UTAH SCIENCE

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

Doyle J. Matthews
DIRECTOR

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UTAH STATE UNIVERSITY

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Research concerning lunar farms and plant physiology also promises to benefit earth-bound agriculture.
The number of elderly—those 60 years of age and older—in the United States has increased dramatically in the last few decades. This trend is expected to continue.

In Cache County, census data indicate that the number of elderly increased from 2,787 in 1940 to 5,680 in 1980; in Box Elder County, the number of elderly increased from 1,534 in 1940 to 3,867 in 1980. By the year 2010, the number of elderly in these counties is expected to increase by nearly 50 percent.

Government and private agencies provide a variety of services to the elderly. To determine the adequacy of existing services and whether additional services are needed, we surveyed the elderly residents of Cache and Box Elder counties during 1986. The survey was sponsored by the Bear River Association of Governments and the Utah Agricultural Experiment Station.¹

Of approximately 1,000 questionnaires delivered, 365 were returned. Questionnaires were returned from 86 percent of the households surveyed in which senior citizens resided.

Females More Likely to Use Services

Of the 12 types of services provided (see categories in Table 2), senior citizens were
TABLE 1. Use of social services.

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>35.4</td>
<td>64.6</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>22.5</td>
<td>77.5</td>
</tr>
<tr>
<td>Female</td>
<td>43.2</td>
<td>56.8</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60-69</td>
<td>20.6</td>
<td>79.4</td>
</tr>
<tr>
<td>70-79</td>
<td>45.4</td>
<td>54.6</td>
</tr>
<tr>
<td>80-89</td>
<td>48.9</td>
<td>51.1</td>
</tr>
<tr>
<td>90+</td>
<td>33.3</td>
<td>66.7</td>
</tr>
<tr>
<td>Income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under $10,000</td>
<td>46.7</td>
<td>53.3</td>
</tr>
<tr>
<td>$10,000-$19,000</td>
<td>32.7</td>
<td>67.3</td>
</tr>
<tr>
<td>$20,000-$29,000</td>
<td>34.0</td>
<td>66.0</td>
</tr>
<tr>
<td>$30,000-$39,000</td>
<td>26.9</td>
<td>73.1</td>
</tr>
<tr>
<td>$40,000+</td>
<td>10.4</td>
<td>89.6</td>
</tr>
<tr>
<td>Marital status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never married</td>
<td>28.6</td>
<td>71.4</td>
</tr>
<tr>
<td>Married</td>
<td>27.1</td>
<td>72.9</td>
</tr>
<tr>
<td>Divorced</td>
<td>42.9</td>
<td>57.1</td>
</tr>
<tr>
<td>Widowed</td>
<td>51.0</td>
<td>49.0</td>
</tr>
</tbody>
</table>

More aware of meal programs, recreation services, and transportation services. Awareness tended not to vary by sex, age, income and marital status.

Although many were aware of the services, only about one-third of the respondents had ever used any of the services (Table 1). Females were twice as likely to use the services as males and, as anticipated, use tended to increase with age. Use of services by widows (51 percent) was higher than among those who were married (27.1 percent).

Table 2 shows how users perceived the services and the services in which nonusers were interested.

Users gave services high ratings. More than three-quarters of users rated the services as "excellent" or "good." About one-third who had not used the services said they were interested in using these services, particularly legal services, meal programs, assistance in income tax, insurance, and Social Security, and health clinics. About two-thirds of the respondents ranked meal programs and transportation services among the three most important services.

Fewer Than Half Visited a Senior Center

Only about 42 percent of the elderly ever visited a senior center, and 62 percent of the users visited centers less than once a month. More than 90 percent of the respondents reported that they were able to pay for food, clothing, housing and rent, and three-fourths said they were able to pay for utilities and health care. However, about a third of those with low incomes said they were unable to pay for utilities, medicine, and health care.

Fewer than 7 percent of the respondents received food stamps, welfare assistance or church assistance. About three-fourths received Social Security and Medicare, while about 20 percent were on Medicaid.

Senior citizens were also asked where they went for advice about personal and other problems. Of those who had received advice the previous year, about 40 percent received advice from family doctors and about 30 percent received advice from family members and friends. Fewer than 10 percent obtained advice from counselors, social or case workers, mental health centers and police; about 15 percent had received advice from church representatives.
Survey results indicated that a large proportion of the elderly were neither aware of nor utilized many social services. Most elderly seem to be able to meet household and personal expenditures. However, it appears that the social service needs of a significant proportion of the elderly, particularly those with low incomes, are still not being met.

1Survey results are reported in Research Report 119, “An Assessment of Social Service Needs of the Elderly in Northern Utah.” Copies of the report are available from the UAES Information Office.

REFERENCES


ABOUT THE AUTHORS

Yun Kim is professor of sociology and director of the Population Research Laboratory at USU. His main research interests concern migration and the use of demographic data in planning.

Maria Wilson is a Ph.D. student in sociology at USU.

Setsuko Chiba is a M.S. student in sociology at USU.
Since the early 1900s, several studies have examined the economic feasibility of growing and marketing vegetables in Utah. Generally, these studies have concluded that these enterprises would not be profitable due to the relatively short growing season, limited markets, relatively low returns and potential reluctance of farmers to switch from traditional crops.

We recently completed a study of the costs and returns for a vegetable processing facility located in Richfield, Utah.* Although land and related costs are site specific, the general findings are applicable to similar enterprises at

other locations in the state.

Current Production

In the western states, most vegetables are produced in California, Washington and Oregon, a pattern that is likely to continue in the foreseeable future. Of the major types of vegetables, Utah now has significant acreage in onions (1,600 acres) and potatoes (6,500 acres). While many other vegetables could be grown in the state, production might not be profitable in certain counties. Budgets, based on current prices and recommended practices, were prepared for snap beans, broccoli, carrots, sweet corn, onions, peas, potatoes, zucchini and apples, the crops most likely to result in a favorable return when produced in Utah.

The average yields, costs and returns for selected vegetables are shown in Table 1. Even though it apparently would be profitable to produce many types of vegetables, Utah farmers have little experience producing these vegetables on a commercial scale and would need much more information before beginning production. Profitability also hinges on the availability of markets and arrangements for harvest. The budgets were prepared following the assumptions that custom harvesting was available, even though none now exists.

Potential Markets

The food-processing industry has been characterized by consolidation, over capacity and increased foreign competition, especially for the more labor-intensive crops. In spite of efforts to modernize processing facilities and cut costs, many of the major vegetable processing firms in the United States have recently lost money. However, the economic outlook has been more favorable for freezing plants than for canning plants. Consumption of frozen fruits and vegetables increased 20 percent between 1980 and 1984, and has only recently leveled off. Frozen food processing plants have also operated at higher capacities than canning plants.

