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Regardless of age, sex, or income each of us has access to the same amount of time each day. It is the one resource that we all share equally. The supply is consistent; it does not vary from day to day or from year to year. Throughout the world, every person has a daily allotment of 1440 minutes to allocate to his/her chosen activities. As Benjamin Franklin said, "Time is the stuff of which life is made."

Nevertheless, rarely can any one of us account accurately for his or her 1440 minutes. More commonly we can be heard asking ourselves "where did the day go?" During 1977-78, Utah participated in an eleven state study to help shed some light on this question. As far as could be determined, this family time-use study was the first done in our state.

Data were gathered from 210 Utah families. Half were urban families living in Salt Lake County, including Salt Lake City. The other half of the sample (designated as rural) lived in Washington and Iron Counties. The families were all two-parent, two-child families and were stratified according to the age of the younger child. This was done because time use by family members changes as children become older. Records were gathered over a full year so that changes in activities could be studied in relation to the seasons.

The time diary used to gather the data had activities listed vertically, while the twenty-four hour day (broken into ten-minute segments) was listed horizontally. The homemaker in each family recorded the time use of all family members for two days. All diary entries were to be checked with the other family members to be sure they were an accurate record of how each person had spent his or her 1440 minutes.

When the data were analyzed, just three activities consumed most of the time of the Utah adults we studied. These were: personal care of self, which included sleeping, grooming, etc.; paid employment; and household work. Paid employment and household work are both productive activities that are necessary for families to function. The time allotted to them has a large impact on the other activities in which families participate and are interrelated with each other.
Until recently, productive activities were popularly considered to be clearly divided between men and women. Men were responsible for doing labor-market work to earn the money needed to buy the goods and services desired by the family. Women were in charge of household work, which included shopping for goods and services, making the necessary transformations in the goods purchased, such as cooking food, sewing clothes, and caring for family members and family possessions.

The well-documented increase in the number of women employed in the labor market has given rise to some assumptions about the accompanying changes that have occurred in household work. Among the assumptions is: as more women spend more time in paid employment, husbands and children contribute additional time to household work. Another is that the introduction of prepared foods, easy-care clothing, and numerous appliances has greatly reduced the amount of time needed to do household work. Our analysis of the time-use data from 210 Utah families provided some interesting insights into the hazards inherent in such assumptions.

WHO DOES WHAT?
The adults in our study did allocate their time along traditional lines (Table 1) with the 210 homemakers, defined as the person having the major responsibility for operating the household, averaging 6 1/2 hours per day for household tasks and less than 1 1/2 hours to paid employment (McCullough 1980). During the time our data were being gathered, 121 of the women surveyed were full-time homemakers, 55 worked between 1 and 30 hours, and 34 worked 30 hours or more per week outside the home. The time use of husbands was almost the reverse that of wives. Husbands averaged nearly seven hours per day in paid work and about 1 3/4 hours in household tasks. Ten of the husbands were not employed during the time of the study, 9 worked part-time, and 191 worked 30 hours or more per week. If our data had not been gathered over all seven days of the week, the average hours spent in paid employment may have been higher.

Despite the modernization of household machinery and goods, a substantial amount of time was spent doing household tasks by our Utah families. As can be seen in Table 2, when contributions of all family members (six years of age and over) were considered, household production occupied a large block of time each day. On a weekly average the families were devoting over 66 hours per week to household work. Of the total time, 70 percent was contributed by the wives, 18.5 by the husbands, and 11.5 by the children.

When the time spent in paid employment was added to the time spent doing household work, our Utah adults were found to be living up to the state’s motto of “industry.” The women averaged eight hours per day in productive activities, while the men averaged eight hours and 38 minutes. As data were gathered over all days of the week, the daily time must be multiplied by seven, not five, to obtain an average work week.

When time spent in household work was examined in relation to time spent in paid employment, we found some interesting relationships. As husbands' time spent in paid employment increased, their contributions to household production decreased significantly, as would have been predicted. Concomitantly, the time spent in household tasks by a wife increased with the time her husband spent in paid employment. Evidently some wives did more household work to compensate for long hours spent by their husbands on their jobs. The relationship was positive, but not strong enough to be statistically significant.

When the same relationships were analyzed for the employed women in the study, we found that they also reduced their time spent doing housework as their hours in paid employment increased. Women who were full-time homemakers averaged seven hours and 23 minutes per day in household tasks, while those who were employed full-time (35 or more hours per week) averaged three hours and 15 minutes, a striking difference.

Contrary to popular belief, husbands' participation in household production did not increase greatly when their wives were employed in the labor market. Husbands of full-time homemakers spent one hour and 46 minutes per day doing household tasks while the husbands of women who were employed 35 hours or more per week averaged two hours and nine minutes. The correlation between the two variables was very weak and not statistically significant.

Household work time was added to the paid employment time of the men and women in the study who were employed 35 or more hours per week.
This allowed us to compare the total time devoted to productive activities by the men and women who were employed full-time. Women spent about one hour more per day in these activities than did men, a difference approaching significance (.06).

The household work time of the 200 children in the study was analyzed to see how it related to the time parents spent in paid employment (Osborne 1979). It is often assumed that when both parents are employed, children do more household work. We found, however, an unexpected negative relationship. This was true for the relationship between children's household work time and fathers' hours of paid employment, mothers' hours of paid employment, and the combination of those two values. The positive relationships between boys' household work time and the household work time of their fathers surprised us, as did the comparable relationship between the time daughters and mothers spent in household work. Apparently children participate more in household production when a parent is home to supervise, guide, or nag, and they are even more likely to participate when the parent of the same sex is the one who works along with them.

We also found a difference in the activities of boys and girls. Girls spent the majority of their household work time in the traditionally female tasks of food preparation, dishwashing, clothing care, housecleaning, and caring for other family members. Boys put most of their "household" time into "maintenance of home, yard, car, and pets." The differences were small for children aged six to eight, but increased dramatically with age.

<table>
<thead>
<tr>
<th>TABLE 1. Mean Minutes Per Day Allocated to Activities</th>
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<tbody>
<tr>
<td><strong>Homemakers</strong></td>
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<tr>
<td><strong>mean min.</strong></td>
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<tr>
<td>Food preparation</td>
</tr>
<tr>
<td>Dishwashing</td>
</tr>
<tr>
<td>Shopping</td>
</tr>
<tr>
<td>Housecleaning</td>
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<tr>
<td>Maintenance of home, yard, car, and pets</td>
</tr>
<tr>
<td>Care of clothing</td>
</tr>
<tr>
<td>Construction of clothing</td>
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<tr>
<td>Physical care of family members</td>
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<tr>
<td>Nonphysical care of family members</td>
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<tr>
<td>Management</td>
</tr>
<tr>
<td>School work</td>
</tr>
<tr>
<td>Paid work</td>
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<tr>
<td>Unpaid work</td>
</tr>
<tr>
<td>Organization participation</td>
</tr>
<tr>
<td>Social &amp; recreational activities</td>
</tr>
<tr>
<td>Personal care of self</td>
</tr>
<tr>
<td>Eating</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Unaccounted for</td>
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</table>

<table>
<thead>
<tr>
<th>TABLE 2. Time Spent Doing Household Tasks Per Day</th>
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<tbody>
<tr>
<td><strong>Mean</strong></td>
</tr>
<tr>
<td>Wives</td>
</tr>
<tr>
<td>Husbands</td>
</tr>
<tr>
<td>All family members</td>
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</tbody>
</table>

s.d. = standard deviation (which indicates the amount of variation among the time reported by the families).

