a surface compound on plant roots "recognizes" the surface of the pseudomonads, short, rod-shaped bacteria, and may help these bacteria adhere to the root. Bacteria which stick to the surface of the root are then better able to defend their position against other soil organisms, including pathogens. Other researchers have found that pseudomonads promote plant growth because they restrict the availability of iron in the root zone, thus preventing pathogen growth in the area. Anderson thinks colonization by pseudomonads may also affect root metabolism in such a manner as to make plants more resistant to attack by pathogens.

Anderson's group discovered peroxidase on the surface of roots. This enzyme produces hydrogen peroxide that may act as an antibiotic against pathogenic bacteria. Colonization of plant roots by the beneficial pseudomonads apparently stimulates production of the enzyme.

"If we learn which genes control aggressive colonization by the pseudomonads, this ability to colonize plants might be transferred to other microorganism. Perhaps we could even engineer 'superpathogens' capable of attacking specific weeds."

Techniques to Tame Harmful Bacteria and Fungi

Plant pathologist Neal Van Alfen is studying several potential biological controls of plant diseases, including methods to make fungi less virulent, and bacteria modified to live in plants and produce beneficial substances such as insecticides.

Clues to one potent biological control may be found in the virus that reduces the virulence of the fungus causing chestnut blight, the most devastating plant disease yet known. Naturally occurring hypovirulent (low virulence) strains of this fungus have essentially controlled chestnut blight in several European countries.

The hypovirulent strains have not yet controlled chestnut blight in the U.S., apparently because of the larger and more-diverse populations of the fungus in this country. Even though the artificial spread of hypovirulent strains has not been successful in the eastern U.S., hypovirulent strains appear to be spreading naturally in Michigan and have been found in other U.S. locations.

Van Alfen says the genetic control of virulence in most fungi appears to involve nuclear genes, although virulence in *Rhizoctonia solani*, a soil-borne fungus which he is also studying, appears to be controlled by cytoplasmically transmitted agents. *R. solani* attacks potatoes and a variety of other plants. Knowledge of how virulence is controlled cytoplasmically may lead to methods to control virulence by transmission of the cytoplasmic regulatory elements.

Fortunately, fungi appear to easily transmit these cytoplasmic elements, double-stranded, segmented bits of RNA which, in some ways, resemble both viruses and plasmids. Should the elements which control virulence be identified and transferred, the trait apparently will readily spread to virulant strains. Since there's no selection pressure against the trait, hypovirulent fungi would persist and continually transfer the trait.

Van Alfen is now determining how these agents replicate and interefere with the expression of virulence, and will see if these agents have the same effects in other strains of fungi. It might then be possible to engineer low-virulent strains to control a variety of diseases.

Van Alfen's research concerning bacterial wilt in alfalfa may provide other potent new weapons against plant diseases. Infected alfalfa plants are particularly susceptible to plugging of vessels by small amounts of extracellular polysaccharides (EPS), macromolecules produced by the pathogen. Some forms of EPS may be associated with virulence while other forms may allow bacteria to harmlessly grow and reproduce within plants.

Engineering bacteria that produce certain types of EPS may make it possible to create bacteria that harmlessly reside within a plant and simultaneously protect the plant from other pests. These "resident" bacteria could be engineered to produce a variety of beneficial chemicals, such as insecticides.

"I think we have already modified bacteria so they are no longer virulent," Van Alfen says. "It is much easier to engineer bacteria than plants. Rather than genetically transforming plants, we may be able to insert organisms in plants that have been modified to perform a wide variety of functions."

These modified bacteria are currently obtained via induced mutations, but recombinant DNA and other biotechnological techniques will eventually be applied.

Understanding the Capricious Great Salt Lake

G. E. BINGHAM, E. A. RICHARDSON, and G. L. ASHCROFT

Levels of the Great Salt Lake have been of concern since Mormon pioneers settled the area in the mid-1800s. Residents were first concerned with the rising level of the lake, but after peaking in 1877, levels declined for nearly 100 years and many observers concluded that the lake might eventually disappear. Many of the studies conducted only 20 years ago, when the lake was at its all-time low, were concerned with methods of preserving the lake.

Since that time, the lake level has increased nearly continuously; the nearly 4-foot per year rise in the lake level in 1983 and 1984 returned the lake to near-record levels. Because the lake is in a shallow basin, even small changes in lake level result in large changes in its shoreline, and the relatively quick rise of the lake caused damage to surrounding property estimated at nearly $200 million.

Weather data and levels of the lake have been recorded since the region was settled. Tree ring widths often show a high degree of correlation with weather, especially precipitation. Data for a few sites around the Great Salt Lake are available and might help determine if long-term weather patterns exist that would allow us to extend our knowledge of lake behavior beyond the 100 to 130 years for which reliable recorded data are available.

Historic Climate Data

Early weather data are lacking or inconsistent. Some information, however, is available from journals and other unofficial sources. Utah's first official weather station was opened by the U.S. Army Signal Corps in February 1870. In 1874, the official Utah Station was moved to Salt Lake City. Thus, maximum and minimum temperature records for Corinne are not available from 1874 to 1895 but precipitation records have been kept from 1870 to the present. Corinne was re-opened as an official climate station in January of 1897, and all observations taken in Corinne are from sites within a few blocks of the original location. As a result, data from this station are among the best for comparing lake level with local weather data.

After the Salt Lake City Station was opened in 1874, observations continued until the City Office station was closed in 1954. The Salt Lake City Office station was moved several times during this period and records from these different locations are often not comparable. In 1928, a separate weather station was opened at the Salt Lake City Airport. The Airport station later became the official station for the area (see Figgens, 1984 for details).

In the 1880s, an increased number of weather stations were sponsored, first by the Smithsonian Institute and later by the Civilian Weather Bureau under the Department of Agriculture (established in 1890). Since the early 1900s, fairly consistent data are available for the populated regions around the Great Salt Lake. Most of the stations in the current National Weather Service NOAA cooperative data collection network collect daily precipitation and temperature data. In recent years, some of the stations have been closed due to reduced funding and the difficulties in arranging for continuous weather observation.

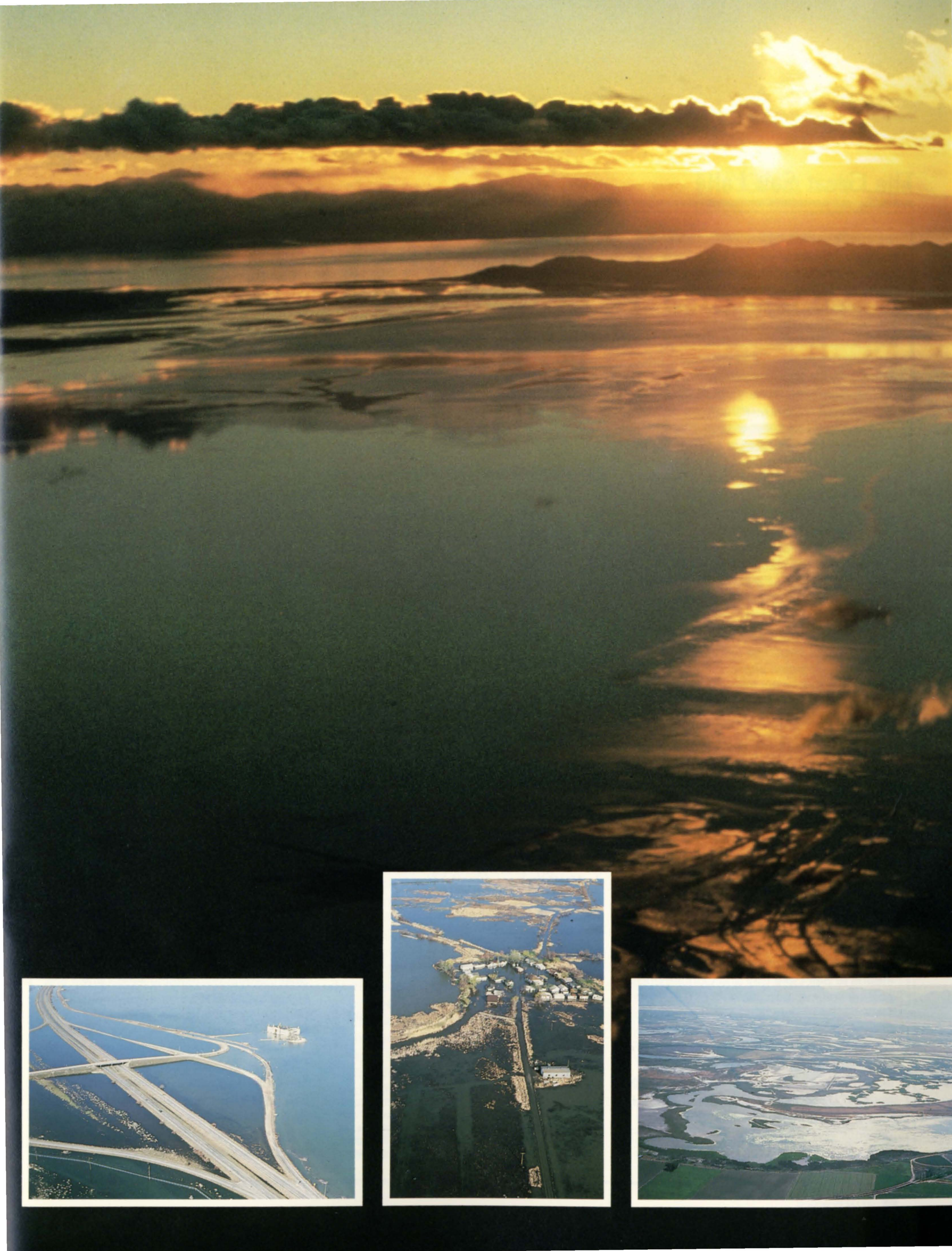
Historic Precipitation and Lake Levels

Before retiring as State Climatologist, E. A. Richardson made several studies comparing average precipitation and Great Salt Lake levels. Continuous data are not available from most of the prominent stations; thus, data for an accurate comparison were difficult to obtain. For example, weather data from the Salt Lake City Office is available only until 1954 and, as noted previously, the station was moved six times. Data from the Airport, which differs from the City Office data, must be used after 1954. To extend the record, a statistical procedure was used to estimate the City Office Data from Airport data.

The recorded hydrograph of lake level also has several gaps. Significant periods during the early part of the record are based on interviews with early pioneers who had noted the height of the lake on their horses when they drove cattle to Antelope Island (Arnow, 1985). Water was withdrawn from the river systems that feed the lake for irrigation and to fill the reservoirs. Stauffer (1985) estimated the amounts of water diverted each year, and used these estimates to develop two artificial hydrographs. One of the resulting hydrographs simulates lake levels as though the dams and irrigation systems had always existed (modified), and one estimates the lake level as though no water had been withdrawn for irrigation and other uses (pristine). Since the lake

The Great Salt Lake at sunset facing the southern tip of Antelope Island. Insets, from left to right, show the ravages of flooding: Saltaire; Waterfowl Habitat north of Salt Lake International Airport; and the Chesapeake Duck Club and the Bear River north of Brigham City.

—Photos by John S. Flannery



lies in a flat-sided basin, the relationship between volume and level is not linear. Lake volume is the variable best compared to climatic factors and most of the comparisons in this study use pristine lake volume as a dependent variable. Richardson's early studies of the relationship between precipitation and lake state used actual lake stage. During these periods, however, the amount of water diverted was relatively uniform.

After many trial comparisons, Richardson concluded that there is a rather stable relationship between average precipitation over 10-13 year periods and lake levels. Such a relationship was based on precipitation data from both Salt Lake City and Corinne stations. Adding data from Heber did not significantly improve the predictive power of the two-station regression, however, adding stations that represent larger portions of the Bear River drainage (Logan, Grace, Idaho, etc.) did improve the predictive power somewhat. The relationship never becomes extremely good; at best, precipitation alone accounted for only about 70% of the lake variation. At first, it was assumed that the increase in predictive power when data from Corinne were included was due to lake-effect precipitation at Salt Lake City when lake levels were high. The analysis of data from more weather stations and of tree rings in the region, however, indicated that shifting storm-track patterns also effect the relationship between precipitation and lake levels.

Over the whole period of the historic record, the relationship between precipitation near the Great Salt Lake and pristine lake volume was not as strong as we expected to find. The multiple regressions between 11-year running precipitation means at Salt Lake City and Corinne and pristine volume (a multiple R^2 of 0.66 from 1885 to 1984) were low because the model seriously underestimates the extremes in the lake level. Over certain 30-to 50-year periods, however, the predictive power of the model approached 90 percent. Using the model to predict the following year's level of the lake (using the previous year's lake volume as a dependent variable) increased the R^2 to 0.96.

The poor correlation between precipitation and lake stage is not surprising when one considers that the collection basin for the lake is significantly larger than the region represented by the few stations used in the model. The low predictive power of the simple regression model also reflects the poor correlation that exists between valley and mountain precipitation. The precipitation-based model also does not reflect variable evaporation rates and snow melt.

Tree Ring Index and Lake Volume

Some samples of tree ring width data for the region were examined to determine whether the historic lake and climate data were representative. The tree ring index data provided by the University of Arizona Tree Ring Laboratory consisted of normalized ring width data for 11 sites near the Great Salt Lake Basin, but none within the basin itself. Nine of the sites were in Nevada, one was in Idaho, and one in Utah. The Utah site was near the center of the Uinta Mountains (UMT) and the Idaho site was City of Rocks (COR). These two sites and one Nevada site, White Horse Summit (WHS), were then selected for detailed comparison with pristine lake volume. Contiguous data sets for the three tree ring sites and the lake were available for the period 1851 to 1971. To be consistent with the precipitation analysis, 11-year running means of the tree ring width records were used. Tree ring data sets began with 1841, so that an 11-year mean point was available for each year in which lake volume was available. COR and WHS data were available until 1982, but the UMT record terminated in 1971.

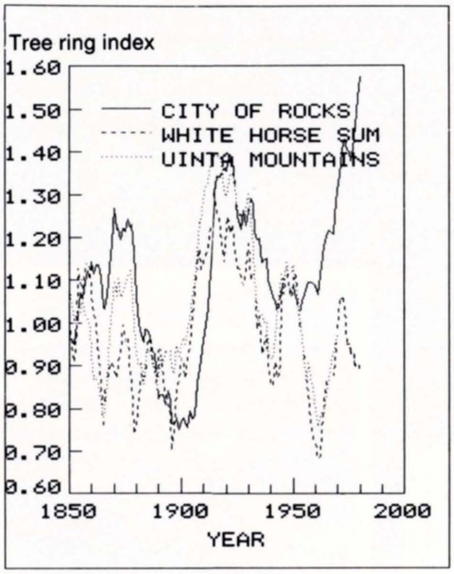


FIGURE 1. Tree growth (as measured by tree ring indexes in which "1" is average growth) at three locations near the Great Salt Lake Basin. Note the wide differences in tree growth during certain periods, an indication of wide climatic differences in different regions of the basin. Growth data are 11-year running means.

There was an even poorer relationship between averaged tree ring data and lake level ($R^2 = 0.36$) when the whole period, and all three tree ring sites were compared. However, there was a much better correlation between data from some sites and the lake during certain periods. For instance, the lake peak and decline between 1865 to 1905 was closely related to the 11-year averaged data from Corinne ($R^2 = 0.83$). Between 1895 and 1971, tree ring data from the two southern sites, WHS and UMT, showed a poorer but consistent correlation with lake level (adjusted $R^2 = 0.68$). This difference in the relationship between site and lake volume may indicate that there was a significant shift in the precipitation pattern in the Great Salt Lake Basin around the turn of the century; the severe drought in the northern part of the state at this time was probably associated with this shift. The peak lake level in 1876 seems to have resulted from heavy precipitation in the northern portion of the Great Salt Lake Basin, probably related to winter and spring frontal storms from precipitation patterns over the whole Basin, and may have been similar to current conditions. The 1952 peak is entirely missing from the COR data, an indication of more precipitation over the southern portion of the Great Salt Lake watershed, a result of frequent summer showers.

Richardson (1977) analyzed the combined tree ring data for the Colorado River

Basin (CRB) between 65 BC and 1970 to determine if tree rings could be used to indicate future climatic trends. He concluded that the Colorado River Basin was at the end of a severe drought and speculated that the precipitation in the Great Salt Lake Basin would increase considerably in the near future. Since over 10 years had lapsed since his original work, we decided to check his analysis using more recently acquired tree ring data from sites more representative of the Great Salt Lake Basin. "Normally" averaged tree ring index data were prepared for the three indicator sites between the period 1500 to 1980 (1970 for UMT). (Normal averages are essentially 30-year running means in which data are added or dropped at 10-year intervals).

Average data from the three Great Salt Lake Basin sites indicate that the climate since 1900 has been wetter than in the Colorado River Basin. When Richardson conducted his analysis, the precipitation from the three Great Salt Lake Basin sites was very close to the average during the period. The relationship between precipitation in the Great Salt Lake Basin and the Colorado River Basin varies. During the late 1600s and the mid 1800s, trees in the Colorado River Basin grew much better than those to the north and west. There is an obvious difference in phases between trees in the Great Salt Lake Basin and those in the Colorado River Basin, and even among different regions of the Great Salt Lake Basin.

Average precipitation data seem to shift every 30 to 50 years in the Great Salt Lake Basin, an indication that wet and dry patterns occur persistently over the region. These persistent wet and dry weather patterns seem to shift locations, and further study might make it possible to predict their movements. It appears that our current inability to predict these movements limit the ability to use tree ring data to predict lake levels.

The area covered by these shifting precipitation patterns is often smaller than the Great Salt Lake Basin. This means that a very wet period in one region can have as much effect on the lake level as more moderate precipitation levels over a larger area. A generally wet pattern, however, appears to always cause a significant change in the level of the lake. When an unusually wet pattern covers the entire watershed, lake level shows a dramatic increase. This occurred from 1980 to 1985. When the trees at the COR site were sampled in 1980, the tree-ring index at that site was at an all-time high. This wetter and cooler than normal pattern suddenly shifted sharply to the south in the 1980s, causing a record increase in lake levels.

Persistent wet and dry weather patterns seem to shift location every 30 to 50 years in the Great Salt Lake Basin. Further research might make it possible to predict their movements.