Overall, the market for frozen fruits and vegetables should remain strong. Some analysts predict it will grow by 7.5 percent through 1994. The greatest increase in consumption is predicted for broccoli, carrots, onions, sweet corn and potatoes. Consequently, we examined the economic feasibility of a plant processing frozen fruits and

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield value of price (tons/A) ($/A) ton</th>
<th>Total costs acres ($/ac)</th>
<th>Gross receipts ($/lb.)</th>
<th>Net returns ($/lb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onions</td>
<td>10.00 160</td>
<td>990</td>
<td>1,600</td>
<td>610</td>
</tr>
<tr>
<td>Broccoli</td>
<td>6.00 356</td>
<td>1,680</td>
<td>2,136</td>
<td>457</td>
</tr>
<tr>
<td>Potatoes</td>
<td>13.00 90</td>
<td>821</td>
<td>1,170</td>
<td>349</td>
</tr>
<tr>
<td>Carrots</td>
<td>18.00 48</td>
<td>652</td>
<td>864</td>
<td>212</td>
</tr>
<tr>
<td>Snap beans</td>
<td>3.50 20 174</td>
<td>454</td>
<td>629</td>
<td>175</td>
</tr>
<tr>
<td>Broccoli (transplant)</td>
<td>6.00 356</td>
<td>1,972</td>
<td>2,136</td>
<td>164</td>
</tr>
<tr>
<td>Corn, sweet</td>
<td>9.00 25 66</td>
<td>481</td>
<td>619</td>
<td>138</td>
</tr>
<tr>
<td>Zucchini</td>
<td>8.00 100</td>
<td>689</td>
<td>800</td>
<td>111</td>
</tr>
<tr>
<td>Peas</td>
<td>1.50 20 212</td>
<td>391</td>
<td>338</td>
<td>-53</td>
</tr>
<tr>
<td>Apples*</td>
<td>18.00 100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Since apples are a perennial crop that requires 3-4 years for initial production, no farm level receipts or costs are shown.
vegetables.

To be economically feasible, a processing plant must operate as efficiently as possible and/or as long as economically possible each year. Storage facilities are also essential since any surplus product must be stored until demand and prices are more favorable.

A major factor in the frozen food industry is the investment in food stocks. In any given year, the total supply of food equals the sum of the carry-over from the previous year, imports and the current year’s production. Annual consumption is only a portion of the total supply of frozen food available in any given year. Thus, processors can either hold carry-over supplies through part of another year or try to sell the excess at reduced prices. The former alternative requires an expensive investment in storage and may cause problems if farmers must adjust production to deplete inventory while the latter alternative can reduce profits.

As shown in Table 2, the frozen vegetable processing industry is concentrated in California and the Pacific Northwest, regions which will probably remain the major processing areas for frozen vegetables.

A major problem facing any vegetable processor in Utah is the relatively small population of the Rocky Mountain region. Large processing plants generally are located near large population centers, which explains why most of the vegetable and fruit processing plants in the West are located in California, with a population of almost 24 million. This is far greater than the combined population of the Rocky Mountain area—Utah (1.5 million), Colorado (2.9 million), Wyoming (0.5 million), Idaho (0.9 million) and New Mexico (1.5 million). Given the current population distribution, it is likely that processing will remain concentrated in California and the Pacific Northwest.

However, some secondary food processors that serve the entire western United States have recently located in Utah. These firms will require more processed vegetables and fruits. Of course, sales to these secondary processors will still depend largely on price and quality. It is also likely that many of these firms would contract only a portion of their total production to a local firm in order to ensure an adequate supply of produce. Nonetheless, these firms could be a substantial new market for frozen foods raised and processed in Utah.

Frozen food can be sold in the local retail and wholesale markets that cover Boise-Salt Lake and peripheral communities. The local retail market is relatively small—less than 0.5 percent of total national shipments and less than 1 percent of annual packs are shipped into this market. The wholesale market for frozen vegetables is divided primarily between the retail grade market (where shipments enter grocery chains) and food-service and fast food outlets.

Currently, frozen vegetable wholesalers in the Salt Lake-Boise market contract for supplies from California, Oregon, Washington and Idaho. Potato products are supplied primarily by Idaho and Oregon packers. Some local produce is purchased in Salt Lake City, mainly sour cherries and other fruits, but most is procured outside of the local market. The limited local and regional markets mean that procurement operations on the west coast would have to be contacted to gain access to larger markets.

### TABLE 2. Western states’ market share of frozen vegetables (1986).

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Percentage of market held by California, Oregon &amp; Washington</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broccoli</td>
<td>92</td>
</tr>
<tr>
<td>Green beans</td>
<td>50</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>70</td>
</tr>
<tr>
<td>Carrots</td>
<td>72</td>
</tr>
<tr>
<td>Cut corn</td>
<td>64</td>
</tr>
<tr>
<td>Green peas</td>
<td>58</td>
</tr>
</tbody>
</table>

Transportation Costs

We estimated transportation costs to and from several points as far from Richfield as the
Imperial Valley of California and Yuma, Arizona, to determine the economic feasibility of shipping processed commodities to other markets and for procuring alternative sources of various commodities. Transportation costs do not appear to prohibit the possibility of shipping processed commodities to other markets nor do they preclude the importation of commodities for processing.

**The Proposed Facility**

Information was obtained from industry advisers, experts at Utah State University and other sources regarding design, equipment and costs of the processing facility. The resulting site layout would require 11 acres for offices, processing area, frozen storage, truck loading, etc. Another 11-acre plot would be required to temporarily store waste water, which could eventually be used to irrigate surrounding cropland. About 500,000 gallons of water would be used daily, though recycling could reduce water consumption by about half.

Table 3 shows the schedule of capital requirements and interest expenses for the multi-commodity processing facility. Almost $12 million will be required before processing starts.

**Maximizing Revenue**

The production and harvesting periods for many of the commodities examined in the study overlap. Consequently, it was necessary to select the combination of crops that provided the highest net return to farming and processing. Linear programming was used to make this selection. It is a very flexible tool that makes it possible to maximize or minimize some objective, given various constraints.

As used in this study, linear programming maximized the net returns from competing production and processing activities, subject to the constraints of plant capacity, in-state consumption and institutional demand, and planting/harvesting periods. Returns from the combined activities of farming and processing were considered. Estimated plant capacity was 5 tons/hour. It was assumed that only 25 percent of local demand, whether for consumption or further processing, could be

<table>
<thead>
<tr>
<th>TABLE 3. Capital requirement schedule and interest expense (first two years).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project year</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Processing center</td>
</tr>
<tr>
<td>Freezing/storage center</td>
</tr>
<tr>
<td>Additional facilities</td>
</tr>
<tr>
<td>Water supply/treatment</td>
</tr>
<tr>
<td>Subtotal</td>
</tr>
<tr>
<td>Construction contingency (10%)</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Start-up funds</td>
</tr>
<tr>
<td>Operating capital</td>
</tr>
<tr>
<td>Manufacturing</td>
</tr>
<tr>
<td>Inventory</td>
</tr>
<tr>
<td>Interest</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Note: Year 1 involves only 4 months; year 2 involves 9 months.
We also analyzed the optimal combination of crops from the standpoint of both the farmer and the processor. The results indicated that those crops that return the highest profit to the processor were not necessarily those which returned the highest profit to the producer. For example, while it was profitable to process peas during June, it was not profitable to produce them during that period. On the other hand, even though it was quite profitable for farmers to produce all types of carrots, only baby carrots could be processed profitably. These differences could be a major potential problem for the proposed multi-commodity processing facility.

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<table>
<thead>
<tr>
<th>Commodity</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Total (lb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peas</td>
<td>XXX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XXX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,128,960</td>
</tr>
<tr>
<td>Beans</td>
<td></td>
<td>XXX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,419,200</td>
</tr>
<tr>
<td>Carrots*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XXX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>967,680</td>
</tr>
<tr>
<td>Zucchini</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XXX</td>
<td>XXX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,881,600</td>
</tr>
<tr>
<td>Sweet corn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XXX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,419,200</td>
</tr>
<tr>
<td>Broccoli</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XXX</td>
<td>XXX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,881,600</td>
</tr>
<tr>
<td>Onions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XXX</td>
<td>XXX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,419,200</td>
</tr>
<tr>
<td>Potatoes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XXX</td>
<td>XXX</td>
<td></td>
<td></td>
<td></td>
<td>4,838,400</td>
</tr>
<tr>
<td>Apples</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,419,200</td>
</tr>
</tbody>
</table>

*The only carrots purchased for processing and sales were baby carrots.

