Alfalfa has long been Utah's most important forage crop. When irrigated, three and sometimes four cuttings can be obtained during the growing season. Since it is a relatively long-lived perennial, good stands are possible for 5 to 7 years. Because of nitrogen-fixing bacteria that form nodules on the deep reaching roots of alfalfa, farmers value its ability to restore fertility and tilth to the soil. In addition, its high protein, mineral and vitamin content, causes it to be widely valued as an animal feed.

But, this valuable and prodigious crop is subject to a number of diseases and parasites. One of these parasites is the alfalfa stem nematode. The effect of a heavy nematode infestation — white flagging — is shown on this issue's cover. Read more about this problem starting on page 74.

Alfalfa, Utah's main forage crop, is susceptible to a number of diseases and pests. Among these is a recent one found to be caused by a tiny nematode Ditylenchus dipsaci known as white flagging. This condition can become a serious threat to older stands of susceptible alfalfa varieties that are subject to nematode attack. The main symptoms as shown on the cover photo are branch tips almost totally lacking in chlorophyll. Read more about this latest problem to alfalfa growers in this issue of Utah Science.
Deawn - a new spring barley

R. S. ALBRECHTSEN AND W. G. DEWEY

Seed of a new spring feed barley was released in limited quantity to growers in Utah in the spring of 1973. The new variety was named Deawn because of its tendency to drop many beards from the head (deciduous awns) as the plant approaches maturity. Deawn was developed through cooperative efforts of personnel of the Utah Agricultural Experiment Station and the United States Department of Agriculture.

ORIGIN AND HISTORY

Deawn was derived from the cross Bonneville x Nepal 2x Bonneville Dwarf. Nepal is a six-row, hooded, hulless spring barley that is believed to have originated in Nepal, India. Bonneville Dwarf is a selection from Bonneville. The final cross was made by Dr. R. W. Woodward in 1957. The initial selection (B1742) was made from an F₃ population in 1960. This population was re-selected in 1963 and a number of the resulting strains were further evaluated. Deawn stems

Table 1. Height and lodging percentage of Deawn and varieties with which it was compared, 1970-1972

<table>
<thead>
<tr>
<th>Variety</th>
<th>Height (inches)</th>
<th>Lodging percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5-nursery avg.</td>
<td>15-nursery avg.</td>
</tr>
<tr>
<td>Deawn</td>
<td>28 38 27</td>
<td>37 41 22</td>
</tr>
<tr>
<td>Gem</td>
<td>32 39 33</td>
<td>28 46 45</td>
</tr>
<tr>
<td>Steveland</td>
<td>26 33 26</td>
<td>29 49 29</td>
</tr>
<tr>
<td>Bonneville</td>
<td>33 42 34</td>
<td>38 49 33</td>
</tr>
<tr>
<td>Bonneville 70</td>
<td>33 41 35</td>
<td>35 62 31</td>
</tr>
<tr>
<td>Vale</td>
<td>31 41 32</td>
<td>38 52 23</td>
</tr>
<tr>
<td>Woodvale</td>
<td>28 37 30</td>
<td>36 42 20</td>
</tr>
<tr>
<td>Hiland</td>
<td>34 43 35</td>
<td>43 67 41</td>
</tr>
<tr>
<td>Trebi</td>
<td>31 40 33</td>
<td>61 78 61</td>
</tr>
<tr>
<td>Piroline</td>
<td>32 40 35</td>
<td>50 48 41</td>
</tr>
</tbody>
</table>

Figure 1. Deawn is a new, six-row barley that has a tendency to drop many beards from the head as the plant approaches maturity.
from one of these single F<sub>1</sub> plants and was tested as B1742-16. It has been evaluated in Utah irrigated nurseries since 1965 and was tested in nurseries grown throughout the western area of the U.S. at 23 locations in 1969 and at 25 locations in 1970.

**AGRONOMIC CHARACTERISTICS**

Deawn is a six-row, white aleurone, semi-smooth awned, spring feed barley adapted to irrigated production. It is similar to Woodvale in height, lodging resistance and test weight (tables 1 and 2). Heading date of Deawn is similar to that of Woodvale and Hiland, but maturity date is 4-8 days earlier than these varieties. This shortened maturity period makes it comparable to Steveland in maturity date. It is outstanding in threshability (table 3), a characteristic for which many of our presently grown varieties show serious deficiencies. Many of the beards (awns) fall from the head prior to harvest time. The remaining ones are easily removed during the threshing operation.

**PATHOLOGIC CHARACTERISTICS**

Deawn has good resistance to diseases prevalent in the area in which it will be grown. It has excellent resistance to loose smut, the most destructive disease of barley in Utah (table 4).

### Table 2. Heading date, maturity date and test weight of Deawn and varieties with which it was compared, 1970-1972

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Deawn</td>
<td>18</td>
<td>18</td>
<td>16</td>
<td>16</td>
<td>20</td>
<td>48.3</td>
<td>49.0</td>
<td>48.2</td>
<td>48.5</td>
</tr>
<tr>
<td>Gem</td>
<td>7</td>
<td>10</td>
<td>4</td>
<td>7</td>
<td>21</td>
<td>47.8</td>
<td>49.6</td>
<td>47.9</td>
<td>48.5</td>
</tr>
<tr>
<td>Steveland</td>
<td>7</td>
<td>11</td>
<td>4</td>
<td>7</td>
<td>20</td>
<td>48.0</td>
<td>49.3</td>
<td>47.8</td>
<td>48.4</td>
</tr>
<tr>
<td>Bonneville</td>
<td>21</td>
<td>24</td>
<td>15</td>
<td>20</td>
<td>27</td>
<td>48.1</td>
<td>47.6</td>
<td>47.4</td>
<td>47.7</td>
</tr>
<tr>
<td>Bonneville 70</td>
<td>21</td>
<td>23</td>
<td>15</td>
<td>20</td>
<td>26</td>
<td>48.2</td>
<td>47.7</td>
<td>47.9</td>
<td>47.9</td>
</tr>
<tr>
<td>Vale</td>
<td>22</td>
<td>25</td>
<td>16</td>
<td>21</td>
<td>27</td>
<td>46.9</td>
<td>47.2</td>
<td>46.7</td>
<td>47.0</td>
</tr>
<tr>
<td>Woodvale</td>
<td>17</td>
<td>20</td>
<td>12</td>
<td>16</td>
<td>24</td>
<td>47.9</td>
<td>49.7</td>
<td>47.7</td>
<td>48.5</td>
</tr>
<tr>
<td>Hiland</td>
<td>18</td>
<td>17</td>
<td>12</td>
<td>16</td>
<td>28</td>
<td>48.0</td>
<td>47.8</td>
<td>48.7</td>
<td>48.1</td>
</tr>
<tr>
<td>Trebi</td>
<td>17</td>
<td>16</td>
<td>9</td>
<td>14</td>
<td>21</td>
<td>48.8</td>
<td>48.0</td>
<td>47.9</td>
<td>48.2</td>
</tr>
<tr>
<td>Piroline</td>
<td>13</td>
<td>18</td>
<td>10</td>
<td>14</td>
<td>24</td>
<td>51.2</td>
<td>51.9</td>
<td>52.7</td>
<td>51.9</td>
</tr>
</tbody>
</table>

### Table 3. Thresholdability rating of Deawn and varieties with which it was compared at five locations in 1971

<table>
<thead>
<tr>
<th>Variety</th>
<th>Formington</th>
<th>Bothwell</th>
<th>Morgan</th>
<th>Springville</th>
<th>Ephraim</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deawn</td>
<td>Ex</td>
<td>Ex</td>
<td>VG</td>
<td>VG</td>
<td>VG</td>
</tr>
<tr>
<td>Gem</td>
<td>G-</td>
<td>G+</td>
<td>G-</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Steveland</td>
<td>P</td>
<td>G-</td>
<td>P</td>
<td>G-</td>
<td>G</td>
</tr>
<tr>
<td>Bonneville</td>
<td>P</td>
<td>P</td>
<td>G</td>
<td>G</td>
<td>G+</td>
</tr>
<tr>
<td>Bonneville 70</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G+</td>
<td>VG</td>
</tr>
<tr>
<td>Vale</td>
<td>P</td>
<td>P</td>
<td>VP</td>
<td>F</td>
<td>P</td>
</tr>
<tr>
<td>Woodvale</td>
<td>F</td>
<td>F</td>
<td>P</td>
<td>G-</td>
<td>P</td>
</tr>
<tr>
<td>Hiland</td>
<td>G</td>
<td>G-</td>
<td>F</td>
<td>G-</td>
<td>G</td>
</tr>
<tr>
<td>Trebi</td>
<td>G-</td>
<td>G</td>
<td>F</td>
<td>G+</td>
<td>VG</td>
</tr>
<tr>
<td>Piroline</td>
<td>VG</td>
<td>VG</td>
<td>VG</td>
<td>VG</td>
<td>VG</td>
</tr>
</tbody>
</table>

*Ex = Excellent
VG = Very good
G = Good
F = Fair
P = Poor
VP = Very poor

**PERFORMANCE**

Yield of Deawn is slightly lower than that of Woodvale, but is equal or superior to that of Steveland, Gem, Bonneville and other varieties widely grown in Utah (table 5). Deawn is recommended for growing on the fertile irrigated lands of Utah and surrounding states. It has performed well when grown under such conditions and with proper management. It is not recommended for production on dry land or under water-deficient irrigated conditions.

It appears to be influenced by adverse growing conditions to a greater degree than some barley varieties; therefore, special attention should be
Table 4. Loose smut reaction of Deawn and varieties with which it was compared, 1968-1971

<table>
<thead>
<tr>
<th>Variety</th>
<th>Artificial inoculation</th>
<th>Natural infection</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent</td>
<td>Infected heads</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1968 1969 1971</td>
<td>(Logan)</td>
<td>1971</td>
</tr>
<tr>
<td></td>
<td>Infected heads</td>
<td>(Farmington)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>rating*</td>
<td></td>
</tr>
<tr>
<td>Deawn</td>
<td>3 0 0</td>
<td>0</td>
<td>VS</td>
</tr>
<tr>
<td>Gem</td>
<td>40 1 7</td>
<td>0</td>
<td>Tr</td>
</tr>
<tr>
<td>Steveland</td>
<td>60 10 3</td>
<td>0</td>
<td>Tr</td>
</tr>
<tr>
<td>Bonneville</td>
<td>75 50 75</td>
<td>0</td>
<td>Tr</td>
</tr>
<tr>
<td>Bonneville 70</td>
<td>50 25 36</td>
<td>0</td>
<td>Tr</td>
</tr>
<tr>
<td>Vale</td>
<td>0 0 0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Woodvale</td>
<td>0 0 0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hiland</td>
<td>0 0 0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Trebi</td>
<td>0 0 0</td>
<td>0</td>
<td>MS</td>
</tr>
<tr>
<td>Piroline</td>
<td>50 3 18</td>
<td>0</td>
<td>S</td>
</tr>
</tbody>
</table>

*0 = No smut
Tr = Trace
MS = Moderately severe
S = Severe
VS = Very severe

It can be concluded that given to provide adequate moisture and fertility at the proper time.

Its early maturity, short stiff straw, loose smut resistance and excellent threshability, combined with good yielding ability, should make Deawn a popular variety.

**SEED AVAILABILITY**

Foundation seed increase fields of Deawn are being grown in northern Utah in 1973. A limited amount of registered seed will be available for planting in the spring of 1974. This seed will be distributed through commercial seed channels.