Conclusions

- There is a persistent relationship between 11-year running precipitation means (based on records from Salt Lake City and Corinne) and lake level or estimated pristine volume. The correlation increases during specific 30- to 50-year periods, and when data from sites that represent a larger portion of the basin are included. The ability to determine the relationship between precipitation and lake level is limited by other known, physical factors. Incorporating the previous year's lake level increases the ability to predict the next year's peak level of the lake.
- Average tree ring index data from sites on the perimeter of the Great Salt Lake Basin are an even poorer predictor of changes in the level of the lake than the local precipitation data. However, there are significant long-term correlations between specific sites and lake levels during certain periods. Data indicate that there are persistent long-term (50- to 75-year) wet and dry cycles that rotate around the Basin; they apparently influence precipitation in an area smaller than the total drainage. A wet or dry pattern covering the entire Basin rapidly changes the level of the lake.
- Richardson's early analysis of the climate in the Great Salt Lake Basin, which was based on tree data from the Colorado River Basin, underestimated precipitation levels at the time because increasing moisture levels in the northern portion of the Basin were not included. A wet weather pattern, then over southern Idaho, later moved south

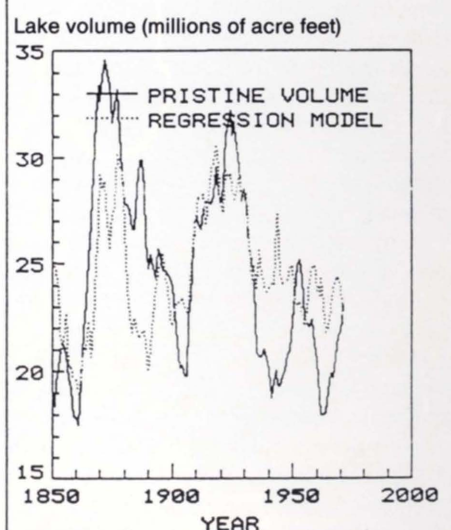
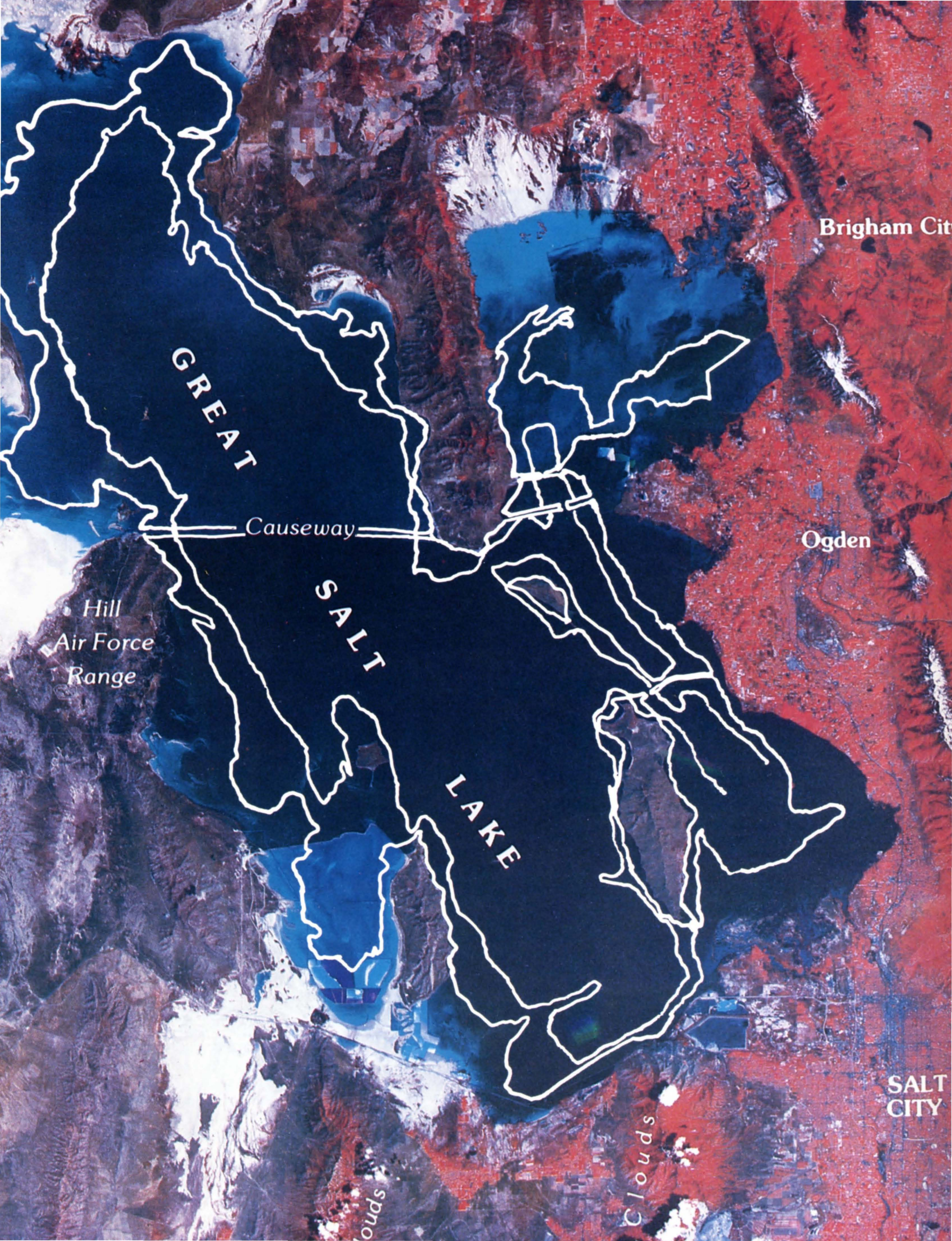


FIGURE 2. The relationship between the pristine lake volume (no water removed for irrigation or other purposes) and average tree growth at three sites around the Great Salt Lake. There is a little correlation during certain periods, resulting in a low R^2 of 0.36.


GREAT
SALT
LAKE
Causeway
Hill
Air Force
Range
Brigham Cit
Ogden
SALT
CITY
Clouds

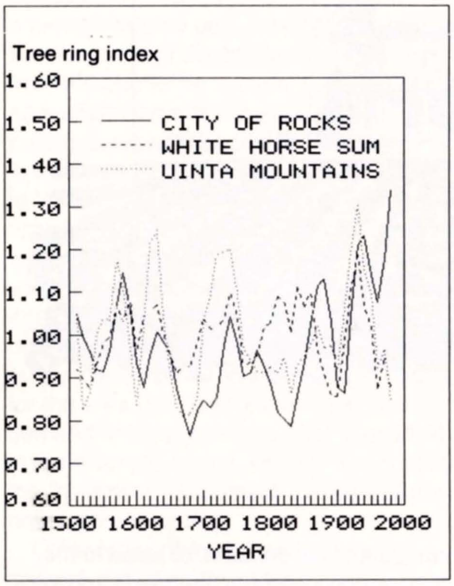


FIGURE 3. The relationship between "normal" averaged tree ring data from three sites from 1500 to 1980. Note the periodic peaks in tree growth, and the dramatic differences in growth between regions during some periods. Growth of trees at the City of Rocks, Idaho, differs markedly from tree growth at the other two sites.

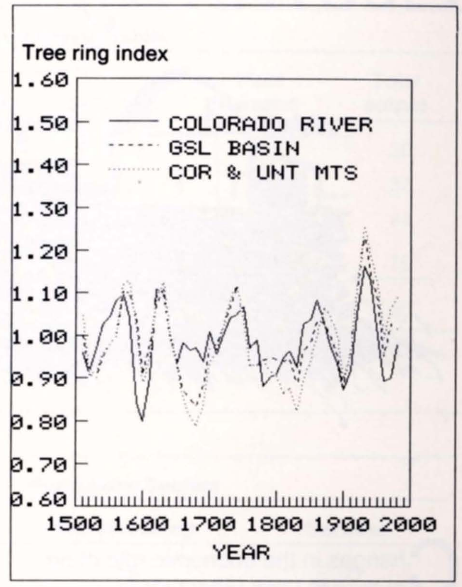


FIGURE 4. A comparison of average tree growth in the Colorado River Basin, three sites in the Great Salt Lake Basin, and two sites in the Great Salt Lake Basin. Note the significant differences in the phases of tree growth, and in the relative growth rates of trees in the two basins. Results indicate that climate differs not only between the two basins, but also within regions of the Great Salt Lake Basin, thus making it difficult to use tree ring data to predict lake levels.

over the Great Salt Lake Basin. Increased precipitation associated with the weather pattern caused lake levels to increase by record amounts.

- We anticipate a return to more normal precipitation levels during the next 2 years, a shift from the extremely wet conditions observed over the northern portions of the state during the last 5 years. However, this outlook should not be interpreted to mean that we have reached the end of the long-term trend toward more precipitation in the Basin; rather, we believe it is a moderation in rate of increase in precipitation observed during the last 20 years. This outlook was based on three factors; a trend analysis of regional precipitation and temperature patterns, the observed return to expected conditions in the Pacific, and the observed northward movement of the wetter than normal precipitation patterns in the southern part of the state.

- A better understanding of the climatic relationships of the Basin and the rest of the state would result from further study of the tree ring and regionalized weather data including general weather patterns. Additional tree ring data in the immediate Great Salt Lake drainage, such as along the Wasatch Front, would be particularly valuable.

A satellite photograph of the Great Salt Lake taken during the recent high water episode. Contour lines show the great change in the lake surface area which has occurred in the last few years. They show the lake at two previous levels, the inside (4200 ft. mean sea level) is near the historical average for the lake. The outside contour, 4205 ft. was the level of the lake in May 1983. (The photograph was taken from a satellite image map 40111-E&-SI-125 available from the U.S.G.S., Denver, Colorado, 80225).

LITERATURE CITED

Arnow, T. Water-level Changes in Great Salt Lake, 1943-1984. In P. A. Kay and H. F. Diaz, ed., Problems of an prospects for predicting Great Salt Lake levels. Papers from a conference held in Salt Lake City, March 26-28, 1985. Center for Public Affairs and Administration, University of Utah, Salt Lake City, Utah.

Barfuss, B. W. E., E. A. Richardson and G. L. Ashcroft. Utah Weather Reporting: Its Origin and Destiny. *Utah Science*, Utah Agricultural Experiment Station, Utah State University, Logan, Utah (1967) 28(1):22-25.

Figgins, W. E. Climate of Salt Lake City, Utah, NOAA Technical Memorandum NWS WR-152, U.S. Dept.of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, National Weather Service Forecast Office, Salt Lake City, Utah. October 1984, p.88.

Karl, T. R and P. J. Young. A historical perspective of recent heavy precipitation in the vicinity of the Great Salt Lake. In P. A. Kay and H. F. Diaz, ed., Problems of an prospects for predicting Great Salt Lake levels. Papers from a conference held in Salt Lake City, March 26-28, 1985. Center for Public Affairs and Administration, University of Utah, Salt Lake City, Utah.

Richardson, E. A., Cycles, circles and scythes—(Weather through the ages). *Utah Science*, Utah Agricultural Experiment Station, Utah State University, Logan, Utah. (1977)

Stauffer, N. E. Jr., 1985, Great Salt Lake water balance model. In P. A. Kay and H. F. Diaz, ed., Problems of an prospects for predicting Great Salt Lake levels. Papers from a conference held in Salt Lake City, March 26-28, 1985. Center for Public Affairs and Administration, University of Utah, Salt Lake City, Utah.

Stockton, C. W. and D. W. Meko. Tree ring inferences on levels of the Great Salt Lake, 1700 to present. In P. A. Kay and H. F. Diaz, ed., Problems of an prospects for predicting Great Salt Lake levels. Papers from a conference held in Salt Lake City, March 26-28, 1985. Center for Public Affairs and Administration, University of Utah, Salt Lake City, Utah.

ABOUT THE AUTHORS

Gail Bingham received his BS in Biometeorology from Utah State University, MS in thermal mechanics and PhD in Micrometeorology at Cornell University. He became the Utah State Climatologist in 1983.

Gaylen Ashcroft obtained a BS and MS degree in Soils from Utah State University. He received his PhD at Oregon State University with training in soils and meteorology, and has done research on the interaction of atmosphere and soil water on plant growth and development.

E. Arlo Richardson is the emeritus Utah State Department of Agriculture Climatologist, Department of Soil Science and Biometeorology.

Determining Agriculture's Contribution To Utah's Economy

Changes in the economic role of agriculture in Utah reflect other changes in the state. Employment in production agriculture has declined although this decline has been partially offset by increased employment in industry related to agriculture. Agricultural businesses are larger and more integrated. Agriculture, like the state's industrial sector, is adjusting to current economic pressures. Many Utahns have questions regarding agriculture's role in state, of agriculture's relationship with other economic sectors, and the effects of changes in other sectors on agriculture. Answers to these and related questions provide some indication as to the future economic role of agriculture in the state.

All economic sectors in a developed economy are interrelated. Each economic sector produces and consumes goods and services produced by itself and other sectors. These relationships and interactions can be measured by several sophisticated economic modeling techniques. One of the most common of these techniques is input-ouput anlaysis which identifies products and services produced and utilized by each economic sector. An input-output model also shows the interrelationships among industries and represents a "quantitative" flow chart of economic activity.

Multipliers derived from input-output models are used to assess the impact of economic development. Multipliers reflect the fact that local businesses, households, and government agencies purchase goods and services from one another. These interactions increase local and regional sales, thus multiplying the effects of a sale or purchase. The multipliers summarize the total direct and indirect effects of this "re-spending."

If, for example, 50 percent of the money for goods and services (including taxes) is spent locally and 50 percent is spent outside of the local area, one dollar spent in the area will initially stimulate a dollar's worth of local economic activity. As local merchants and consumers re-spend that dollar, they will generate an additional 50 cents worth of local economic activity. And re-spending of that 50 cents will generate an additional 25 cents worth of local economic activity, etc.

Input-output models estimate the total economic effect of an initial change in business activity, information which helps identify the economic contribution of specific sectors and predict the impacts of various economic adjustments.

Table 1 depicts a highly simplified transactions table. A transactions table shows the economic value of goods and services among sectors in an economy for a certain accounting period. The sales and purchases are placed in rows and columns. Sales of a particular sector are in rows; the final column in each row represents final demand, or sales to the ultimate consumers of the goods and services. The columns of the table show current purchases by economic sectors. Thus, the first column shows that agriculture purchased $10 worth of goods and services from itself, $4 worth from the manufacturing sector, $6 from mining, and $16 from primary inputs for a total outlay of $36.

The figures in the row show that agriculture sells $10 worth of goods and services to itself, $6 to manufacturing, $2 to services, and $18 to final demand, the final consumers of the goods and services. The total output is $36. Note that an entry represents purchases (in the column) and sales (in the row).

Table 2 shows the direct coefficients based on the transactions shown in Table 1. These direct coefficients are determined by dividing the column entries of the economic sectors by the total outlay of the respective column. In this example, the manufacturing sector requires 16.2 cents worth of input from agriculture, 10.8 cents from manufacturing industries, and 5.4 cents from services in order to produce output worth one dollar. (These are the minimim requirements from each sector to produce one dollar's worth of output.)

The total requirements table, also known as the Leontief inverse matrix, is shown in Table 3. This shows the economic impact of purchases by ultimate consumers (final demand), such as when a foreign country purchases goods and services so that the product is removed from the economic system. For example, if agricultural exports increase by $1, agriculture sales to final demand would equal 1, and manufacturing and services sales to final demand would be zero. After multiplying through, agriculture's total output will be $1.45 (1 times the coefficient associated with agriculture); manufacturing's output equals $0.20; and services output equals $0.26. The sum of the three outputs equals the total increase in output for the area from a $1 increase in final demand of the agriculture sector, or $1.91 in the example above. This then becomes the "multiplier" discussed so frequently in development circles.

Other types of multipliers can be derived, including those for income, employment, value added, and business. Input-output make it possible to identify separate business sectors in a regional economy, and to estimate a sector's purchases and sales from other sectors. If the model has been carefully developed, results of an input-output analysis are more accurate than those derived from many other impact models.

TABLE 1. Example transactions table.

	Purchasing Sectors				
Sectors	**Agriculture**	**Manufacturing**	**Services**	**Final demand**	**Total output**
Agriculture	10	6	2	18	36
Manufacturing	4	4	3	26	37
Services	6	2	1	35	44
Primary inputs	16	25	38	0	79
Total outlay	36	37	44	79	196

TABLE 2. Direct requirements table.

	Purchasing Sectors		
Processing Sectors	**Agriculture**	**Manufacturing**	**Services**
Agriculture	.8	.16	.05
Manufacturing	.11	.11	.07
Services	.17	.05	.02
Primary	.44	.68	.86

TABLE 3. Total requirements table.

	Purchasing sectors		
Processing Sectors	**Agriculture**	**Manufacturing**	**Services**
Agriculture	1.45	.27	.09
Manufacturing	.20	1.16	.09
Services	.26	.11	1.04
Total or Output Multiplier	1.91	1.54	1.22

The IMPLAN Input-Output Model

Multipliers from an input-output model are usually based on data from direct surveys, which are expensive to conduct. Other techniques have been developed that use secondary data to construct input-ouput models, one of which is the IMPLAN (U.S. Forest Service) system used in this study.

The IMPLAN model lets planners develop interindustry models to evaluate alternative management programs and problems using data already collected by various federal agencies, including census information collected by the U.S. Department of Commerce and the U.S. Department of Agriculture. Localized crop budgets were also used to identify area relationships not identified through IMPLAN. A detailed discussion of the approach used in IMPLAN can be found in the IMPLAN Users Guide (Forest Service, U.S. Department of Agriculture, 1983).

Study Areas

In this study, separate input-output models were developed for various regions within Utah and for the entire state. The regional divisions are shown in Tables 3 and 4.

Sector Definitions

Except for separate categories for grain and alfalfa, we retained the agricultural sectors used in the original IMPLAN model, but combined many of the other sectors. There are 486 sectors in the IMPLAN model, each corresponding to one or more Standard Industrial Classification (SIC) codes. The IMPLAN model used in our analylsis included 113 sectors because many of the non-agricultural sectors were combined.

Results

After making the adjustments described above, output and employment multipliers were developed for each of the defined regions and the for the entire state (Tables 5 and 6).

Interpreting Multipliers

Multipliers are often misused or misunderstood. Among the more common errors are interchanging different multipliers and "double-counting" multipliers. Different multipliers, e.g. output, income, employment, value-added, are not interchangeable since each measures totally different types of economic activity. Furthermore, unless indicated otherwise, the direct effect (initial change) is included in all multiplier calculations. For example, if the multiplier is 2.50, then the total change that can result from a $1 expenditure is $2.50—not $2.50 in addition to the original $1.00 purchase or sale.

An input-output model lets policy makers assess the economic impacts of programs before programs are implemented. For example, they can estimate the regional impact statewide sales of a commodity, assess the impact of regional or local sales on the state's economy (given certain assumptions), and assess impacts associated with a project or development. Multipliers are most often used as to estimate changes in sales or employment.

For example, Table 6 shows that a $1,000 increase in hay sales in the Southwest Planning District would result in total regional sales of $1,320. (This is calculated by taking the multiplier for hay sales, 1.32 × $1,000.) Note that this includes the hay sales as well as the increased value of input and household purchases. Similar calculations could be made for each region and each agricultural sector for employment as well as output. As output or sales increase, it is reasonable to assume that employment changes according.

TABLE 4. County groupings by river basin.

River Basin	Counties
Bear River	Box Elder, Cache, and Rich
Wasatch Front	Davis, Morgan, Salt Lake, Summit, Tooele, Utah, Wasatch, and Weber
Central	Garfield, Piute, Sanpete, and Sevier, and Wayne
Lower Sevier	Juab and Millard
Southwestern	Beaver, Iron, Kane, and Washington
Southeastern	Carbon, Emery, Grand, and San Juan
Uintah Basin	Daggett, Duschesne, and Uintah

TABLE 5. County groupings by planning districts.

Planning Districts	Counties
Bear River	Box Elder, Cache, and Rich
Wasatch Front	Davis, Morgan, Salt Lake, Tooele, and Weber
Mountainlands	Summit, Utah, and Wasatch
Central	Juab, Millard, Piute, Sanpete, Sevier, and Wayne
Southwestern	Beaver, Garfield, Iron, Kane, and Washington
Southeastern	Carbon, Emery, Grand, and San Juan
Uintah	Daggett, Duschesne, and Uintah

Agriculture makes a significant contribution to the State's economy. Muliplers for agricultural sectors are at least as large as those for the industrial sectors.

The results of this study suggest that agriculture makes a significant contribution to the state's economy. The multipliers obtained for the agricultural sectors are at least as large as those for the industrial sectors.

ABOUT THE AUTHORS

Donald L. Snyder is an associate professor in the Economics Department. He received his PhD from Utah State University. His primary areas of work are in marketing and prices, and production economics.