We also analyzed the optimal combination of crops from the standpoint of both the farmer and the processor. The results indicated that those crops that return the highest profit to the processor were not necessarily those which returned the highest profit to the producer. For example, while it was profitable to process peas during June, it was not profitable to produce them during that period. On the other hand, even though it was quite profitable for farmers to produce all types of carrots, only baby carrots could be processed profitably. These differences could be a major potential problem for the proposed multi-commodity processing facility.

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TABLE 5. Commodities required when plant operates at 90 percent of capacity.

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Quantity process (lb.)</th>
<th>Processing days</th>
<th>Farm equivalent (lb.)</th>
<th>Acreage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peas</td>
<td>1,128,960</td>
<td>8</td>
<td>1,254,400</td>
<td>418</td>
</tr>
<tr>
<td>Beans</td>
<td>2,419,200</td>
<td>17</td>
<td>2,688,000</td>
<td>384</td>
</tr>
<tr>
<td>Carrots</td>
<td>967,680</td>
<td>7</td>
<td>1,728,000</td>
<td>48</td>
</tr>
<tr>
<td>Zucchini</td>
<td>1,881,600</td>
<td>13</td>
<td>2,090,667</td>
<td>116</td>
</tr>
<tr>
<td>Sweet corn</td>
<td>2,419,200</td>
<td>17</td>
<td>8,064,000</td>
<td>448</td>
</tr>
<tr>
<td>Broccoli</td>
<td>1,881,600</td>
<td>13</td>
<td>2,352,000</td>
<td>196</td>
</tr>
<tr>
<td>Onions</td>
<td>2,419,200</td>
<td>17</td>
<td>3,225,600</td>
<td>161</td>
</tr>
<tr>
<td>Potatoes</td>
<td>4,838,400</td>
<td>34</td>
<td>6,720,000</td>
<td>258</td>
</tr>
<tr>
<td>Apples</td>
<td>2,419,200</td>
<td>17</td>
<td>3,256,000</td>
<td>90</td>
</tr>
<tr>
<td>Total</td>
<td>20,375,040</td>
<td>141</td>
<td>31,348,267</td>
<td>2,120</td>
</tr>
</tbody>
</table>

TABLE 6. Projected net receipts at different operating intervals and operating capacities.

<table>
<thead>
<tr>
<th>Operating Interval</th>
<th>Net receipts 80%</th>
<th>Net receipts 90%</th>
<th>Net receipts 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>133 days</td>
<td>$239,000</td>
<td>$560,000</td>
<td>$916,000</td>
</tr>
<tr>
<td>150 days</td>
<td>$540,000</td>
<td>$896,000</td>
<td>$1,293,000</td>
</tr>
<tr>
<td>170 days</td>
<td>$811,000</td>
<td>$1,195,000</td>
<td>$1,630,000</td>
</tr>
</tbody>
</table>

Plant Capacity

The smallest plant that could be competitive with other plants would have to process 5 tons per hour. It was assumed that the plant would operate two 8-hour shifts. Sanitation and start-up time meant the costs were based on a 20-hour operating day, which meant that a plant operating at full capacity would produce 160,000 pounds of finished product daily.

The economic feasibility of this facility depends largely on actual operating capacity and the number of days in which vegetables are processed. Actual operating capacity of freezing facilities nationwide has been about 85 percent during the past few years, and has been as low as 70 percent. The longer the plant is operated, the more likely there will be a positive return to investment. Thus, if there are markets for the processed commodities, it might be economical to locate alternative sources of supply to extend the processing season.

In most years, it should be possible to process locally-grown commodities for 133 or 150 days. If operated at full capacity, the plant would break even even if it operated for fewer than 133 days. However, the lower the percentage of operating capacity, the longer the plant must operate in order to show a positive return to risk. Table 6 shows estimated net receipts at various operating capacities and operating intervals. The facility would apparently be viable only if the operating season was longer than 133 days and operating capacities exceeded 85 percent.

Conclusion

There are successful plants elsewhere in the
United States with similar operating capacity. However, most of these plants are not located in areas where the growing season is limited, nor do they process the variety of products that would have to be processed in the proposed facility.

Our analysis indicated considerable economic risks associated with such a facility. One potential difficulty is the fact that several commodities must be processed throughout the growing season. This requires complicated harvesting schedules and timely production of vegetables and other commodities, which would be difficult given the limited (and variable) growing season in the state. We considered only locally grown commodities that required relatively simple processing (freezing and packaging). The need to operate the plant as many days as possible and at the greatest operating capacity means that it may be possible to switch to other products, such as tart cherries and raspberries, stored produce such as apples, potatoes or onions, or crops grown outside the region.

A second difficulty is that producers lack experience growing many of the commodities projected to be processed by the plant. It is very possible that two or more crops may mature at the same time, which could mean that a way would have to be found to compensate those growers who are not able to deliver their production due to limited plant capacity.

Third, the commodities that are most profitable to produce might not be those that are the most profitable to process, and vice versa. Fourth, markets must be found for the processed commodities, which will depend on processing high-quality commodities at the lowest possible price. Regional markets are limited so access to markets on the west coast is essential. Fifth, the processor must also shoulder the risks associated with changes in supplies and prices associated with a market characterized by relatively large carry-over stocks and processing capacity.

These and other factors mean that such a multi-commodity processing facility involves considerable planning and substantial economic risk.

*This study was funded by the Utah Department of Agriculture, the Sevier County Committee for Agricultural Development, the Utah Agricultural Experiment Station and the USU Cooperative Extension Service.

ABOUT THE AUTHORS

D. L. Snyder is associate professor, T. F. Glover is professor, L. K. Bond is associate professor, D. Bailey is associate professor, J. C. Andersen is professor, W. C. Lewis is department head and professor, and H. H. Fullerton is professor, Economics Department at USU.
In Utah, employment in ornamental horticulture increased from 7,800 in 1979 to 11,740 in 1986. Employers indicated that they would hire almost 2,500 more employees during 1987 and 1988.

EMPLOYMENT OPPORTUNITIES IN ORNAMENTAL HORTICULTURE AND AGRICULTURAL MECHANIZATION

G. A. Long

The agricultural mechanization program offered by the Agricultural Education Department prepares students to work in local farm-machinery dealerships. One-year certificates or two-year diplomas are offered. The two-year ornamental horticulture program offered by the Plant Science Department prepares students for a variety of careers related to greenhouse, turf and landscaping.

In both programs, placement in supervised jobs offers students valuable employment experience.

Even though production agriculture in general requires fewer workers, employment opportunities are increasing in several agricultural vocations, particularly ornamental horticulture and agricultural mechanization. From 1978 to 1986, we conducted several studies of these trends.

The results have helped us make the curriculum more relevant and identify employment opportunities for graduates. This is particularly important since many systems used to report job opportunities do not accurately categorize employment opportunities in agriculture.

More Jobs in Ornamental Horticulture

Employment continues to expand in ornamental horticulture. In Utah, employment in ornamental horticulture increased from 7,800 in 1979 to 11,740 in 1986. Employers indicated that they would hire almost 2,500 more employees during 1987 and 1988.

Data from surveys conducted in 1979 and 1986 indicated that employment in occupations related to ornamental horticulture increased by 7.3 percent annually. Full-time employment in greenhouses increased by 24 percent annually and part-time employment increased by 13 percent. Full-time employment opportunities increased by 15 percent annually in landscape maintenance and 13 percent in landscape construction.

Most of the employers surveyed indicated that they preferred to hire experienced, trained employees, but relatively few had hired graduates of the ornamental horticulture program at USU. This indicates that communication can be improved between employers and instructors.