Table 5. Yield summary (bu/A) of Deawn and nine widely grown barley varieties with which it was compared in Utah tests, 1967-72

<table>
<thead>
<tr>
<th>Variety</th>
<th>2-Nurs. averages</th>
<th>5-nurs. avg.</th>
<th>6-nurs. avg.</th>
<th>5-nurs. avg.</th>
<th>22-nurs., 6-year avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deawn</td>
<td>95.3 132.1 90.0</td>
<td>103.4</td>
<td>118.4</td>
<td>112.2</td>
<td>110.1</td>
</tr>
<tr>
<td>Gem</td>
<td>102.6 122.8 78.6</td>
<td>102.3</td>
<td>99.9</td>
<td>111.6</td>
<td>103.5</td>
</tr>
<tr>
<td>Steveland</td>
<td>101.3 122.1 100.6</td>
<td>110.8</td>
<td>109.9</td>
<td>115.0</td>
<td>110.7</td>
</tr>
<tr>
<td>Bonneville</td>
<td>93.4 130.6 103.0</td>
<td>96.9</td>
<td>102.8</td>
<td>105.8</td>
<td>103.8</td>
</tr>
<tr>
<td>Bonneville 70</td>
<td>97.9 122.9 105.5</td>
<td>103.1</td>
<td>102.6</td>
<td>110.8</td>
<td>106.3</td>
</tr>
<tr>
<td>Vale</td>
<td>95.8 128.7 107.4</td>
<td>94.1</td>
<td>108.0</td>
<td>109.8</td>
<td>106.0</td>
</tr>
<tr>
<td>Woodvale</td>
<td>104.4 144.3 106.9</td>
<td>107.6</td>
<td>117.7</td>
<td>119.3</td>
<td>116.0</td>
</tr>
<tr>
<td>Hiland</td>
<td>99.9 122.7 109.0</td>
<td>105.2</td>
<td>109.1</td>
<td>109.0</td>
<td>108.6</td>
</tr>
<tr>
<td>Trebi</td>
<td>88.0 108.1 97.9</td>
<td>99.3</td>
<td>99.2</td>
<td>114.9</td>
<td>102.5</td>
</tr>
<tr>
<td>Piroline</td>
<td>80.8 116.8 99.2</td>
<td>100.3</td>
<td>104.0</td>
<td>109.4</td>
<td>103.0</td>
</tr>
</tbody>
</table>

**PULLING PANTY HOSE OVER MOTHER GOOSE’S EYES**

The Nebraska Game and Parks Commission reports those little egg-shaped containers used by one brand of panty hose are being used as dummy eggs for nesting waterfowl.

In a cooperative project with the Lincoln Parks Department, the Commission is incubating swan eggs to help produce cygnets for the waterfowl area at one of the city’s parks. The hosiery containers have been used successfully for two years to fool nesting geese in that state.

The plastic containers are filled with sand, then sealed and traded for real eggs which are then placed in incubators. They are just about the same size and appearance of goose eggs. If eggs are stolen without a convincing replacement, the bird is likely to abandon her nest and establish another in a more remote spot. The replacement keeps her happy with her first choice until she finishes her clutch. Then technicians steal the dummies and cover the nest. Five days later, they uncover it and the bird returns to start the whole procedure again. Waterfowl production is about doubled in this way — at least with geese. Commission personnel are not sure whether the swans will be so gullible.
SOME HOWS AND WHYS OF CEREAL BREEDING IN UTAH

W. G. DEWEY AND R. S. ALBRECHTSEN

IMPORTANCE OF CEREALS IN UTAH

Compared with states such as Kansas, Nebraska and Washington, Utah is not a major producer of wheat, oats and barley. However, almost every farm in the state grows one or more of these grain crops, and together they comprise a very significant part of Utah’s agricultural economy. In addition, their annual “raw” farm value of approximately $20 million increases several-fold as they are converted into end products by the state’s multi-million dollar milling and baking and livestock industries.

The cereals are especially important on the approximately one-third of Utah’s total cropland that is non-irrigated. On much of this dryland acreage the choice of crops is very limited. Wheat and barley are often not only the best choice, they frequently are about the only feasible choice.

BREEDING FOR UTAH CONDITIONS

A common observation of Utah farmers and home gardeners alike is that varieties brought in from other areas frequently fail to perform up to their expectations. The greater the diversity in growing conditions (e.g., climate, soil type, topography, day length, etc.) between the region where a variety is developed and the area in which it is grown, the greater the disparity between expectations and performance. Varietal performance is the product of the plant’s genetic make-up interacting with the environment in which it is grown. The same variety may interact very favorably (i.e., be highly productive) with one environment and interact quite poorly (mediocre yields) with another.

Wheat varieties brought into Utah from the large wheat producing states of the Great Plains, for example, seldom do as well as our locally developed wheats. Conversely, our wheat varieties have found relatively little use outside the Intermountain area. In addition to major differences in topography and climate, the Great Plains and the Intermountain area differ in cereal disease problems. The main problem in the Great Plains is rust, while our major problem is smut. Their varieties invariably lack the smut resistance needed in our area while our varieties are usually too late maturing and too rust susceptible to serve their purposes.

Even within our own state, growing conditions are so variable that no one wheat or barley variety could possibly fit all situations. Utah is chopped up into a diversity of climates by its spectacular geography. Varieties bred specifically to perform well under irrigation on the fertile soils of our high mountain valleys are usually ill-adapted to the more shallow soils and limited moisture that characterize our dryland areas. The varieties that perform well in the relatively cool and high northern counties frequently do not do best in the semi-desert climate of Utah’s Dixie. This extreme intra-state variability is quite in contrast with the large, relatively uniform wheat pro-

Figure 1. Each wheat or barley flower has three anthers which are the pollen bearing structures.

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W. G. DEWEY is a professor in the Department of Plant Science.

UTAH SCIENCE
ducing regions of the Great Plains states or even of the extensive Palouse wheat growing area of the Pacific Northwest. Consequently, we must tailor-make varieties to fit a wider range of local environments.

A LONG RANGE PROCESS

The development of new varieties is not unlike the priming of a pump: it takes a lot of pouring in and some vigorous pumping before anything comes out (and then it may be only muddy water for awhile). It is normally 10-12 years from the time a cross (a hybrid) is made until a new variety is released to the farmer, and there is no assurance that any given cross will result in a new, superior variety. In fact, most do not. A truly superior gene combination is rarely achieved. Within each cross, even those that are ultimately abandoned, thousands of individual plants are examined and discarded for every one that is saved for further testing. Of the thousands of crosses made by a plant breeder during his professional lifetime, probably less than a dozen will ever result in superior new varieties.

Making the cross itself is probably the easiest and least time-consuming part of the whole breeding operation. A wheat or barley cross can be made in a few minutes. Each flower has three anthers (pollen bearing structures). These are removed with tweezers. Pollen from another variety is then introduced to produce the cross. The resulting hybrid combines the genetic make-up of both parents. The different genetic combinations represented by the descendants of this hybrid plant are almost limitless. The great majority of these plants are usually inferior to the best original parent plant. The challenge to the breeder is to find the “one in a million” that may be good enough to release as a variety.

The problem would be relatively simple if the variety had to be outstanding in only one or two characteristics, e.g., smut resistance and yield. Even then, thousands of plants would have to be grown, artificially inoculated, checked for smut reaction, and the smut resistant plants grown in comparative yield tests under various growing conditions for several years in several locations. The farmer, however, may want to sell this smut-resistant, high yielding wheat to the mill. The miller has his own set of requirements: the kernels must be high in test weight and must yield a high percentage of low ash flour. The baker in turn requires flour with very specific mixing and baking properties: the quantity and quality of the protein components, particularly gluten, must be such that the dough will hold up well under mechanical mixing and will bake into a loaf with good volume, texture and color. All of these are genetic characteristics and must be tested for, sorted out, and

Figure 2. To make a cross (hybridize) the anthers are removed with tweezers and pollen from another variety is introduced to the remaining flower fruiting body).
assembled by the breeder into a variety that will satisfy the needs of the growers, processors, and consumers. To these must be added: resistance to several other diseases (e.g., mildew, stripe rust, snow mold, root rot) along with resistance to lodging and shattering, suitable harvesting and threshing characteristics, etc. Plant breeding thus exemplifies the proverbial search for a "needle in a haystack."

A GOOD INVESTMENT

Although the process of varietal development is sometimes painfully slow, it is the only way to produce new and better varieties, and in the long run is usually a profitable investment. The savings realized in a single serious disease year by the widespread use of a new disease resistant variety will frequently more than pay for all of the breeding work ever done on that particular crop. For example, it is estimated that when the wheat variety "Cache" was released back in the late 1930s, it prevented losses due to dwarf smut of up to $2 million per year in the Intermountain area.

An increase in productivity of only a few bushels per acre through the use of improved varieties can return significant dividends. Over the past 15 years the average yields of winter wheat in Utah have increased from 18 bushels to 28 bushels per acre. Considering Utah's present winter wheat acreage at about 200,000 acres and the price of wheat at $2.25 per bushel, this increase amounts to over $4 million annually. While the 10 bushels per acre increase is certainly not all due to better varieties (such factors as increased fertilizer use, better irrigation, improved tillage practices, etc., have all contributed), the use of improved varieties has played a significant part.

The same story can be told for barley. Average per acre yields in Utah have gone from 45 bushels 15 years ago to 60 bushels at the present time. With our present barley acreage at about 140,000 and the price at $1.25 per bushel, this 15 bushel per acre increase in yield represents an additional income of $2.5 million annually for Utah barley growers.

THE DYNAMICS OF VARIETAL CHANGE

The varietal picture is never static, due to the continually changing requirements imposed by new farming practices, changing quality concepts and standards (miller, baker, housewife, export market), new diseases and new races of old diseases, etc. The evolution of winter wheat varieties in Utah is a typical example.

The wheat breeding program in Utah began in 1925 in response to requests from farmers for help with a serious new smut problem. This new smut was not responding to the usual seed treatment practices that had been effective in the past. By 1929, 75 percent of the wheat arriving at the Ogden and Salt Lake milling terminals was graded smutty, and Utah was about to lose its wheat growing industry.

In 1931, the seed of a new smut resistant variety, appropriately named "Relief," was distributed to commercial growers. Smut began to decline. "Relief" was followed by "Cache" in 1937 and by "Wasatch" in 1944. As these new dwarf-smut resistant varieties replaced the older susceptible wheats such as "Turkey" and "Utah Kanred", the incidence of smut fell off until by 1950 less than 5 percent of the wheat arriving at the Ogden and Salt Lake mills was graded smutty.

Attention then was turned to improving bread-making quality. "Cache" and "Wasatch" were deficient in certain gluten properties needed by the large commercial bakers. This had not been a problem as long as most housewives were baking their own bread. The variety "Delmar" was released in 1961 in an attempt to remedy the quality problem. "Delmar" has excellent mixing and baking quality and retains the level of smut resistance of "Cache." "Delmar" has especially stiff straw and a brittle head, however, and growers have experienced some difficulty in getting it to feed into the combine harvester. In spite of this, it has been widely used in northern Utah and western Colorado, particularly in areas where lodging is a common problem and stiff straw constitutes an advantage.

"Bridger," released in 1969, combines the smut resistance of "Cache" and the quality of "Delmar," and it overcomes the harvesting problems of "Delmar."