John E. Keith is an associate professor of Economics. He received his BS and MS degrees in Range science from USU, and a PhD in Economics from USU. His current project is the impact and potentials for agricultural markets in Utah.

J. C. Andersen is a professor in the Department of Economics at USU specializing in agriculture policy and production problems. He received an MS from Utah State University and a PhD from Iowa State.

Charles Diamond is an assistant professor in the Department of Economics. He received his PhD from Texas A&M in Econometrics and Regional Economics,

Table 6. Type III total output multipliers.

	Agricultural sector											
Area or region	**Dairy**	**Poultry**	**Meat animals**	**Grains**	**Alfalfa**	**Fruits/ Nuts**	**Vege- tables**	**Oil- bearing crops**	**Greenhouse and Nursery**	**Forestry Fishery**	**New con- struction**	**Construction maintenance**
State of Utah	2.16	2.89	2.65	2.00	2.04	2.33	2.0	1.67	1.76	1.77	2.26	1.98
Hydrologic Basins												
Bear River	1.72	1.93	2.00	1.37	1.30	1.47	1.4	——	1.38	1.30	1.54	1.45
Wasatch Front	1.98	2.73	2.41	1.92	1.88	2.26	1.98	1.63	1.72	1.71	2.18	1.91
Central	1.61	2.03	2.00	1.34	1.26	1.45	1.4	1.22	1.36	1.30	1.62	1.53
Lower Sevier	1.87	2.30	2.42	1.40	1.30	1.43	1.42	——	1.40	——	1.53	1.48
Southwestern	1.75	1.71	2.34	1.50	1.36	1.56	1.5	——	1.43	1.38	1.77	1.60
Southeastern	1.66	1.63	2.20	1.37	1.31	1.49	1.4	—	—	1.29	1.55	1.46
Uintah	1.51	1.58	2.01	1.54	1.41	——	1.4	——	1.42	1.41	1.59	1.51
Planning Districts												
Bear River	1.72	1.93	2.00	1.37	1.30	1.47	1.4	——	1.38	1.30	1.54	1.45
Wasatch Front	1.93	2.68	2.30	1.89	1.98	2.26	1.98	1.62	1.71	1.69	2.09	1.86
Mountainlands	1.63	1.81	2.10	1.60	1.56	1.77	1.65	——	1.48	1.45	1.86	1.63
Central	1.72	2.14	2.15	1.38	1.29	1.47	1.4	1.24	1.43	1.31	1.63	1.54
Southwestern	1.74	1.69	2.33	1.49	1.32	1.56	1.53	——	1.42	1.37	1.78	1.60
Southeastern	1.66	1.63	2.20	1.37	1.31	1.49	1.4	——	——	1.29	1.55	1.46
Uintah	1.51	1.58	2.01	1.54	1.41	——	1.4	——	1.42	1.41	1.59	1.51
SMSA[1]												
Salt Lake City	1.94	2.64	1.89	1.85	1.85	2.18	1.0	1.59	1.65	1.66	——	——
Provo	1.66	1.72	2.11	1.55	1.55	1.71	1.60	——	1.44	1.42	——	——
Ogden	1.82	2.43	2.17	1.67	1.67	1.94	1.78	——	1.66	1.56	——	——

[1]Standard metropolitan statistical area.

Table 7. Type III employment multipliers.

	Agricultural sector											
Area or region	**Dairy**	**Poultry**	**Meat animals**	**Grains**	**Alfalfa**	**Fruits/ Nuts**	**Vege- tables**	**Oil- bearing crops**	**Greenhouse and Nursery**	**Forestry Fishery**	**New con- struction**	**Construction maintenance**
State of Utah	2.63	4.92	4.97	2.77	2.82	2.22	2.21	3.23	2.14	2.32	2.54	2.25
Hydrologic Basins												
Bear River	2.10	3.22	3.48	1.91	1.81	1.68	1.73	——	1.79	1.72	1.82	1.77
Wasatch Front	2.45	4.67	4.45	2.70	2.63	2.19	2.16	3.06	2.11	2.27	2.53	2.23
Central	1.99	3.08	3.33	1.88	1.77	1.65	1.70	2.03	1.77	1.78	1.81	1.77
Lower Sevier	2.21	3.50	4.26	1.92	1.79	1.62	1.68	——	1.82	——	1.67	1.66
Southwestern	2.21	3.12	4.35	2.14	1.94	1.76	1.83	——	1.83	1.90	1.90	1.77
Southeastern	2.14	3.01	3.96	1.94	1.85	1.73	1.74	——	——	1.75	1.73	1.68
Uintah	1.86	2.85	3.32	1.95	1.78	——	1.70	——	1.69	1.72	1.70	1.64
Planning Districts												
Bear River	2.10	3.22	3.48	1.91	1.81	1.68	1.73	——	1.79	1.72	1.82	1.77
Wasatch Front	2.37	4.54	4.18	2.62	2.74	2.17	2.13	3.01	2.09	2.22	2.46	2.18
Mountainlands	2.10	3.41	3.74	2.22	2.16	1.90	1.92	——	1.87	1.95	2.10	1.90
Central	2.09	3.27	3.69	1.93	1.80	1.66	1.72	2.08	1.85	1.76	1.80	1.75
Southwestern	2.21	3.08	4.32	2.13	1.90	1.76	1.83	——	1.84	1.90	1.91	1.78
Southeastern	2.14	3.01	3.96	1.94	1.85	1.73	1.74	——	——	1.75	1.73	1.68
Uintah	1.86	2.84	3.32	1.95	1.78	——	1.67	——	1.69	1.72	1.70	1.64
SMSA[1]												
Salt Lake City	2.31	4.36	3.35	2.50	2.50	2.07	2.02	2.87	1.97	2.12	——	——
Provo	2.06	3.17	3.71	2.13	2.13	1.83	1.86	——	1.82	1.89	——	——
Ogden	2.31	4.09	3.87	2.34	2.34	2.05	2.05	——	2.08	2.08	——	——

[1]Standard metropolitan statistical area.

Fig. 5. Ethidium bromide used to stain DNA lets researchers see DNA fragments when exposed to ultraviolet light. Agarose gel electrophoresis is used to separate DNA fragments obtained by restriction enzyme digestion.

Fig. 1. Hand pollination of wheat, a time-consuming process that now makes it impossible to economically produce high-yielding hybrid wheat.

Fig. 2. Clonal propaga genesis. The structure pepper.

Hybrid Crop

J. G. CARMAN, C. F. CRANI

Flowering plants of some species produce seed that are genetically identical to their mother plants through a developmental anomaly known as apomixis. The genetic transfer of apomixis to important food crops would permit development of superior-yielding hybrid cultivars that "clone" themselves through seed-propagation.

Seed formation in the vast majority of flowering plants begins with the union of egg and sperm nuclei. Either inbred or hybrid seed develop, depending on whether the egg is fertilized by pollen of the same or different genotype. Utah agriculture depends on both naturally self-fertilized crops, such as wheat, barley, oats, various wheatgrasses, beans, peas, and tomatoes, and naturally cross-fertilized crops, such as alfalfa, alsike clover, corn, smooth bromegrass, watermelons, pumpkins, beets, onions, and apples. Plant breeders can artificially hybridize carefully selected parental lines to develop superior-yielding plants, regardless of whether the crop is naturally self- or cross-fertilized. However, capitalizing on yield superiority in self-fertilized crops brought about through hybrid vigor is frequently impossible due to the prohibitive cost of producing hybrid seed.

Heterosis, a measure of hybrid vigor, is the improvement in yield of the hybrid over the average yield of the two parents. Genetically, it is believed that heterosis results when gene products of both parents come together in a favorable combination to produce synergistic effects. For example, yields from some hybrid rice varieties are 59 percent higher than from

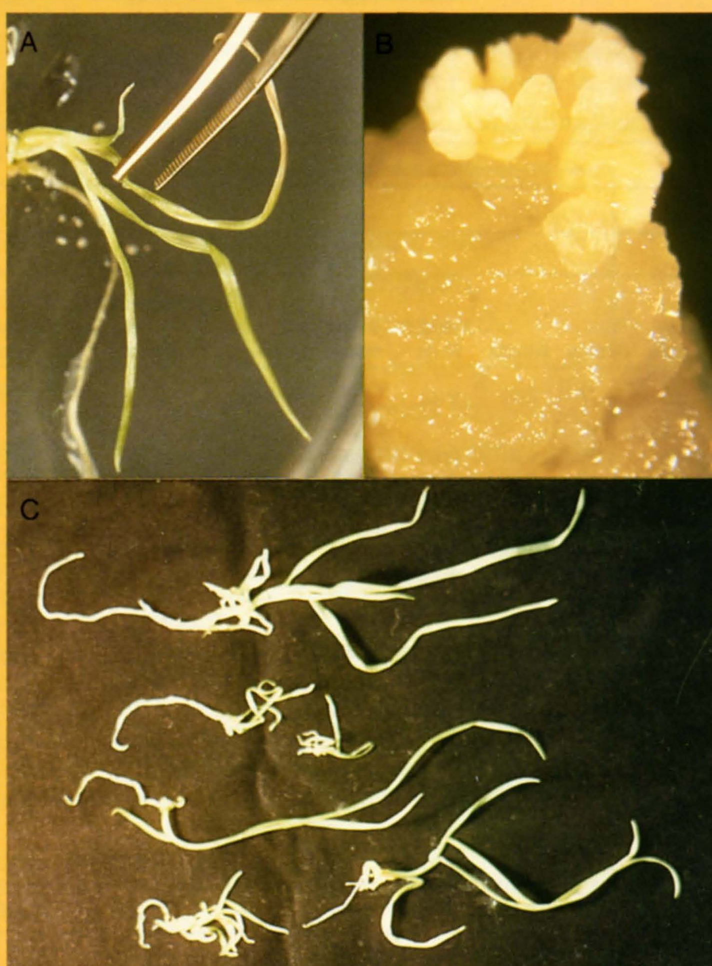
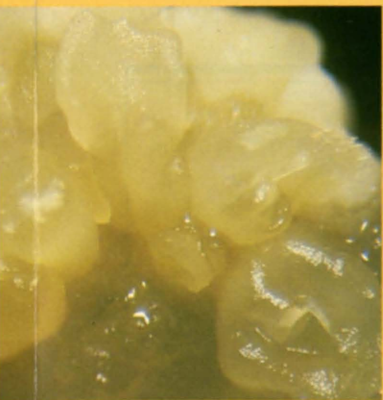


Fig. 6. Wheat plantlets (6a and c) can be routinely regenerated from callus cultures that undergo somatic (asexual) embryogenesis (6c). Chromosomes sometimes exchange segments in callus cultures. The resulting plant tissue culture may be of value in transferring apomixis genes from *E. rectisetus* to related grasses and cereals.

Photos by John Carman, Charles Crahe, and Jim Gown.



gation of wheat in tissue culture by somatic embryo-
res are asexual embryos about the size of a flake of

Fig. 3. Asexual embryos are germinated in tissue culture, transplanted to pots, and grown in growth chambers.

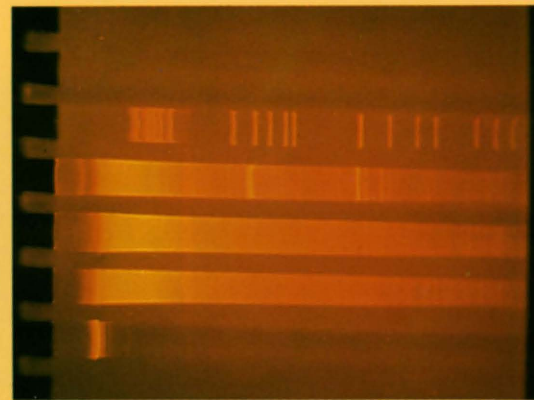


Fig. 4. Lanes (from top to bottom) contain DNA from a plasmid marker, rye, wheat, and *E. rectisetus.* Prominent bands of plant DNA are highly repeated sequences.

ps That 'Clone' Themselves

NE, and J. E. HUGHES

inbred or pure-line varieties (Virmani et al. 1982). Of course, unfavorable combinations can result in hybrids with less vigor and yield than the parents. Thus some parental lines have what is called favorable "combining ability," while others have poor, or negative, combining ability. Breeding lines of high combining ability have also been identified for corn, wheat, oats, barley, sorghum, alfalfa, sugarbeets, sunflowers and other crops. Unfortunately, many hybrid crops are not available because of the expense in producing hybrid seed.(Figure 1).

In self-fertilized crops such as wheat, barley, oats and rice, self-pollination and fertilization generally occur prior to flower opening. Using watchmaker forceps, breeders of these crops must carefully remove the anthers (male organs) from the floral cup prior to pollination. The flowers are covered to prevent random pollination until the stigmas (female organs) are receptive. The stigmas are then hand-pollinated by the breeder with pollen from the desired male parent. It is uneconomical to use this tedious process to produce agricultural quantities of hybrid seed.

Recently, limited amounts of hybrid rice and wheat seed have been commercially produced by the genetic manipulation of cytoplasmic (non-nuclear) male sterility genes and nuclear restorer genes. In principle, it is possible to use these techniques to propagate breeding lines that are either (a) homozygous recessive for restorer genes with a male sterile cytoplasm and are thus male sterile (meaning that their stamens fail to produce viable pollen), or (b) male fertile and homozygous dominant for restorer genes.

When male sterile plants (the female parents, in this case) are planted next to male fertile restorer plants (the male parents), hybrids can be produced that can pollinate themselves and produce high yields of grain. Such hybrids now account for approximately 17 percent of all rice planted in China (Virmani et al. 1982). Similar systems are used to produce hybrid corn, sorghum, onions and sugarbeets.

The male sterile/restorer technique has limitations. First, male sterility genes are only found in a few self-fertilized crops. Second, flowers of most self-fertilized crops have evolved morphological mechanisms that discourage cross-pollination. Third, pollen of the major grain crops is short-lived, only two or three minutes in some cases, so cross-pollination and fertilization seldom occurs, especially when female and male plants are planted in separate strips to facilitate harvest. Fourth, hybrid vigor is associated with the initial hybrid generation only; genetic recombination and segregation mean farmers must purchase expensive hybrid seed each year. Each of these shortcomings could be overcome if a developmental anomaly known as apomixis could be transferred to important food crops.

Apomixis and Seed-propagated Hybrid Cultivars

Gametophytic apomixis occurs sporadically within many families of flowering plants. These plants produce seeds that are genetically identical to themselves. Incorporating this trait into major food crops would permit breeders to develop self-perpetuating hybrid cultivars that are (for anatomical reasons) now mainly inbred (Bashaw 1980). The development of hybrid cultivars of wheat, rice and other typically inbred crops has tremendous appeal because, like hybrid corn, substantial yield advantages over pure lines are possible. If such cultivars were developed, farmers in underdeveloped or developed nations could propagate their own supply of hybrid seed, increase production per acre, and use substantially less fossil fuels and agricultural chemicals.

Technically, gametophytic apomixis refers to seed formation in flowering plants without the union of egg and sperm nuclei (Battaglia 1963, Nogler 1984), and is thus a form of asexual reproduction. It can occur by a number of different mechanisms, many of which are not well understood. The genetic control of apomixis is even less well understood, although significant progress has recently been made. Additional research is needed before scientists can readily transfer genes responsible for apomixis to various crop species.

Our research funded by the Utah Agricultural Experiment Station and by a grant from the USDA, is attempting to (a) determine the physiological and anatomical mechanisms of apomixis in *Elymus rectisetus* (formerly *Agropyron scabrum*), a wild relative of wheat, and (b) determine the number, chromosomal location and dominance relations of apomixis genes in this species.

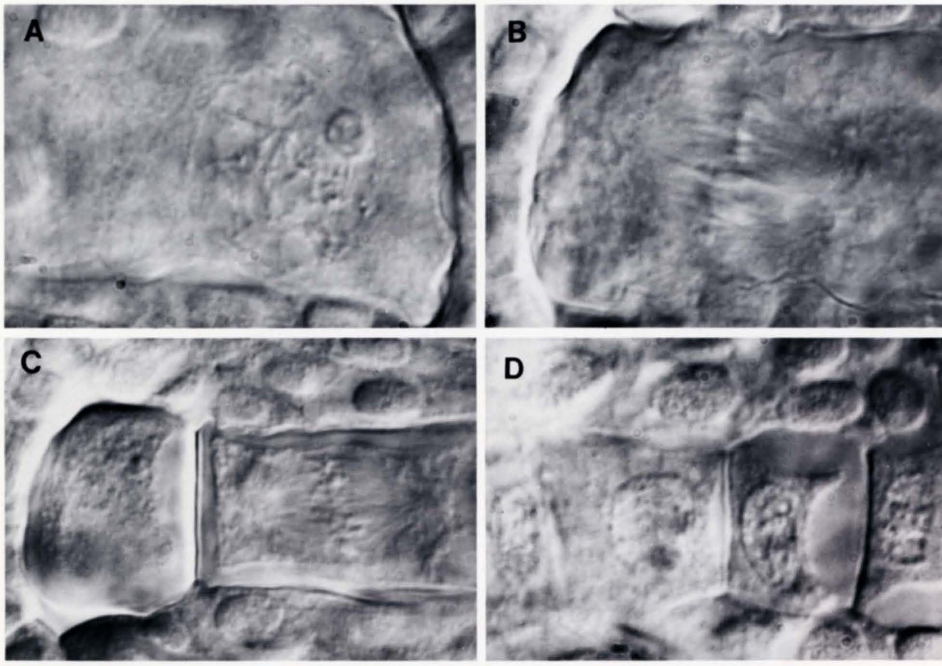


Fig. 7. Nomarski photomicrographs of sexual megasporogenesis in *E. rectisetus.* Bars represent 10 m. (a) Megaspore mother cell (MMC) in the pachytene stage of meiosis; (b) MMC in the metaphase I stage of meiosis (note spindle apparatus in preparation for chromosome separation); (c) two dyads resulting from metaphase I (the dyad to the right is in the metaphase II stage of meiosis); (d) four megaspores forming a linear tetrad. One megaspore develops into the sexual embryo-sac.