<table>
<thead>
<tr>
<th>TABLE 3. Hours of Employment Per Week</th>
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<tbody>
<tr>
<td><strong>Men</strong></td>
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<tr>
<td>Hours of employment per week</td>
</tr>
<tr>
<td>Less than 1 hour</td>
</tr>
<tr>
<td>1-35 hours</td>
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<tr>
<td>35+ hours</td>
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</table>
THE APPLIANCE MYTH

Household appliances are usually regarded as time-savers. It is also often assumed that employed women own and use more of these as a way of substituting for or enhancing their household production time. Using a base list of nine common household appliances we determined the number owned per family. It turned out that families of women who were employed full-time (35 or more hours per week) did not own more than did families of women who were employed part-time or were full-time homemakers. Of the 20 families in the study who owned microwave ovens, just one belonged to a woman who was employed full-time (Nilson 1981).

Our results suggest that the time-saving potential of many household appliances has been overestimated. When we related the household appliances owned to the time spent in the related household tasks, the results indicated that, except for dishwashers, owners and non-owners spent about the same amount of time doing housework. In fact, food preparation times did not differ between wives who owned a microwave oven and those who did not. Husbands, however, increased their average daily food preparation time from 6 to 13 minutes when they owned a microwave oven, a thought-provoking phenomenon.

The fact that many appliances such as a vacuum cleaner or power yard equipment cannot operate alone is often overlooked. Appliances may make certain kinds of work more pleasant to do, but regarding all appliances as time-saving can lead to false conclusions.

MEALS AND EMPLOYMENT

While the hours men spend in the labor market are regarded as part of a normal lifestyle, there has been concern about the effects on their families and on themselves when women follow the same pattern. Our data analyses led to some interesting findings in this regard.

When family meal patterns were examined, it was found that employed homemakers (defined as putting 15 or more hours per week into the labor market) spent less time in meal preparation than did those employed fewer hours. There was a decrease from 84 to 65 minutes per day, a difference significant at .005. Husbands of employed wives increased their food preparation time from 5 to 11 minutes, which was also statistically significant (Peterson 1979).

The families of the employed women ate more meals away from home than did those of non-employed women; 1.36 per day as compared to 1.02. Interestingly enough, the number of meals the families ate together each day was not different for the two groups; each had about one meal per day when all four members were present. Although the homemakers' employment did have an impact on where the family ate, it did not have an impact on family togetherness for meals.

THE QUESTION OF LEISURE

Many people express a desire for more leisure time. Specific activities considered to be leisure occupations vary, however, from person to person. To analyze how adults in our sample allocated leisure time, we designated the categories "organization participation" and "social and recreational activities" as leisure. The average time per day spent in these activities by the adults we studied was 4.6 hours, with men averaging 4.5 and women 4.7 (Swapp 1979).

It would commonly be assumed that a relationship would exist between the time spent in paid employment and that available for leisure. Our data indicate that this is indeed the case (Table 3). Men who were employed less than one hour per week had the most leisure time, 6 1/2 hours per day, while women employed 35 or more hours per week had about 2 1/2 hours.
As both labor market work and household production are required for a household to function and many men and women participate to some degree in both, we combined the times recorded as being spent in each of the two to see the effect on leisure time. Strong negative correlations resulted. For homemakers the correlation between productive work and leisure time was -0.6993 and for men it was -0.7219, both significant at .000. Predictably, the total time spent in paid employment and doing household work limits what is available for leisure.

THE OVERVIEW

Productive activities consumed much of the time of the Utah adults we studied, with the traditional division of labor prevailing. Many assumed circumstances such as employed women enjoying an increased family participation in housework, and a reduction in housework time resulting from household appliances, had not occurred to any large degree. In-depth analyses of specific aspects of our data are available in the theses that are cited in this article. Additional information is also available from Utah Agricultural Experiment Station Research Report Number 57 (USU). The data from all eleven states are being combined into a publication that will be available early in 1982.

The expanded research has been published as "Time Use in Utah Families," UAES Research Report 57, and is available at the USU Bulletin Room (108 Eccles Conference Center or UMC 50B).

LITERATURE CITED


ABOUT THE AUTHOR

Jane McCullough is Assistant Professor of Home Economics and Consumer Education. She received her PhD in 1980 from Michigan State University, and is involved in Regional Research Project NE 113 which supplied the data for this article.
THE IMPROVEMENT OF WATER advance in furrow irrigation utilizing the new Surge Flow technology was first announced in UTAH SCIENCE (Vol. 41, No. 2, 1980). Since the 1979 cropping season research, additional soils, slopes, and flow rates common to surface irrigation have been tested. Hundreds of advance, recession, and runoff measurements were made in several locations during the summers of 1980 and 1981. In all cases, the Surge Flow system required less water to achieve the desired advance than did conventional furrow irrigation.

Another important advantage of Surge Flow is that it has much less variation in the water volume required for advance during the season and across the field than does a continuous flow operation. This means that the difference between wheel rows and non-wheel rows, or between first and second irrigations is greatly reduced with Surge Flow, which results in more uniform advance from furrow to furrow and irrigation to irrigation.

As the 1979 research experiments used a time-averaged flow rate of 10 gpm for all trials, we did not know whether it was the Surge Flow or the larger instantaneous rates of the Surge Flow treatments that produced the differences. Our 1980 work was designed to answer this question. The same instantaneous flow rate of 5 gpm (0.3 l/sec) was used for all tests.

Continuous flow was compared with Surge Flow with various combinations of "on" and "off" sequences. The on times were: 5, 10, and 20 minutes; the off times were: 5, 10, 20, and 40 minutes.

Typical results of the 1980 tests with the 5 gpm inflow stream appear in Figure 1. Advance and recession for a 20-minute cycle time and cycle ratio of 0.5 (10 minutes on and 10 minutes off) are shown as solid lines together with the continuous flow advance superimposed as the broken line. The advances of continuous flow and Surge Flow did not differ much in the first 250 feet of the run over a given time, but Surge Flow required only one-half the water for this portion of furrow since it was running only half the time. Surge Flow completed the 330 feet of advance in 83 minutes. The continuous stream required 108 minutes, and two and one-half times the amount of water required for Surge Flow to reach the end of the run.

The advance of surge and conventional flow in the dry, rough furrow (dry advance) was about the same during the first surge (Figure 1). The advance rate for a subsequent surge was comparatively fast in the initially wetted portion of the furrow (wet advance), but the rate dropped sharply at the point of contact with the dry furrow—the terminal point of a previous surge. The dry advance rate of the
surged treatments was essentially maintained while the conventional flow advance continued to decline with time. Surge Flow thus advanced as far or further with the combination of a fast "wet advance" and a faster "dry advance." In addition, less than half the volume of water was required to complete the advance phase.

Another characteristic of Surge Flow is depicted in Figure 2, which shows the runoff hydrographs for the furrow advance tests of Figure 1. Surge Flow produced runoff from the end of the furrow 25 minutes before continuous flow. The first runoff surge peaked at 1 gpm, with the second at more than 2.5 gpm, and subsequent surges peaking at more than 3 gpm. By comparison, the runoff from the continuous flow furrow peaked at less than 1 gpm without a subsequent increase. These data clearly indicate that Surge Flow markedly affects the furrow intake rate, which is especially noticeable in the first irrigation.

In 1981, the Surge Flow research was expanded to three locations outside Logan. The first was a corn field on sandy loam soil near Flowell, Utah. The second was a bean field on a loam soil near Kimberly, Idaho, and the third a silt loam fallow field near Nibley, Utah. The advance and recession results from one of the Flowell tests are shown in Figure 3. Data from the other sites showed essentially the same characteristic difference between Surge Flow and conventional continuous applications. Figure 3 shows the advance and recession data for a 40-minute cycle with a cycle ratio of 0.5. The furrow was a non-wheel furrow being irrigated with a 32 gpm flow rate. The advance curve for a continuous flow furrow similar to the surged furrow is plotted as a dashed line. From the figure, it can be observed how each surge progressively covered more of the previously unwetted furrow. The first surge advanced about 400 feet, the second about 600 feet, and so on until the 13th surge reached 1180 feet, the end of the field. It can also be noted that the 40-minute cycle Surge Flow treatment covered the field in about eight hours, whereas the continuous flow had effectively stopped advancing at about 800 feet. The average applied depth for the surged furrow was just over two inches. For the continuous flow it was about six inches (see illustration).