At about the time the quality and harvesting problems were showing signs of solution, smut began to move back into the picture. New races capable of attacking the previously resistant varieties were apparently building up in the area. In 1971 almost half of the carloads of wheat arriving at the Ogden elevators again graded smutty. Fields of "Cache" and "Bridger" in some of the worst smut areas were running as high as 50 percent smutted. One large wheat grower in Box Elder County estimated his losses to smut in 1971 at nearly $35,000.00.

In an attempt to bring the smut problem back into check, two new breeding lines are being increased. One or both of these will probably be released on a limited scale in the fall of 1973. Both have shown a high level of resistance to the dwarf smut races that are decimating our present varieties.

The life expectancy of new varieties is shrinking as the demands being made on them become more specific. Farmers are becoming more variety-conscious as farming practices become increasingly sophisticated. Whereas one variety used to occupy essentially all of the dryland wheat acreage over several counties, it is not unusual now to see several varieties on the same farm, e.g., one for the fertile bottom ground where lodging may be a problem and another for the higher, rocky slopes where...
Figure 3. Wheat breeders are in a constant battle against smut mutations. In the Intermountain area, smut is the major wheat disease problem. As a resistant variety is developed and comes into wide use, a new race of dwarf smut mutates, becomes infective, and the plant breeders must develop another resistant variety that will still possess desirable yield, threshing, and milling characteristics.

drought stress may be a factor. Farmers are beginning to "shop" for grain varieties about like their wives do for specific brands of items on the grocery shelves.

OUTLOOK

As new disease, quality and agronomic problems continue to arise, new varieties will be needed to meet the changes. Hopefully if we can keep the pump primed, the required varieties will be developed reasonably near the time they are needed.

WILDLIFE NOTES

The bat, which is a marvelous flyer, usually drinks while in flight by passing back and forth over a pool of water, scooping up a small tongueful of water on each pass.

A female fly can lay its first batch of eggs in less than a week after its birth.

The four-horned antelope of India and Burma is the only wild animal in the world with four horns. Only the males have horns.

Fish have no vocal organs, but are by no means silent. They make sounds by grinding their teeth or setting up vibrations in certain organs such as the swim bladder.
Stem nematode-induced injury to alfalfa plants

W. F. CAMPBELL AND G. D. GRIFFIN

Alfalfa (Medicago sativa L.) is by far the most important forage crop in Utah as well as in the United States. Since alfalfa is a relatively long-lived perennial, once it is established, the farmer or rancher can realize good monetary return for his investment.

As a forage, alfalfa contains about twice as much digestible protein as clover, and about four times as much as timothy-clover hay or corn silage. Moreover, the alfalfa leaf protein may have potential as a source of protein for humans. Alfalfa has a high mineral content and contains at least ten different vitamins. It is an especially important source of vitamin A. Furthermore, alfalfa encourages the formation of a well-structured and nitrogen-enriched soil layer.

NEMATODES LOVE IT

Unfortunately, this prodigious crop is subject to attack by various diseases and parasites. Many fields of alfalfa are weakened each year by one of these, the alfalfa stem nematode (Ditylenchus dipsaci Kuhn), which is a microscopic, slender, roundworm about 0.5 mm (1/2 inch) long and 0.03 mm (1/900 inch) wide. The first grossly visible symptom of infection by the alfalfa stem nematode, D. dipsaci, is the formation of a gall or a swelling on the stem (figures 1, 2). Once the alfalfa plants are weakened by the stem nematodes, bacteria and other organisms can easily move in.

W. F. CAMPBELL is an Associate Professor of Agronomy in the Department of Plant Science.

G. D. GRIFFIN is a Federal Collaborator for the Agricultural Research Service.

UTAH SCIENCE
Losses to the alfalfa nematode in Utah amount to about 1½ million dollars annually. In the United States the losses equal about 86 million dollars annually. Nematodes take a toll of various crops in the United States estimated at 1.6 billion dollars. This value plus the amount spent for nematode control approaches 1.7 billion dollars annually.

Chemical control of the nematodes is not yet feasible. Therefore, protection can only come through the breeding and developing of resistant varieties. In alfalfa, there is apparently no relationship between severity of host response and numbers of invading nematodes. Since one organism can do so much ultimate damage to a plant as several, the resistance has to be absolute to be effective.

CELL RESISTANCE

Scientists at Utah State University thought that nematode-induced changes might occur at the cellular level long before visible symptoms were evident. If so, definition of such changes might elucidate subtle, yet important, differences between susceptible and resistant (not subject to invasion) or tolerant (not injured by invasion) alfalfa varieties. These differences could aid plant breeders in developing consistently resistant lines.

Light microscopic studies of D. dipsaci (the nematode) on alfalfa have indicated distinct varietal differences in young seedlings following infection (figures 3, 4). In Lahontan

**FIGURE LEGEND**

C — Chloroplast  
CO — Cortex  
CW — Cell Wall  
D — Dictyosomes  
ER — Endoplasmic Reticulum  
G — Granum (Grana)  
M — Mitochondrium (a)  
N — Nucleus (ei)  
NE — Nematode  
PG — Plastoglobuli  
PL — Plasma Lemma  
R — Ribosomes  
S — Stroma  
SG — Starch Grains  
T — Tonoplast  
VB — Vascular Bundles

Figure 3. Light micrograph of a cross section of hypocotyl region below cotyledons of seven-day-old control alfalfa. X 600.

Figure 4. Light micrograph of a cross section of a hypocotyl region below cotyledons of seven-day-old nematode infected alfalfa seedling. Note the infection is only in the cortical region. X 600.
alfalfa (tolerant variety), the nematodes were found in cavities in the plant. Cell walls adjacent to such cavities had a strong affinity for safranin stain. The cells in surrounding tissues were intact, and the cellular structure around the cavities showed very little disruption. By contrast, a very pronounced swelling followed infection in Ranger alfalfa (susceptible variety). The cellular structures were disrupted in the vicinity of the nematodes. Moreover, the cell walls seemed to dissolve, with a gradient of damage extending in all directions away from the nematode-infested cells. The cell walls of Ranger plants did not exhibit an affinity for the safranin stain. Further, the adjacent cells enlarged, chloroplasts disappeared and intercellular space increased in the parenchyma tissue following infection. These effects appeared to precede direct contact of the nematodes with the cells, suggesting that salivary secretions might be diffusing in advance of the nematodes. Many plant-parasitic nematodes, e.g., Rotylenchulus, affect only those cells upon which they feed, or a limited number of cells in the immediate vicinity of the feeding site. D. dipsaci, however, causes changes in cells at great distances from itself.

The electron microscope revealed that the types of damage inflicted on Lahontan (tolerant) and Ranger (susceptible) alfalfas were the same (figures 5, 6). Only the infection rate (in percent) and degree of damage differed between the alfalfa varieties, and among the different temperatures (15, 20, and 25 C at which control and infected plants were grown in one experiment. The higher the temperature, the more the injury.

**FLAGGING**

During the summer of 1971, irrigated Ranger alfalfa growing in Cache Valley in northern Utah developed a condition known as stem-nematode-induced white flagging. This type of nematode-induced injury had been identified on irrigated alfalfa in Utah in Salt Lake County in 1970, but had not previously been observed in northern Utah. The condition had been reported in central Washington State and in western Nevada. The symptoms, as observed and described in these states, include partial to complete loss of normal green pigmentation of the leaf and stem tissues (figure 7). The less severe forms of this “flagging” have been categorized...
as: "(a) shoots are green part way up from the base and white at the top; (b) leaves are white while the stem is green (all the leaves or only alternate leaves may be affected); and (c) the stem and leaves are green but the axillary shoots (and often the stem apex) are white."

Although the white flagging is conspicuous, in Utah only about 1 percent of the plant population exhibited this phenomenon. The symptoms have been seen under conditions of high light intensity, high temperature and high relative humidity due to recent over-irrigation. Preliminary examination of the weather records for the past 10 years in northern Utah, however, indicates no unusual deviations from the normal. Greenhouse studies have not yet reproduced the white flagging symptoms.

Electron micrographs indicate that cells from green, non-infected, control leaf tissues have normal walls and cytoplasm, and contain normal organelles (figure 8). By contrast, when an infected plant exhibited a gradient of leaf discoloration from pale green to complete white, there was progressive degradation of leaf cells (figure 9). The significance of the observed changes is that the chloroplasts in affected leaves contain all of the necessary enzymes for photosynthesis, but their activity is partially, to completely, destroyed by the alfalfa stem nematode.
The provision of health-related services in rural and urban areas

STAN L. ALBRECHT AND MICHAEL K. MILLER

Providing an improved quality of life to rural Americans constitutes one of the principal reasons for the programs that can be described by the general heading "rural development." It is generally accepted that the "quality of life" of a given group of people or segment of a population is greatly affected by the degree to which basic services (health, education, etc.) are available to them. As such services become available in areas that have lacked them, the quality of living in those areas is said to have improved.

In Utah, health care services vary among the counties and the multi-county planning districts as evidenced by: (1) a special report entitled "Utah Health Facts," prepared by the Utah Center for Health Statistics, State Division of Health, and (2) survey data collected over the past several months by trained interviewers in the homes of randomly selected residents of Beaver, Piute, and Wayne counties, and in the Valley West Communities of Salt Lake County. Indicators or measures of the extent of this program, along with some innovative programs that are being used to alleviate it are described in this article.

THE RURAL HEALTH PROBLEMS

National figures show that while counties in the U.S. that can be classified as metropolitan adjacent have an average of about 140 physicians per 100,000 population, the same figure for counties classified as rural or semi-rural is about 80. Not only are there not enough doctors in rural areas, but:

1. Rural people must travel longer distances at greater cost to obtain health care.

2. The United States Public Health Service calls heart conditions, arthritis, rheumatism, high blood pressure, and visual impairment the chronic health conditions that lessen productive work and drain on family finances. The incidence of such illnesses increases with rurality.

3. Although emergency ambulance service is most needed in rural areas because of distance factors, it is precisely in these areas where ambulance teams are nonexistent or operate at very low efficiency. This has important implications when one considers that farming ranks third in accident fatalities.

The health care problems of rural areas can be attributed, at least in part, to changes that have been occurring for decades in this country. While some of these changes reflect such things as declining rural populations and increased gaps between educational and cultural opportunities in rural and urban America, others relate directly to the medical profession itself. For example, the trend toward specialization in the medical profession has largely eliminated the general practitioner who previously carried much of the load of rural medicine. In addition, the rapidly expanding, urban-oriented medical technology requires vast amounts of complex and expensive equipment posing major obstacles, especially of an economic nature, for rural areas. In sum, the urban environment, with its extensive drawing power in the form of cultural advantages, higher income potentials, access to more highly sophisticated technology, etc., has naturally tended to attract physicians.

In addition to this original influx of physicians to urban areas, the once-rural doctor has increasingly tended to gravitate toward urban areas. For example, in isolated rural areas (defined as counties with no townships as large as 2,500 inhabitants) the number of physicians decreased about six times as fast as did the population between 1950 and 1960. This disproportionate decline seems to be continuing when small towns and rural areas are compared with larger population centers.

Further, as numbers of health personnel decrease in rural areas, expectations have been rising. Public health agencies have successfully created a greater health consciousness among Americans, which has generated demands for quality health services and personnel.