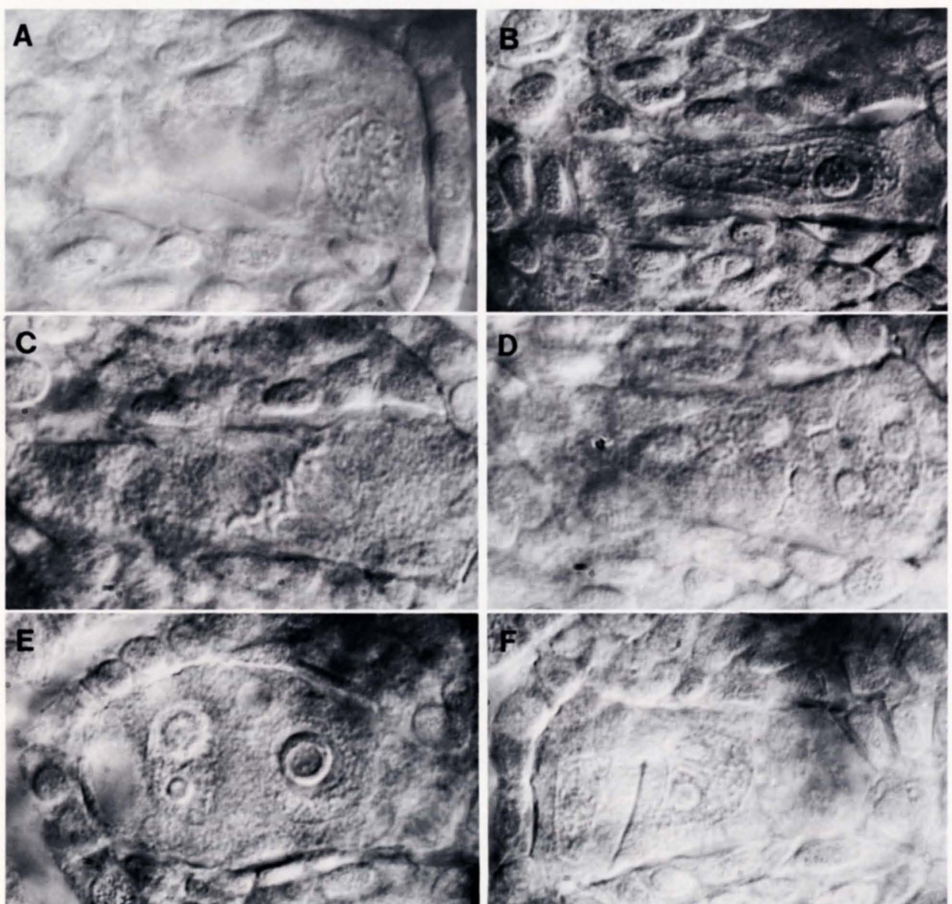


Fig. 8. Nomarski photomicrographs of apomictic megasporogenesis in *E. rectisetus.* Bars represent 10 m. (a) apomictic megaspore mother cell (MMC) with large vacuole that differentiates it from typical sexual MMCs; (b) MMC stretched by spindle fibers (arrows); (c) metaphase II or first embryo-sac division; (d) unreduced megaspore dyad with crenulate cross wall; (e) binucleate embryo-sac without a megaspore remanent; (f) megaspore hemidyad (intermediate to d and e).

Our research funded by the Utah Agricultural Experiment Station and by a grant from the USDA, is attempting to (a) determine the physiological and anatomical mechanisms of apomixis in *Elymus rectisetus* (formerly *Agropyron scabrum*), a wild relative of wheat, and (b) determine the number, chromosomal location and dominance relations of apomixis genes in this species.

Apomixis Found in Some Accessions

We have 43 accessions of *E. rectisetus* from continental Australia, seven from New Zealand, and four from Tasmania. Growing this perennial grass in the field in northern Utah is impossible because it lacks winter hardiness. However, most accessions flower year-round in the greenhouse while others require vernalization. We have determined that 11 accessions are highly apomictic while five are completely sexual.

To determine the reproductive mode in *E. rectisetus,* flowers at various stages of female and male gamete (sex cell) development are collected. Certain abnormalities in the female ovary indicate apomixis. Intact ovaries are placed in a clearing solution that makes them transparent and are examined with interference contrast microscopy, a techique that does not require ovaries to be dissected or sliced into thin sections. Developmental maturity of the ovule is carefully monitored by comparison with the stage of pollen development in the same flower at the same time. We have found that the nuclear and cell divisions leading to the egg cell in apomictic accessions occur later than in sexual accessions, while male development is generally unaltered (Crane and Carman 1984).

Megasporogenesis is the technical term for the first stage in the formation of the egg cell. In sexual accessions, megasporogenesis results in the production of female gametes that contain only half the parental number of chromosomes. Fertilization by a male gamete, which also contains half the parental number of chromosomes, restores the entire complement of chromosomes. Megasporogenesis in the sexual ovule begins in an enlarged cell (Figure 7a) known as the megaspore mother cell (MMC). Prior to cell division each chromosome within this cell replicates, and similar chromosomes generally exchange segments. The first cell division of meiosis (in progress in Figure 7b) then results in two cells, each con-

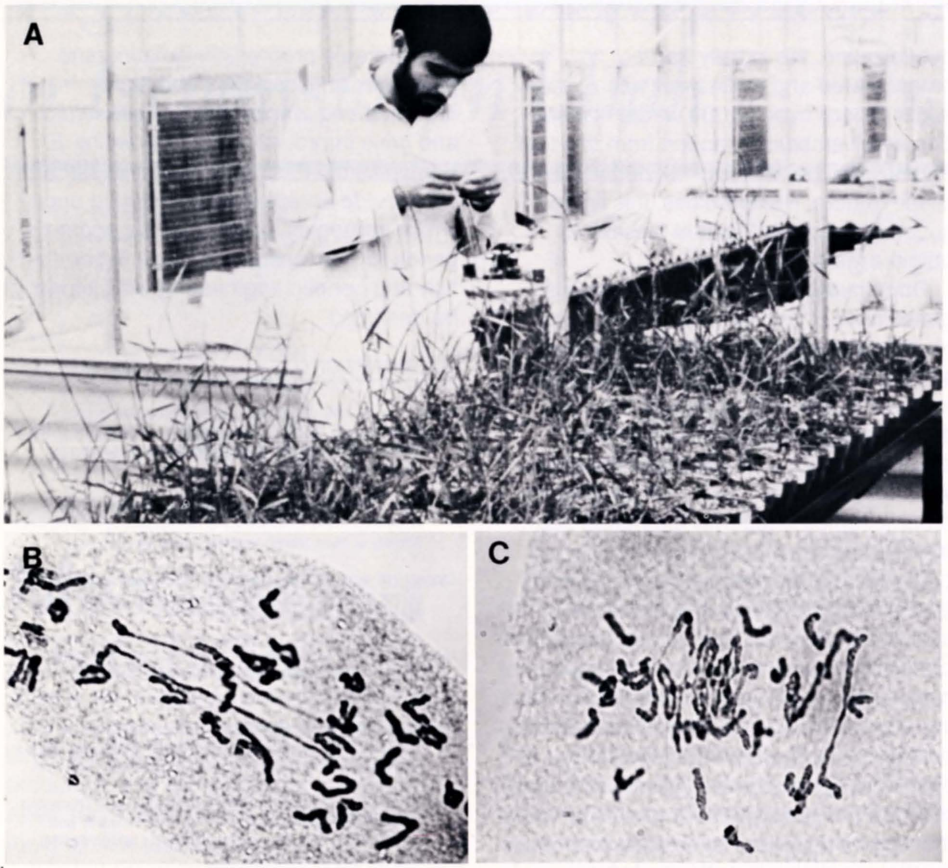


Fig. 9. (a) Hybrids cared for by graduate student Javad Torabinejad. Photomicrographs of acetoorcein squares of pollen mother cells in metaphase I of meiosis: (b) *E. longearistatus* × *E. rectisetus* with two rod bivalents and 31 univalents; (c) *E. longearistatus* × *E. rectisetus* with one trivalent, six ring bivalents, three rod bivalents, and 21 univalents.

taining the original amount of chromosomal material. Both cells rapidly undergo the second meiotic division (Figure 7c) resulting in a tetrad of megaspores (Figure 7d) each containing one-half the number of chromosomes found in somatic (nonsexual) tissues. Three of the four megaspores degenerate; the remaining megaspore develops and forms an embryo-sac that contains the egg cell and also the polar nuclei needed for endosperm development and seed formation upon fertilization.

Normal megasporogenesis is interrupted in apomictic accessions of *E. rectisetus*. Chromosome replication occurs normally in the apomictic MMC, but the normal chromosomal and nuclear divisions of meiosis are omitted or delayed while a vacuole of fluid within the MMC develops (Figure 8a, compare with Figure 7a). Further activity in the MMC is not initiated until reaching the male developmental stage contemporaneous with megaspore degeneration in sexual plants. At this stage the MMC nucleus moves from one end of the MMC toward the center of the MMC as if it were being pulled by spindle fibers (Figure 8b). The nucleus sometimes becomes so tightly stretched that pieces appear to be pulled away.

Upon moving to a more central location in the MMC, the nucleus again becomes round; no first meiotic division occurs. A division similar to the second meiotic division then ensues (Figure 8c) yielding either a megaspore dyad (Figure 8d), a binucleate embryo-sac (Figure 8e) or, more rarely, a hemidyad that is intermediate between the two (Figure 8f). Only one division of chromosomes has occurred, hence the nuclei within these early embryo-sacs and dyads contain the same number and types of chromosomes as the somatic tissues of the mother plant. Hence, the egg cells are, for practical purposes, genetically identical to the mother plant. Pollination triggers egg cells to develop, without fertilization, into embryos and then into plants that are exact clones of their mother plants.

Mapping Apomixis Genes

Before we can genetically transfer genes for apomixis from *E. rectisetus* to crop species, we must first know the location of such genes and what processes they control. Our research suggests that apomixis gene(s) in *E. rectisetus* modify a biochemical pathway that regulates megasporogenesis. Such pathways are probably common to all flowering plants; thus it may be possible to incorporate genes controlling apomixis into crops by genetic engineering, particularly since recent research indicates that apomixis is controlled by only one gene in Guinea grass, *Panicum maximum* (Savidan 1981) and in a member of the buttercup family, *Ranunculus auricomus* (Nogler 1984).

To determine the number of genes responsible for apomixis in *E. rectisetus*, we will hybridize sexual and apomictic individuals and observe percentages of sexual and apomictic progeny (segregation) in the initial hybrid generation and in subsequent self-fertilized and backcrossed generations. Segregation studies should provide us with a fairly accurate estimate of the number of genes involved in apomixis and whether these genes are dominant or recessive.

Once we know the number of genes responsible for apomixis in *E. rectisetus*, we will attempt to locate the genes to specific chromosomes. In preparation for this step we have hybridized *E. rectisetus* with four other *Elymus* species (Figure 9, Torabinejad et al. 1984). Through chromosomal manipulation, we plan to breed a series of *Elymus canadensis* plants each with an additional *E. rectisetus* chromosome, and a series of *E. rectisetus* plants with additonal *E. canadensis* chromosomes. Evidence for gene location will be obtained if a single *E. rectisetus* chromosome (or set of chromosomes) added to *E. canadensis* induces *E. canadensis* to be apomictic, or if an *E. canadensis* chromosome added to *E. rectisetus* induces sexual reproduction in *E. rectisetus*.

It may be necessary to locate apomixis genes with genetic marker-genes whose location is already known and that produce a distinct phenotype (the visible expression of a gene). If such markers are located near (linked to) an apomixis gene, then both apomixis and the respective marker gene phenotypes will segregate together.

There are presently no appropriate known genetic markers for determining linkage to apomixis genes in *E. rectisetus*. However, over 70 potentially useful marker genes have been located in wheat (Hart 1983), a not too distant relative of *E. rectisetus*. Recent research has shown that gene location on chromosomes has changed relatively little as wheat and related grasses evolved (Hart and Tuleen 1983), so wheat genetic markers will probably also apply to *E. rectisetus*.

To test this hypothesis, we are searching for genetic markers in *E. rectisetus* that correspond to those in wheat. This requires development of *E. rectisetus* addition lines in *E. canadensis*. With such addition lines, the relevant markers from *E. rectisetus* will appear as distinct bands of enzyme activity on an electrophoretic gel. These bands represent isozymes (different molecular forms of a particular enzyme) that would not normally be found in *E. canadensis*. Refinement of electrophoretic procedures for isozyme analysis in *E. rectisetus* is underway.

Because most *E. rectisetus* chromosomes look alike, sophisticated cytogenetic markers, in addition to genetic markers, must also be developed. Fortunately, between 10 and 20 percent of *E. rectisetus* chromosomes are composed of thousands of identical, very short DNA segments (repeated sequences) uniquely distributed in groups along each chromosome.

We are now isolating and purifying repeated sequences that will be cloned using recombinant DNA procedures (Figures 4 and 5) and chemically labeled with biotin. Under conditions created on the microscope slide, such biotin-labeled "DNA probes" bind, by *in situ* hybridization (Gall and Pardue 1971), to regions of chromosomes composed of the same repeated sequence. Individual chromosomes can then be identified by their unique banding patterns when the microscope slide is exposed to a stain specific for biotin (Rayburn and Gill 1985).

Strategies to Transfer Apomixis

Determining the number and location of apomixis genes in *E. rectisetus* will facilitate their manipulation either by conventional breeding or, eventually, by recombinant DNA techniques. Unfortunately, methods have not been developed to purify plant genes for which a gene product has not yet been characterized, as is the case for apomixis genes, nor have suitable genetic engineering vectors to transform cereal crops been developed. Even though genetic engineering techniques to transfer apomixis have not yet been developed, progress toward developing apomictic cultivars of wheat, barley and rye may occur through interspecific hybridization and backcrossing with their common relative, *E. rectisetus*.

The transfer of apomixis from *E. rectisetus* to wheat will probably occur only after the obstacles that prevent hybridization between the species have been surmounted. We are among several researchers who have attempted this hybridization. We initially hand-emasculated and pollinated (with *E. rectisetus* pollen) over 13,000 wheat flowers. Ten small embryos rescued from this trial appeared to be true hybrids, but all died in tissue culture. Nevertheless, this limited success suggests that it is feasible to obtain a viable hybrid.

Once hybrids are obtained, apomixis genes from *E. rectisetus* chromosomes must be transferred to wheat chromosomes. As natural chromosome pairing followed by genetic exchange between the desired chromosomes cannot be expected to occur in such a wide hybrid, we will utilize plant tissue culture in which chromosomes frequently exchange segments at random (translocation). We are currently regenerating wheat plants from tissue culture (Figures 2, 3, and 6), a technique which we plan to use to regenerate numerous clones of the original hybrids, thus perhaps inducing and isolating a desirable translocation. Repeated backcrossing to wheat coupled with screening for apomixis (or genetic markers linked to apomixis genes) should then lead to the desired transfer. Except for the use of tissue culture, such a translocation-mediated transfer of genes has often been used to transfer various disease-resistance genes to wheat.

Conclusions

Gametophytic apomixis, asexual reproduction by seed, occurs sporadically in many families of flowering plants. It can proceed by a number of different mechanisms, and neither the mechanisms nor their genetic control are well understood. In principle, the transfer of apomixis to food crops would let farmers raise their own hybrid seed, and would simplify varietal development for plant breeders. Hybrid cultivars of wheat, rice and other crops that are now usually inbred could offer substantial yield increases such as those associated with the development of hybrid corn.

We have morphologically characterized apomixis in *Elymus rectisetus* and have identified isozymically different sexual and highly apomictic forms. The correlation of biochemical or cytological genetic markers with apomixis genes in segregating generations will permit us to precisely determine the number, chromosomal location, and dominance relations of apomixis genes. The proposed markers we are developing include isozymes and bands produced by *in situ* hybridization of biotin-labeled DNA sequences. We have made considerable progress in isolating and characterizing isozymes and highly repeated sequences from *E. rectisetus*, and have improved ways to examine *E. rectisetus* ovaries. Such basic research will provide an essential foundation upon which strategies for transferring apomixis genes to crop species by wide hybridization and genetic engineering will ultimately be designed.

LITERATURE CITED

Bashaw, E. C. 1980. Apomixis and its application in crop improvement. In: W. R. Fehr and H. H. Hadley (eds.) Hybridization of crop plants. *American Society of Agronomy Press*, Madison, WI.

Battaglia, E. 1963. Apomixis. In: P. Maheshwari, (ed.), Recent Advances in the Embryology of Angiosperms. International Society of Plant Morphologists, University of Delhi.

Crane, C. F. and J. G. Carman. 1984. The nature and distribution of apomixis in *Elymus rectisetus* from eastern Australia. Agron. Abstr., p. 60.

Gall, J. G. and M. L. Pardue. 1971. Nucleic acid hybridizations in cytological preparations. Meth.in Enzymology. 21:470-480.

Hart, G. E. 1983. Hexaploid wheat (*Triticum aestivum* L. em Thell.) In: S. D. Tanksley and T. J. Orton (eds.), Isozymes in Plant Genetics and Breeding, Part B. Elsevier, New York.

Hart, G. E. and N. A. Tuleen. 1983. Introduction and characterization of alien genetic material. In: S. D. Tanksley and T. T. Orton (eds.). Isozymes in Plant Genetics and Breeding, Part A. Elsevier, New York.

Nogler, G. A. 1984. Gametophytic apomixis. In: B. M. Johri (ed.), Embryology of Angiosperms, Springer-Verlag, Berlin.

Rayburn, A. L. and B. S. Gill. 1985. Use of biotin-labeled probes to map specific DNA sequences on wheat chromosomes. *J. Hered.* 76:78-81.

Savidan, Y. H. 1981. Genetics and utilization of apomixis for the improvement of guineagrass (*Panicum maximum* Jacq.). Proc. XIV Int. Grassl. Cong., Lexington, KY, pp. 182-184.

Torabinejad, J., C. F. Crane, and J. G. Carman. 1984. Genomic structure of hybrids of *Elymus rectisetus* with *E. canadensis*, *E. longearistatus*, and *E. tsukushiensis*. *Agron. Abstr.*, p. 92.

Virmani, S. S., R. C. Aquino, and G. S. Khush. 1982. Heterosis breeding in rice. *Theor. Appl. Genet.* 63:373-380.

ABOUT THE AUTHORS

John G. Carman received his PhD in genetics from Texas A&M University and is currently an assistant professor of crop genetics in the Plant Science Department. His research interests involve crop improvement through genetic manipulation and plant tissue culture.

Charles F. Crane received his PhD from the University of Texas, Austin, in botany and is currently a research associate in the Plant Science Department. His research is focused on comparative apomictic embryology and associated cytogenetic phenomena.

Joanne E. Hughes received her PhD in molecular biology from the Australian National University, after which she worked as a post-doctoral fellow for two years at the Max Planck Institute for Biochemistry. She recently joined Utah State University as a Research Associate in the Plant Science Department and is applying recombinant DNA technology to develop chromosome markers for genetic and cytogenetic analyses.

Agricultural Development or Expansion in Utah

D. L. SNYDER and T. F. GLOVER

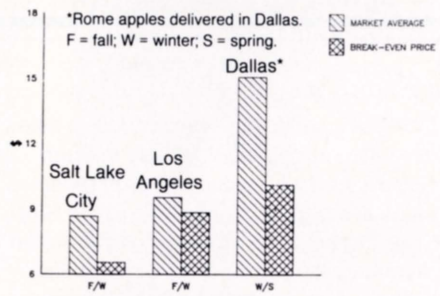


FIGURE 1. Seasonal apple prices.

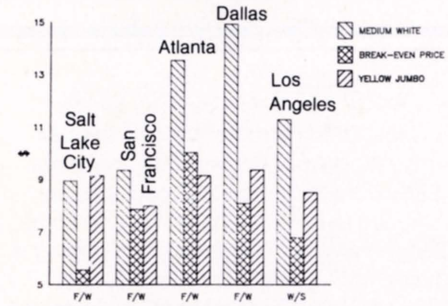


FIGURE 2. Seasonal onion prices.

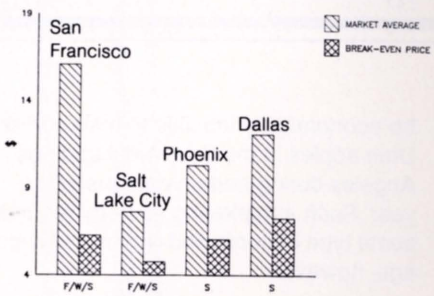


FIGURE 3. Seasonal chipper potato prices.

Many factors contribute to the expansion of existing industries and/or the development of new ones, including population shifts, changes in the business climate, the discovery or availablity of valuable resources, and changes in market structure or organization. Enterprising producers and technological change can often serve as catalysts in the development of new enterprises.

It is far easier to determine why shifts in business activity occurred than it is to predict when and how these shifts will occur. With that caveat in mind, this study examined the potential for developing or expanding markets for agricultural commodities. However, identifying these opportunities does not guarantee access to markets. Producers in other states will compete for these markets. And production and transportation costs, marketing arrangements, the personal relationships between buyers and a variety of other factors will affect access to these markets.