Fewer Machinery Dealers Hasn't Reduced Employment

Farm machinery dealerships are a major source of employment for graduates of our program in agricultural mechanization. Utah dealers were surveyed in 1981 and 1985 to determine employment opportunities and needs.

There were six fewer farm machinery dealers in 1985 (43) than in 1981. This consolidation did not appear to be associated with any appreciable reduction in employment. We estimated that these dealers employed 421 full-time workers and 55 part-time employees.

Experience and Training an Asset

Almost all of the dealers surveyed indicated they preferred to employ workers who had been trained or who had experience. If 5 percent of the workers are replaced annually and full-time employment increased by 8 percent, there would be approximately 55 full-time employment opportunities annually. Currently, about one-third of those hired in 1984-85 were graduates of high school or post-secondary institutions, which indicates that there is considerable potential demand for graduates of the USU agricultural mechanization program.

There is a higher ratio of full- to part-time employees in agricultural mechanization (7.6 to 1) than in ornamental horticulture (1.2 to 1). The decline in the farm economy has apparently adversely affected part-time employment more than full-time employment at farm machinery dealers in the state. In contrast, most of the new jobs in fields such as landscape construction are part-time rather than full-time.
More than a century ago, the Industrial Revolution transformed civilization. About 50 years ago, the Chemical Revolution began as scientists learned how to make nylon, rubber, plastics and thousands of other compounds.

Now, even these achievements may be dwarfed by progress during the Biological Revolution, a revolution resulting from our ability to alter living organisms.

Creation of the Biotechnology Center ensures that USU will participate in this revolution.

The Center, a cooperative, campus-wide venture involving the Utah Agricultural Experiment Station, was created to support research, to help researchers compete for outside funds, and to vigorously market innovations developed at USU. Among the services offered to researchers are the production of monoclonal antibodies, a fermentation facility, and the synthesis and analysis of proteins and DNA.
The Center will tap the optimism and vitality characteristic of USU. It is not one of the largest centers for biotechnology research, but I am convinced that it can be one of the best.

As shown in the following pages, a variety of exciting biotechnological research is already underway.

This is only the start.

Agriculture will be a major beneficiary of genetic engineering. Miracle drugs, new vaccines, hardier crops, more productive livestock, improved utilization of natural resources, and more nutritious foods will result. We will make better use of our natural resources. Several threats to environmental quality can be reduced or eliminated.

The bottom line—advances in biotechnology will help Utah agriculture remain competitive. These advances can create remarkable new opportunities for many other industries and enterprises.

USU and the Agricultural Experiment Station are celebrating their centennial. The Center is an appropriate way to mark the start of another century of innovation and service.

The Biotechnology Center will reflect the best traditions of a great land-grant university.
Steven D. Aust

Steven D. Aust earned his Ph.D. in dairy science from the University of Illinois. He joined USU as professor with joint appointments in the Chemistry and Biochemistry Department and Nutrition and Food Science Department, and as director of the Biotechnology Center. He was a professor with the Department of Biochemistry, associate director of the Environmental Toxicology Center, and director of the Center for the Study of Active Oxygen in Biology and Medicine at Michigan State University. He is the author of almost 200 scientific publications, a member of numerous professional organizations, and the recipient of several professional awards. His continuing interest in agriculture reflects the fact that he grew up on a dairy farm in western Washington.
Research for healthier, more productive livestock...

Bill B. Barnett
Virologist Bill Barnett is developing methods to attach antiviral drugs to monoclonal antibodies. Monoclonal antibodies carry the drug to infected cells in the animal. Once in the cell, enzymes cleave the drug from the monoclonal antibody, and the drug then inhibits replication of the virus. The drug-targeting techniques are currently being developed for application to several virus diseases, including hemorrhagic fever and retrovirus infections.

Dennis L. Welker
Molecular biologist Dennis Welker is studying the gene regulation of *Dictyostelium discoideum*, a single-celled organism which lives in the soil. *D. discoideum* is more closely related to mammals and other higher animals than the bacterium *E. coli* now widely used in genetic engineering. Findings will help engineer the micro-organism to “manufacture” livestock vaccines and other products to combat viruses and protozoan and fungal diseases.
Aflatoxins (AFB₁) are potent carcinogens and toxicants that can contaminate cottonseed, rice, corn and other feeds. The milk of cows fed contaminated feed contains a different form of aflatoxin, AFM₁. It is known that metabolically “activated” AFB₁ binds to a particular DNA base (guanine). Coulombe and molecular biologist Joe Li are determining whether neighboring DNA bases also affect AFB₁ binding, and whether AFM₁ binding is similar to that of AFB₁. Results will clarify how aflatoxins interact with cancer-causing genes. The ability to detoxify or activate aflatoxins varies among species. Coulombe is also studying the enzymes involved in aflatoxin metabolism, findings which may explain why species differ in their ability to detoxify or activate aflatoxins as well as define the risks posed by these compounds.

Mark C. Healey

Ram epididymitis is a costly reproductive disease that affects young rams and decreases fertility in flocks. Veterinary scientist Mark Healey has identified the bacterial strains causing the disease and is identifying the surface proteins in order to develop vaccines against the disease. Healey plans to identify and isolate the bacterial genome that encodes those surface proteins and use biotechnological techniques to mass produce these protective proteins for use as a vaccine.
Robert W. Sidwell

Antiviral chemotherapy, the use of virus-inhibiting drugs, is an attractive method of treating serious virus infections. Virologist Robert Sidwell is designing and developing new drugs or substances that modify biological responses that will effectively control virus diseases in livestock and humans. In addition to collaborative research with Bill Barnett, he is studying the Friend leukemia virus, an animal virus similar to the virus which causes Acquired Immune Deficiency Syndrome (AIDS) in humans. The Friend virus does not infect humans.

Joseph K. K. Li

Molecular biologist Joseph Li is working to “manufacture” a synthetic vaccine against bluetongue viruses, which cause a costly livestock disease. The viruses primarily attack sheep and goats. In the U.S., bluetongue-related losses total $40-$50 million annually. He is also a cooperative investigator in several other biotechnology research projects.
Scrapie, a virus-like infection of the central nervous system, affects sheep and goats and is included in the group of slow virus diseases involving spongiform encephalopathy. The disease is always fatal. USU researchers are determining whether embryo transfer can result in disease-free offspring, either from infected donor parents or infected foster mothers. In addition to determining how the disease is transmitted, the procedure might be used to obtain scrapie-free sheep from infected herds, help control and eradicate the disease, and facilitate the import and export of sheep. So far, it appears that scrapie-free offspring result when embryos from donor animals artificially injected with the scrapie agent are transferred to ewes from scrapie-free flocks.
Better dairy products...

Jeffery K. Kondo

Microbiologist Jeffery Kondo is genetically engineering better strains of dairy starter cultures that are used to manufacture cheese and other fermented dairy products. These improved cultures could enhance processing efficiency, reduce spoilage and lead to new, tastier products.
Higher yielding, disease-resistant crops...

Neal K. Van Alfen
It might be possible to control plant diseases by engineering hypovirulent (low-virulent) strains of disease-causing organisms. Research in Van Alfen’s laboratory involves the source of hypovirulent strains of the fungus that causes chestnut blight. Molecular sleuthing has already identified virus-like double-stranded RNA and the genes associated with hypovirulence. Other research involving bacterial wilt in alfalfa will help engineer beneficial bacteria that can harmlessly reside in a plant and protect it from other pests.
Plant geneticist John G. Carman has developed several tissue culture techniques that will make it possible to mass produce high-yielding wheat hybrids by the production of artificial seeds. With these new techniques, he has produced more than 2,400 wheat embryos per gram of plant tissue. A good percentage (25-50 percent) germinated normally after having been stored under cool dry conditions for three weeks. This production level is more than seven times greater than could be achieved with conventional tissue-culture techniques.