THE UTAH SITUATION

A common way to assess the adequacy of medical services in a given area, is to compute a physician-population ratio or to develop some similar type of measure such as the number of hospital beds per 1,000 population. Utah’s State Office of Comprehensive Health Planning has defined multi-county districts as health planning units. Adequacy of medical services has been calculated for these units and for specific counties (table 1). The tabulated data indicate that county or other political boundaries are
relatively meaningless when measuring adequacy of services in a given area. For example, although Wayne and Piute counties have no physicians or hospitals, residents of these counties can go to adjacent areas to seek hospital and medical care. Travel-distance boundaries are therefore more important than arbitrary political divisions.

The physician-population ratio demonstrates that the more urban counties and districts in the state, with the exception of the counties that comprise district VI, have the more favorable situation. Salt Lake County has well over half of all of the physicians in the entire state. At the opposite extreme, four counties (Wayne, Piute, Rich, and Daggett) have no physicians practicing within their borders. The same four counties, plus Emery and Morgan have no hospital facilities.

The situation changes rather dramatically when the criterion is the number of hospital beds per 1,000 population. With the exception of those counties having no hospitals, rural areas generally fare somewhat better than do the urban areas. On a strictly district level, even the counties with no hospital beds are quite well served. Two rural districts, VI and VIII, lead the state in number of hospital beds per capita.

It can legitimately be argued, however, that neither the number of physicians per 1,000 population nor the number of hospital beds per 1,000 population are very good indicators of adequacy of health services. The number of physicians per given unit of population tells us nothing about the quality of service available. Rural areas generally have a fairly high percentage of their MDs falling into the older age categories, where efficiency may very well have declined. Thus, the quality of service available needs a different measure than the presence of a practicing physician.

Turning to the hospital issue, the types and quality of medical care that can be obtained in rural hospitals is not likely to compare favorably with that in the larger urban hospitals with their highly sophisticated technology. Persons needing such care therefore cannot be treated in rural hospitals and are frequently transferred to urban areas. In addition, the utilization of the beds available varies greatly between urban and rural areas.

### Table 1. Licensed physicians and hospital beds per 1,000 population and 100 square miles by county and district*

<table>
<thead>
<tr>
<th>District and County</th>
<th>Physicians** per 1,000 population</th>
<th>Physicians** per 100 square miles</th>
<th>Hospital Beds*** per 1,000 population</th>
<th>Hospital Beds*** per 100 square miles</th>
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<td>State</td>
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<td>Rich</td>
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<td>.88</td>
<td>14.26</td>
<td>2.53</td>
<td>39.97</td>
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<td>.75</td>
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<td>8.96</td>
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<td>2.38</td>
<td>.76</td>
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<tr>
<td>Utah</td>
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<td>20.56</td>
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<td>.....</td>
<td>.....</td>
<td>.....</td>
<td>.....</td>
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<td>Sanpete</td>
<td>.54</td>
<td>.38</td>
<td>4.18</td>
<td>1.14</td>
</tr>
<tr>
<td>Sevier</td>
<td>.58</td>
<td>.31</td>
<td>2.18</td>
<td>1.14</td>
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<td>Wayne</td>
<td>.....</td>
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<td>.....</td>
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<td>.92</td>
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<td>.93</td>
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<td>.61</td>
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<td>.45</td>
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<td>1.69</td>
</tr>
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<td>District VII</td>
<td>.37</td>
<td>.09</td>
<td>3.15</td>
<td>.77</td>
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<td>.....</td>
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<td>Duchesne</td>
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<td>.09</td>
<td>4.25</td>
<td>.95</td>
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<td>Uintah</td>
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<td>.76</td>
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<td>Grand</td>
<td>.65</td>
<td>.11</td>
<td>5.68</td>
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<td>San Juan</td>
<td>.49</td>
<td>.06</td>
<td>6.77</td>
<td>.84</td>
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*These figures were compiled from data presented in "Utah Health Facts," prepared for the Utah Center for Health Statistics, State Division of Health.

**Taken from a November, 1971 list of all licensed physicians in the State of Utah, published by the Department of Business Regulations. List includes specialists and physicians not in private practice.

***Refers to short-term general hospitals only. Excludes specialty, federal, long-term, and institutional hospitals.
Because of the problems associated with the computed ratios of physicians and hospital beds per population unit, another measure was devised. The numbers of physicians and hospital beds per 100 square miles are also detailed in table 1.

The data presented demonstrate what other researchers have referred to as the “social cost of space.” It seems ironic that the crowded conditions of the central city are sometimes seen as casual factors in many health-related problems, while the opposite situation, a sparse population, contributes significantly to health-related problems of rural areas. For areas of low population density, space itself adds to social overhead costs by limiting the ability of one doctor or one dentist to serve as many people as would be possible in a more densely populated area.

While districts such as district VI compare somewhat favorably with urban areas on physician-population ratios and hospital bed-population ratios, the number of physicians and hospital beds per 100 square miles is nowhere near the level of the most urbanized areas. The situation in districts such as district V is even more serious when utilizing such a measure.

Our survey results obtained from Salt Lake, Beaver, Wayne, and Piute Counties generally support the above observations. Each of our respondents was asked to indicate the number of miles he or she must drive (one way) to obtain what was felt to be adequate medical service (table 2).

While 98 percent of residents from our Salt Lake sample travel less than 25 miles to obtain what they feel is adequate service, 100 percent of the Wayne County sample travel over 25 miles one way to obtain what they would define as adequate medical care. The cost of having to travel such distances in terms of both time and money is significant.

The individuals in our Wayne and Piute samples recognize clearly the seriousness of their medical care problems. Each subject was asked to rate the adequacy of health and medical services in their area (table 3). As indicated in table 3, 100 percent of the Wayne County respondents and 96 percent of the Piute County respondents rated their situation as poor. Beaver and Salt Lake County respondents, on the other hand, rated their communities much more favorably on health care services.

Since people are generally opposed to paying taxes, this should be one good measure of the extent to which services are viewed as satisfactory. If people are willing to pay more taxes to improve a certain service, then its present level must be seen as inadequate (table 4). The data in table 4 support the argument that people in Wayne and Piute Counties perceive their lack of adequate medical services as one of the most, if not the most, serious problem facing their community today. Even in Beaver County, residents expressed a greater willingness to pay more taxes to provide better health and medical facilities than to improve any other service.

By contrast, the Salt Lake sample was less willing to pay increased taxes for health-related services than for several others. Health services ranks fifth, preceded by willingness to pay taxes to upgrade law enforcement, improve recreational opportunities, improve schools and other educational facilities, and to help clean up pollution. Even so, a considerable percentage of the urban respondents indicated a willingness to pay increased taxes to improve the quality of existing services. Though all of the figures on willingness to pay increased taxes appear to be rather inflated, it is clear that medical care delivery is of major concern, particularly in rural areas of the state.

Several other results of our interview data seem significant. For example, there is a good deal of evidence in the literature that socioeconomic factors are the major determinants of medical-related behavior. Our data, however, suggest that availability of medical personnel agencies may be the most important determinant of medical behavior (table 5).

---

**Table 2. One-way miles to obtain "adequate" medical service**

<table>
<thead>
<tr>
<th>Miles</th>
<th>Wayne</th>
<th>Plute</th>
<th>Beaver</th>
<th>Salt Lake</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-25</td>
<td>0 %</td>
<td>1.9%</td>
<td>88.8%</td>
<td>97.7%</td>
</tr>
<tr>
<td>26-50</td>
<td>7.2</td>
<td>61.1</td>
<td>7.8</td>
<td>1.7</td>
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<tr>
<td>51-75</td>
<td>333</td>
<td>16.7</td>
<td>1.1</td>
<td>0.6</td>
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<tr>
<td>76-100</td>
<td>23.2</td>
<td>5.6</td>
<td>0</td>
<td>0</td>
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<tr>
<td>101-150</td>
<td>2.9</td>
<td>3.7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>151-200</td>
<td>26.1</td>
<td>3.7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>over 200</td>
<td>7.2</td>
<td>7.4</td>
<td>2.2</td>
<td>0</td>
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</table>

*Question: "Approximately how many miles must you travel in order to receive what you feel is adequate medical service?"

**Table 3. Rating of community as a place with adequate medical and health facilities**

<table>
<thead>
<tr>
<th>Rating</th>
<th>Wayne</th>
<th>Plute</th>
<th>Beaver</th>
<th>Salt Lake</th>
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<tbody>
<tr>
<td>Excellent</td>
<td>0 %</td>
<td>0 %</td>
<td>33.3%</td>
<td>18.5%</td>
</tr>
<tr>
<td>Good</td>
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<td>0</td>
<td>51.0</td>
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<tr>
<td>Fair</td>
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<tr>
<td>Poor</td>
<td>100.0</td>
<td>96.3</td>
<td>7.8</td>
<td>11.6</td>
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</table>

*Question: "How would you rate the community where you now live as a place with adequate medical and health facilities."
### Table 4. Percent of persons willing to pay increased taxes for selected services*

<table>
<thead>
<tr>
<th>Service</th>
<th>Wayne Yes %</th>
<th>Wayne No %</th>
<th>Piute Yes %</th>
<th>Piute No %</th>
<th>Beaver Yes %</th>
<th>Beaver No %</th>
<th>Salt Lake Yes %</th>
<th>Salt Lake No %</th>
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<tr>
<td>To provide better health and medical service</td>
<td>85.5</td>
<td>14.5</td>
<td>92.6</td>
<td>7.4</td>
<td>63.9</td>
<td>35.6</td>
<td>64.2</td>
<td>35.8</td>
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<tr>
<td>To improve schools and other educational facilities</td>
<td>72.5</td>
<td>27.5</td>
<td>48.1</td>
<td>51.9</td>
<td>62.2</td>
<td>36.7</td>
<td>76.3</td>
<td>23.1</td>
</tr>
<tr>
<td>To provide more jobs for local residents</td>
<td>73.9</td>
<td>26.1</td>
<td>68.5</td>
<td>29.6</td>
<td>63.9</td>
<td>35.6</td>
<td>62.4</td>
<td>36.4</td>
</tr>
<tr>
<td>To develop local industry</td>
<td>78.3</td>
<td>21.7</td>
<td>72.2</td>
<td>27.8</td>
<td>63.3</td>
<td>35.0</td>
<td>48.0</td>
<td>52.2</td>
</tr>
<tr>
<td>To improve recreational opportunities</td>
<td>55.1</td>
<td>44.9</td>
<td>42.6</td>
<td>57.4</td>
<td>53.3</td>
<td>46.1</td>
<td>79.2</td>
<td>20.2</td>
</tr>
<tr>
<td>To upgrade law enforcement</td>
<td>65.2</td>
<td>33.2</td>
<td>40.7</td>
<td>59.3</td>
<td>51.1</td>
<td>47.8</td>
<td>81.5</td>
<td>17.3</td>
</tr>
<tr>
<td>To train local government officials</td>
<td>50.7</td>
<td>49.3</td>
<td>33.3</td>
<td>64.8</td>
<td>48.3</td>
<td>51.1</td>
<td>42.2</td>
<td>57.2</td>
</tr>
<tr>
<td>To provide better housing</td>
<td>52.2</td>
<td>46.4</td>
<td>44.4</td>
<td>53.7</td>
<td>56.7</td>
<td>42.8</td>
<td>41.6</td>
<td>58.4</td>
</tr>
<tr>
<td>To help clean up pollution</td>
<td>44.9</td>
<td>55.1</td>
<td>31.5</td>
<td>68.5</td>
<td>46.1</td>
<td>52.2</td>
<td>75.7</td>
<td>24.3</td>
</tr>
<tr>
<td>To help provide opportunities for cultural refinements</td>
<td>58.0</td>
<td>42.0</td>
<td>33.3</td>
<td>63.0</td>
<td>56.7</td>
<td>42.8</td>
<td>52.6</td>
<td>47.4</td>
</tr>
</tbody>
</table>

*Question: "Below is a list of services which frequently require taxes to support and maintain: Would you be willing to pay more taxes for these services if you knew the money would be spent in this area?"
Numbers do not always total 100% because of a small number of non-responses to some of the items.