Three basic groups of commodities appear to have the greatest potential: fresh fruits and vegetables; meat products processed by an intermediate-sized, multi-species packing and fabricating plant; and processed fruits and vegetables, handled by a fruit/vegetable processing facility. An assessment of the fruit/vegetable processing facility will not be available until completion of a detailed engineering study.

Fresh Fruits/Vegetables

Several fruits and vegetables have been produced in Utah, although acreage devoted to most vegetables and some fruits has declined. Reversing that trend requires additional local and out-of-state markets for fruits and vegetables grown in Utah.

To determine potential new markets, this study employed a marketing analysis tool known as the "market window," a technique first developed to help small farmers in Florida evaluate the economic potential of alternative vegetable crops. The approach considers both production costs and the prices at the major markets accessible to producers. Since most markets already have a number of suppliers of any fruit or vegetable, there will only be opportunities for a new supplier if the market price exceeds production and delivery costs. The market window approach is essentially a pre-screening technique to identify these crops which appear to have the greatest market potential, or which would could be marketed if production and marketing costs decreased.

In market-window analysis, wholesale prices in alternative markets are compared with break-even prices for entry into these markets. The break-even price reflects fixed and variable costs which must be covered by the expected market price in order to continue to produce and market a commodity. There is a favorable or "open" market window if recent wholesale prices exceed the break-even price.

For example, if total (fixed and variable) costs for apples were $8.50 per box, and the price in the Los Angeles wholesale market was $9.50 per box during a 2- or 3-month period, there is some potential for increasing sales of apples in that market during that period.

Marketing Opportunities for Utah Fruit

Utah produces a number of fruits for retail and wholesale markets, the most important of which are apples, tart cherries, sweet cherries, peaches, and pears. Some raspberries and watermelons are also produced. Table 1 shows the estimated break-even prices of selected Utah fruits, excluding marketing costs, shipped to the Salt Lake City wholesale market.

Apples. A comparison of the seasonal wholesale prices and break-even prices suggests that there is a market window for Utah red delicious apples in the Salt Lake market from September through January. However, there is little difference between wholesale and break-even prices in this market, even when we assume that yields increase and the market window is extended into February. This is also true for Utah's golden delicious apples but not for rome apples. Wholesale prices for rome apples provide a market window from October through December and from January through mid-March.

It appears that Utah apple producers could maximize returns by marketing rome apples on the Salt Lake wholesale market for shipment out of state. More than 70 percent of Utah's apple crop is shipped out of state; between 30 and 40 percent of Utah-grown apples are exported to California.

There appears to be a market window for red delicious apples in California from late October through December, but the margin is rather small. There is also a market window for red delicious apples from late October through January; market prices during this period exceed regular storage costs if yields exceed 12,000 pounds per acre. While no Utah rome apples have apparently been shipped into Los Angeles, it appears that there is a market window for them, particularly during January through March. Although there are marketing windows for both red delicious and rome apples in the Southwest (Houston and Dallas), returns for rome apples appear to be higher in these markets. In summary, it appears to be economically feasible to market more Utah apples in the Southwest and Los Angeles during certain portions of the year. Such a marketing strategy requires some type of controlled-atmosphere storage, however.

Sweet Cherries. Most of the sweet cherries now produced in Utah are packed and shipped to a variety of distant urban markets Most Utah-grown cherries are sold on the Salt Lake wholesale market, except for some lots sold directly to grocery chains.

There is a market window for Utah cherries in the Salt Lake market, but California cherries now dominate the market because they are available before most Utah cherries are harvested. It does not appear that Utah growers can expand their shipments in this market.

There is a market window for Utah cherries, particularly for early cherries, in Montana. Prices in Montana markets fall quickly when Montana-grown sweet cherries, which tend to be slightly larger than those grown in Utah, are harvested. For this reason, only limited amounts of Utah cherries can be marketed in Montana.

Cherries from California and Washington dominate the Los Angeles markets. Utah ships some cherries to Los Angeles in July; the market window extends through July and into the first week of August. However, it does not appear to be feasible to increase cherry shipments from Utah into Los Angeles, although the market will probably continue to be an outlet for small lot shipments of Utah cherries. More sweet cherries might be marketed in the south and east. Overall, however, there appear to be limited marketing opportunities for sweet cherries.

Peaches. There appears to be a limited wholesale market window for peaches in the Salt Lake market during the harvest and shipping season in Utah. The earlier varieties command higher prices, and profit margins in the Salt Lake markets compare favorably to prices in other outlets.

Most Utah peaches are sold in retail markets in Utah and surrounding areas. Early-variety tray-packed peaches are shipped to neighboring states and some other markets. The margin in Wyoming is higher than in Montana, but prices in Wyoming decrease more rapidly after the first shipments enter the state. The early market in Montana and Wyoming requires larger fruit, and is obviously limited. Other regions are also shipping peaches into these markets. There is little if any opportunity to market Utah peaches in the major Western and Southern markets.

Pears. A market window apparently exists during the harvest and shipping season for Utah pears (late August through November). The Salt Lake market appears to be a favorable outlet for Bartlett pears grown in Utah. However, most of the year the market is dominated by winter pear shipments from Washington, Oregon (during January and February) and California (Bartlett pears during July, August, and September). There appear to be marketing windows for Utah pears on the the wholesale markets in both Montana and Wyoming. Some Utah pears already compete with California-grown pears for these markets, and there appears to be little opportunity for expansion in this market. Utah-grown pears apparently have not been shipped to the Los Angeles market, but it appears that Bartlett pears could be marketed there during October. Pears would have to be stored prior to shipment. It may also be possible to ship more pears to the Southwest during some periods.

Raspberries. Raspberry production in Utah is concentrated in primarily in Rich, Cache, Box Elder, and Utah counties. Most raspberries are sold in retail markets although it may be possible to increase sales to wholesale markets.

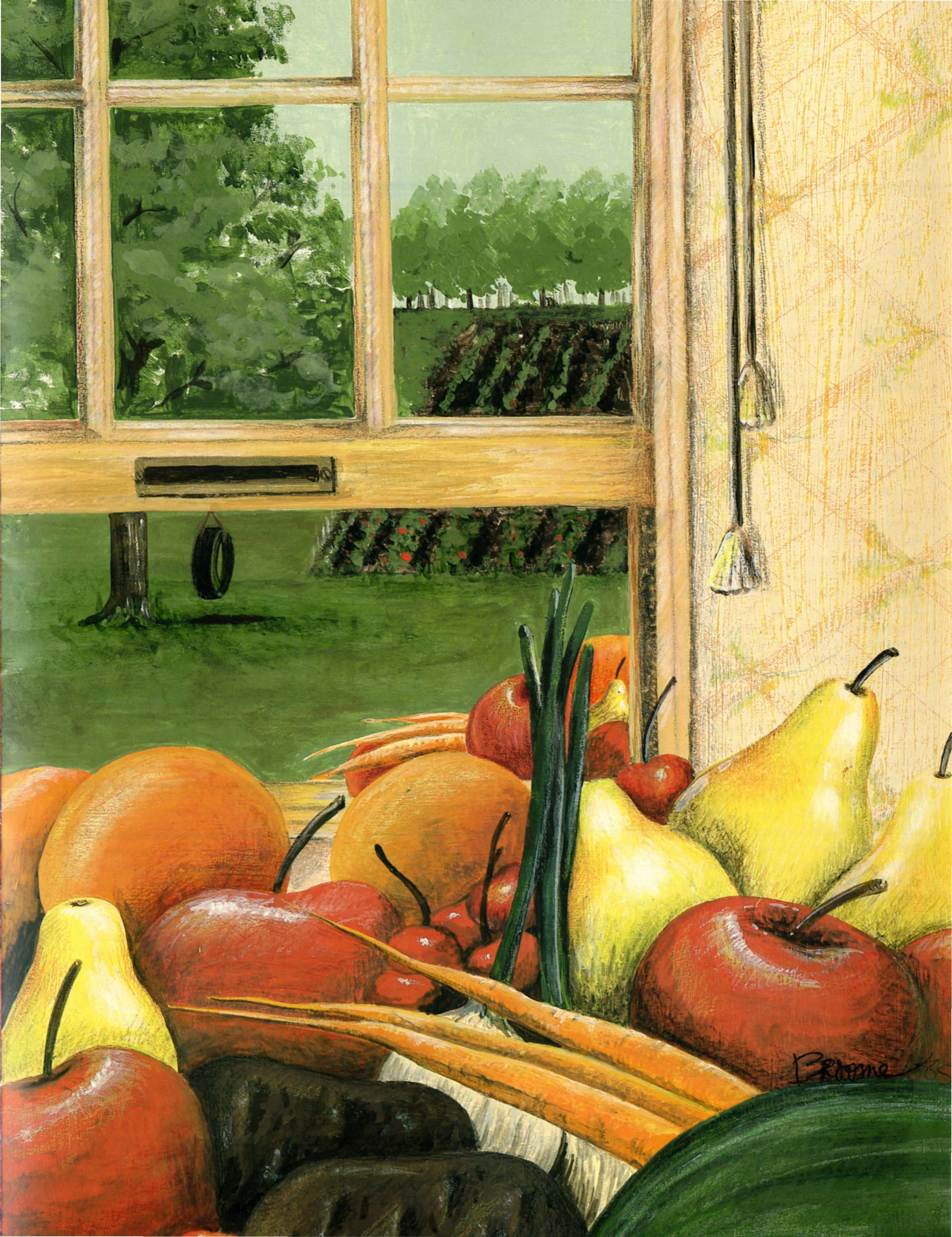
There is a market window in the Salt Lake market throughout the short harvesting season. Utah berries are now shipped to various wholesale markets in eastern Idaho, Montana, and Wyoming. There is a marketing window to eastern Idaho cities from the second week of July through August, and wholesale prices in these cities are slighter higher than in the Salt Lake market. The window in Montana and Wyoming is from the third week of July through August. Wholesale prices are higher in the early part of the season and decrease significantly in August. Wholesale prices are higher in Wyoming than in Montana, Idaho, and Salt Lake but the Wyoming market is relatively small. Prospects for expansion are more favorable in other more distant urban markets, such as Denver, or perhaps in the Southwest. In the Los Angeles market, there appears to be a profitable market window for Utah raspberries during July and August.

Raspberries grown in Utah are very sweet, but tend to be smaller than those from Oregon and Washington. Utah growers would benefit if they produced larger fruit and capitalized on the high sugar content of the raspberries they now produce. The lack of packing facilities and short-term storage facilities in Utah may limit attempts to market raspberries in other states.

Watermelons. There is a small market window for watermelons in the Salt Lake market and in Montana and Wyoming. Producers in several other regions ship watermelons into the Salt Lake and surrounding markets. Utah melons generally enter the market just when supplies are plentiful and prices tend to be low. Since watermelons are shipped from Mexico and many other southern areas during this same period, it is unlikely that Utah-grown melons can be marketed in Houston and Dallas markets. Consequently, the small market window does not appear to favor any large expansion of watermelon production in the state.

Vegetables

Except for dry onions the production of vegetables in Utah has declined precipitously in recent decades. There do appear to be additional marketing opportunitees


Broome

for Utah-grown potatoes, onions, and carrots.

Onions. While Utah onions are sold in the Salt Lake market only during January-February and August-September, prices of yellow and white onions shipped in from Idaho, California, and Texas indicate that the marketing window for Utah onions could be extended. California onions capture only 69 percent of the Los Angeles wholesale market. The most favorable market window for Utah onions, particularly yellow onions, in the Los Angeles market is January through the first two weeks of April. The marketing window in Los Angeles for white onions extends from the last two weeks of August through December. Although prices for white onions are not available for January and February, these months also appear to be favorable marketing months.

Yellow jumbo onions appear to command lower returns than yellow mediums. During the winter months, the white mediums appear to bring the greatest returns. It appears that Utah shippers could improve their position in the market and increase returns by concentrating shipments in the late fall and January-February.

It is possible that six times as many Utah onions could be shipped to the Los Angeles market. Prices are generally higher during January and February. (Oregon onions are shipped during this period, but fewer than during May, June, and the other summer months.) It appears that white medium onions could be marketed during the fall and early winter months in the Los Angeles market. Improved storage would be required but recent wholesale prices appear to justify investment in storage and shifting the onion marketing.

The marketing period for yellow jumbo onions appears to be from October through December. Yellow medium, yellow jumbo, and white medium onions are shipped into the Dallas wholesale market. The market window appears to justify shipping Utah yellow medium and jumbo onions from September through March. The current marketing period of medium whites in both Dallas and Fort Worth markets extends only from December through February. Utah growers might reap higher returns by growing yellow onions instead of white onions.

Yellow medium onions are shipped to Houston during January and Feburary and it might be more profitable if Utah producers shipped white onions to this market. Utah-grown onions are also shipped to many distant markets including New York, Baltimore, Philadelphia, Providence, Chicago, Indianpolis, Minneapolis, St. Louis, New Orleans, Memphis and Atlanta.

Potatoes. While some fresh potatoes from Utah enter the Salt Lake wholesale market during August and September, most Utah potatoes sold on the Salt Lake wholesale market are used as chippers. Chipping potatoes command lower prices than fresh potatoes, but the chipping market helps Utah producers compete with high quality, fresh potatoes from Idaho, Washington, and Oregon. The market window for chipper potatoes in the Salt Lake market is from August through September and from January through May. Most of the chippers are shipped by March.

Improved storage facilities may let producers and shippers obtain higher returns by selling more potatoes later in the spring. The market window for fresh table Russets in the Salt Lake market is from September through May. The market window for the round red potatoes is from late August through March; the lowest prices occur in February.

Other areas to the South and Southeast provide other viable processing options. Utah chipper potatoes are primarily shipped to the Dallas and Fort Worth markets during March and April. It appears that Utah chippers could enter the market slightly earlier and that shipments could be extended through February.

Chipper potatoes from Utah enter the San Francisco market in August and September and again from January through May. Our analysis indicates that the market window extends from August through May, so it may be possible to expand shipments to the San Francisco market, particularly during the late fall and late winter. Phoenix receives some Utah chipper potatoes during August and September and again from March through May.

The marketing period for the Salt Lake fresh potato market is relatively long and flexible. Shipments are warranted during the entire marketing period from September through May. The Los Angeles market is primarily a fresh table potato market. Occasionally, fresh market potatoes are shipped to San Francisco during September and October. There appear to be market windows for Utah potatoes in this market during September and October, and during the winter months.

Carrots. Many carrots grown in the areas surrounding Salt Lake City. Prices have increased recently and carrot production may offer economic opportunities, particularly if local production costs can be reduced and yields increased. Even at projected costs, there is a window into the Los Angeles market from July through September, but the margin is rather slim. If Utah carrots are to compete in these markets, production, harvest, and storage costs must be minimized. While there are no records of carrot shipments into the Dallas market, it does appear that Utah carrots could compete with Washington carrots from September through December.

Livestock

While it is unlikely that another large packing facility will locate in Utah (Andersen, et al., 1983), the competitive structure of the livestock sector could be improved with alternative processing options. One possible option is the development of a relatively small lamb and calf packing facility; a plant capable of slaughtering between 150,000 and 200,000 lambs and between 25,000 and 40,000 cattle annually. The plant, which would break and fabricate carcasses, would cost approximately $4,500,000. An abbreviated preliminary analysis is provided in Table 2. The major problem facing such a plant would probably be seasonal procurement shortages. As noted in Table 3, reductions in operating capacity caused by seasonal shortages can significantly reduce profits.

TABLE 1. Estimated break-even prices and yields per acre for selected Utah fruits and vegetables, 1984.

Fruits	Break-even price[1]	Yield/acre (lbs)
Apples	20.5 ¢/lb	12,000
Apples	18.7	20,000
Sweet cherries	30.5	10,000
Peaches	26.7	10,000
Pears	19.9	12,500
Raspberries	42.8	7,000
Watermelons	5.5	18,000
Vegetables		
Dry onions	$5.37 $/cwt	30,000
Potatoes	$4.55	23,000
Carrots	$6.06	21,000

[1]Includes transportation to the Salt Lake wholesale market.

TABLE 3. Financial computations for various operating capacities.

	At projected capacities	At 90 % of projected capacities	At 80% of projected capacities	At 70% of projected capacities
Sales	$37,756,437	$33,980,793	$30,205,150	$26,429,505
Costs	$33,495,000	$32,787,500	$29,508,750	$26,230,000
Net Returns (of operating costs only)	$ 4,261,437	$ 1,193,293	$ 696,400	$ 199,505

Producer Support Essential

In summary, it appears that there is the potential for further agricultural development in Utah. Production of certain fruits and vegetables production could be increased if carefully planned marketing programs are developed; these programs must have the support of producers and other interested parties. In addition, a multiple-species packing/fabricating facility might also be viable if the supply of animals can be guaranteed.

REFERENCE

Andersen, J. C., R. H. Anderson, R. A. Christensen, H. H. Fullerton, T. F. Glover, D. L. Snyder. A study of meat packing in Utah. Research Report 72, Utah Agricultural Experiment Station, September 1983.

ABOUT THE AUTHORS

Donald L. Snyder is an associate professor in the Economics Department. He received his PhD from Utah State University. His primary areas of work are in marketing and prices, and production economics.

Terrence F. Glover is a professor in the Department of Economics doing research on production, energy, and policy problems.

TABLE 2. Financial computations for alternative kill options.

		250,000 head of lambs 25,000 head of cattle	200,000 head of lambs 35,000 head of cattle	150,000 head of lambs 40,000 head of cattle
1.	Net Sales	38,041,750	41,166,850	40,714,300
	(Less 3/4 of 1%)	285,313	308,752	305,357
		37,756,437	40,858,198	40,408,943
2.	Cost of sales	32,787,500	35,380,000	34,922,500
3.	Salaries	434,000	434,000	434,000
4.	Wages	1,269,000	1,269,000	1,269,000
5.	Supplies, packaging and processing	612,500	595,000	542,000
6.	Supplies and miscellaneous operating	210,000	210,000	210,000
7.	Utilities	250,000	250,000	250,000
8.	Taxes and insurance	64,000	64,000	64,000
9.	Waste disposal	60,000	60,000	60,000
10.	Inspections	105,000	90,300	73,500
11.	Miscellaneous plant expense	78,000	78,000	78,000
12.	Miscellaneous administrative expense	125,000	125,000	125,000
13.	Management incentive plan (max. payable)	15,000	15,000	15,000
14.	Accounts receivable	2,615,000	2,828,000	2,797,500
15.	Inventories	790,000	809,495	799,936
16.	Accounts payable and accrued expenses	900,000	941,327	948,700
	Net position	4,261,437	4,984,066	5,014,179

Vacant Federal Grazing Allotments in the West

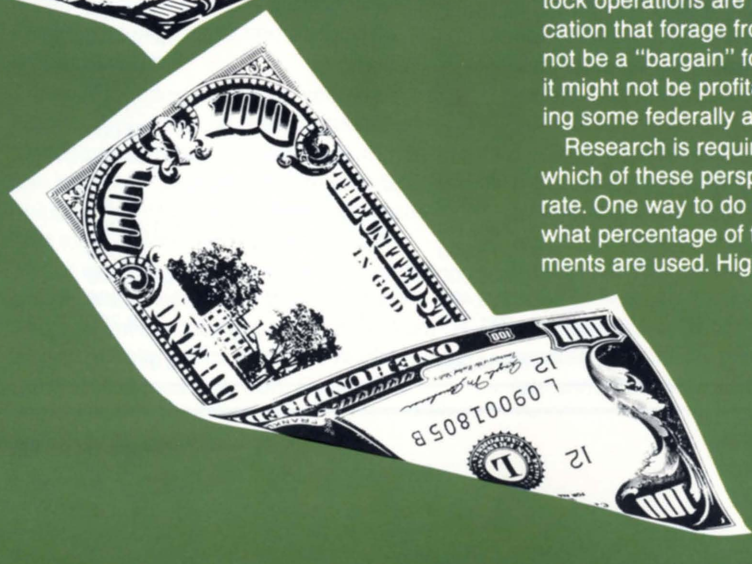
Livestock have been allowed to graze lands administered by agencies of the federal government for more than a century. Allowing such grazing has been a controversial issue and, for various reasons, many critics say grazing should be reduced. Such restrictions on grazing have been opposed by farmers and ranchers whose livestock are allowed to use these lands.