Keith Mott studies the biochemical and biophysical processes in plants that determine photosynthetic rate and water use efficiency of plants. This information will help identify advantageous traits suitable for genetic engineering.
A new method of "fingerprinting" substances may improve crop yields. The method, pyrolysis-gas chromatography, identifies the unique characteristics of entire cells, not just individual compounds.

Chemist Grant Gill Smith and plant scientist William F. Campbell will compare the "fingerprints" of various strains of nitrogen-fixing Rhizobium bacteria from around the world with their performance on legumes grown in a greenhouse. If the most efficient and effective rhizobia have unique fingerprints, the technique can be used to quickly screen hundreds of other strains, thus avoiding costly and time-consuming greenhouse trials. The most promising rhizobia strains will then be tested in greenhouses.

The technique is being tried with rhizobium strains on chickpeas and pigeonpeas, two important legumes in India. In addition to increasing yields, inoculating plants with better rhizobia strains could also reduce the need for nitrogen fertilizers.

Pattern recognition of pyrolysis-gas chromatography (chemometrics) at USU has already been employed to identify salt-resistant strains of rhizobia, and to determine otherwise undetectable differences between types of sagebrush, insect pests, leafy spurge, and Africanized bees.
Anne J. Anderson
Microbiologist Anne Anderson is studying the molecular interactions between plants and both beneficial and pathogenic microorganisms. Her research involves *Pseudomonas putida*, a common soil bacteria that can aggressively colonize the surfaces of plant roots, and may enhance plant growth and yields. Studies also involve the fungal pathogen *Colletotrichum lindemuthianum*, which causes large lesions on the stems and leaves of bean seedlings. Understanding how microbes alter key metabolic functions of plant cells may lead to methods to improve their resistance to pathogens or enhance their reactions with beneficial microorganisms.

Jon Y. Takemoto
*Pseudomonas syringae* is a bacterium found on the foliage of most plants. The toxin it produces can cause extensive losses in crops such as corn and beans. Molecular biologist Jon Takemoto is studying the structure of the toxin, how the toxin affects the membranes of plant cells, and the molecular interactions involved. Learning the molecular basis of plant-toxin interactions will help genetically engineer plants to resist toxins, either by preventing unfavorable interactions or by promoting favorable interactions.
Wade G. Dewey

New varieties of cereal crops must continually be developed to stay a step ahead of plant diseases. For almost a century, cereal breeders have relied on crosses among varieties within the same species for disease-resistant genes. While this intraspecific supply of resistance has not been exhausted, wheat breeder Wade Dewey is experimenting with wider crosses (intergeneric hybridization) as a source of genes for resistance to devastating wheat diseases such as rust and smut. Barley is a particularly promising donor of useful genes.

Several years ago, breeders elsewhere crossed wheat and rye to develop Triticale, a protein-rich grain whose productivity has been improved markedly in just a few years to rival that of conventional cereals. Dewey is employing similar techniques in his wide hybridization with barley. So far, he has made thousands of pollinations of wheat and barley to obtain a few viable barley-wheat hybrids. These few surviving embryos are carefully nurtured through a combination of hormones, growth regulators, and embryo rescue and culture techniques.

These first hybrid plants are sterile; essentially, they only combine wheat and barley chromosomes in the same cell. The next step may involve biotechnological techniques to restore fertility to these crosses and to transfer the desirable disease-resistant barley genes to wheat chromosomes. This genetic transfer might be achieved through the use of restriction enzymes, which cut and splice desirable gene segments, or by irradiation and repeated backcrossings.
A safer environment...

Steven D. Aust

Steven Aust is studying the white-rot fungus *Phanerochaete chrysosporium*, which shows a remarkable ability to degrade more than 50 different chemicals, including such environmental pollutants as DDT and polychlorinated biphenyls, which resist biodegradation by most microorganisms. Although the fungus occurs naturally in the environment, and may already be degrading chemicals introduced into the environment, it may not exist at all locations. Aust is culturing the fungus so it is available for use wherever pollutants are found.

Conly Hansen

Food engineer Conly Hansen is determining how various types of bacteria process and remove the mercury found in many types of industrial wastes. Findings will help develop biological systems to remove and/or detoxify mercury and other toxic metals in waste water and sludges. There may be another advantage: disposal of waste byproducts from dairy manufacturing plants. In Hansen’s system, whey and other byproducts of dairy processing serve as the energy source for the waste-processing bacteria.
Thwarting insect pests...

T. H. Hsiao

The alfalfa weevil, a serious pest of alfalfa in North America, was accidentally introduced from the Old World on three separate occasions. Three closely related but morphologically indistinguishable strains are now found in all 48 contiguous states, as well as Canada and Mexico. Entomologist T. H. Hsiao employs cytogenetic, molecular, genetic, microbiological, and physiological techniques to discriminate between weevil strains, and to determine why parasitic microorganisms attack some strains but not others. Results will determine whether the weevil’s food preferences can be altered so they no longer attack alfalfa, and whether the parasites can be genetically engineered to attack other strains. If so, biotechnology could provide potent new biological control agents against these insect pests.

Nabil N. Youssef

There are several types of apple maggots in Utah; one infects apples, one infects cherries, and a third infects hawthorns. Control of these insect pests and of the western cherry fruit fly, a related species, hinges on accurate identification of different types. So far, however, it has been difficult to identify adult types of these insects, and impossible to distinguish between their larvae. Monoclonal antibodies developed by biologist Nabil Youssef can identify these different types and could eventually be used in a diagnostic kit.
Cattle that avoid poisonous plants. Sheep that graze so they gain more weight and make more efficient use of forages. And lambs and calves that go on—and stay on-feed as soon as they enter a feedlot.

These prospects aren't as far-fetched as they might seem. While much remains to be learned, it now appears that we can train livestock to eat certain feeds and avoid others. If so, it could mean some remarkable new management tools for farmers and ranchers.

The techniques could mean substantial savings. For example, USU economists recently estimated that poisonous plants in 17 western states cause livestock losses of several million dollars annually. These losses could be avoided by training livestock to avoid poisonous plants. Producers also incur huge losses when livestock go off feed when they enter feedlots—another problem that might be solved by training calves and lambs to eat the grains they will encounter later.

Preliminary results are promising. In one experiment, we reduced finishing times of lambs by about 2 weeks after training them to eat certain grains. If these techniques were applied commercially, an operator finishing 30,000 lambs every 4 months could save about $100,000 annually.

The fact that training involves no chemicals or other types of additives is another extremely important advantage—training involves only "natural" ingredients.

Our efforts to discover what underlies animals' feed preferences could transform livestock production on farms and ranches. In addition to the prospects outlined above, it
It appears that livestock can be trained to avoid poisonous plants, graze more efficiently, and gain weight faster in feedlots. But that's not all. Similar techniques might help train livestock to graze the understory vegetation in forests, eat sagebrush and other less desirable plants, and eat supplements.

Learning Improves During Weaning

Young livestock apparently learn more readily when they are about to be weaned, a period when their digestive system changes from a single stomach (monogastric) to a ruminant. In one experiment lambs that had been fed mountain mahogany when 4–8 weeks of age, a period when their digestive systems are in transition, later ate far more of the shrub than younger (1–4 weeks of age) or older (8–12 weeks of age) lambs.