Over 50 percent of our Wayne and Piute samples indicate that they would visit a doctor more frequently if one was more readily available. This was true of only 12 and 4 percent of our Salt Lake and Beaver County samples, respectively. Apparently, with doctors more readily accessible geographically in these two latter counties, persons visit them whenever they feel it is necessary.

In further support of this argument, almost a third of the respondents in Wayne and Piute counties state that they have needed medical services they were unable to receive (table 6). Most attributed this not to economic reasons (such as they didn't feel they could afford to go to the doctor), but rather to such variables as time and distance between where they lived and the nearest physician.

Respondents from Wayne and Piute Counties are also more likely to consult a doctor only when it is absolutely necessary (table 7). Subjects from Beaver and Salt Lake Counties are more likely to contact a physician as soon as they suspect a problem. Accessibility, again, appears to be a crucial variable. It should be noted, however, that a fairly significant percentage of the people in rural Beaver County consult a doctor only when they perceive it as being absolutely necessary. Both accessibility and rurality are apparently important factors in this instance.
INNOVATIVE HEALTH-CARE PROGRAMS

The Medics Program is one outstanding example of an innovative program that seems to be working very well in areas where it is being tried. The assistance of two medics in Beaver County may very well be an important factor contributing to the part of local residents that things are going well as far as health delivery in their area is concerned. Certainly, the program is being well received by Beaver residents (table 8).

As can be seen from table 8, a higher percentage of Beaver County residents than of any other area in our sample expressed a willingness to patronize a non-M.D. for medical care. This seems to indicate good success of the existing program. The other two rural counties also had a high percentage who would be willing to patronize a non-M.D. The situation in urban Salt Lake County (where residents probably feel they would never have a need for paramedical service) is different.

Another example of an effective innovative program is the establishment of weekly clinics in Hanksville, Wayne County. Trained medical professionals are flown into Hanksville to provide service and care to a relatively isolated population.

Efforts to improve the quality of health care through such programs deserve continued attention from medical professionals as well as others interested in this crucial problem. While local concern is essential, outside help is frequently needed to help communities solve their problems. If local programs must depend upon the development of grant proposals and programs of action initiated on the local level, the more advantaged communities are likely to remain so. The communities that are most in need of help often lack the qualified manpower to do the planning, obtain the support, and implement the programs. Such communities require inputs from outside interests in developing and operating innovative programs if these programs are to be successful.

### Table 7. Stage at which a doctor is consulted*

<table>
<thead>
<tr>
<th>Stage of Consultation</th>
<th>Wayne</th>
<th>Piute</th>
<th>Beaver</th>
<th>Salt Lake</th>
</tr>
</thead>
<tbody>
<tr>
<td>As soon as a problem is suspected</td>
<td>33.3%</td>
<td>29.6%</td>
<td>48.0%</td>
<td>43.3%</td>
</tr>
<tr>
<td>After using non-prescription medicines to try and remedy the problem</td>
<td>10.1%</td>
<td>13.0%</td>
<td>9.0%</td>
<td>22.8%</td>
</tr>
<tr>
<td>After using non-prescription medicine and consulting non-professional persons</td>
<td>2.9%</td>
<td>3.7%</td>
<td>0.6%</td>
<td>4.1%</td>
</tr>
<tr>
<td>Only when absolutely necessary</td>
<td>53.6%</td>
<td>53.7%</td>
<td>42.3%</td>
<td>29.8%</td>
</tr>
</tbody>
</table>

*Question: "Which of the following describes what stage you most often consult a doctor?"

### Table 8. Percent of respondents willing to patronize paramedical person*

<table>
<thead>
<tr>
<th>Answer</th>
<th>Wayne</th>
<th>Piute</th>
<th>Beaver</th>
<th>Salt Lake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>87.0%</td>
<td>83.3%</td>
<td>91.1%</td>
<td>59.0%</td>
</tr>
<tr>
<td>No</td>
<td>13.0%</td>
<td>16.7%</td>
<td>8.9%</td>
<td>41.0%</td>
</tr>
</tbody>
</table>

*Question: "Would you be willing to patronize a person such as someone who has had experience in the Medical Corps of the Army but does not hold the M. D. degree as a means to help alleviate the problem of lack of doctors?"
The Utah Prairie Dog—Decline of a Legend

G. DONALD COLLIER
AND J. JUAN SPILLETT

The status of the Utah prairie dog (Cynomys parvidens) has been in question for several years (figure 1 illustrates a typical specimen). The species was classified as endangered in 1968, then dropped from that listing in 1970, and subsequently replaced on the list in 1973. This report summarizes findings of a 3-year study* concerning this species, and updates an earlier Utah Science report on the Utah prairie dog.

PRAIRIE DOG CENSUS

The status of the Utah prairie dog was evaluated by two methods. First, over 300 residents of south-central Utah were interviewed to determine when, if ever, prairie dogs were present in specific localities, and to evaluate possible factors influencing the species' distribution and abundance. Second, every known dogtown inhabited by the species was measured and censused. These two procedures enabled us to compare recent and long-term trends in both distribution and population.

* A contribution of the Utah Cooperative Wildlife Research Unit (Utah Division of Wildlife Resources, Utah State University, U.S. Bureau of Sport Fisheries and Wildlife, and Wildlife Management Institute, cooperating), Logan, Utah 84321. This study was financed by the U.S. Bureau of Sport Fisheries and Wildlife.

G. DONALD COLLIER is a Research Assistant in the Department of Wildlife Science.

J. JUAN SPILLETT is an Assistant Professor in the Department of Wildlife Science and Assistant Leader, Utah Cooperative Research Unit.
Our findings were alarming, especially with regards to population. Since 1920, Utah prairie dog numbers have declined from an estimated 95,000 to 3,300 in 1972 (figure 2). Population estimates prior to 1970 are based on interviews with knowledgeable persons, while actual censuses were taken between 1970 and 1972. Population reductions corresponding to periods of intensive poisoning, occurred around 1933, 1950, and 1960. Recovery also probably occurred following each poisoning campaign. If a prairie dog colony is not completely eliminated, generally it will recover after poisoning. However, each poisoning campaign resulted in complete elimination of colonies in some areas. Thus, successive recoveries did not reach former abundance.

DECLINE

The present population trend of the Utah prairie dog indicate it will be extinct prior to the turn of the century. The population decline of 62 percent between 1970 and 1972 resulted primarily because of poisoning by private individuals. No federal agency has been involved in poisoning since 1963. However, more Utah prairie dogs occur on private lands (although a larger acreage is inhabited on public lands). Elimination of a single dogtown in 1972 reduced the population by 20 percent.

A second method of estimating abundance trends is by counting the number of living dogtowns. Elimination of entire dogtowns often occurs. The total of 59 dogtowns in 1970 declined to 37 dogtowns in 1972, a 37 percent decline in 3 years.

Constriction in distribution of the Utah prairie dog has been almost as
dramatic as its decline in numbers (table 1). The greatest reduction has taken place on the western margin of the species' range. Utah prairie dogs have completely disappeared from the Escalante desert during the past 50 years. At one time, they occurred almost as far west as the Nevada line. In localities where the species has not been eliminated, its range has been reduced by approximately two-thirds (figure 3).

MAIN FACTORS

Obviously, poisoning is a factor which has rapidly influenced the distribution and abundance of this prairie dog (figure 4). A second factor, disease, is well known for its potential to reduce or eliminate prairie dogs. However, evidence of disease was found in only two of the five major localities where the species presently occurs. Even in these two areas (Sevier River and East Fork of

Figure 4. Poisoning of prairie dogs is usually done by placing treated grain (often 1080 or strychnine) into the entrance of each burrow.

Figure 5. Terrain near Bryce Canyon, typical of the barriers which face the Utah prairie dog on the eastern and southern margins of its range.
Table 1. Present and recent distribution (numbers of inhabited sections of the Utah prairie dog in Utah)

<table>
<thead>
<tr>
<th>Locality</th>
<th>Historically</th>
<th>1971</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquarius Plateau</td>
<td>95</td>
<td>1</td>
</tr>
<tr>
<td>Awapa Plateau</td>
<td>212</td>
<td>32</td>
</tr>
<tr>
<td>East Fork of the</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sevier River</td>
<td>103</td>
<td>20</td>
</tr>
<tr>
<td>Iron County</td>
<td>65</td>
<td>16</td>
</tr>
<tr>
<td>Fremont Valley</td>
<td>35</td>
<td>4</td>
</tr>
<tr>
<td>Grass Valley</td>
<td>38</td>
<td>6</td>
</tr>
<tr>
<td>Mountain Valley**</td>
<td>55</td>
<td>12</td>
</tr>
<tr>
<td>Paria Valley</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>Salina Canyon**</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Sevier River Valley</td>
<td>89</td>
<td>4</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>713</td>
<td>96</td>
</tr>
</tbody>
</table>

*Term used to describe location of dogtowns in isolated mountain valleys.

**Presence of living prairie dogs reported, but not validated.

the Sevier River) disease apparently did not cause permanent reductions.

Factors influencing the status of the Utah prairie dog are not as simple as the magnitude of poisoning might suggest. Several long-term factors also are contributing to the Utah prairie dog’s plight.

Major long-range factors influencing the Utah prairie dog appear to be a combination of climatic and vegetational changes. Several lines of evidence indicate that climatic conditions in the Great Basin were cooler and more moist during the past 10,000 years than at present. In fact, the Great Basin has grown progressively drier during the past 4,000 years. The net result of this drying trend is that the western and major portion of the species’ range has become less favorable for prairie dogs, concurrent with higher temperatures, drier climates and the development of a salt-shrub vegetation type.

These long-term climatic and vegetational changes also have been accelerated since the coming of the white man and his misuse of rangelands. Overgrazing has caused a decline in grasses and the invasion of woody species, such as big sagebrush and juniper. Recent elimination of the Utah prairie dog in the Escalante desert was probably a result of the combined pressures of vegetational changes, droughts, and poisoning. Evidence currently being analyzed indicates that prairie dog densities are closely related to vegetation and climate.

Other factors that have influenced the distribution of the Utah prairie dog are the physiographic barriers on the eastern and southern margins of its range. Vast stretches of rough terrain, together with forested or barren land, are uninhabitable and uncrossable by prairie dogs (figure 5).

Finally, past competition with the Uinta ground squirrel (Spermophilus armatus) is the most logical factor explaining the absence of the Utah prairie dog in north-central Utah. Vegetational and climatic factors in this area appear to favor prairie dogs, although none are present.

**SOME CARE**

We believe the general decline in distribution and abundance throughout the past 50 years and especially

*Figure 6. Method used to capture prairie dogs for transplant. Notice the water hose and snare stick.*
during the past 3 years are causes for concern. Of the five restricted localities where the Utah prairie dog now occurs, only two seem to be safe from poisoning. In our opinion, at least three or four “safe” localities are needed to ensure the survival of this interesting species. Efforts are now being made by the Utah Division of Wildlife Resources to establish Utah prairie dogs in localities where it will be safe from poisoning. Several transplants (figures 6 and 7) have been made within the past year, but at least 2 or 3 years will be needed to evaluate the success of these efforts. Because people care, it now appears that this unique citizen of Utah will survive.