The 1981 field research also included detailed infiltration measurements made with a small recirculating infiltrometer developed at USU. A sample of Surge Flow and continuous flow intake rates is shown in Figure 4. As had been theorized for some time, surging causes improved advance characteristics by reducing intake. The differences between surged and continuous intake rates vary by soil type. At Flowell, the surging effect reduced intake rates by about 50 percent. At Kimberly and Nibley, the reductions were only 20 percent to 30 percent. Surge Flow technology can substantially increase the rate of field coverage, thus allowing an irrigator to apply significantly less water per irrigation, if desirable. Tests near Flowell, Utah, indicate that the associated energy savings amount to about 60 percent over an existing sidetroll sprinkler system. In Idaho, the test results suggested a potential for lessening erosion with Surge Flow. In Northern Wyoming, independent tests showed that Surge Flow reduced fertilizer leaching and thereby improved crop yields. To date, Surge Flow has been found superior to conventional practices in every situation. A major surface-irrigation breakthrough has been achieved.

The major advantages of Surge Flow irrigation include:

☐ More efficient irrigation
☐ More uniform water distribution
☐ More uniform advance throughout the season and across the field
☐ Longer runs without increasing inlet streams
☐ More equal irrigation time requirements
☐ Capable of automation

Unfortunately, the concept is not yet entirely ready for commercial application. Nor are the optimal flow rates, length of run, cycle times, and cycle ratios precisely predictable for every surface-irrigated field. Surge Flow parameters (flow rates, length of run, cycle ratios, and cycle times) can be chosen which do not achieve an optimum result even though they are more effective than a continuous irrigation regime with a similar flow. Fine tuning will probably be required on a field by field basis. Additional study and demonstration efforts will correct these deficiencies.

ABOUT THE AUTHORS

Dr. A. Alvin Bishop is Professor Emeritus and former Head of USU’s Department of Agricultural and Irrigation Engineering. His life of teaching, research, and international consulting has been dedicated to the improvement of on-farm water management.

Dr. Walker came to USU in July 1980 from Colorado State University, where he was engaged in research on agricultural water pollution problems. He has authored numerous technical reports on the agricultural salinity questions of the Colorado River. He is Associate Professor of Irrigation Engineering at USU, responsible for research and teaching related to surface irrigation. Both authors were born and raised in Delta, Utah, where they gained their practical irrigation experience.
Advance length and recession with time for Surge Flow for a cycle period of 20 minutes and cycle ratio of 0.5 with comparison to continuous flow advance.

Runoff hydrographs from first irrigation continuous and Surge Flow tests. (Surge Flow cycle time of 20 minutes, cycle ratio of 0.5.)

Advance recession data for a 40-minute cycle on a sandy loam soil near Flowell, Utah.

Comparison of Surged and continuous intake rates for the Flowell, Utah soil.
FIGURE 1  Alfalfa Stem Nematode
(Ditylenchus dipsaci)
The Biology and Control of Parasitic nematodes on alfalfa

G. D. GRIFFIN
Research Leader
Nematology, USDA

ALFALFA IS UTAH'S PRIMARY CROP and may be the most important forage crop in the world. It is grown throughout Utah, from the cool short-growing areas in the northern part of the state to the tropical conditions in southwestern Utah. Unfortunately, it is susceptible to many disease-producing organisms (pathogens). These include organisms belonging to the phylum Nemata that are called nematodes.

THE ALFALFA STEM NEMATODE (DITYLENCHUS DIPSACI)

The alfalfa stem nematode, D. dipsaci, is the most important nematode pathogen on alfalfa. It is most frequently a serious pest in areas with heavy soils, high rainfall, heavy spring rains, and irrigation. D. dipsaci was first reported on alfalfa in Germany in 1881. It was noted in the United States in 1923 (18).

Among the eleven distinct biological races of D. dipsaci (which attack more than 300 host species), (16), the alfalfa race was believed specific only for alfalfa. A Utah population of the alfalfa race, however, can parasitize several plant cultivars, but it reproduces only on alfalfa and sainfoin (10).

All stages of the nematode except the first, which molts in the egg, are able to attack the alfalfa plant (Figure 1). The nematode enters the primordial bud tissue and migrates into developing buds. Infected stems become enlarged and are usually discolored, the nodes swell, and the internodes become shortened (Figure 2A). Growing stems may succumb to the infection or

FIGURE 1
Life cycle of the alfalfa stem nematode Ditylenchus dipsaci, on alfalfa. (A = eggs; B-E = second, third, and fourth stage larvae; F = adults.)

FIGURE 2
A. Stunting of alfalfa by D. dipsaci. Left: noninfected alfalfa stem.
B. Blackening of susceptible Ranger alfalfa plant succumbing to pathogenicity of D. dipsaci.
C. Four-year-old Moapa alfalfa plant succumbing to pathogenicity of D. dipsaci.
D. Alfalfa field infested with weeds after death of Ranger alfalfa due to D. dipsaci. Notice resistant Lahontan alfalfa in background.
E. White flagging of second cutting of Ranger alfalfa caused by D. dipsaci.
F. Three-year-old resistant Lahontan and susceptible Ranger alfalfa plot infested with D. dipsaci.
overcome the swelling and grow normally. Stem necrosis results as the nematode multiplies, and during a period of prolonged parasitism accompanied by moderate temperatures and high humidity, the stem may blacken for a foot or more above the ground (Figure 2B). Great numbers of nematodes (several thousand per gram), can be found in the matrix inside such blackened stems. The numbers of stems per crown become less and less as the alfalfa crown is destroyed, and eventually the entire plant dies. As the stand of alfalfa is thinned, weeds and grasses can invade (Figures 2C, 2D).

Soil temperature affects the host/parasite relationship (Table 1), as does warm humid weather. Under some conditions, nematodes may migrate into the leaf tissue, causing a curling and distortion of the leaves. "White flagging" (Figure 2E), a symptom found in second-cutting alfalfa, is attributed to nematode infection of the leaf tissue and destruction of the chloroplasts (1).

Nematodes may also infect the seed if the inflorescences are infected. Infected roots will have internal cavities or gall-like outgrowths that may girdle the root crown. Large numbers of nematodes have been found in crowns of parasitized alfalfa plants. This may be a mechanism by which the nematode survives periods of environmental stress. The great adaptability of this nematode is indicated by its ability to parasitize plants over a large temperature range (5°C to 30°C) (5,7).

A stem nematode infection can reduce resistance of some alfalfa selections to Corynebacterium insidiosum (12) (Table 2).

**Distribution**

Seed was once considered the major avenue for dissemination of D. dipsaci, and up to 17,000 nematodes have been found in a pound of fine screenings from uncleaned alfalfa seed (18). They are, however, easily spread by harvesting machinery and by rain and irrigation water from infected alfalfa debris left in the fields. The reuse of waste irrigation water is probably the most common method of nematode dissemination (3).

In northern Utah, nematodes overwinter mainly in alfalfa crown tissue and in young stem tissue that is protected by snow cover. Very few nematodes are found in plant debris and soil throughout the winter and no more than 50 nematodes per pound have been found in soil at any time of the year.

Nematode survival is short at high soil moisture levels in the absence of a host, and few or no nematodes can be recovered from fields after three years of grain crops. In desert areas with little or no rainfall, however, stem nematodes can survive in fallowed soil for several years.

**Control**

Without resistant alfalfa cultivars, the alfalfa stem nematode would be much more devastating than it is. Resistance to the alfalfa race of D. dipsaci was first observed in a Turkistan alfalfa selection planted in nematode-infested fields in northern Utah. From this Turkistan selection came the alfalfa cultivar Nemastan (18), which is also resistant to bacterial wilt. Lahontan was later selected from Nemastan (Figure 2F). Resistance to the alfalfa stem nematode has also been found in the Turkish introduction, Kayseri. Deseret, a selection from Kayseri, has resistance to downy mildew as well as to stem nematode (14). Several alfalfa cultivars, such as Washoe, Resistador, Caliverde 65, and Appalachee, contain some degree of stem nematode resistance.