The Influence of Other Animals

Other animals influence what young animals learn. This was apparent in a trial in which lambs were fed when either alone, with a ewe, or with their mothers. When the lambs were offered the same feed (either rolled barley or serviceberry) several weeks later after weaning, those who originally ate the food with their mothers ate twice as much as those who ate with another adult. And solitary lambs ate just half as much as those who were with an adult female.

The fact that young livestock learn more readily and tend to remember what they have learned when they are with their mothers could be an integral part of programs developed to train young livestock.

Food Aversion

Several studies have examined whether animals can be trained to avoid certain feeds or forages (food aversion). In the studies, animals received lithium chloride, a substance that causes gastrointestinal upsets, after eating a new food such as larkspur (a poisonous plant). In cooperation with researchers at the USDA Poisonous Plant Lab, we learned that heifers aversively conditioned to larkspur still avoided the plant a year later.

When lithium chloride was administered to lambs that had just consumed a novel food and a familiar food, the lambs later avoided the new food—not the familiar food. This was true even when lambs were offered one new food and several familiar foods. We also found that animals can be aversively conditioned as long as 4 hours after they have eaten the new food. The fact that aversive conditioning need not occur immediately after the food is eaten means animals could be treated in a group several hours after they were conditioned, thus making the practice much more practical on farms and ranches.

We have also investigated how livestock learn to distinguish between "good" and "bad" foods. When we administered lithium chloride after lambs had eaten two novel foods, the lambs avoided both of the new foods. It appears that livestock have a "strategy" for dealing with familiar and unfamiliar feeds, but do not know how to distinguish between several new foods that are offered simultaneously.

Another experiment involved the relationship between aversive conditioning and the influence of other animals. When lambs that had been trained to avoid a plant joined lambs that had not been trained, some of the averted lambs copied the behavior of the untrained lambs—they tended to "lose" their aversion to the plant. A similar experiment involved adult sheep. This time, however, the adult sheep that had been averted were more reluctant to change their behavior. Thus, it appears that young animals learn more readily than adults, but are also more likely to change their behavior than adults.

Next year, we will try to identify the strategies that livestock use to select forages on rangelands. Do they select one new type of forage at a time, or several types? The results will be useful in relating animal behavior in pens to behavior in other settings.

Stimulating the Digestive System

Exposure to limited amount of grain at the right times appears to stimulate the development of young ruminants' digestive tracts. Some lambs 5–6 weeks old were fed whole barley and others received none. The rumen papillae, tiny finger-like protrusions in the
rumen, developed much more rapidly in lambs that had been offered barley for only 10 minutes daily for as few as 8 days. The papillae are essential in the absorption of volatile fatty acids (energy) and ammonia (protein) released in the rumen. Moreover, the rumen papillae in these lambs still had 41 percent more surface area several months later, after lambs had been on summer range. This favorable development of the digestive tract should enhance growth and development when animals enter feedlots.

Learning Motor Skills
Anyone who has used chopsticks knows how motor skills can affect our ability to eat. The same principle applies to the foraging ability of livestock, as we learned when we let lambs eat shrubs for varying lengths of time. The “skilled” lambs, those who spent the most time with their mothers, ate more than unskilled lambs. In another experiment, several pairs of twin lambs were divided into two groups, one that ate shrubs and another that ate grass. When offered these forages several weeks later, lambs were more efficient at eating the type of forage that they had been exposed to when young, another indication that motor skills learned by young animal affect grazing efficiency.

The Effects of Previous Experience
Researchers with the U.S.D.A. Sheep Experiment Station at Dubois, Idaho, report that ewes that have previously grazed the summer range are usually in excellent shape by fall, while the replacement ewes, which have spent several months in feedlots and have never been to the range, usually lose weight while on the rangelands. Does this failure to thrive reflect inexperience with novel foods, a lack of motor skills, failure to learn during a sensitive period when young, or other factors? We are cooperating with the Station to find out.

More “Schooling” for Livestock
The learning behavior of livestock is somewhat analogous to that of humans, and we have applied many of the same concepts in our research. Piecing together how livestock learn may eventually help us train livestock to make better use of rangelands and other feeds. Sending livestock to “school” could also make life a lot easier—and more profitable—for ranchers and farmers.

ABOUT THE AUTHOR

Frederick D. Provenza is an associate professor with the Range Science Department.

ACKNOWLEDGMENTS

The experiments outlined in this report are being conducted by Beth Burritt, Enrique Flores, Mark Lane, Dale Nolte, Luis Ortega-Reyes, Ron Squibb and Anna Thorhallsdottir.
Soil fertility research for alfalfa in Utah has emphasized phosphorus. Potassium has received less attention. Boron and other minor nutrient elements were seldom emphasized because no deficiencies were observed in the state. This report concerns a survey to assay the levels of boron in irrigated soils and crops in Utah.

Boron is a unique plant nutrient element because there is only a small difference between deficiency and toxicity. Reisenauer et al. (1973), for example, reported that a soil test boron level of less than 1 mg/kg (ppm) might not satisfy the needs of a growing crop while available soil boron levels exceeding 5 mg/kg might be toxic to crops.

Factors Affecting Boron Availability

In semi-arid areas such as Utah, soil pH is neutral to alkaline (i.e., pH 7.0 to 8.2) and limited rainfall means soil leaching is not extensive. Boron deficiency under these conditions is not common, but it has been observed in some areas in the west (James and Weaver 1964).

Under certain conditions available boron may reach toxic levels in soils of arid environments (Kanwar and Singh 1961). Irrigation water contains some dissolved boron (James and Jurinak 1986) and boron toxicity in crops may occur if irrigation water contains excess boron.

Boron Requirements

All plants require small amounts of boron for proper growth and development. Alfalfa is considered to have a sufficient level of boron when the top one-third of the plant contains 20 to 40 ppm boron at early bloom (Meyer and Martin 1976).

The greatest amounts of boron seem to be required in the youngest parts of plants where cell growth and development is most active (e.g., new leaves and buds). Boron is essential in certain enzymatic reactions, translocation and utilization of sugars, and protein synthesis.

Boron deficiency symptoms may appear in alfalfa if the top of the flowering plant contains less than 20 ppm (James and Weaver 1964). Deficiencies may occur when the available soil boron is less than 1 ppm (Reisenauer et al. 1973). The new leaves of
Boron-deficient plants become yellow-red and alfalfa fields take on a bronze coloration. Boron deficiency in alfalfa is also characterized by shortened internodes near growing tips and plants acquire a rosette appearance. Flowers may fail to form and buds may be white or light brown. In severe cases the terminal bud may die and the upward growth or expansion ceases.

Boron deficiency is easily corrected by applying borax or soluble sodium borates in solid or solution form. No more than 4 lb. of elemental boron should be applied per acre.

Toxicity symptoms in alfalfa may appear when the top of the flowering plant contains more than 200 ppm of boron (Meyer and Martin 1976). This may occur when the available boron in the soil exceeds 5 mg/kg (ppm) (Reisenauer et al. 1973). The first symptoms of toxicity are the yellowing or burning of edges of older leaves. Later, the whole leaf will turn yellow and leaves will drop prematurely. In extreme cases the whole plant may die.

Boron toxicity can be induced if excessive boron is applied, e.g., doubling the recommended rate. Naturally occurring boron toxicity usually is in association with saline marine shales. Applying irrigation water that originates in these high-boron shales may induce boron toxicity in soils and crops.

### Table 1. Boron concentrations of various Utah soils and alfalfa samples. Corresponding irrigation water compositions are from James and Jurinak (1986).

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<th>Plant B (mg/kg)</th>
<th>Irrigation water B (mg/L)</th>
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</table>

**Boron Status**

Irrigated alfalfa and soils in Utah were surveyed to determine the status of boron in the area (Radtke 1986). Figure 1 shows where plant and soil samples were collected for chemical analyses.