SOIL TESTING . . .

A developing aid to farm management

REUEL E. LAMBORN

It is common knowledge that soil testing properly done can help a farmer improve his efficiency by (a) identifying special problems such as salinity, and/or (b) providing a quantitative basis for his fertilizer management. However, soil testing that is improperly done is worthless, and can be very misleading.

SAMPLING AND TESTING

What constitutes properly done? The three principal elements comprising soil testing are:

1. Soil Sampling. The sample sent to the laboratory must be representative of an area that is uniform with respect to soil type, topography, and cropping and fertilizing history. Anyone who plans to obtain soil samples is advised first to become familiar with instructions available at his fertilizer dealer or County Agent’s office. The reliability of the soil test results can be no better than the sample sent to the laboratory.

2. Testing. Any reputable laboratory having appropriate experience can perform soil tests. Only a few laboratories, however, use test procedures and correlation data that are proper for Utah. The standard package at USU consists of tests for phosphorus, potassium, pH, salinity, lime, and texture. Additional tests sometimes requested are organic matter, nitrogen, and zinc. Many other tests can be done for special purposes.

RECOMMENDATIONS

3. Interpretation and recommendations. Soil tests provide an index

Figure 7. A wet bedragled Utah prairie dog headed for a new home.
of nutrient availability or potential problems, which must be interpreted before it can have meaning to the farmer. Such interpretations must be based upon field trials or "soil test calibrations" for Utah crops and conditions. Some general statements can be made for Utah soils, based on 30 years of soil testing experience:

(a) many soils are deficient in phosphorus; some have been overfertilized. High concentration of subsoil phosphorus is a complicating factor in some areas;

(b) only a very few soils are deficient in potassium;

(c) salty soils are a common problem;

(d) no sulfur, calcium or magnesium deficiencies have ever been noted, and testing for these is not encouraged on a routine basis;

(e) zinc deficiencies have very recently been noted in a few areas for some crops. The soil test correlates well with the deficiencies;

(f) determination of the nitrogen supply in a soil requires special deep soil samples. This kind of test is available but is not encouraged unless the special sampling procedures are followed; and

(g) soil tests are of limited usefulness for orchards, evergreen plantations, and ornamentals.

**BETTER PRODUCTION**

Since the beginning of the 20th century, scientists have devoted many years to defining soil fertility factors and ways to optimize these factors for best crop production. They soon recognized that the results from fertilization applications in one area or on a particular soil could not necessarily be duplicated in another area or soil. This was attributed, among other reasons, to wide variations in the nutrient-supplying capacity of the soils. Over the years, many procedures for extracting nutrients from the soils were tried and evaluated by comparing the test values with the nutrient status and yields of plants grown on the soils. The best procedures were selected and gradually improved. Gradually they became valuable aids to farm management.

Nationally, soil testing is widely used. In 1968, over 3½ million samples were tested in the United States, most of them in the Midwest. In Utah that year, however, only 1,080 samples were tested. Many Utah farmers and gardeners have been overlooking this valuable, inexpensive, and increasingly reliable tool that could help them achieve better crop production and/or reduce their fertilizer costs.

**UTAH LAB**

The Soil Testing Laboratory at Utah State University was established cooperatively in 1943 by the United States Department of Agriculture and the Utah Agricultural Experiment Station. It was set up with capabilities for testing soils, plants, and irrigation water. In 1945, the Extension Service began active support for soil fertility testing by providing some funds and publicity. Utah farmers were encouraged to use the new service as a guide to crop fertilization and an aid to identifying soil problems. Acceptance of soil testing in Utah was rather slow, however, roughly paralleling the amount of publicity and the refinements in testing procedures and field evaluation data.

Utah is fortunate in having a very well equipped soil analysis laboratory maintained on a year-around basis. Recent improvements in instrumentation and coordination of testing procedures among the northwest states have made the Utah State University laboratory comparable to the best in the region. Gradually increasing awareness among gardeners, farmers and fertilizer dealers concerning the value of soil testing has also helped to increase the usefulness of soil testing as a tool in garden and crop production in Utah.

**FERTILIZER GUIDES**

The USU Soil Testing Laboratory is directly involved in the soil fertility and crop production research programs being carried on by USU personnel throughout the state. As new or better information is obtained from these projects, appropriate modifications are made in the USU Fertilizer guides to keep them current. The improved interpretation of soil test values is then applied to samples being analyzed, for the immediate benefit of those who take advantage of the soil testing service.

Fertilizer guides representing the present "state of the art" have been prepared for major Utah crops under average Utah growing conditions.

Soil test values and the recommendations resulting from them are only one part of the process of devising the best fertilizer program for any particular farm and operator. Other important factors that the operator must consider are:

(a) subsoil conditions; (b) water quality and amount; (c) length of growing season; (d) yield goal and capability; (e) plant population or stand; (f) past crop/fertilizer history; (g) weed control; and (h) amount and quality of manure used.

Soil testing can supplement — but not replace — other good management practices.

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**S.M.V.**

Slow Moving Vehicle emblem. In most states, S.M.V. is the law. If you drive your farm vehicle on the road, you need S.M.V. protection. Get it. S.M.V. could save your life.

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**UTAH SCIENCE**
WHAT ABOUT PHOSPHORUS ON DRYLAND WINTER WHEAT IN UTAH?

REX F. NIELSON AND REUEL E. LAMBORN

Dryland winter wheat is one of the major farm crops in Utah, with a value in excess of 7 million dollars in 1971. The acreage planted has varied from a high of 362,000 acres in 1953 to a low of 183,000 in 1971 largely because of governmental control programs. Wheat yields over the past 30 years have increased from 18 bushels in 1940-60 to 21 bushels in 1961-65 and 26 bushels in 1966-71. This increase has resulted from a number of factors, one of which is the use of fertilizer. The wheat yields during the 1960s closely parallel fertilizer usage for the same period.

Dry farming in northern Utah was initiated near the turn of the century. With the practice of fallowing every other year, this means 35 or more wheat crops have been removed from some sites. This cropping program has resulted in nitrogen depletion in a number of soils. Trials conducted by Peterson in the early 1940s showed nitrogen fertilizer increased wheat yields on a number of soils. During the past 25 years, numerous trials have demonstrated the need for nitrogen fertilizer on all but a few of the dryland wheat producing soils. The use of nitrogen has grown from near zero in the late 1940s to where the majority of the winter wheat farmers are now using nitrogen fertilizer.

The first significant yield response from the addition of phosphorus on winter wheat in Utah was measured at the Nephi Station in 1957. Subsequent tests at Nephi showed that low rates of nitrogen and phosphorus applied with the seed increased yields more than nitrogen alone. The Levan Ridge near Nephi has been identified as an area with a number of phosphorus-deficient sites.

The fact that a phosphorus deficiency existed in central Utah suggested the need to determine the phosphorus status on the winter wheat soils in northern Utah. Trials conducted during the 1940s and 1950s in Box Elder and Cache Counties had shown no response to phosphorus.

FIELD SURVEY

A survey was made in 1969 to sample soils and plant material on the major winter wheat producing areas of Box Elder and Cache Counties. The objective of the study was to provide a reliable index of the phosphorus status of the area. Few, if any, of these soils have ever been fertilized with phosphorus.

A total of 74 paired plant and soil...
samples were collected on 12 major soil series in May 1969 with sites being located from soil survey photographs. Each site was sampled at two depths in at least three locations within a square rod area (subsamples were composited). Samples were taken at the 0 to 6-inch and 6 to 36-inch depth unless lime was encountered. When lime was noted at the surface, the subsoil was sampled 6 to 24 inches. A plant sample in the early boot stage was collected immediately adjacent to each soil sample site. The total aboveground portion of the plant was analyzed for phosphorus. Soil samples were analyzed for bicarbonate-soluble phosphorus, and a separate test was used to measure the phosphorus-adsorption properties of the soils. These two tests are briefly described as follows:

Bicarbonate-soluble phosphorus: \(^1\) 2.5 grams of soil and 0.5 grams of decolorizing carbon were shaken for 1/2 hour in 50 milliliters of 0.5 molar sodium bicarbonate. The solution was filtered, and the amount of phosphorus extracted from the soil was determined.

Phosphorus-adsorption test: \(^2\) 3 grams of soil, 15 milliliters of 0.2 molar calcium chloride and 15 milliliters of water solution containing 8 parts per million phosphorus as potassium phosphate were shaken overnight. After centrifuging, the concentration of phosphorus remaining in the solution (Pr micrograms of phosphorus per milliter of solution) was determined.

RESULTS

The phosphorus content of the plants was used as the best indicator

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**Figure 2.** Relationship of bicarbonate-soluble phosphorus in 74 paired samples of 6 to 24-inch-depth soil and plant materials taken from 12 major soil series in Cache and Box Elder counties, 1969.

**Figure 3.** The frequency distribution of high P and low P plant samples as related to bicarbonate-soluble soil P, 1969.
of phosphorus availability in the soil.

The data in figure 1 shows the relationship between the bicarbonate-soluble phosphorus measured in the 0 to 6-inch soil sample (A) and that found in the plant material.

The circles in the graph refer to soil samples with lime in the surface, with the solid dots indicating samples without lime. It is of interest to note that most samples containing lime test low in both soil and plant phosphorus. When data from all samples are considered, a good relationship exists between soil and plant phosphorus. The correlation coefficient or r value was 0.71.

When evaluating the data in terms of soil series, only general conclusions can be drawn. Some series are usually high in soil phosphorus while others may be predominantly low, with exceptions found in all cases. Since series are usually related to geographic areas, this information is of value in delineating suspected deficient sites.

The data from the 6 to 24-inch (B) samples are shown in figure 2. As would be expected, the subsoil phosphorus values are considerably lower than those measured in the top 6 inches, although 10 percent of the samples show relatively high values. As noted in figure 1, the samples with lime in the surface layer tested very low in soil phosphorus without exception. Although not conclusive, the data suggest that the subsoil phosphorus may be important in determining deficient areas.

**EVALUATION OF SOIL TESTS**

For the purpose of comparing the ability of the two soil test procedures (bicarbonate and adsorption) to reflect plant phosphorus, the plant samples were arbitrarily placed into two categories: "low" (0.17 percent phosphorus or less) and "high" (0.18 percent or more).

The frequency distributions of the low phosphorus and high phosphorus plant samples as a function of the soil test values are shown in figures 3 and 4. It is apparent that the ability of either test to segregate high-phosphorus from low-phosphorus plant samples was only fair when applied to the A soil samples but much better when applied to the B samples. The adsorption (Pr) test on the B sample was outstanding. It predicted correctly 95 percent of the low-phosphorus plants and 86 percent of the high-phosphorus plants.

**GREENHOUSE STUDY**

The second phase of the phosphorus investigations involved collecting bulk soil samples from 12 sites located in the 1969 survey. Soil was collected at the 0 to 6-inch (A) and 6 to 36-inch (B) depths at each site. These samples were brought to the greenhouse, set up in pots with four levels of added phosphorus and six replications. These pots were planted to winter wheat, with nitrogen and moisture being maintained at near optimum levels. The wheat was grown to the early boot stage and then harvested for yields and plant analysis. The soils were analyzed for phosphorus as before.