**Cultural**

A two- to three-year rotation using non-host crops such as grain, beans, or sugarbeet will usually reduce a nematode population to below the detection level. Machinery, animals, or waste irrigation water, however, can quickly reinfect a field.

Certain agronomic practices can partially alleviate the parasitism of the nematode. In Utah, the alfalfa stem nematode is usually a problem only in the first cutting of alfalfa. Since subsequent growth is primarily reinfected from the soil, infection can be reduced by cutting the alfalfa when the top two to three inches of the soil are dry. This minimizes nematode infection of subsequent plant growth. With rainfall immediately before or after cutting, however, the nematodes can reduce quick tillering and plant regrowth, depending on the nematode population density.

Nematode infection in spring plant growth was significantly decreased by fall burning for weed control. Spring burning is not recommended, however, because it initiates growth of new plant tissue and encourages increased infection. Two- to three-year-old alfalfa fields have been completely devastated by this nematode because of regular spring burning.

Declines in yields normally vary with the source of nematode infestation. If the nematode source is from irrigation water or if the number of nematodes in the soil at the time of plant establishment is high, decline occurs in two to three years. If the source of infestation is from seed or machinery or from a reduced population in the soil, the decline is more gradual, over five to seven years.

**Chemicals**

Many systemic nematicides have been used successfully in experimental trials, when application occurs soon after spring growth is initiated. In most areas, however, the high cost of chemicals and their application make this type of control impractical.
FIGURE 3
Life cycle of the northern root-knot nematode, *Meloidogyne hapla*. (A = egg; B-C = second stage larvae; D-F = third and fourth stage larvae; G = adults. Note female with gelatinous matrix enclosing eggs.

FIGURE 4
A. Third stage root-knot larvae inside plant root. B. Adult root-knot female in root tissue. A) female, B) giant cells formed from dissolution of cell wall. Note multinucleated condition of giant cells. C. Resistant Nevada Synthetic XX (center) and susceptible Ranger alfalfa to *Meloidogyne hapla*. Note galling and proliferation of root growth caused by the nematode. D. Adult root-knot female in plant root depositing eggs in gelatinous matrix. Matrix will contain from 350 to 400 eggs. A) female, B) matrix with eggs.
E. Migration of all stages of root-lesion nematode in root tissue. A) necrotic area caused by nematode feeding on cell tissue, B) adult, C) larvae, D) egg.
F. Necrosis of root tissue caused by root-lesion nematode, *Pratylenchus brachyurus*.

Figures 1, 2A, and 3 (with modifications) courtesy of Department of Nematology, University of California, Riverside. Figures 2F and 4C courtesy USDA, Reno, Nevada. Figures 4B, 4D, and 4F courtesy of R. S. Hussey.
ROOT-KNOT NEMATODES  
(MELIOIDOGYNE SPP.)

Root-knot nematodes, Meloidogyne spp., are probably the most widely distributed plant-parasitic nematodes, and they rank high in economic importance as plant pathogens. Root-knot nematodes now include approximately 35 species (15).

Two of these species are important in Utah: the northern root-knot nematode (M. hapla) and the southern root-knot nematode (M. incognita), which is found only in Washington County. Although present in most soils, root-knot nematodes generally prefer sandy loam soils.

Alfalfa roots infected with root-knot nematodes become branched, stunted, and galled when heavily infected. A severe infection may cause high mortality in young alfalfa plantings. When lightly infected, alfalfa plants may appear normal and give satisfactory hay yields.

Root-knot nematode pathogenicity, reproduction (Table 3), and survival (6,9) are extremely sensitive to soil temperatures. Utah’s northern root-knot nematodes are greatly reduced in numbers in soils where the frost line extends below the feeder root zone. They can infect plants at soil temperatures of 5°C, but maximum nematode reproduction occurs at soil temperatures of 20 to 28°C.

Root-knot nematodes can create important economic problems relative to highly susceptible crops such as vegetable truck garden crops and certain field crops when they are grown in rotation with alfalfa. These nematodes also may be involved in disease complexes with other alfalfa pathogens. The northern species has increased the incidence of Fusarium wilt in alfalfa, with the degree of wilting being correlated with the severity of the nematode infection (8). This nematode also increases the incidence of bacterial wilt in both wilt-resistant and susceptible cultivars (Tables 4 and 5). There is also a synergistic interaction between M. hapla and D. dipsaci; D. dipsaci can predispose root-knot-resistant alfalfa to the northern root-knot nematode (4).

Root-knot nematodes are infective in their second stage or as newly hatched larvae. The larvae are approximately 0.40 to 0.45 mm long and possess a delicate spear (Figure 3), which limits them to the tender plant tissue near the root tip, where they feed and cause cell hypertrophy (Figure 4A). The larvae become oriented towards the root meristem, feed on this tissue, and prohibit its differentiation into vascular tissue. The cells enlarge and wall tissue is no longer formed during cell division. The adjoining cells coalesce to form giant cells that become a continual food source for the nematodes. Larvae become sedentary and increase in both length and width. Gall size differs with the root-knot species (e.g., M. hapla galls are small and oval, those of M. incognita are large and more cylindrical).

Reproduction occurs without males; however, males have been found in large numbers in the soil, in egg masses, and occasionally in the root tissue. We do know that the ratio of males to females increases with a corresponding increase in the number of root-knot larvae invading the host plant.

During reproduction, the female enlarges, becomes pear-shaped, and deposits eggs in a protective gelatinous matrix that adheres to the outer surface of the root (Figure 4B). The number of eggs produced on susceptible alfalfa is about 100 to 350 per egg mass. When temperature and soil moisture are favorable, eggs hatch and the larvae move into the soil. The life cycle of M. hapla on alfalfa is complete in approximately 30 days at 25°C (6).

Control

Since chemical control is not economically feasible, plant resistance is the only practical method of control. Resistance to the northern root-knot nematode has been found in Vernal alfalfa selection, and incorporated into resistant germplasm (Figure 4C), Nevada Synthetic XX (13). The African type alfalas, such as Moapa, are resistant to M. incognita, and a resistant selection, Nevada Synthetic YY, was recently released (11).

Root-knot nematodes are not as devastating to alfalfa as stem nematode but their wide range of susceptible host plants make crop rotations unsatisfactory as a means of control.

ROOT-LESION NEMATODES  
(PRATYLENCHUS SPP.)

Root-lesion nematodes, Pratylenchus spp., occur widely throughout Utah. They attack a wide range of plants and are primary factors in destroying roots of both cultivated and non-cultivated plants.

Although research on the relationship between Pratylenchus and alfalfa has not been conducted in Utah, this nematode has been shown to cause extensive root damage. It severely reduces spring-sown alfalfa stands in other states (2). A high incidence of root-lesion nematode infection can reduce forage yields, decrease cold tolerance (17) and increase infections by Fusarium spp. Damage caused by root-lesion nematodes is difficult to evaluate accurately because other soil microorganisms usually invade and further damage nematode-infected roots.

Above-ground symptoms can resemble those caused by other pathogens that cause plant stunting. No symptoms develop when nematode numbers are low, but when numbers are high and environmental conditions are ideal, infected plants become stunted. Feeding by root-lesion nematodes generally causes dark lesions, an overall browning of the roots, and reduced root growth.

The most important root-lesion nematode associated with alfalfa is Pratylenchus penetrans, but at least six other Pratylenchus species can affect alfalfa. The life cycle of root-lesion nematodes is simple. Females deposit eggs in root tissue or in the soil; both larval and adult forms enter roots by forcing their way between or through the cortical cells. They feed on the cell contents while migrating through the root tissue (Figure 4E, 4F).