Some critics contend that the fees charged for grazing federal lands represent a subsidy to these producers because these fees are lower than those for "comparable" privately owned lands.

Livestock producers contend, however, that the use of these lands is no "bargain." For example, it has been shown that the fees charged for use of federal or private land are generally only a portion of the total cost of grazing livestock. This suggests that the total costs of using these lands, not simply the grazing fees, determine whether producers decide to graze livestock on a parcel (Nielsen 1982). It has also been shown that non-fee costs associated with grazing public lands usually exceed grazing fees (Obermiller and Lambert 1984, Torell, Godfrey and Nielsen 1985).

Recent changes in federal grazing policies indicate that the non-fee costs of using federal lands have increased more than grazing fees, and the use of these lands may not be as low-cost as some contend. Most of the studies of the costs and returns of livestock operations throughout the western United States also indicate that net returns for range livestock operations are not high, another indication that forage from federal lands may not be a "bargain" for producers, and that it might not be profitable to continue grazing some federally administered lands.

Research is required to help determine which of these perspectives is most accurate. One way to do so is to determine what percentage of federal grazing allotments are used. High use of federal grazing allotments would indicate that the total cost of grazing these lands to be lower than on comparable privately owned land, and that an increase in grazing fees might be justified. Low use of federal grazing allotments might mean that those who graze livestock on federal lands incur high total costs and correspondingly low net returns. If so, further increases in grazing fees would decrease demand for and use of federally administered lands.



This study sought to determine the extent of non-use of grazing permits on federal lands in the West and, if some allotments are vacant, the reasons why producers do not use these allotments. To obtain this information, a questionnaire was developed and sent to every the Forest Service and Bureau of Land Management (BLM) office managing grazing land in the 11 western states. Questionnaires were mailed during the summer of 1984.

High Response Rate

Nearly 90 percent of the questionnaires were returned. These responses included information on 90 percent on the land that these two agencies had allocated for grazing. The results are therefore believed to be a good representation of the grazing land administered by these two federal agencies.

Personnel in some of the offices that did not send a completed questionnaire indicated that they managed land that had relatively high numbers of unused allotments, more than in other forests or BLM districts. Agency personnel indicated that it would have been too much trouble to assemble information on these vacant allotments (see, for example, footnote 1, Table 2). For that reason, the estimates of the number of vacant federal grazing allotments outlined below may not be complete.

Each forest supervisor or district manager was asked to provide the following information about grazing allotments that had not been used during the last 3 years:

1. Reason(s) these allotments had not been used.
2. Number of acres and Animal Unit Months (AUM) of forage that could be removed from these vacant allotments.
3. Type of livestock (cattle, sheep, horses) and season of use.
4. Name and location of each vacant allotment identified.
5. Name and address of the last person(s) who held the grazing permit.

Vacancy Rates Appear To Be Low

The data shown in Tables 1-3 summarize the information obtained from agency personnel. These data indicate that several allotments were vacant during the 1980-1983 period. However, the data shown in Table 4 indicate that less than 1 percent of the allotments administered by the BLM and Forest Service were vacant during this period, although the percentage of vacancy varied by agency and type of use.

For example, nearly 7 percent of the sheep allotments administered by the Forest Service were vacant, while relatively few cattle allotments were vacant. Vacancy rates for cattle and sheep allotments administered by the BLM were lower than for those administered by the Forest Service, a trend which is also evident in Figures 1 and 2. These data indicate that the difference between actual and allotted (permitted) use in the Forest Service is greater than in the BLM. Vacant allotments have decreased on BLM land and increased on Forest Service land. It should be noted, however, that authorized use of Forest Service lands decreased until 1976 and then tended to increase while permitted use of BLM land continued to decline.

Data are not readily available that can be used to determine what percentage of the total AUMs available from the BLM and Forest Service Lands is not used. Some indication of this percentage is suggested by comparing the actual use data in Table 4 with the data in Tables 1-3. This comparison suggests that the number of AUMs that are not being used is a small percentage (less than 1 percent) of the total number of AUMs available from BLM or Forest Service lands.

The data shown in Tables 1-3 concern allotments that were vacant during a 3-year period (1981-1983), and underestimate actual non-use for several reasons. First, some livestock operators may not use grazing allotments during certain years, and this land is generally not reported as vacant. Second, not all questionnaires were returned, a factor which, as explained above, may underreport actual vacant allotments. Third, some allotments are no longer considered to be useable by domestic livestock. Even though these allotments are not grazed, the lack of demand means they are generally not recorded as being "vacant." For example, the Supervisor for the Wenatchee National Forest in Washington reported that an additional 20,000 AUMs of forage could be allocated for sheep, but said they could not afford to develop these allotments and doubted whether sheep producers would want to use these allotments. The omission of these data

TABLE 1. Vacant BLM allotments.

	Cattle			Sheep		
Eleven Western States	Number of Vacant Allotments	AUMs	Acres	Number of Vacant Allotments	AUMs	Acres
Arizona	1	Ephemeral*	10,099	0	0	0
California	3	424	6,241	0	0	0
Colorado	36	3,042	44,863	7	957	17,969
Idaho	6	5,220	69,778	1	108	2,365
Montana	78	2,229	49,084	0	0	0
Nevada	7	35,389	748,225	2	18,167	207,701
New Mexico	27	1,696	32,559	0	0	0
Oregon	15	516	15,665	0	0	0
Utah	14	4,264	99,012	4	889	55,339
Washington	14	623	5,215	0	0	0
Wyoming	16	2,796	31,889	4	6,198	20,834
TOTALS	217	56,199	1,113,241	19	26,319	304,208

*Ephemeral = transitory, dependent on rainfall.

TABLE 2. Vacant Forest Service allotments.

	Cattle			Sheep		
Eleven Western States	Number of Vacant Allotments	AUMs	Acres	Number of Vacant Allotments	AUMs	Acres
Arizona	2	3,485	86,527	0	0	0
California	27	5,771	95,916	10	6,254	77,142
Colorado[1]	14	6,670	119,997[2]	24	14,425	383,705
Idaho	1	600	3,000	28[3]	17,217	196,934
Montana	4	1,329	47,833	0	0	0
Nevada	0	0	0	0	0	0
New Mexico	11	19,678	170,930	0	0	0
Oregon	4	1,949	57,924	5	4,243	132,326
Utah	0	0	0	4	4,643	88,395
Washington	4	1,515	72,590	1	1,048	4,817
Wyoming	7	1,359	35,541	27	9,964	235,482
TOTALS	74	42,356	690,258	99	57,794	923,997

[1]Colorado has another 41 vacant allotments on the Arapoho and Roosevelt National Forest, but the type of use, AUMs, and acres of these allotments are unknown.
[2]The acreage for 1 vacant allotment was not provided.
[3]Two allotments included as vacant for which the acres and AUMS are unknown.

slightly biases the results of this study, but probably not enough to alter the basic results.

Fee Increases Might Decrease Demand

While the data above indicate that relatively few federal grazing allotments in the West are vacant, there are indications that more allotments could become vacant in the future. Agency personnel and former permit holders cited a variety of reasons for vacant allotments, most of which centered around one basic factor—grazing these allotments had become too expensive. This suggests that increases in grazing fees and/or increases in the non-fee costs of using these lands could result even more vacant allotments. These findings also suggest that some grazing lands administered by the Forest Service and the BLM may not provide "bargain" forage to some livestock producers.

The results of this study indicate that some grazing lands are in high demand and are of value for grazing livestock. The results also indicate that there is little demand for other federally administered grazing lands, and that vacancy rates might increase if either the fee or nonfee costs of using these lands were to increase.

TABLE 3. Vacant allotments in the Eleven Western states.

	Cattle			Sheep		
Eleven western states	**Number of vacant allotments**	**AUMs**	**Acres**	**Number of vacant allotments**	**AUMs**	**Acres**
Arizona	3	3,485+	96,626	0	0	0
California	30	6,195	102,768	10	6,254	77,142
Colorado	50	9,712	164,860	31	15,382	401,674
Idaho	7	5,820	72,778	29	17,325	199,299
Montana	82	3,558	96,917	0	0	0
Nevada	7	35,389	748,225	3	18,167	207,701
New Mexico	38	21,374	203,489	0	0	0
Oregon	19	2,465	73,589	5	4,243	132,326
Utah	14	4,264	99,012	8	5,532	143,734
Washington	18	2,138	77,805	1	1,048	4,817
Wyoming	23	4,155	67,430	31	16,162	257,316
TOTALS	291	98,555	1,803,499	118	84,113	1,371,939

+ = plus ephemeral.

TABLE 4. Selected characteristics of BLM and Forest Service grazing allotments.

	BLM	Forest Service	Total
Acreage in allotments	155,737,348	89,144,903	244,902,251
Cattle allotments, number	16,470	5,434	21,904
Sheep allotments, number	1,246	1,495	2,741
Other allotments, number	3,464	338	3,802
Total allotments	21,180	7,267	28,447
Number of permits	21,255	10,091	31,208
Number of operators	21,555	9,969	31,524
Number AUMs cattle (active)	11,297,905	5,395,490	16,693,395
Number AUMs sheep (active)	2,123,012	2,650,977	4,773,989
Number AUMs other (active)	61,341	56,561	117,982
Total AUMs (active)	13,482,258	8,103,108	21,585,366

Source: Forest Service and BLM grazing appraisal report.

REFERENCES

Nielsen, Darwin B. 1982. Grazing fees for public lands: What's fair? *Utah Science* 43:1-5

Torell, L. Allen, E. Bruce Godfrey and Darwin B. Nielsen. 1985. Forage utilization cost differentials in a ranch operation: a case study. *Journal of Range Management.* In press.

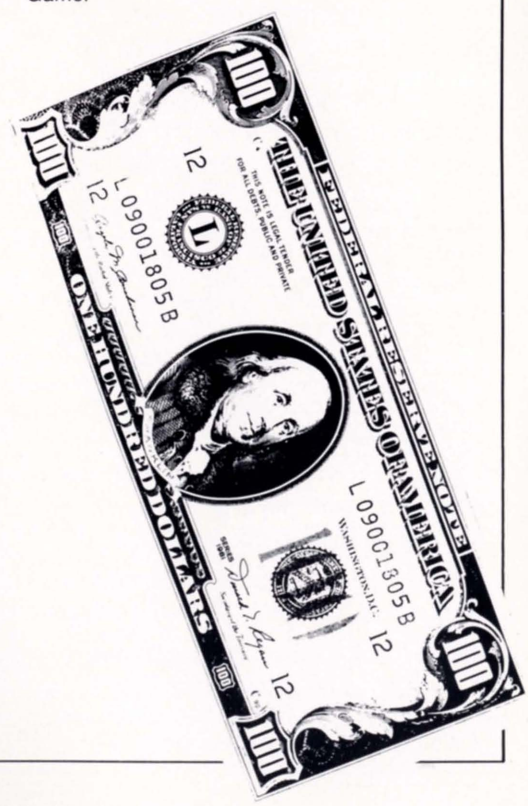
Obermiller, Frederick W. and David K. Lambert. 1984. Costs incurred by permittees in grazing livestock on public lands in various western states. Oregon State University Cooperative Extension Service. EM 8283. 73 p.

ABOUT THE AUTHORS

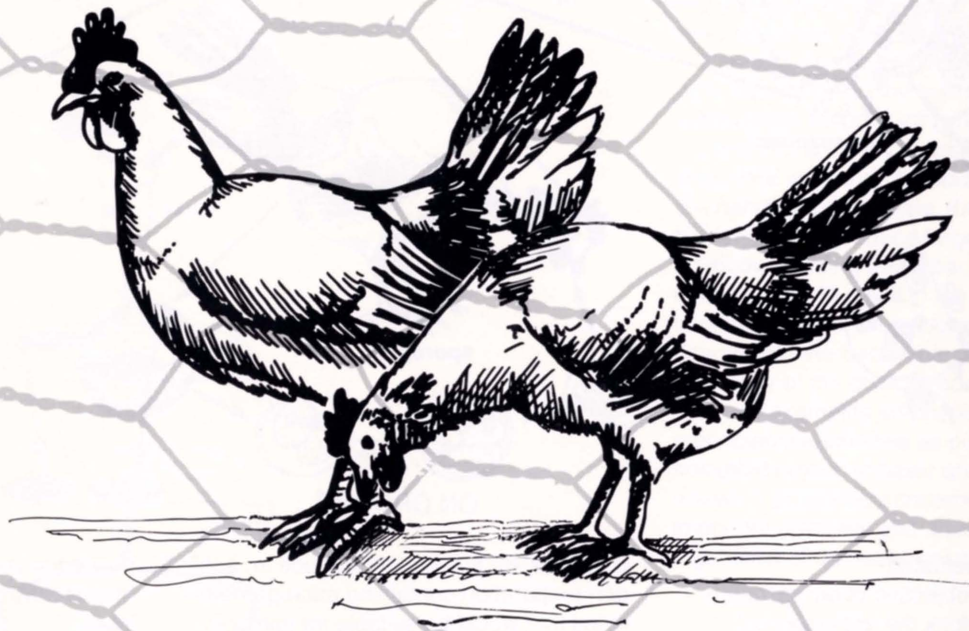
E. Bruce Godfrey is an associate professor in the Department of Economics at Utah State University.

Darwin B. Nielsen is professor of Agricultural Economics. His research interests are in range and ranch economics of beef cattle and sheep production, emphasizing management decision making. In addition, he is interested in the economic impacts of federal government regulations and policies on the range livestock industry. He has worked on contract research and consulting for the U.S. Forest Service over the past twenty years. Dr. Nielsen received his PhD in 1965 from Oregon State University.

Denny D. Lytle is a research associate at Utah State University. He has done wildlife and range research for the Wyoming Fish and Game.



APPLICATION OF HYBRIDOMA TECHNOLOGY TO AVIAN COCCIDIOSIS



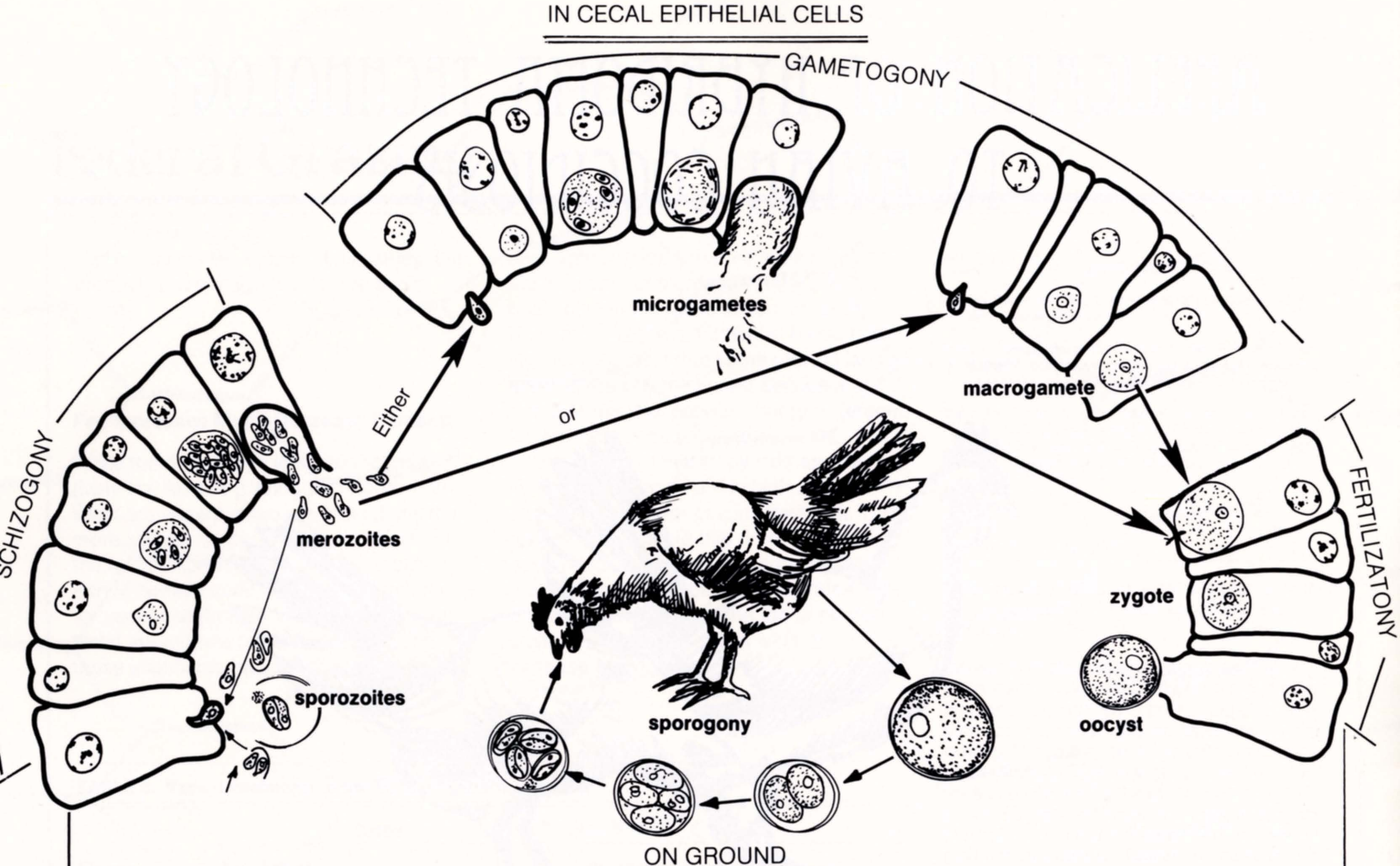
M.A. LAXER, M. C. HEALEY, and N. N. YOUSSEF

Many Americans mistakenly believe parasitic diseases are confined to remote tropics and pose little threat to our agriculture. However, in 1965, the United States Department of Agriculture estimated that American poultry producers lost approximately $35 million dollars due to avian coccidiosis, a disease caused by a protozoan parasite. The 1985 estimate has increased to $300 million. Researchers with the Departments of Biology and Animal, Dairy, and Veterinary Sciences are studying the basic immunobiology of a specific type of avian coccidiosis (cecal coccidiosis of chickens) caused by the protozoan parasite *Eimeria tenella.*

Cecal coccidiosis is an infection of the two blind pouches (ceca) that branch off from the small intestine of a chicken. The parasite is very host-specific and is known to infect only birds (chickens) of the genus *Gallus*. In addition, *E. tenella* parasitizes birds of any age and clinical disease results in birds with limited immunity. Clinical signs of infection include unthriftiness, failure to gain weight, bloody diarrhea, and in severe cases, debilitation and death. The infective stage of the parasite, the oocyst, is produced in very large numbers and intermittently shed in chicken feces. The disease is highly contagious, especially among floor-raised flocks that ingest accumulated oocysts.