The addition of phosphate fertilizer significantly increased the growth and plant phosphorus levels of winter wheat on 8 of the 12 soils used in the greenhouse study. It is likely that the greenhouse test can make a more refined evaluation of phosphorus deficiencies that can be measured under
field conditions. This is not unusual as it provides a favorable environment for growth with few limiting factors. In the field, soil moisture conditions and adverse temperatures can have an effect on a plant’s response to fertilizer.

All soils that failed to respond to the addition of phosphate had test values greater than 10 parts per million bicarbonate soluble phosphorus. The adsorbed phosphorus values were not effective in delineating deficient soils in the greenhouse studies.

Typical data from a soil deficient in phosphorus are shown for soil number 18 in figure 5. Note the increase in yields and plant phosphorus when fertilizer was applied at rates as low as 9 parts per million phosphorus. Yield increases were measured on both the surface (A) and subsoil (B) samples. The bicarbonate soluble soil test values were 3 and 2 parts per million phosphorus respectively.

FIELD TRIALS

A series of 14 field experiments was established with local growers the fall of 1970. Sites were selected on the basis of information obtained from the survey and greenhouse studies. Fertilizer treatments were various levels of nitrogen alone and nitrogen and phosphorus in combination. All sites were planted by the grower with his seed and equipment.

Yield data and plant material were collected from 11 of the 14 trials set out in the fall of 1970. Three trials were abandoned due to poor stands. It is probable that these failures were due in part to the soils being highly deficient in phosphorus.

The data in figure 6 shows the relationship between the phosphorus in the plant and the soil test values on the check plots for each experiment. The three trials denoted as Xs on the graph were sites where yields were increased by the addition of phosphorus. It is of interest to note that these soils all test less than 10 parts per million bicarbonate soluble phosphorus. These data are in agreement with the earlier survey and greenhouse studies. The adsorption soil test did not correlate with the field crop response.

The 1970-71 growing season was most favorable for grain production. Precipitation was timely and considerably above average, resulting in record yields. It is possible that the results from the field trials may have been different if precipitation had been more near normal.

SUMMARY AND CONCLUSION

The information collected during the 3-year study involving the survey, greenhouse and field trials has an-
The Pros and Cons of Fertigation

D. W. James

The use of irrigation water as a vehicle for spreading fertilizer on land, often referred to as fertigation, is a growing practice in the irrigated west. In some areas, such as Nebraska, it is being strongly encouraged as a routine of irrigated crop production.

There are, at the outset, some distinctive advantages to the water application of fertilizer. As compared to the conventional methods, for example, there is a manpower saving and also a saving in equipment costs and maintenance. In addition, commercial fertilizer can be added during the growing season (to offset nutrient deficiencies developing in the crop) when mechanical damages to the crop made by ground application rigs, would be prohibitive.

The relative ease and simplicity of fertilizer application via irrigation water, must be weighed against certain limitations inherent in the practice. These limitations are related to uniformity of water application and to the chemistry in water and soil of the fertilizer elements. It is the specific purpose of this article to briefly survey these limitations and to suggest guidelines wherein fertigation can be done successfully.

**SURFACE METHODS**

Flood, furrow, or border irrigation methods are least adaptable to fertilizer distribution in irrigation water. Lack of uniform water application arises from non-uniform water distribution in the furrows at the headlands and to the differential of water intake by the soil between different parts of the field. In general, fertilizer distribution in water by surface methods would result in heavier fertilization of the upper part of the field, as compared to the middle and lower parts of the irrigation run.

An important point to consider in this connection is the risk of fertilizer loss in runoff waters. This represents not only a direct economic loss to the farmer, but constitutes also a very undesirable contamination of rivers and lakes wherever the drain water may ultimately be found. One way of controlling fertilizer loss in runoff water would be to collect the water at the bottom of the field and to recycle it to the head ditch by pump.

**OVERHEAD IRRIGATION**

Commercial sprinkler irrigation systems do not distribute water perfectly. In general, the water application is heaviest near the sprinkler head and decreases to the perimeter of the sprinkler circle. This feature is taken into consideration in the design of overhead systems. A certain amount of overlap between adjacent sprinklers is designed into the systems to smooth out the variation in area coverage.

The coefficient of uniformity (Cu) is used as an index of sprinkler irrigation uniformity. If distribution is perfect, Cu equals 100 percent. In practice a compromise is made between the cost of the sprinkler system and the Cu because closer spacing of risers and laterals is required for higher uniformity values. A Cu of 80 percent is typical and is considered acceptable in sprinkler irrigation design.

Figure 1 illustrates the uniformity...
of water distribution at three values of Cu. It can be seen that with a Cu of 80 percent when 1 inch of water is applied to 90 percent of the area, an average of 1.47 inches of water will need to be applied over the entire area. Furthermore, 10 percent of the area would be under-irrigated, 80 percent would be slightly over-irrigated and 10 percent would be heavily over-irrigated.

Using the foregoing data, for a typical well-designed sprinkler system, it is apparent that for every pound of required fertilizer, an average of 1.47 pounds would have to be applied, and even with the extra 47 percent, 10 percent of the land would still be under-fertilized.

Atmospheric conditions, including wind, very high temperature and low humidity, can radically alter the distribution pattern of water from a sprinkler system. It is readily apparent that fertigation should be studiously avoided during adverse weather conditions.

**PHOSPHORUS**

Treble-superphosphate (0-45-0) is only moderately water soluble and as such cannot be considered for fertigation. This statement may sound contradictory because in the fertilizer trade, treble-superphosphate (TSP) is legally classified as being water soluble. But actual dissolution of TSP in water is limited because the monocalcium-phosphate, which is the main constituent of treble-superphosphate, changes spontaneously to dicalcium phosphate which is very insoluble in water. Whereas this phenomenon does not affect the ability of TSP to satisfy plant needs when placed in the soil, it does disqualify TSP as a likely agent for fertigation.

**AMMONIUM PHOSPHATE**

Several kinds of ammonium phosphates are available on the market and are commonly used for both nitrogen and phosphorus in fertilizer. These include ammonium phosphate sulfate (16-20-0), monoammonium phosphate (11-48-0), and diammonium phosphate (16-46-0). All of these are very soluble in water. Therefore, these phosphorus forms may be adaptable to fertigation. However, the quality of the irrigation water must be considered before injecting any phosphorus into the system. If the water contains appreciable amounts of calcium, the phosphorus in the ammonium phosphate will precipitate as dicalcium phosphate in the pipe line and nozzles and eventually restrict flow of water. This precipitation of calcium phosphate would occur with any soluble form of phosphorus that might be applied.

Another important facet regarding phosphorus is its immobility in soil. Soluble phosphorus transforms to insoluble dicalcium phosphate almost as soon as it contacts calcium in the soil. Therefore, fertilizer phosphate applied in irrigation water would be localized essentially at the soil surface and as such would be positionally unavailable to the crop. Although this would not help the current crop, subsequent crops would be benefitted because with the next plowing the fertilizer would be mixed throughout the plow layer.

**NITROGEN**

Anhydrous ammonia (82-0-0) and aqua-ammonia (24-0-0) can be injected into pipes and furrows containing irrigation water. Loss of fertilizer efficiency because of volatilization of gaseous ammonia is highly probable, however.

Ammonia in water is unstable and rapidly forms ammonium hydroxide which in turn ionizes into ammonium ions and hydroxide ions. The practical implications of these ammonia-water relationships are that volatilization, or gaseous loss of ammonia injected into a sprinkler system, increases sharply as the rate of ammonia injection increases. Figure 2 illustrates this point. It shows the effects of both water temperature and ammonia injection rate on ammonia loss. Note that with the 52°F water, losses as high as 45 percent occur. With the 70°F water the losses reach 55 percent. Even with only 10 pounds of ammonia per acre inch of water, the loss is as high as 35 percent.

Another aspect of ammonia fertigation has to do with the rise of hydroxide ion concentration in water. With ammonia injection, there is a rise in pH and a precipitation of soluble calcium and magnesium in the water. This has been observed as a coating inside pipes and a constriction around nozzles. This kind of problem has been overcome by injecting calgon (a commercial water softener) ahead of the ammonia gas. Calgon complexes the calcium and magnesium and eliminates this kind of problem, but it adds
considerably to the cost of fertilization.

**NITROGEN SALTS AND UREA**

Most of the nitrogen fertilizers dissolve readily in water. However, the nitrogen-containing fertilizers mentioned under phosphorus should not be considered in this context because of the indicated interactions involving phosphorus in water and soil.

Ammonium sulfate (\(\text{NH}_4\text{SO}_4\) (21-0-0) and ammonium nitrate (\(\text{NH}_4\text{NO}_3\) (35-0-0) are very common fertilizer materials. In the former, all the nitrogen is in the ammonium form while in the latter about 26 percent by weight of the fertilizer is ammonium nitrogen and 8 percent is nitrate nitrogen. Urea (44-0-0) is a very soluble nitrogen fertilizer. It should be noted that this material does not react with water to form ions and as such is a neutral molecule. Mixtures of urea and ammonium nitrate in water are made to give a fairly concentrated liquid mixture of these compounds. This kind of fertilizer is marketed as 32-0-0. When injected into irrigation water the individual components of this fertilizer behave exactly like the dry materials dissolved and injected separately.

All of these nitrogen materials may reasonably be applied by fertigation with no side effects in the water or irrigation system. Other kinds of effects associated with \(\text{NH}_3\)-soil interactions are discussed below.

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**NITROGEN IN SOIL**

Both urea and nitrate-nitrogen tend to stay in the soil in solution and as such drift in whichever direction the soil moisture is going. This means that these materials are highly susceptible to leaching loss if excessive water is applied. The chemical nature of ammonium nitrogen makes the behavior of this material quite different. Being a positively charged ion, it enters into cation exchange reactions in soil. A small change in either soluble constituent will alter the relative amount of the ions in exchangeable form. In the exchangeable form, ammonium is immobile. Since cation exchange reactions are very rapid, ammonium in irrigation water is immobilized almost instantly upon contact with soil. As such, it remains essentially on the soil surface when applied in water.

Ammonia or ammonium applied in water readily converts to exchangeable ammonium and simultaneously generates an equivalent amount of solution potassium. In semi-arid and arid regions soils are naturally neutral to alkaline in reaction (pH 7 to 8.2), depending on how much free lime or calcium carbonate is present. In these kinds of soils, where exchangeable ammonium exits at the soil surface there is a certain probability of volatilization. This mechanism of ammonia loss is very sensitive to temperature and moisture conditions. Water vaporizes very rapidly from soil following an irrigation and while drying, ammonium is especially susceptible to gaseous loss. Note that ammonium coming to the soil in irrigation water will concentrate in or near the soil surface. As such it is especially vulnerable to gaseous loss.

**TIME OF APPLICATION**

In evaluating the efficiency of fertigation, alternate times and methods of application should be considered. Mechanical methods of fertilizer application (broadcast-plow down, shanking into the soil before planting, banding at planting time, sidedressing after seedling establishment) can give (Continued on page 99)
Microbial activity in acid soils

ROBERT C. RYCHERT AND J. SKUJINS

After 40 miles of traveling on Route 30 south from Snowville, Utah, you can look left and see a good portion of south Curlew Valley. On a clear day, and they are common, the northern salt flats of the Great Salt Lake are visible.

Curlew Valley, part of the Great Basin Desert, is a representative study area selected by the U.S. Desert Biome (part of the International Biological Program) for work to define the ecology of the western American deserts. The summers in Curlew Valley are hot and dry with soil surface temperatures soaring to 130°F (72°C) or greater. By contrast, during the winter, 2 feet (60 centimeters) or more of snow may cover the ground, while the soil beneath the snow be frozen to 1 foot (30 centimeters) deep. Snow is the major source of annual precipitation, and certainly the term “cold” desert is appropriate.