Control

Root-lesion nematodes have an extensive range of hosts, and more than one species may infect a given host. No alfalfa cultivars are resistant to root-lesion nematodes. Recent studies indicate, however, that it may be possible to develop adapted cultivars with satisfactory resistance to one or more Pratylenchus species. Certain nematicides will control root-lesion nematodes on alfalfa, but costs are generally prohibitive.

Other Nematodes

In addition to stem, root-knot, and root-lesion nematodes, several other species of plant parasitic nematodes are associated with alfalfa in Utah. These include one or more species of the genera: Aphelenchoides, Criconemoides, Hoplolaimus, Tylenchorhynchus, and Xiphinema.
LITERATURE CITED


NOTE: The full research report of "The Biology and Control of Plant-Parasitic Nematodes on Alfalfa" (Research Report 64) will be available from the USU Bulletin Room (108 Eccles Conference Center or UMC 50B).

ABOUT THE AUTHOR

Gerald D. Griffin is the Research Leader in Nematology, USDA, Agricultural Research Services, Logan. Dr. Griffin has been affiliated with the U.S. Department of Agriculture for over 25 years. He is internationally known for his expertise in the biology and control of plant-parasitic nematodes on alfalfa. He is also an authority on nematode problems on sugarbeets, field vegetables, and tree fruits.

### TABLE 1. Pathogenicity of Ditylenchus dipsaci on resistant and susceptible alfalfa

<table>
<thead>
<tr>
<th>Soil temp(C)</th>
<th>Lahontan</th>
<th>Ranger</th>
<th>Plant weight</th>
<th>Plant weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% galled</td>
<td>% control</td>
<td>% galled</td>
<td>% control</td>
</tr>
<tr>
<td>15</td>
<td>35</td>
<td>59</td>
<td>100</td>
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<tr>
<td>20</td>
<td>25</td>
<td>74</td>
<td>92</td>
<td>39</td>
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<tr>
<td>30</td>
<td>10</td>
<td>92</td>
<td>68</td>
<td>72</td>
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</table>

### TABLE 2. The interaction of Ditylenchus dipsaci and Corynebacterium insidiosum on alfalfa

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>D. dipsaci</th>
<th>C. insidiosum</th>
<th>D. dipsaci + C. insidiosum</th>
<th>Control</th>
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<tbody>
<tr>
<td>Moapa</td>
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<td>78</td>
<td>0</td>
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<tr>
<td>Ranger</td>
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</tr>
<tr>
<td>Vernal</td>
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### TABLE 3. Effect of soil temperature on reproduction of Meloidogyne hapla on susceptible alfalfa

<table>
<thead>
<tr>
<th>Soil temp(C)</th>
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<th>DuPuits</th>
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<td>52</td>
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<td>49</td>
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<td>32</td>
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<td>974</td>
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### TABLE 4. Interaction of Meloidogyne hapla and Corynebacterium insidiosum and on alfalfa cultivars

<table>
<thead>
<tr>
<th>Alfalfa cultivars</th>
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<td>0</td>
<td>12</td>
<td>12</td>
<td>16</td>
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</tbody>
</table>

### TABLE 5. Effect of temperature on interaction of Meloidogyne hapla and Corynebacterium insidiosum on Moapa alfalfa

<table>
<thead>
<tr>
<th>Temperature (C)</th>
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<th>B</th>
<th>C</th>
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<tr>
<td>16</td>
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<td>18</td>
</tr>
<tr>
<td>28</td>
<td>80</td>
<td>76</td>
<td>12</td>
</tr>
</tbody>
</table>

### TABLE 6. Least Square Test

LSD (cultivars) 0.05 = 20.6
LSD (treatments) 0.05 = 29.1

### TABLE 7. Pathogenicity of Ditylenchus dipsaci on resistant and susceptible alfalfa

<table>
<thead>
<tr>
<th>Soil temp(C)</th>
<th>Lahontan</th>
<th>Ranger</th>
<th>Plant weight</th>
<th>Plant weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
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<td>59</td>
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</tr>
<tr>
<td>30</td>
<td>10</td>
<td>92</td>
<td>68</td>
<td>72</td>
</tr>
</tbody>
</table>
2. Shifting late January fog uniformly rimed this Cache Valley tree.

3. Seed pods weighted by rime forming into a north wind.

4. Rime formation increases with height on a haystack, and . . .

5. Frozen droplets of early December fog coat the smaller twigs of a Logan tree with rime.

6. Open flow channels and screening boughs surround the detail shown in Figure 7.

7. Large rime variation in a small volume is shown in this detail from the lower left of Figure 6.
The fog comes
on little cat feet.
It sits looking
over harbor and city
on silent haunches
and then moves on.
Carl Sandburg
A catlike fog lay silently in Cache Valley for a seeming eternity during the Winter of 1980-81. Occasionally strolling to a more comfortable position, still it remained—silently watching. It was both gently enfolding and fearfully blinding. It was cold fog, painting the landscape white with frozen droplets and growing crystals of feathery ice. White sky . . . white air . . . white land . . . white bushes . . . white . . .

L. F. HALL
Research Associate Professor
Soil Science & Biometeorology

IT BEGAN IN EARLY DECEMBER, first the fog, then rime and hoarfrost growing on trees, bushes, grass, wires—anything small. A rime-coated birch tree observed during a momentary break in the December fog is shown in Figure 1. Rime also covers another tree photographed during the lingering fog of late January in Figure 2. These trees were uniformly covered on their smaller branches and twigs by frozen fog droplets which had been carried into and through the tree crowns from all directions by variable winds.

Rime forms when supercooled droplets of fog or cloud strike a surface and immediately freeze to it. If either the droplets or the surfaces are too warm, the droplets will first wet the surface, subsequently freezing as a clear glaze. Under the right conditions, however, the droplets freeze quickly in nearly spherical shape, trapping air and creating a frosty white rime.

Fog or cloud droplets normally remain unfrozen at air temperatures well below the freezing point for a plane surface of water, that is, they are supercooled. Theory predicts and experiment confirms that, if undisturbed and if no freezing nuclei are present within the droplets, they may remain unfrozen to temperatures as low as -40°C (-40°F). When supercooled droplets contact a surface, they freeze rapidly because their surface is distorted and a conduction path for removal of latent heat released during freezing is then available. The droplets are able to follow the gently curving flow of air around a large object, such as a tree trunk, without contact. Small twigs, however, cause sharply curved flow very near their surface and the inertia of the droplets carries them into contact, where they freeze to the twig. Since rime is formed by impact, it always grows into the wind.

Rime formation on a smaller scale is shown in Figure 3. The wind was from the left (north) during rime formation. The building, and a large dumpster just to the south, suppressed wind from other directions. The figure illustrates rime growth upwind with nearly perfect horizontal structure, except for the seed pods at the top. They slowly bowed under the growing weight of rime, forming a heavy beard. Rimming is minimum on the grass and increases with height along the plant stem. This happens because increasing numbers of fog droplets pass the stem as distance from the ground increases. This is partially due to grass and other vegetation combing droplets from the air upwind, but it is principally due to a normal increase of wind velocity with height, since ground drag retards air motion near the surface.

Figure 4 illustrates both the increase of wind velocity with height and consequences of air being deflected around large objects. Greater riming is evident at the top of each side of the haystack in the figure. The edges of the end of the stack are also more strongly rimed than the central area, because the droplets carried to the sides by the deflected air flow pass very near the corners. This does not occur on large cylindrical objects, because the flow is less concentrated than at rectangular corners and the droplets tend to glance off when striking a surface at a grazing angle. Projecting straw on the end of the stack is also rimed, indicating variable winds and a thin deflected boundary layer in the fog-filled air.