No symptoms of boron deficiency were observed at any of the locations. Also, boron content of plants was sufficient. The boron levels in soil and irrigation waters for the sampling sites are shown in Table 1. Only in Grand County were soil boron levels low enough to indicate a possible deficiency. However, no symptoms of deficiency were apparent and the alfalfa samples contained sufficient quantities of boron, indicating that boron soil fertility was adequate.

Symptoms of boron toxicity were observed in Duchesne County in two small areas that irrigate with water from Indian Creek and Antelope Creek. Both waters contained 3 to 6 mg/L (ppm) boron. Boron levels in soil ranged between 7 and 11 mg/kg and alfalfa contained between 91 and 254 ppm (Table 2). The effect of excess boron was not as severe as expected.
Soil and alfalfa contained adequate levels of boron. Boron toxicity occurred naturally in two areas where low-quality irrigation water is applied.

<table>
<thead>
<tr>
<th>Soil test B (mg/kg)</th>
<th>Plant B (mg/kg)</th>
<th>Irrigation water B (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.86</td>
<td>135.00</td>
<td>6.00</td>
</tr>
<tr>
<td>9.85</td>
<td>149.00</td>
<td>6.00</td>
</tr>
<tr>
<td>9.85</td>
<td>232.00</td>
<td>6.00</td>
</tr>
<tr>
<td>6.74</td>
<td>91.00</td>
<td>2.92</td>
</tr>
<tr>
<td>7.72</td>
<td>132.00</td>
<td>2.92</td>
</tr>
<tr>
<td>8.78</td>
<td>150.00</td>
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<td>8.78</td>
<td>254.00</td>
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<td>7.18</td>
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<td>3.49</td>
</tr>
<tr>
<td>7.57</td>
<td>102.00</td>
<td>3.49</td>
</tr>
</tbody>
</table>

Boron levels could be reduced by using higher quality water, e.g., Duchesne river water. This would not be economically feasible unless yield improvements covered the costs of the change in irrigation practices.

Conclusions

Soil and alfalfa that were sampled contained adequate levels of boron; yields would not improve by applying fertilizers that contain boron. Boron toxicity occurred naturally in two areas of the state where low-quality irrigation water is applied. Excess boron could be reduced by using higher quality water, but it is not known if such a change would be economically feasible.

Literature Cited


About the Authors

David W. James is professor in the Soil Science and Biometeorology Department at USU.

R. N. Radtke, Jr. earned his M.S. degree in the Soil Science and Biometeorology Department at USU in 1986.
Research underway in the College of Agriculture plays an important role in our national space program. This article concerns several projects supported by the National Aeronautics and Space Administration in the college. Some of this research has been reported previously in Utah Science (Bugbee and Salisbury 1985; Salisbury et al. 1982a and 1982b).

**Gravitropism in Dicot Stems**

Turn almost any potted plant on its side and the stem tips grow upright again within a few hours. This is gravitropism. Plants also bend toward a light (phototropism), but gravitropism occurs in the dark as well as the light. W. over 100 years ago, plant scientists began to study this phenomenon.

In 1873, Julius Von Sachs described a clino-stat, a turntable that could be tipped so a plant could be rotated slowly around a horizontal axis. Exposing a plant to gravity from all directions might cancel its gravity responses so it might respond as though it were weightless. Sachs knew this approach...
was not perfect, but it was the best method until satellites provided a true low-gravity environment. (For various reasons, an object in an orbiting satellite experiences acceleration about one thousandth to one millionth of the force of gravity at the Earth's surface; therefore we refer to microgravity conditions rather than zero gravity.)

Although the clinostat and many other laboratory approaches prompted research that resulted in well over a thousand technical papers on gravitropism, we still do not fully understand how plants respond to gravity. At the turn of the century, for example, it was suggested that the gravity-response mechanism was activated by the falling of amyloplasts, starch-containing bodies within plant cells. Of the plants examined, virtually every stem or root that responded to gravity contained starch grains in the cells of the growing region where bending occurred. These starch grains settled toward the bottom of cells in response to gravity. Yet, if starch is absent but gravitropism occurs anyway, falling starch grains must not be essential. Such a situation was recently reported for a mutant form of mouse-eared cress (Arabidopsis) whose cells contain no detectable starch. Scientists now wonder if starch grains might be involved most of the time but if plants have some other backup system not requiring starch.

We have been examining another problem—the role of auxin in the bending of stems. In 1926, Frits Went discovered the stem growth hormone, which he named auxin. He and N. Cholodny independently suggested that stems bend up because the auxin accumulates in the bottom tissues of a horizontal stem, causing them to grow more. Went soon obtained evidence that more auxin accumulated in the tissue on the side away from the light, causing the stem to bend toward the light. His colleague, Herman Dolk obtained similar evidence for gravitropism. For 61 years, scientists have assumed that bending in stems is caused by a transport of auxin from the upper to the lower tissues in a horizontal stem. (The theory also assumed that auxin inhibited the growth of root cells, accounting for the downward bending of roots.)

But there are problems. Some workers were unable to detect increased levels of auxin in the bottom tissues of broad-leaved plants (dicots) such as sunflower. Most evidence for the transport hypothesis is based on studies with the coleoptile, the sheath that covers the emerging first leaf of a grass seedling. But even in coleoptiles, the difference in auxin concentration between the top and the bottom tissues is quite small; perhaps 60 percent of the auxin is in the bottom tissues and 40 percent is in the top. There is evidence that only the outer layer of cells, the epidermis, is important. The auxin difference between the upper and the lower epidermis could be much greater, but it is virtually impossible to measure.

Several hundred papers on gravitropism have concerned the auxin transport hypothesis. Critics of the theory note that large changes in auxin concentration (applied artificially to stem sections) are required for even small changes in the growth rate of the tissues, but turning a stem on its side leads to only slight differences in the auxin content of top and bottom tissues.

For the past 4 years, we have been considering an alternative suggestion: Perhaps bending occurs because tissues differ in their sensitivity to auxin. It is well known that the tissue sensitivity varies with the age of the cells. Extremely young cells at the stem tip contain the most auxin but don’t respond to it. Older cells farther down the stem don’t respond very much even when large amounts of auxin are applied, but the cells between the extremely young and older cells readily respond to auxin. Anthony Trewavas (1981) suggested that this change in sensitivity might be the key to one phase of gravitropism.

Could a change in the direction of the gravitational force change the sensitivity of the cells to auxin? Specifically, could bottom cells become more sensitive to auxin than vertical cells while upper cells became less sensitive? Even if the bottom cells remained only as sensitive to auxin as vertical cells, the stem would bend if top cells became less sensitive, whether or not auxin was transported.

We have good evidence that sensitivity changes bring about gravitropic bending. Sensitivity is a measure of the response of a tissue, organ, or organism to some external stimulus. If a large stimulus is required to produce a small response, the system is not very sensitive; small stimuli producing large responses suggest high sensitivity. Thus, the way to measure sensitivity is to vary the stimulus over a wide range and observe the response.

Our basic experiment involves the use of
eight tanks, one of which contains only water with a buffer to control acidity. Auxin (indoleacetic acid) concentration in the other seven tanks ranges from 0.00000001 to 0.01 moles per liter of water. Sections of stem from sunflower seedlings, marked to measure growth, are mounted in plastic holders and placed so they are on their sides in the auxin solutions. Another set of tanks contains the same solutions but stem sections are held in a vertical position. The tanks are photographed with two large-format cameras (4 × 5) at half-hour intervals. The negatives are then projected from below onto a desk-top screen, part of a digitizer connected to a computer, to measure the angles of bending and changes in length of top and bottom surfaces and of vertical stem sections.