With annual rainfall of only 6-8 inches (15-20 centimeters), water is limiting in the area; but both plant and animal life is being supported by this system. The area’s superficial ecology (coyotes eating rodents, insects and rodents eating vegetation, birds eating insects and vegetation, etc.) can be seen by even a casual observer. But the source of nutrients for the vegetation, and thus ultimately for the entire food web of plants and animals, is the soil, with its much less visible relationships.

A great deal of information has been gathered about agricultural soils and soils of temperate, relatively wet regions, and understandably enough; these have been our highly productive soils, furnishing food and other products. Only recently have desert soils been subjected to similar investigations as growing food needs indicate possible greater utilization of marginal regions like the desert.

BIOLICAL ACTIVITIES

To understand the biological activities of the soil in Curlew Valley, counts of microbes such as fungi, streptomycetes, and bacteria are performed; pH and moisture are determined. Chemical composition is analyzed. The proteolytic activity in the soil, or the ability of soil microorganisms to degrade protein is determined, and soil respiration is assessed by incubating soil at a specific temperature and determining CO₂ released. A general measure of soil metabolic activity is provided by a dehydrogenase assay. Dehydrogenase is representative of the enzymatic oxidation-reduction processes occurring in the soil, and exhibits a high correlation with proteolytic activity and respiration. This is important, since microbial counts, per se, do not tell us how active the soil microbial population is. The activities are 5-10 times higher in the upper 3 centimeters (1 inch) of the soil than the rest of the profile. This is the layer where the blue-green nitrogen-fixing algae are involved; the layer that is exposed to intermittent water availability, where the plant and rabbit litter falls, where most of the microscopic and not so microscopic desert life may be found.

THE NITROGEN FACTOR

While water is certainly the limit-
ing factor in a desert ecosystem, other factors are also significantly limiting. For example, nitrogen, as nitrate or ammonium, is necessary for plant growth.

Much of the desert surface is covered with a dark crust, a few millimeters (1/16 inch) deep, which upon moistening or following a rainfall, becomes green. This crust is composed of various algae, some in combination with a fungus as lichens. Some species of blue-green algae within this crust can utilize atmospheric nitrogen as a nitrogen source, and consequently supply nitrogen to the soil. In fact, nitrogen-fixation by the blue-green algae probably provides the major input of nitrogen to the desert ecosystem.

We have been assessing nitrogen-fixation with a number of techniques. Dr. Paul Eberhardt, a post-doctoral researcher in our laboratory, is using the stable isotope of nitrogen (N\(^{15}\)) to quantify the various aspects of nitrogen flux. In another assay, acetylene gas is reduced to ethylene (gas), yielding a representative measure of the quantity of atmospheric nitrogen fixed by microorganisms. This technique utilizes gas chromatography and is the most sensitive assay yet devised for determining nitrogen-fixation.

It is interesting that nitrogen-fixation is greatly reduced under the desert shrub canopy compared to the interspaces between the plants. Evidence suggests that chemicals released from some of the plants may inhibit the blue-green algae’s ability to grow and fix nitrogen. Ecologically, the inhibition of the algae may be incidental, with the prime purpose being to keep potential competitor seeds from germinating and/or growing.

Beneath the surface crust and deeper in the soil profile, there are microorganisms capable of fixing atmospheric nitrogen. These organisms require organic carbon sources for energy, and in this desert ecosystem the supply of plant litter (organic carbon) is limited.

Surprisingly, water limits microorganism activity to a much lesser extent than in agricultural soils. Water potential, in negative bar pressure, is the force required to extract or remove water from the soil. While —15 bars is generally considered to be the wilting point for most plants, microorganisms in the desert soil can function metabolically down to —50 bars and some even to —150 bar pressure. So although the soil may “appear” dry, and water might not be available to plants, microorganisms within the soil remain metabolically active, satisfying their water needs.

Figure 3. Mid-summer view of area dominated by winterfat (Eurotia lanata), a desert shrub.

Figure 2. Curlew Valley soil surface with patches of nitrogen-fixing algal crust and lichen.
by extracting the thin film of water sorbed around the soil particles.

**NITROGEN CONVERSION AND LOSSES**

In the process of nitrification, ammonium is oxidized to nitrite by *Nitrosomonas* organisms. Nitrite is subsequently oxidized to nitrate by *Nitrobacter* bacteria. Thus nitrate is made available to plants. The process of nitrification can take place in the desert soil at any time if ammonium is available. Unfortunately, considerable amounts of nitrogen are lost from the soil due to the volatilization of ammonia into the atmosphere since the soils are alkaline. Nitrogen may also be lost by the chemical and microbial process of denitrification. While the low organic carbon level should limit denitrification, some of Dr. Eberhardt’s work suggests that, potentially, denitrification may be significant.

**CYCLES OF BIOLOGICAL ACTIVITY**

In addition to the significant microbial activity in “dry” soil during the summer months, there may be algal crust activity beneath the snow during winter. The greatest peaks of biological activity, however, occur during the fall and spring rainy periods. The ammonium level is highest in October and November, while the nitrate-nitrogen values are generally less than 1 ppm. The highest values for both ammonium and nitrate are found in the upper surface layer.

An increase of about .05 percent in organic nitrogen is evident in October and November, and in April and May. This additional nitrogen is apparently lost during the summer and late fall, mostly as ammonia. Seasonal variations are slight in the 5 to 20 centimeter layer and is negligible in the deeper soil profile.

Some of the nitrogen-containing soil organic matter, especially in the surface soil layer, seems to be rapidly decomposed in the wet fall months. Not more than 10 percent of the released ammonium-nitrogen appears as nitrate, and it is unlikely that the ammonium-nitrogen is immobilized in the soil, due to the lack of excess carbon compounds. Although some ammonium-nitrogen is fixed by soil clays, the major process of loss appears to be ammonia volatilization.

Leaching of nitrogen components to deeper soil strata is of little importance in these desert soils, since soil moisture due to precipitation and melt water fluctuates only to a depth of 50 centimeters.

The organic carbon values fluctuate between 2.5 percent and 0.3 percent and parallel the total nitrogen values in distribution and seasonal variation.

The carbon/nitrogen (C/N) ratios are rather low, falling between 8 and 12, and decreasing by 1 to 3 units from the surface to the 5 to 20 centimeter depth. This pattern might reflect the nitrogen-poor, undecomposed organic matter (litter) present in the surface layer and a complete carbon utilization for nitrogen immobilization in deeper layers.

So while water is critical in this ecosystem, there are also other important factors. For example, the microbial population is significantly active when the soil is “dry.” Agricultural soils and wet soils of temperate regions do not behave this way. Thus the microbial population of desert soils differs qualitatively and quantitatively from that of other soils, and the differences are vital to the total ecological picture.*

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*Research on these problems of desert biology is being supported by the United States-International Biological Program, Desert Biome.

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**WILDLIFE NOTES**

The meadow lark is really not a lark at all. He belongs to the blackbird family.

* * *

A male black bear, hit recently by an auto in Parley’s Canyon, measured 6 feet 7 inches tall, when standing on his hind legs, and weighed 387 pounds. Though the bear was golden in color, it was a true black bear (*ursus americanus*). The black bear is the smallest of the bears and ranges in color from black, in the East, to nearly white, in British Columbia. True big brown bears, often called Kodiak bears, are the largest of the bears.

* * *

Snakes and fish have ears, but these ears have no outside opening. They “hear” mostly through vibrations in the ground or water.

* * *

Deprived of its food, a mole will die in about a day.

* * *

A trout begins eating approximately four weeks after it is hatched.

* * *

Birds have many shapes of eggs, from almost perfect circles to cone-shaped, depending on the environment. An example is the case of oceanic birds that lay their eggs on bare, rocky ledges high above the water. The eggs of these birds would roll off and be smashed if they were round. Instead, they are sharply pointed at one end and broad at the other end, like a top. Because of this shape they roll in a small, tight circle.

* * *

Many cow moose are barren; less than half of the females produce young each year. However, Utah has one of the fastest growing moose populations in the world with a better than average cow-calf ratio.

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The mature bighorn sheep ram measures about 40 inches tall at the shoulder, is nearly 5 feet long and weighs up to 350 pounds.
Pros and Cons of Fertigation

(Continued from page 95)

very uniform distribution of material. In addition no special benefits from mid-season fertilizer applications have been observed if leaching and erosion losses are avoided. In other words, with soils of medium to fine texture where leaching is generally not a problem, fertilizer applied at the beginning of the season is good and sufficient for the entire season. Thus fertigation could only be justified as a stop-gap measure to overcome problems of leaching losses in light textured soil or to supplement soil fertility reserves that were not recognized as being in short supply at the outset.

SOME CONCLUSIONS

Inherent in the practice of fertigation are several distinctive advantages and disadvantages. These should be carefully evaluated and weighed against alternative methods of fertilization.

The advantages of fertigation are:

1. The cost of fertilizer application is minimal. This includes both manpower and equipment costs.
2. Fertilizer can be applied during the growing season when crop damage by conventional methods would be serious.
3. Fertilizer can be applied to offset any nutrient shortages that may develop anytime during the growing season.

The disadvantages are:

1. Uniformity of water distribution governs the uniformity of fertilizer distribution in the water. The best uniformity of water application is obtained with overhead systems but sprinkling systems are not designed to give perfect water distribution. Systems having a Cu of 80 percent would require a rate of at least 147 percent of normal to offset lack of uniform distribution. Even this expedient would result in 10 percent of the area being underfertilized.
2. Phosphorus-containing fertilizers cannot be injected into many irrigation waters because of undesirable side reactions.
3. Anhydrous ammonia or aqua ammonia cannot be applied in irrigation water without large losses from volatilization to the air.
4. Ammonium-containing fertilizers are low in efficiency when applied to calcareous soils by fertigation because of gaseous loss from the soil surface.

If fertigation is considered a necessity, urea or nitrate-nitrogen materials should be the only forms applied and these should be applied only with careful control. These controls include:

1. Do not apply water faster than the soil will absorb it; runoff water will take dissolved fertilizer with it.
2. Do not overirrigate; mobile nitrogen materials in the soil will leach out.
3. Do not apply fertilizer in water during windy weather; fertilizer distribution will be very erratic.

FOUR KEYS TO PESTICIDE SAFETY

READ THE LABEL ON EACH PESTICIDE CONTAINER BEFORE EACH USE. Follow instructions, heed all cautions and warnings. Why read the label each time? Because the chemical nature of pesticides and their uses vary greatly. You should refresh your mind each time on the material’s specific uses.

APPLY PESTICIDES ONLY AS DIRECTED. Apply them only to the crops specified, in amounts specified and at times specified in label instructions, or by your agricultural authorities.

DISPOSE OF EMPTY CONTAINERS SAFELY. It is almost impossible to remove all material from a container. "Empty" containers contain small amounts of pesticides which could harm children or animals who might get into them. It is best to dispose of empty containers by burying them at least 18 inches deep in an isolated area provided for this purpose away from water supplies.

STORE PESTICIDES IN THEIR ORIGINAL, LABELED CONTAINERS. Keep them out of the reach of children and irresponsible people. They cannot be properly identified unless they are in original labeled containers. Lock pesticides in a shed away from feed, seed, and other farm supplies.

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