The normally extreme variation of wind speed with height very near the surface is indicated in the rime formations on individual grass blades in Figure 5. Reduced fog density near the surface may have contributed to the observed rime formation, but air deflected downward by the pine boughs above the grass probably reduced the effect. The strong variation of rime with height is in accord with wind profile theory and measurement, and has been observed on several other occasions, even over open, snow-covered fields. A similar variation of rime thickness may be observed on the pine needles, increasing outward due to flow deflection around the bough tip. While wind velocity continues to increase with height, its rate of increase lessens rapidly; thus there is little difference between the maximum thicknesses of rime on the grass and the needles.

Figure 5 is a close-up of the area at the lower right of the tree shown in Figure 6. The tree is more heavily rimed on the right (west) side, due to persistent west winds, partially channeled between two buildings. This large scale uniformity is not reflected at smaller scales, however, as is illustrated by the bough tip near the lower left of the pine which is shown in Figure 7. This bough tip has been rimed from the west only along its lower edge, while it has been rimed from the east over its entire left side. As rime thickness is a measure of movement of droplets past the needles, the lower needles have clearly been subjected to oscillating flow, with west winds dominant, while the upper needles have been subjected to only east winds bearing fog droplets. The mystery of this
strong spatial variation of riming is partially solved by the clarification of the physical setting provided in Figure 8.

The bough tip of Figure 7 lies in the center of Figure 8, while another bough is shown just to the west. The east-west flow channel is only open across the lower edge of the tip. If any flow from the west occurred at the upper edge of the tip, it would be slowed and cleared of droplets by the bough to the west. Since rime thickness depends on both wind velocity and fog density, it provides only a fairly good measure of the wind. It would be virtually impossible to experimentally determine air currents through pine boughs with equal accuracy because of flow interference by the sensors. Thus, the rime pattern may be viewed as a moderately accurate, spatially detailed natural experiment, revealing air flow through a pine tree. Note that the east wind did not affect the rime formations in Figure 5.

Figures 9 and 10 illustrate the narrowness of rime formed on a twig. This twig is again located near a building, thus the flow is primarily from the right (south) or left (north), with south winds dominating. Except for a few bulges along the twig sides, the rime is essentially the same width as the twig. Rime on the spherical berries is even more concentrated toward the center, probably due to droplets glancing off the smooth berry surfaces at grazing angles. At the tip of the twig, flow deflection around the leaves leads to rime formation along the leaf edges. Only a small amount of low velocity air would enter the folds of the leaves, while the fog droplets were much too small to be carried into the folds by their own inertia, thus the folds are without rime.

Rime from cloud droplets frequently forms in the mountains. One may occasionally observe rime-whitened trees at several miles distance. Mountain rime tends to be much thicker, due to high wind speeds in the cloud-filled air, with examples ranging up to tens of centimeters (feet) in thickness. At the other end of the size scale, a careful observer will note that many snowflakes have some rime on their surfaces.

Hoarfrost formation is favored by thin fog and low temperatures. An example of hoarfrost is shown on the same twig as presented in Figures 11 and 12. Hoarfrost is formed directly from atmospheric water vapor by deposition, without passing through the liquid stage. Many different shapes, including needles (Figures 11 and 12), plates (Figures 13 through 15), cups, feathery forms, or dendritic forms (like snowflakes) occur. The shape which forms in any given case is dependent on the water vapor supply and the removal of latent heat released during crystal formation. These factors are further dependent on temperature, humidity, vapor diffusion, air motion, and heat removal by conduction, convection, and radiation.

In Figures 11 and 12, the rime formed favorable sites for crystal growth to start, while passing air supplied the water vapor required for continued growth. It is clear from Figure 11 that only south winds occurred during formation of the hoarfrost, as hoarfrost also grows into the wind. (In still air, it grows in all directions away from the surface.) Hoarfrost does not form on leeward surfaces in moving air because crystals growing upwind have removed too much water vapor. This is similar to upwind boughs of a pine tree sweeping fog droplets from the air, thereby preventing rime formation on needles to their leeward (see discussion of Figures 6 through 8). A small amount of rime may also form on the upwind surfaces of hoarfrost crystals, but the needles may break off if struck by too large a droplet.
13. Hoarfrost plates on a snowbank near Spring Hollow in Logan Canyon.

12. . . the formation is much wider—still into the wind.

10. . . a downwind view illustrating the narrowness of rime formations.

9. A crosswind view of rime on leaves, berries, and twigs, plus . . .

11. Hoarfrost needles formed by water vapor deposition on the rime surfaces, but . . .

14. A detail from Figure 13 shows the result of competition among the growing plates.

15. Hexagonal forms, characteristic of ice, border the plates.
The hoarfrost in Figure 12 has grown to much greater width than the rime in Figure 10. This simply reflects the differing formation mechanisms. Hoarfrost may grow out into the vapor-filled air, while rime is constrained to grow into lines of droplet motion which intersect an existing surface. The width of the crystal growth is limited only by the strength of the individual crystals as they are struck by droplets and buffeted by air currents. Note that the berries are as thoroughly coated with hoarfrost needles as the twig and leaves, in contrast to the riming example, because transport and diffusion of water vapor to the growing crystals is not affected by the smoothness of the berry surfaces.

Platelike crystalline forms are shown in the foreground of Figure 13, while a closer look at the crystals is provided in Figure 14. Competition for water vapor and the required disposal of latent heat have led to development of separated plates rather than a thick frost layer. The crystal orientation appears to be a compromise between growth perpendicular to the snow surface and a true horizontal. Growth perpendicular to the surface would provide minimum competition for water vapor by the snow, and minimum interference with the diffusion of water vapor to the growing crystal edges. This is the preferred orientation in cases with uniform surroundings. An horizontal orientation, however, would favor radiative cooling of the crystal by presenting the maximum crystal surface to the sky and the minimum surface to warmer objects in the vicinity. Crystal growth is dependent on the removal of latent heat, and both heat removal and growth would be greatest in this position. The hoarfrost thus provides a detailed spatial image of the best compromise among water vapor diffusion, crystal cooling, and competition with the snow and other crystals. Instrumental measurement of these fluxes would again be virtually impossible in such detail.

Figure 15 is a close-up view of the crystals. The crystal dimensions were typically 1 to 2 cm (1/2 to 1 inch). Note the hexagonal shapes along the crystal edges, characteristic of ice. These large crystals formed over a period of several days, during which rime, snow, and chips of other crystals collected on the older plate area. They were later covered by a layer of fresh snow.

Nature is quite casual about the beauty it creates. While devastating to motorized man and blue sky enthusiasts, the fog that occasionally blankets Cache Valley in winter creates many things of beauty. Even as it quietly departs, it leaves behind a shower of falling crystals, glistening in the warm sunlight that released them to drift gently and silently to the earth.

ABOUT THE AUTHOR
Leonard F. Hall is a Research Associate Professor of Biometeorology at USU. He has been photographing natural phenomena for over 10 years with emphasis on atmospheric optics and near surface events. His main research areas are micrometeorology and turbulence.
EMBRYO TRANSFER PROCEDURE

FIGURE 1. The donor cow is restrained in a regular head piece and given a small amount of sedative. The perineal area is prepared for surgery and an epidural anesthetic is administered.

FIGURE 2. A foley catheter is passed through the cervix into the uterine horn. The balloon is inflated to hold the catheter in place. The flushing medium flows through tubing to the catheter. Each horn is flushed separately.

FIGURE 3. The flushing medium is collected in a sterile cylinder.

FIGURE 4. The medium is allowed to stand for 30 minutes and then the top 400 ml is siphoned off and saved. The remaining 100 ml is poured into petri dishes and is searched.

FIGURE 5. The embryos are located using a stereomicroscope at 15X.

FIGURE 6. Once the embryos are found, they are pipetted and transferred into culture media and examined for quality prior to transfer.

FIGURE 7. The suitable recipients are palpated and the CL identified. The flank area is clipped and prepared for surgery.

FIGURE 8. The site is then locally anesthetized prior to surgery.