The parasite continues its life cycle after oocysts are ingested. Through the mechanical actions of the crop and the effects of digestive enzymes such as trypsin, oocysts and their contents (sporocysts) open and release sporozoites that penetrate epithelial cells lining the ceca. Within the epithelial cells, asexual reproduction results in dramatic increases in the number of parasites and new parasites enter additional host cells. Parasites continue to divide, damaging and destroying more epithelial cells. This massive destruction of the cecal epithelium produces the disease's characteristic pathology.

After two or three generations of asexual reproduction, the parasite begins the sexual phase of its life cycle represented by cells called gamonts. These cells further differentiate into microgametocytes ("sperm") and macrogametocytes ("eggs"). The microgametocytes give rise to free-swimming microgametes that seek out and fuse with macrogametes. This fusion, a form of fertilization, results in a zygote that becomes a new oocyst. This oocyst is then passed with feces and the



disease is perpetuated.

The primary objective of our research program is to block the fertilization of macrogametes with monoclonal antibodies. We also will use monoclonal antibodies as immunologic probes to investigate antigen binding sites on host target cells, and determine the stages in the life cycle where the target antigens develop and are lost.

Hybridomas and Monoclonal Antibodies

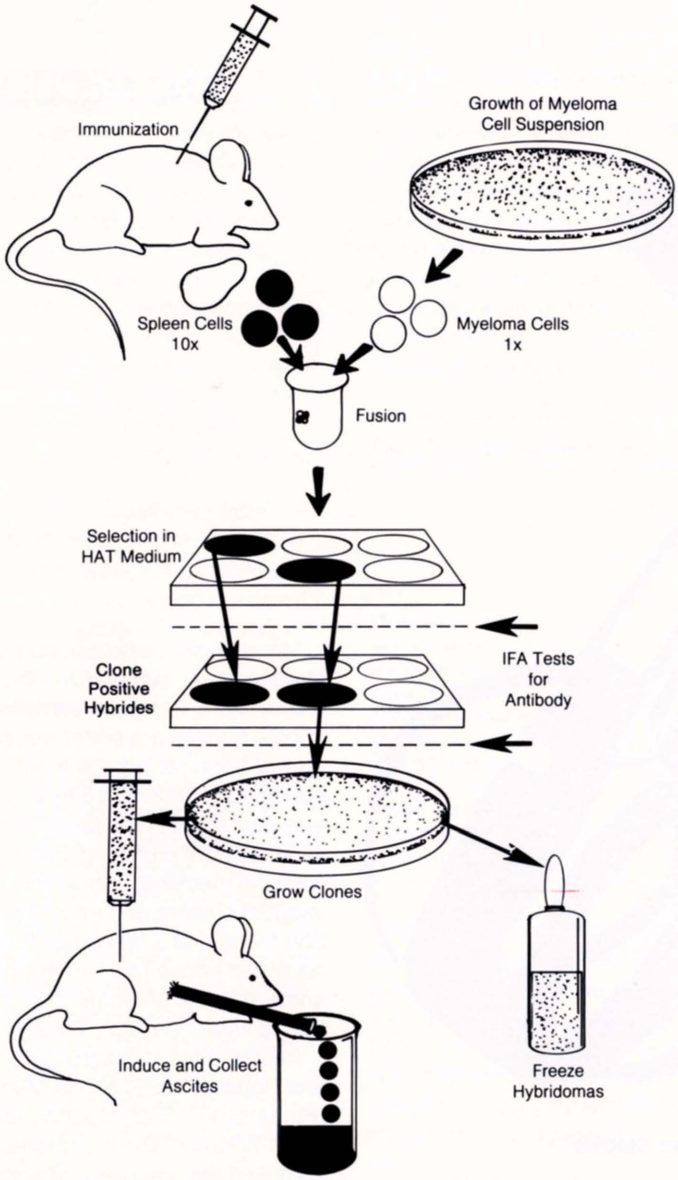
Monoclonal antibody technology became a practical investigative tool in 1975 when Kohler and Milstein fused spleen cells of mice, cells which had been immunized with preselected antigen, with essentially immortal mouse myeloma (cancer) cells. The resultant hybrid cells (hybridomas) were then screened for antibody production. Those producing the desired antibody were cloned and maintained in cell culture. Culture supernatants were then harvested for a continuous supply of antibody.

To produce monoclonal antibodies specific for the microgametocyte stage of *E. tenella*, we first had to produce an antigen preparation containing microgametocytes that would be suitable for immunizing mice. Microgametocytes can be produced either *in vivo* or *in vitro*. Growing parasites *in vitro* using chicken kidney cells resulted in a very clean antigen preparation, although fewer microgametocytes were produced than the *in vivo* method. Several BALB/c mice were subsequently immunized three times by the intraperitoneal route at 2-week intervals, and a booster immunization was given intravenously 3 days prior to sacrifice. Hyperimmune mouse spleens were disrupted to obtain a single-cell suspension, then mixed with an appropriate number of mouse myeloma cells. The actual cell fusion was driven by polyethylene glycol (PEG). Fusion products were transferred to a media that only allowed the growth of hybridoma cells. Developing hybridoma colonies were then assayed for antibody production by the indirect immunofluorescent antibody (IFA) test. Immunoelectrophoresis (IEP) of supernatant from IFA-positive colonies then determined the class and subclass of antibody present. Positive confirmation of the presence of desired antibody was by immuno-electron microscopy (IEM) using collodial gold as a label.

We have now successfully produced four hybridoma cell lines that actively secrete microgametocyte-specific monoclonal antibodies as determined by IFA. One of these hybridomas (clone T1A3B9) has been shown to produce IgG antibody belonging to the IgG2b subclass. Specificity of this monoclonal antibody for the microgametocyte of *E. tenella* has been confirmed by IEM.

Additional Experiments

Experiments were then conducted to determine if the monoclonal antibody could block fertilization *in vitro* systems. The *Eimeria* parasite was grown in chick kidney cells. On the fourth, fifth, and sixth days post-inoculation, while gametogenesis was taking place, monoclonal antibody was added along with the growth media into half the number of experimental tubes. On the seventh day, cell cultures were removed from growing media, fixed, stained, and observed with the light microscope to determine the number of



oocysts, the indicative stage of fertilization. Antibody was added to 20 of 40 tubes. There was a significant reduction in the mean number of oocysts in the antibody-treated tubes (30 vs. 11), an indication that the monoclonal antibody does, in some manner, block fertilization in *E. tenella*.

Additional experiments, utilizing immuno-electron microscopy are underway to determine the location of the antibody-binding sites on target cells, and to determine if morphological changes occur on the microgametocytes as a result of antibody treatment. This work should help in understanding exactly how the antibody inhibits fertilization.

Other experiments using immuno-electron microscopy will determine when the target antigen first appears, where it is located, and how long it persists.

Future Research

Additional areas of research are possible with the availability of monoclonal antibodies specific for the sexual stage of *E. tenella*. For example, these monoclonal antibodies might be used to isolate, purify, and characterize antigens on the microgametocyte. Once purified, these antigens may confer protective immunity to birds. If so, it should be possible to develop a commercial vaccine. Similar vaccines could then be developed for coccidiosis in other domestic animals.

It should also be possible to isolate the gene sequence on the hybridoma DNA responsibile for producing protective monoclonal antibody. If this gene sequence were then introduced into *Escherichia coli* bacteria, the modified bacteria could produce large quantities of antibody. Feeding these bacteria to chickens would result in the secretion of large amounts of monoclonal antibody directly into the ceca where the major pathology of the disease occurs.

These examples emphasize the utility of monoclonal antibodies as powerful immunological probes in basic and applied research programs concerning medically important diseases and disease-causing organisms of domestic animals.

REFERENCES

Kohler, G., C. Milstein. 1975. Continuous cultures of fused cells secreting antibody of predefined specificity. *Nature*. 256:495-497.

Schmidt, G. D., L. S. Roberts. Foundations of Parasitology. C. V. Mosby Co., St. Louis, MO. 1982. pp. 127.

ABOUT THE AUTHORS

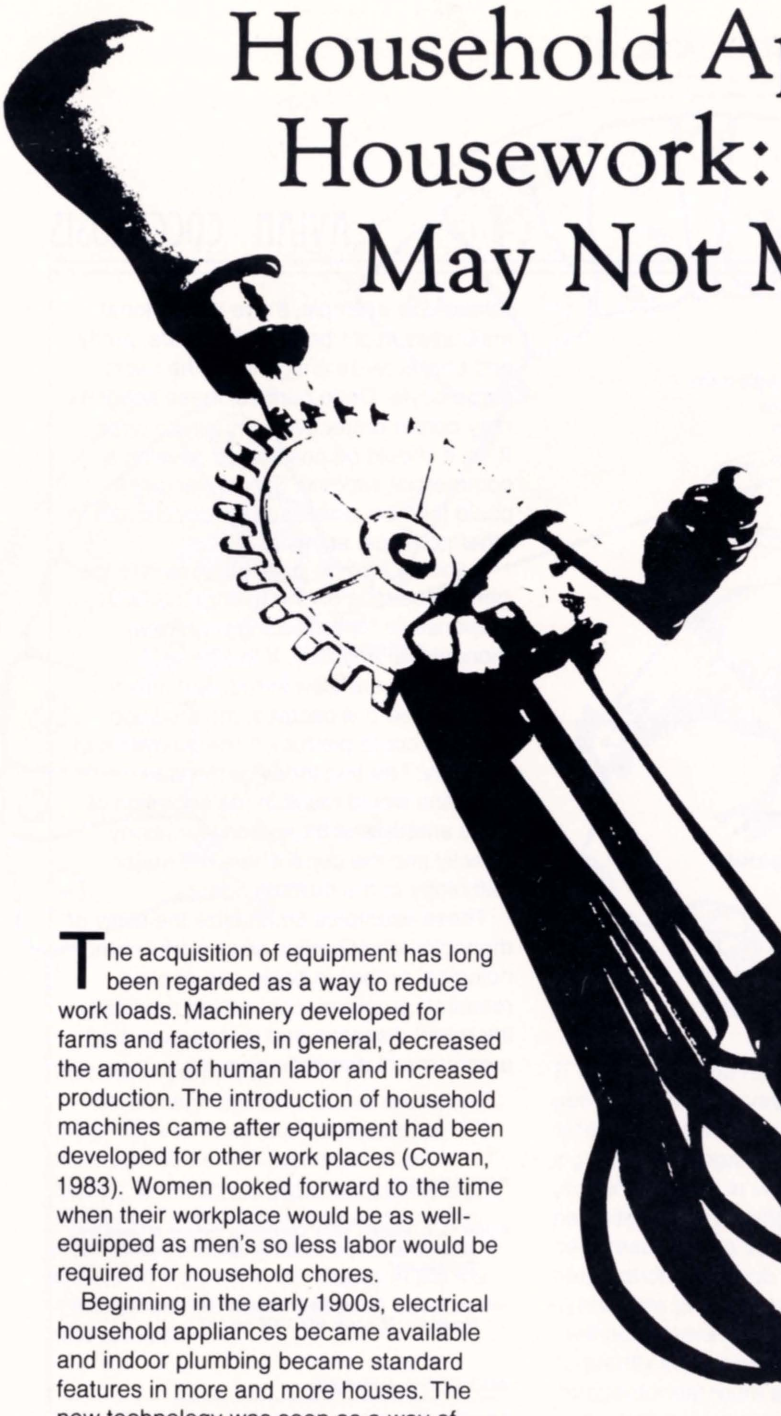
Marc A. Laxer is currently a doctoral candidate in the Department of Biology, Utah State University. His primary research interest is the immunobiology of coccidial infections.

Mark C. Healey is an assistant professor in the Department of Animal, Dairy, and Veterinary Sciences, with joint appointment in the Department of Biology. He received his PhD from Purdue University and his DVM from Mississippi State University. His current research interests center around the application of hybridoma tehcnology to infections and parasitic diseases.

Nabil N. Youssef is a professor in the Department of Biology. He received his PhD from Utah State University. His major research interests are in developmental biology, neurobiology, and host-parasite relationships in animal systems.

Household Appliances and Housework: More Equipment May Not Mean Less Work

JANE McCULLOUGH



The acquisition of equipment has long been regarded as a way to reduce work loads. Machinery developed for farms and factories, in general, decreased the amount of human labor and increased production. The introduction of household machines came after equipment had been developed for other work places (Cowan, 1983). Women looked forward to the time when their workplace would be as well-equipped as men's so less labor would be required for household chores.

Beginning in the early 1900s, electrical household appliances became available and indoor plumbing became standard features in more and more houses. The new technology was seen as a way of reducing the drudgery of housework. In an Experiment Station publication of 1912, Lead D. Widtsoe extolled the virtues of the labor-saving equipment and encouraged men to consider adding it to their homes to reduce women's overload of work:

> This makes one of two things necessary; either the average woman must have ways and means of performing her work with as little expenditure of energy as possible, or else she is going to wear out completely, and the man will have to get a new wife as he gets a new mowing machine (p. 41).

Early Time Use Studies

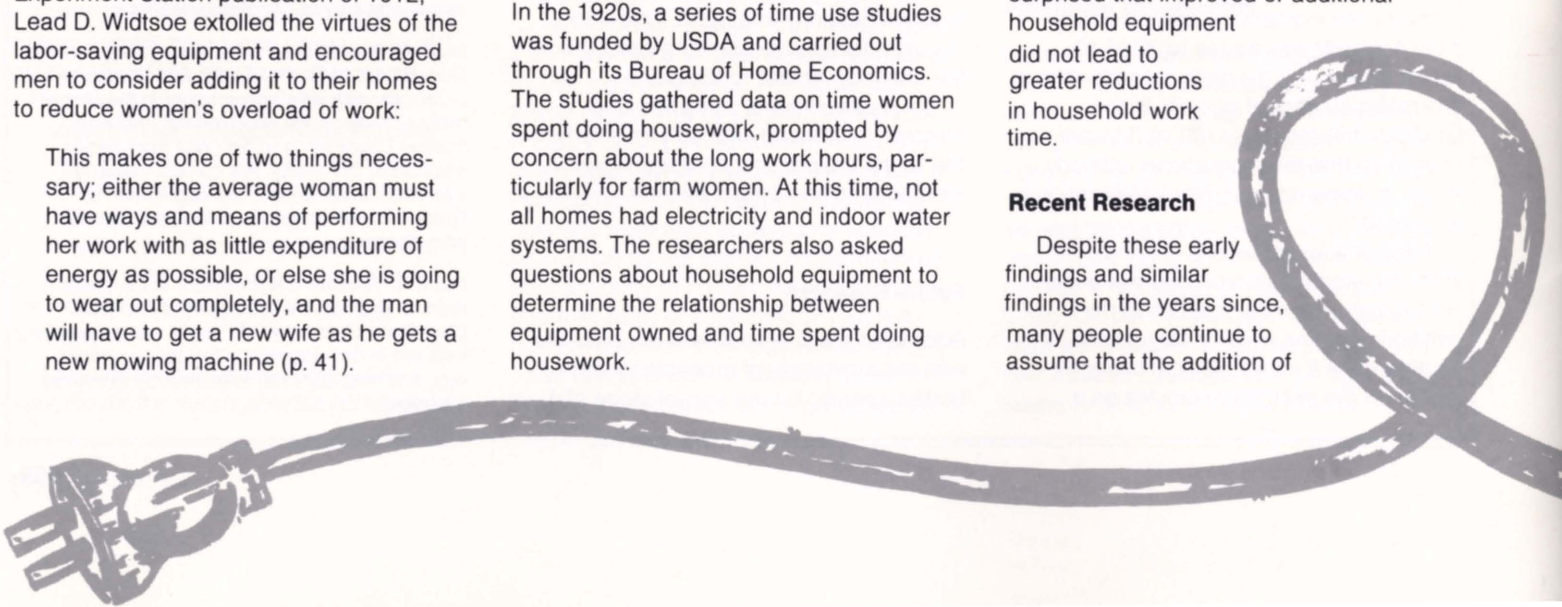
In the 1920s, a series of time use studies was funded by USDA and carried out through its Bureau of Home Economics. The studies gathered data on time women spent doing housework, prompted by concern about the long work hours, particularly for farm women. At this time, not all homes had electricity and indoor water systems. The researchers also asked questions about household equipment to determine the relationship between equipment owned and time spent doing housework.

Maud Wilson, who carried out the Oregon study, summarized the researchers' interest when she asked, "Some houses are better equipped than others. What advantage to the well-equipped?" (Wilson, 1929, p. 10). Wilson was interested in the presence of electricity and indoor plumbing, and the type of washing machine, iron, stove or range, vacuum cleaner and sewing machine. She found that a homemaker in a well-equipped house had "an average net addition to her personal time of about an hour a week" (Wilson, 1929, p. 37).

Researchers in Washington (Arnquist and Roberts, 1929) and in Montana (Richardson, 1933) reported findings similar to Wilson's. The researchers were surprised that improved or additional household equipment did not lead to greater reductions in household work time.

Recent Research

Despite these early findings and similar findings in the years since, many people continue to assume that the addition of



household equipment substantially reduces household work time. The variety of equipment available for household use has increased as has the proportion of households owning many pieces of equipment, such as an automatic clothes washer, clothes dryer, self-defrosting refrigerator and microwave oven.

In the late 1970s, a new household time use study, a USDA Regional Research Project, involved researchers in 11 states, including California, Connecticut, Louisiana, New York, North Carolina, Ohio, Oklahoma, Oregon, Texas, Utah, Virginia, and Wisconsin.

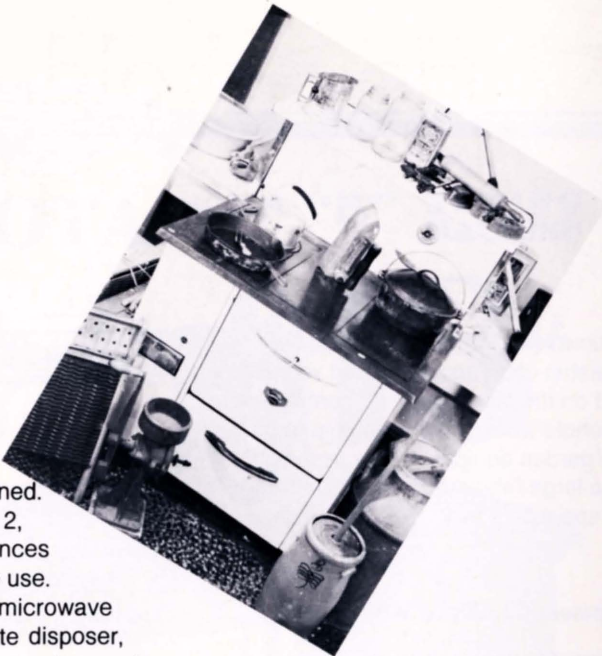
Time-use data were gathered from 2,100 two-parent, two-child families, 210 from Utah. For two days, each family kept track of time use in a diary and indicated the household equipment they owned.

Appliances Owned

The appliances included in the analysis are usually considered to be time-savers. Approximately the same proportion of Utah families owned the appliances as did the families in the total sample (Table 1). Where there were differences, a higher proportion of the Utah families owned the equipment, except for power yard/garden equipment and microwave ovens. On the average, families owned seven of the eleven appliances. In Utah, almost all of the families studied owned a vacuum cleaner and an automatic washer. The trash compactor was the least popular piece of equipment.

Equipment and Housework Time

Time spent on various tasks was studied to analyze the relationship between time use and appliance ownership. Unfortunately, categories of time use did not always correspond to tasks associated with various appliances. For example, washing dishes by hand would also have been recorded in the dishwashing category even if a respondent owned a dishwasher. Even when this was a factor, trends could still be determined.