The results of one such experiment are shown in Figure 1. As auxin concentrations increased, the stems bent less and less in response to gravity; eventually they bent down instead of up. The growth curves indicate that top tissues grow much less than bottom tissues when solutions contain little or no auxin. As auxin concentration increases, however, growth of top tissues increases until the stems bend down. Clearly, much more auxin is required to produce growth in top tissues than in bottom tissues. Thus, bottom tissues are much more sensitive to applied auxins than top tissues.

Maximizing Wheat Yields for Use in Space Exploration

One day, we will almost certainly grow plants in lunar farms to provide food and to purify the atmosphere. It will be too difficult and expensive to send groceries from the Earth to the moon. Air purification alone might justify growing plants in the closed atmosphere of a moon station, although chemical filters could be used to purify air. In photosynthesis, plants use the carbon dioxide expired by humans along with water to make

Figure 1. Stem bending and stem growth as a function of auxin (indoleacetic acid) concentration. Sections (35 mm, marked at a 16-mm interval) of sunflower stems (hypocotyls of 5-day-old seedlings) were immersed in the solutions (see text). Stem bending decreased as auxin concentration increased until, at about 10⁻⁴ M, hypocotyls began to bend down. Increased auxin concentrations caused growth of the top surface to increase and, when auxin concentrations exceeded 10⁻¹ M, inhibited growth of the bottom surface. When auxin concentrations exceeded 10⁻¹ M, the top grew more than the bottom, causing downward curvature. The differences in growth show that bottom tissues are much more sensitive to applied auxin than top tissues and vertical tissues.
edible carbohydrates, proteins, and fats, and gaseous oxygen is expelled.

Farming on the moon or Mars or in a spaceship on a long voyage will be extremely difficult. Mass, volume, and energy must be reduced to the lowest possible levels required to produce a maximum of food. In other words, the maximum amount of food must be grown in the smallest possible space and the shortest time. A first step is to produce sufficient food in relatively small volumes. If this is possible, engineers can then reduce the mass and increase energy efficiency.

Dr. Bruce Bugbee and I have been trying to identify the best genetic material and to determine the optimum environmental factors for wheat. Over one thousand cultivars from all over the world have been evaluated. Cultivars from 22 of our breeding lines are being produced for optimal environmental conditions. So far, however, the available cultivars seem to respond better to those conditions than the cultivars we have produced, although some breeding lines look very good.

The environmental conditions we manipulate include the nutrient medium around the roots, the atmosphere around the shoots, and Dr. F. B. Salisbury preparing an experiment to study gravitropism in sunflower stems.

The incoming light that provides the radiant energy essential for photosynthesis. The roots of our wheat plants are bathed in a carefully formulated, aerated nutrient solution.

We control temperature, humidity and carbon dioxide. The optimal environmental conditions depend to some extent upon the age of the plants and should be changed accordingly. When other conditions are optimal, wheat yields are limited only by the amount of incoming radiation. Figure 2 shows yields plotted as a function of radiation. The upper level of radiation, 2,000 micromoles of photons in the visible region of the spectrum per square meter and per second, is approximately equivalent to the maximum levels

![Figure 2](image-url)

**Figure 2.** Total biomass and edible grain production for wheat plants grown under a range of light levels. Light from metal halide and high-pressure sodium lamps was filtered through a layer of water. Photosynthetic photon flux (PPF) is the number of photons (packets of light energy) effective in photosynthesis, expressed per unit area and per unit time. The highest light level (2000 μmol m⁻² s⁻¹) is about equivalent to full sunlight at noon on a clear day; the arrow indicates the maximum integrated PPF in the field. Light in the growth chambers remained at the same levels for 20 hours daily; so integrated amounts could be much higher than those in the field. Note how yields increased sharply as radiant energy increased and showed no signs of leveling off. There were 3000 plants m⁻² of growing area. Plants were harvested in December 1986.
achieved at noon in mid-summer on a clear, pollution-free day. It does not appear that yields will stop increasing as we further increase the radiation. In our experiment, radiation was applied for 20 hours each day. Thus, wheat plants exposed to the highest radiation received much more total radiant energy than is available anywhere on Earth. The high-pressure sodium lamps that we use, and perhaps other light sources, will soon enable us to test the yields at even higher energy inputs. The arrow in Figure 2 indicates the amount of radiation that is available to be absorbed by plants growing in the field.

Our wheat yields have been phenomenal. Yields are expressed as grams of dry matter produced per square meter (or per cubic meter) per day, the criterion that would be used in a space farm where a new crop would be planted as soon as the previous crop was harvested. On this basis, the record yield of field-grown wheat is about 14 g m\(^{-2}\) d\(^{-1}\). Our top yield (Fig. 2) is 60 g m\(^{-2}\) d\(^{-1}\).

We recently increased yields by lowering the temperature, which slows growth but causes the plant to direct plant biomass from the stems and leaves and into the developing grains. About 45 percent of the total biomass at harvest is edible wheat, which is about the same percentage as in the field.

Another important factor is the density of planting. We grow 3,000 to 7,000 plants per square meter, about 15 times the densities in a typical field. This is possible because of the high levels of radiation, the optimal balance of nutrients, and the enriched CO\(_2\) in the atmosphere (about three to four times normal levels).

How large must a lunar farm be if it produces wheat or other crops that could grow as well as wheat? With yields as high as 60 g m\(^{-2}\) d\(^{-1}\), it would require only about 12 square meters (an area about 10 × 12 feet) to supply food for one lunar inhabitant. Increasing the area four to five times to provide a wide margin of safety suggests that food for 100 people could be produced in an area about the size of an American football field.

**Developmental Processes of Wheat In Microgravity**

Our third project will integrate results of the projects discussed above. A proposal that we submitted to NASA concerning a series of flight experiments has been accepted for further definition and eventual space flight as soon as allowed by NASA launch schedules. Our experiments will examine different phases in the life cycle of wheat that might influence final yields in microgravity. We are particularly concerned whether microgravity will affect photosynthesis and respiration rates, the two processes that determine biomass production. These processes are studied.
by measuring changes in CO$_2$. 

Dr. Gail E. Bingham, state climatologist and associate professor with the Soil Science and Biometeorology Department, is one co-investigator in this project. He developed a miniature infrared gas analyzer that can accurately measure carbon dioxide and water vapor. This device, small enough to hold in the palm of one hand, replaces a laboratory instrument larger than a typewriter. It was designed to measure CO$_2$ and water vapor in the space suits of astronauts but will have many other applications, including our research.

**American Society for Gravitational and Space Biology**

Our gravitropism project is funded by the Space Biology Program of the NASA Life Sciences Division. The American Society for Gravitational and Space Biology was formed 3 years ago to represent those interested in the responses of plants and animals to gravity and to discuss how findings might be used in the exploration of space. Partly due to our active plant research program, this society decided to meet at USU in October 1987. More than 150 participants from Germany, Switzerland, France, Japan, Canada and the United States attended to hear presentations by their colleagues and addresses by Senator Jake Garn and astronaut Mary Cleave. Many of the results presented above were discussed at the meeting. The group also visited our controlled environment research facilities.

The continued interaction with this society will enhance our ability to meet the long-term goals of the space program. And the results of our research concerning the growth of plants in space environments will improve our understanding of plant growth on earth.

**ABOUT THE AUTHOR**

Frank B. Salisbury is professor of plant physiology with the Plant Science Department. His research concerns plant responses to gravity and achieving maximum yields in controlled environments. He was recently designated Distinguished Professor for 1987 in the College of Agriculture.

**LITERATURE CITED**