FIGURE 9. A six-inch incision is made in the flank and the tip of the uterine horn is exteriorized.

FIGURE 10. A satisfactory embryo is then taken from the culture media in a sterile pipette and placed into the lumen of the uterine horn of the recipient.
FIGURE 11. The calf crop from a single donor cow is being incubated in these substitute mothers. Donor cows can be superovulated approximately three times a year, indicating a potential crop of 36 calves per year.
Multiple generations of championship breeding can take place yearly with embryo transfer techniques.

WALTER HEAPE PERFORMED THE FIRST embryo transfer (ET) between rabbits in 1890 at Cambridge University. The popularity and usefulness of ET was not recognized until the 1970s. Since that time a great deal of progress has been made in perfecting transfer techniques. In 1980, 20 million dollars was generated by the ET industry in the United States.

The applications of embryo transfer are the proliferation of desirable genotypes, genetic improvement, import and export, disease control, treatment of infertility, and research. As an example of proliferating desirable genotypes, Australian workers used ET to produce 277 lambs from 86 polled Merino ewes. Genetic improvement can double the selection intensity and the rate of response to genetic selection for traits such as growth, which can be measured in both sexes. Import and export will certainly lead to improved techniques for maintaining embryos in culture and for preserving them by freezing.

The selection of the donor cow is the first step in embryo transfer. The donor should be selected on the basis of her past production performance and the predictability of her passing that capacity on to her progeny. The donor is more likely to respond to superovulation treatments if she comes from fertile blood lines, exhibits regular estrous cycles, usually conceives in less than two services, is in general good reproductive health, and is from three to ten years old.

Embryo transfer procedures require the utmost attention to detail. Following the careful selection of the donor one must also select a sire that will complement the donor, resulting in another genetically superior animal. The donor cow is then given a superovulation drug (Gonadotropin), either Follicle Stimulating Hormore (FSH) or Pregnant Mare Serum-Gonadotropin (PMS-G), to stimulate the production of more than one follicle, which is the normal case. The superovulation treatment is initiated during the luteal phase of the estrous cycle, usually 9 to 12 days following a natural estrus. Following the superovulation treatment, prostaglandins are used to induce estrus, at which time the donor is bred using multiple services. Meanwhile, the recipient herd is observed for heats that will coincide with the heat of the donor cow. To synchronize the recipients, they should be given prostaglandin one day prior to the time the donor receives her injection of prostaglandin. Usually, 15 recipients should be available for each superovulated donor cow. Particular attention needs to be given to recipient selection. The recipients should be selected on the basis of fertility, the ability to give birth to a normal calf, and the capacity to mother the offspring to weaning age. The recipient is usually of commercial grade and can be of any breed or combination of breeds.

Six to eight days after the donor cow is bred, the embryos are removed non-surgically by flushing her uterus. This is accomplished by means of a catheter placed in the uterine horn. The flushing medium is a buffered saline solution fortified with calf serum and antibiotics. Each uterine horn is flushed separately. The recovered media is examined microscopically to locate the embryos, which are placed in suitable media for evaluation and pending transfer. Careful attention must be paid to the conditions under which the embryos are handled.

Prior to embryo transfer the recipients are palpated to determine if a corpus luteum (CL) is present and on which ovary it is located. Recipients that are in synchrony with the donor cow (± 24 hours) and have a CL are then used. The embryo is then placed in the uterine horn on the same side as the ovary with the CL via a small pipette.

The implantation of the embryo can be accomplished either surgically or non-surgically. Generally in heifers it is preferable to use the surgical approach, while in cows the non-surgical procedure is preferred. The viable embryo is placed into the lumen of the uterus at the lower 1/3 of the horn, which is an environment similar to the that of the donor cow. Generally speaking, the surgical approach yields higher conception rates. The surgical method does not require much more time than non-surgical, and has very little if any post-surgical effect on the recipient. Recipients may be used again if pregnancy does not result from the transfer. If she does not conceive after the second transfer it would be indicative that she has a low fertility level and probably should not be used the third time. According to Elsden et al.," from first transfers of transferable quality embryos in 1,365 recipients averaged 59 percent pregnancy rate and from second and third transfers into recipients that had previously failed or remained open, the pregnancy rates are 56 percent and 30 percent, respectively."

With all factors of ET being optimal, on the average, a livestockman could anticipate receiving eight transferable embryos from one superovulation treatment and 3.5 pregnancies resulting. This same donor could be flushed again in 60 days on two more occasions. Generally, it is advisable to breed the donor for conception after the third superovulation to prevent the development of cystic follicles and decreased fertility.

Embryo transfer has already proven to be a valuable research tool. Material and genetic influences on any particular characteristic can be differentiated by embryo transfer.

It is often difficult to determine whether infertility is caused by fertilization failure, an adverse effect on the uterus, or an adverse effect on the embryo. By collecting the embryos, the cause of the infertility can be found.

A research potential exists for the freezing and sexing of embryos. By minimizing the embryo loss using these procedures we could reduce the cost, and enhance a more direct involvement of the commercial and grade producer in embryo transfer.
In summary, embryo transfer should be considered a management tool to potentiate and utilize superior genetic material. Because there are many steps that require attention to detail and substantial numbers of animals involved, one would be ill-advised to undertake such a program without careful planning. First of all, a prospective user should have a goal in mind as to how to best utilize the genetics that can be engineered. Careful selection and management of the donor is important, but no more than are the selection and management of the recipient herd from a reproductive efficiency standpoint. The livestockman must be willing to devote the time needed to treat and breed the donor, give synchronization treatment to the recipients, and watch heat periods and record the data.

Because some livestockmen do not have this time they may choose to enroll their donor cow in a program that provides in-clinic services and furnishes the recipients.

USU embryo transfer program has the capacity for both in-clinic services and on-the-farm embryo transfer, or a modification of either. The goals of the program are to enable the Utah livestockman to utilize the genetic potential his herd indicates.

LITERATURE CITED


ABOUT THE AUTHOR

Dr. Berry was born and raised in western Nebraska, where he practiced Veterinary Medicine for 13 years. After becoming involved in embryo transfer in 1975, he chose to sell his practice and specialize in reproduction in 1977. He completed two years of postdoctoral studies at Colorado State University and became a board-certified theriogenologist in 1979.

Dr. Berry was involved in commercial embryo transfer in Iowa from 1979 until joining the staff in 1981 at Utah State University, where he is in charge of developing and conducting the embryo transfer program.
ENERGY CONSERVATION
IN UTAH HOMES

LARAE B. CHATELAIN and H. CRAIG PETERSEN
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ABOUT 15 PERCENT OF THE TOTAL ENERGY used in the United States each year is consumed by households. Space conditioning (i.e., heating and cooling) and water heating are the main uses of energy in the home. Approximately four-fifths of all household energy purchases are for these purposes.

Until 1973, residential consumers in the U.S. paid relatively low prices for oil, natural gas, and electricity. These low prices caused American families to attach a low priority to improving the energy efficiency of their homes. Energy conservation efforts (such as insulation, weatherstripping, and double-glazed windows) were rarely considered worthwhile by the average homeowner.

As energy prices increased during the decade of the 1970s, so did interest in making homes more energy efficient. Unfortunately, opportunities for improving the energy efficiency of an existing home are more limited and costly than for a new residence. Still, some things can be done. Although it is rarely feasible to add insulation to walls, it is often possible to insulate ceilings. Adding double-glazed windows to an existing home may be prohibitively expensive, but doors and windows can be weatherstripped to prevent heat loss. As a last resort, families can cut heating bills by turning down their thermostats.

Other than anecdotal and subjective impressions, little is known about the ways that Utahns have responded to higher energy prices for space conditioning and water heating. In the spring of 1980, a questionnaire was developed, tested, and mailed to a random sample of 2,150 households. Usable data were obtained from over 70 percent of those receiving the mailing.