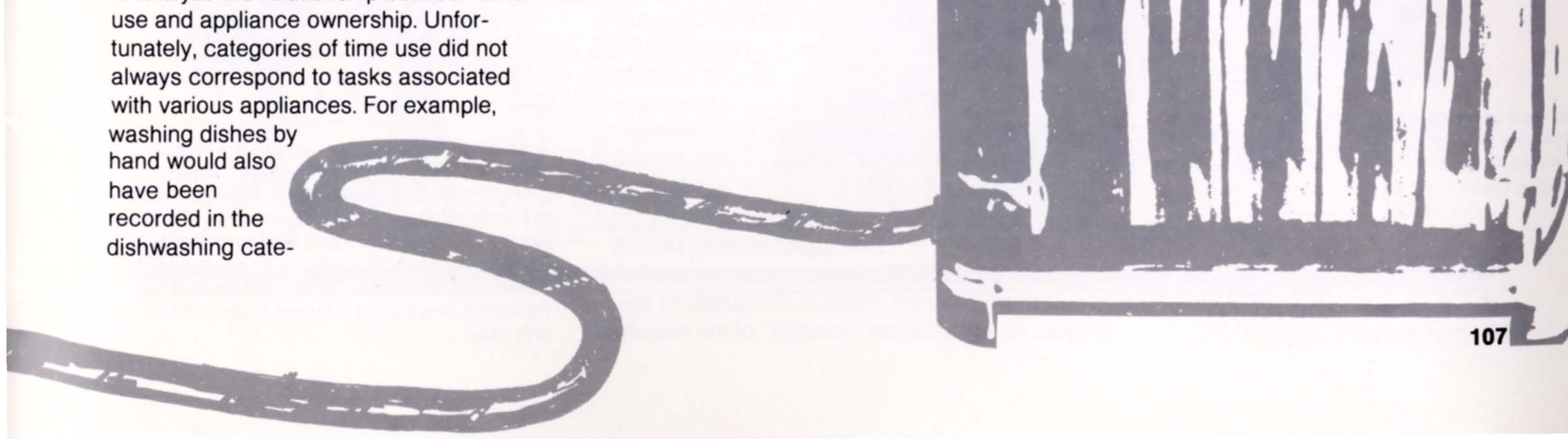


As can be seen in Table 2, ownership of various appliances had different effects on time use. Homemakers who owned a microwave oven, dishwasher, food waste disposer, trash compactor, automatic washer, and clothes dryer spent less time on the related tasks than non-owners. The differences, however, are very small—an average of 3 minutes per day for each task. The most interesting finding is the large increase in time spent on related tasks associated with ownership of a vacuum cleaner, power yard/garden equipment and a sewing machine.

TABLE 1. Appliances owned.

	Utah Families	NEH113 Families
	Percent	
Appliance		
Microwave oven	10	13
Dishwasher	67	62
Garbage disposer	62	43
Trash compactor	8	5
Automatic washer	100	97
Clothes dryer	93	92
Sewing machine	91	88
Vacuum cleaner	100	98
Power yard equipment	78	87
Auto defrost refrigerator	79	81
Auto cleaning oven	33	35

There are two obvious points concerning husbands' time spent on household tasks. One, except for maintenance of home and yard, husbands contribute very



little time to household work; and two, ownership of an appliance had very little effect on the time husbands contributed to household work. Only ownership of power yard/garden equipment was associated with a large (about 50 percent) increase in time spent on a task.

TABLE 2. Household appliances and related housework time.

		Home makers mean min. per day	Husbands mean min. per day
Microwave oven and food preparation	owners	75.4	7.7
	nonowners	78.7	8.3
Dishwasher and dishwashing	owners	32.1	2.9
	nonowners	35.6	3.3
Food waste disposer and dishwashing	owners	32.1	2.8
	nonowners	34.4	3.2
Trash compactor and dishwashing	owners	30.7	2.5
	nonowners	33.6	3.1
Auto defrost refrigerator and housecleaning	owners	60.4	3.2
	nonowners	57.7	3.1
Power yard/garden equipment and maintenance	owners	28.1	48.3
	nonowners	19.8	35.3
Auto washer and clothing care	owners	28.8	1.0
	nonowners	31.6	2.4
Clothes dryer and clothing care	owners	28.6	.9
	nonowners	32.1	2.3
Self-cleaning oven and housecleaning	owners	59.5	3.3
	nonowners	60.0	3.1
Sewing machine and clothing const.	owners	16.5	.1
	nonowners	4.5	.5

Equipment Combined With Time

The results indicate that equipment is used in different ways. Some appliances require relatively little operator attention while others require almost constant attention. For example, a washing machine requires little attention after it has been loaded and started while a sewing machine requires constant attention. All of the appliances related to increased time use (a vacuum clearner, sewing machine, and power yard/garden equipment) require constant attention. The appliances related to decreased time use operate fairly independently but, on the average, saved relatively little time.

Antique collections courtesy of Finders Keepers, Logan, Utah

Household members who purchase equipment to substantially reduce time spent in household work may be disappointed. A consumer should think how the equipment combines with the operator's time before purchasing an appliance. For example, a microwave oven may substantially reduce cooking time but have little effect on preparation and cleanup time, tasks which require the active involvement of the cook. There are many reasons for purchasing a new piece of household equipment in addition to anticipated time savings. The appliance may reduce physical exertion, make the work more pleasant, improve the quality of the product or enhance the "prestige" of the household. None of these are bad reasons for buying new equipment, but they are not related to the goal of saving time. A more thorough analysis of the actual benefits of a new household appliance could make sure the equipment meets the user's expectations.

REFERENCES

Arnquist, I. F., and Roberts, E. H. The present use of work time of farm equipment. Washington State College Agricultural Experiment Station Bulletin No. 234, July 1929.

Cowan, R. S. More work for mother.Basic Books, Inc.:New York, 1983.

Richardson, J. E. The use of time by rural homemakers, Montana State Agricultural Experiment Station Bulletin No. 271, February 1933.

Widtsoe, L. D. Labor saving devices for the farm home. Utah Agricultural College Experiment Station Circular No. 6, June 1912.

Wilson, M. Use of time by Oregon farm homemakers. Agricultural Experiment Station Bulletin No. 256, Corvallis, Oregon: Oregon Experiment Station Agricultural College, November 1929.

ABOUT THE AUTHOR

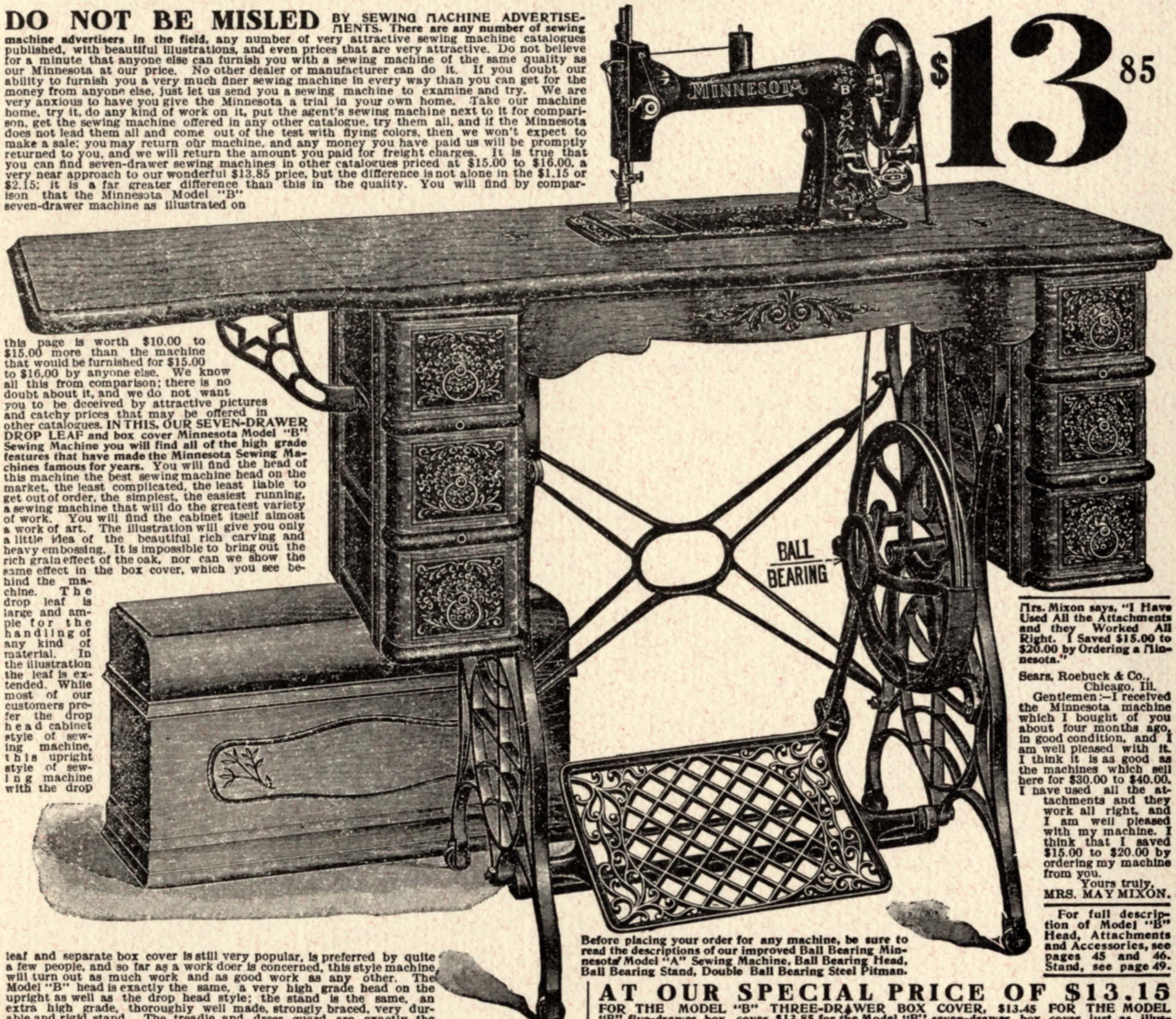
Jane McCullough is the Head of the Home Economics & Consumer Education Department. She received a PhD from Michigan State in Family Ecology, an MS degree from USU in Household Economics and Management, and a BS degree from USU in Home Economics Education. She worked at CSRS (Cooperative State Research Service) as a Home Economist for one year.

Certificate of Guaranty

OUR 7-DRAWER DROP LEAF AND BOX COVER MINNESOTA MODEL "B" SEWING MACHINE

$13.85

DO NOT BE MISLED BY SEWING MACHINE ADVERTISEMENTS. **There are any number of sewing machine advertisers in the field,** any number of very attractive sewing machine catalogues published, with beautiful illustrations, and even prices that are very attractive. Do not believe for a minute that anyone else can furnish you with a sewing machine of the same quality as our Minnesota at our price. No other dealer or manufacturer can do it. If you doubt our ability to furnish you a very much finer sewing machine in every way than you can get for the money from anyone else, just let us send you a sewing machine to examine and try. We are very anxious to have you give the Minnesota a trial in your own home. Take our machine home, try it, do any kind of work on it, put the agent's sewing machine next to it for comparison, get the sewing machine offered in any other catalogue, try them all, and if the Minnesota does not lead them all and come out of the test with flying colors, then we won't expect to make a sale; you may return our machine, and any money you have paid us will be promptly returned to you, and we will return the amount you paid for freight charges. It is true that you can find seven-drawer sewing machines in other catalogues priced at $15.00 to $16.00, a very near approach to our wonderful $13.85 price, but the difference is not alone in the $1.15 or $2.15; it is a far greater difference than this in the quality. You will find by comparison that the Minnesota Model "B" seven-drawer machine as illustrated on this page is worth $10.00 to $15.00 more than the machine that would be furnished for $15.00 to $16.00 by anyone else. We know all this from comparison; there is no doubt about it, and we do not want you to be deceived by attractive pictures and catchy prices that may be offered in other catalogues. **IN THIS, OUR SEVEN-DRAWER DROP LEAF and box cover Minnesota Model "B" Sewing Machine you will find all of the high grade features that have made the Minnesota Sewing Machines famous for years.** You will find the head of this machine the best sewing machine head on the market, the least complicated, the least liable to get out of order, the simplest, the easiest running, a sewing machine that will do the greatest variety of work. You will find the cabinet itself almost a work of art. The illustration will give you only a little idea of the beautiful rich carving and heavy embossing. It is impossible to bring out the rich grain effect of the oak, nor can we show the same effect in the box cover, which you see behind the machine. The drop leaf is large and ample for the handling of any kind of material. In the illustration the leaf is extended. While most of our customers prefer the drop head cabinet style of sewing machine, this upright style of sewing machine with the drop leaf and separate box cover is still very popular, is preferred by quite a few people, and so far as a work doer is concerned, this style machine will turn out as much work and as good work as any other. The Model "B" head is exactly the same, a very high grade head on the upright as well as the drop head style; the stand is the same, an extra high grade, thoroughly well made, strongly braced, very durable and rigid stand. The treadle and dress guard are exactly the same. The only difference is in the style of woodwork of the cabinet. Each and every machine is a leader in its class, and we guarantee you cannot duplicate it, style for style, quality for quality, for much less than double the price we ask, and no matter whether you order the Model "B" sewing machine in this seven-drawer upright style with box cover, or the drop head cabinet style described on the next page, or the Model "A" in any of the various styles we furnish it, you will be getting a wonderful bargain in a sewing machine. You will be saving a great deal of money, getting a very fine sewing machine, much better than the sewing machine offered by any other catalogue house, even very much better than the sewing machines offered by dealers and agents at $40.00.



Mrs. Mixon says, "I Have Used All the Attachments and they Worked All Right. I Saved $15.00 to $20.00 by Ordering a Minnesota."

Sears, Roebuck & Co.,
Chicago, Ill.

Gentlemen:—I received the Minnesota machine which I bought of you about four months ago, in good condition, and I am well pleased with it. I think it is as good as the machines which sell here for $30.00 to $40.00. I have used all the attachments and they work all right, and I am well pleased with my machine. I think that I saved $15.00 to $20.00 by ordering my machine from you.

Yours truly,
MRS. MAY MIXON.

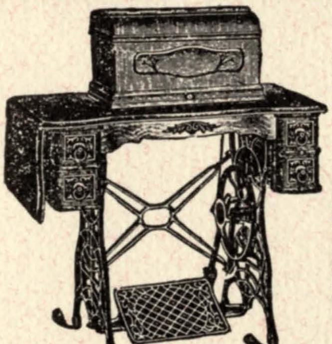
For full description of Model "B" Head, Attachments and Accessories, see pages 45 and 46. Stand, see page 49.

Before placing your order for any machine, be sure to read the descriptions of our improved Ball Bearing Minnesota Model "A" Sewing Machine, Ball Bearing Head, Ball Bearing Stand, Double Ball Bearing Steel Pitman.

AT OUR SPECIAL PRICE OF $13.15

FOR THE MODEL "B" THREE-DRAWER BOX COVER, $13.45 FOR THE MODEL "B" five-drawer box cover, $13.85 for the Model "B" seven-drawer box cover, just as illustrated, we furnish a sewing machine on board the cars at our factory in Dayton, Ohio, from which point the customer pays the freight. However, the freight charges are small compared with your saving in price. The sewing machine weighs, strongly crated for shipment, 120 pounds, and no matter where you live, we guarantee that you will make a big saving at our price after you have paid the freight charges. With each Minnesota Sewing Machine we furnish a complete set of accessories, as shown on page 46. We do not include the case of attachments in making our selling prices, as there are many people who do not want the attachments. If you want attachments, we can furnish them for 75 cents additional, a complete set of the highest grade attachments, as explained on page 46.

DESCRIPTION OF WOODWORK ON OUR MINNESOTA MODEL "B" SEWING MACHINES.



No. 26K231

THE WOODWORK ON OUR MODEL "B" SEWING Machines is of a very much higher grade than is usually used in sewing machines. It is made especially for our machines, under contract, by the largest manufacturers of sewing machine woodwork in the world, who supply cabinets only for the highest grade sewing machines, and it cannot be in any way classed with the woodwork commonly used on machines that sell generally at $25.00 or less.

MATERIALS. ONLY THE MOST SELECT GRADE OF solid oak is used in the construction of our Model "B" woodwork. It is carefully selected with reference to grain and color and is thoroughly aired and kiln dried to insure against warping, splitting or cracking.

DESIGN. THE MINNESOTA MODEL "B" CABINET IS A model of beauty and artistic design, second only to our Model "A." It is made on the lines of the high grade, up to date furniture, especially designed for us and not made for nor used on any other machines.

TABLE. THE TABLE IS MADE OF BUILT UP STOCK AND faced with highly figured quartered oak. This construction has proven the most durable, being practically indestructible. The front edge of the table is handsomely shaped. All tables on the upright box cover Model "B" machines, as illustrated, have a drop leaf, which, when raised into place, is supported by an iron brace and produces a table of ample length for any and all requirements.

DRAWER FRAMES. THE DRAWER FRAMES IN which the side drawers are fitted are of the latest skeleton type, much handsomer in appearance and far preferable to the old fashioned solid cases.

DRAWERS. THE DRAWERS ARE VERY LARGE AND roomy, made with rounded corners to harmonize with the table. The fronts are handsomely decorated with drop carvings of floral design and fitted with brass, nickel plated and polished ring pulls. The center drawer is made of built up stock, with swell front; the interior is partitioned off for bobbins, needles and other accessories, which are in constant demand when the machine is being used. Every drawer is fitted with a lock and one key fits them all.

FINISH. IN POINT OF FINISH OUR MODEL "B" MACHINE is strictly first class and of the very latest golden color, the popular finish put on high grade oak furniture. Before the finish is put on, the woodwork is most carefully sandpapered so that the varnish, which is of the very best quality, produces a hard glossy surface. The table is hand rubbed and polished.

COVER. ALL UPRIGHT MACHINES ARE PROVIDED with box cover, made of built up stock, surfaced with quartered oak and strengthened with mouldings. The front is ornamented with carved, raised panel. The cover is fitted with socket hinges and lock, so that when placed on the machine it can be locked, thereby affording full protection to the head.

No. 26K230	Model "B" Three-Drawer Box Cover.	Price	$13.15
No. 26K231	Model "B" Five-Drawer Box Cover.	Price	13.45
No. 26K232	Model "B" Seven-Drawer Box Cover.	Price	13.85

The above prices do not include attachments. We furnish a complete set at 75 cents extra, as fully explained on page 46
The small illustration shows the Model "B" upright machine with five drawers at $13.45. Attachments, 75 cents extra.

UTAH SCIENCE

UTAH AGRICULTURAL EXPERIMENT STATION
UTAH STATE UNIVERSITY
LOGAN, UTAH 84322-4810

Doyle J Matthews DIRECTOR

Address Correction Requested

U.S. MAIL

BULK RATE

POSTAGE & FEES
PAID AGRI 101
PERMIT NO. G 269

UTAH SCIENCE is a quarterly magazine devoted primarily to the report of experiment station research in agriculture and related fields of study (i.e., crops, land and water resources, animal/dairy management, forestry, home and community life, human nutrition and development). The purpose of the magazine is to offer a tangible and usable representation of the expenditure of tax dollars, that will unite the public with the experiment station through shared research results. Published by the Utah Agricultural Experiment Station, Utah State University, Logan, Utah 84322-4810.

The magazine will be sent free on request. Please include a mailing label from a recent issue of UTAH SCIENCE with any request for change of address.

Printed by USU PRINTING SERVICES, Logan, Utah 84322-3035