This article reports on portions of the data obtained from that study. Although the total sample included renters and owners of mobile homes, only owners of single-family, conventional housing are discussed here. Renters and mobile home owners were excluded because they have different options and incentives for conserving energy.

FINDINGS
The questionnaire provided information on over thirty energy-related topics. The findings with respect to four of these topics are presented here—the impact of higher energy prices, amount of ceiling insulation, thermostat set-backs, and reduction in water heater temperatures.

Impact of Higher Energy Prices. Utah residents were first asked to indicate the degree to which higher energy prices had caused them to change their lifestyles. Forty-two percent of the sample said they made no or only a few changes, while 58 percent made many and/or drastic changes in their lifestyle (Table 1). The poor, the elderly, and those living in rural areas were the groups most affected.

Ceiling Insulation. Adequate ceiling insulation is one of the most effective ways to conserve energy in a residence. Although the optimal amount of insulation is dependent on the insulating material (fiberglass, rock wool, cellulose, or foam), at least ten inches are suggested for all but the southern areas of Utah. Few Utah homes had that amount of ceiling insulation (Table 2). Almost half of the respondents reported that they had six inches or less of insulation.

When asked if they had added ceiling insulation during the last five years, almost one-half of the sample indicated that they had (Table 3). Those who had not added insulation were also asked why they had not done so. The most common explanation was that the existing amount of insulation was considered adequate (Table 4). However, over a third of that group lived in home with six or less inches of insulation. One interpretation of this finding is that many Utah homeowners are not aware of the benefits of energy conservation expenditures.

Thermostat Set-backs. Homeowners were asked to report their normal day and nighttime winter thermostat settings. They were also asked to indicate the level at which they would set their thermostats if heating bills were not a consideration. About one-third of the respondents had made no reduction in daytime temperature settings and a full one-half had not reduced nighttime settings below the optimal level (Table 1). Only about ten percent of the household responding had reduced day or nighttime temperatures by as much as six degrees below their preferred levels.

Reduction in Water Heater Temperatures. The normal setting on a gas or electric water heater provides hot water at a temperature of 140 degrees Fahrenheit. However, except for the operation of dishwashers, a setting of 120 degrees is satisfactory for home
needs and can result in a significant saving in energy. The survey determined that almost two-thirds of the homeowners responding had made some adjustment to reduce the temperature of the hot water used in their homes (Table 6).

CONCLUSIONS
The survey results indicate that most Utah homeowners have altered their lifestyles in response to higher energy prices. Many families have reduced thermostat settings in the attempt to conserve energy. Nearly half of those surveyed added ceiling insulation during the last five years. The data suggest, however, that many opportunities remain for families to conserve energy. For example, a substantial portion of the respondents who considered their homes to have adequate ceiling insulation presently have less than six inches of insulation. This suggests that there is a continuing need to educate Utah residents about the benefits of energy conservation activities.

ABOUT THE AUTHORS
LaRae B. Chatelain, as an Assistant Professor in the Department of Home Economics and Consumer Education, has research interests which include housing and energy. She received her PhD from Florida State University and has been at USU since 1969.

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| TABLE 1. Impact of High Energy Prices |
| RESPONSE | NUMBER | PERCENT |
| High energy prices have caused no real changes in our lifestyle | 43 | 4% |
| High energy prices have required only a few changes in our lifestyle | 423 | 38% |
| High energy prices have required many changes in our lifestyle | 511 | 47% |
| High energy prices have required us to drastically change our lifestyle | 123 | 11% |

| TABLE 2. Inches of Insulation |
| INCHES | NUMBER | PERCENT |
| 0 | 30 | 3% |
| 1 to 3 | 107 | 11% |
| 4 to 6 | 336 | 33% |
| 7 to 9 | 216 | 21% |
| 10 or more | 320 | 32% |

| TABLE 3. Ceiling Insulation Added in Last Five Years |
| RESPONSE | NUMBER | PERCENT |
| YES | 475 | 44% |
| NO | 599 | 56% |

| TABLE 4. Reason for Not Adding Ceiling Insulation |
| RESPONSE | NUMBER | PERCENT |
| Amount already adequate | 316 | 55% |
| Can't afford | 174 | 30% |
| Haven't had time | 31 | 5% |
| Other | 54 | 10% |

| TABLE 5. Differences Between Optimal and Actual Thermostat Settings |
| OPTIMAL-ACTUAL (Degrees) | DAY NUMBER | PERCENT | NIGHT NUMBER | PERCENT |
| 0 | 334 | 33% | 505 | 50% |
| 1 to 2 | 207 | 20% | 108 | 11% |
| 3 to 5 | 358 | 35% | 281 | 28% |
| 6 to 10 | 96 | 10% | 79 | 8% |
| 11 or more | 25 | 2% | 31 | 3% |

| TABLE 6. Reduced Water Heater Temperature |
| RESPONSE | NUMBER | PERCENT |
| YES | 688 | 66% |
| NO | 360 | 34% |
LIFELINE ELECTRICITY RATES IN UTAH: Gainers & Losers

LARAE B. CHATELAIN and H. CRAIG PETERSEN

UNTIL 1970, ELECTRICITY WAS AMONG THE BARGAINS American consumers took for granted. Over the last ten years, however, the cost of providing power and therefore the price of electricity has risen rapidly. Between 1970 and 1980, the consumer price index changed by almost exactly 100 percent. During the same years, electric bills increased 160 percent.

As rates shot upward, so did consumer awareness of electric utility rate structures. Historically, most utilities have used a "declining block" rate structure which charges less per kilowatt-hour (KWH) for successive blocks of consumption. For example, a typical declining block tariff might be structured as follows:

First 100 KWH 10¢/KWH
Next 200 KWH 8¢/KWH
Next 300 KWH 7¢/KWH
All additional KWH 6¢/KWH

Declining block rates are a relic of the time when utilities were promoting electricity consumption so they could take advantage of efficiencies inherent in large-scale power generation. By offering low rates for additional consumption, consumers were encouraged to use their electric appliances more intensively and also to purchase additional electricity-consuming devices. The strategy was very effective. Residential electricity use in the U.S. increased from an average of 80 KWH per month in 1940 to 675 KWH per month in 1973. Since 1973, rapidly increasing prices have kept average consumption essentially unchanged.

THE "LIFELINE" CONCEPT

With the declining block rate structure, low-income consumers who are low-volume users of electricity, pay a high price per KWH used. "Lifeline" rates are frequently suggested as a means of mitigating the impact on the poor of high electricity prices. A typical lifeline tariff would charge a low rate for the first 300 KWH of electricity used per month, with a higher price per KWH for consumption in excess of 300 KWH. (The 300 KWH block represents an amount considered sufficient to supply basic lighting, refrigeration, and cooking needs of a family of four.) The philosophy behind lifeline rates is that electric power is a necessity in modern society and every family should be able to purchase enough electricity to meet its minimum needs without undue budgetary stress.

A generally accepted premise of utility regulation is that electric utilities should be allowed to charge rates high enough to achieve a fair return on invested capital. Normally, individual rates are set to cover the cost of providing service to each class of customers. Lifeline proposals, however, often call for the initial block of power consumed to be priced below cost. The resultant revenue deficiency must be recouped by increasing rates for subsequent usage blocks or for other classes of customers. Some lifeline proposals limit the required increase to higher-volume residential customers. Others solve the problem by increasing electric rates for commercial and industrial customers as well as for high-volume residential.

PROS AND CONS OF LIFELINE TARIFFS

Advocates of lifeline rates are primarily concerned with providing rate relief for the poor. They assert that low-income groups are low-volume users who would thereby have their electric bills reduced. Lifeline advocates also argue that their proposals will promote conservation because, as additional KWH become more expensive, consumers have an incentive to conserve on their use of electricity.

Opponents of lifeline rates argue that the impact would depend on whether consumers make electricity consumption decisions on the basis of the charge for incremental KWH of consumption or on the basis of each month’s electric bill. If the total monthly bill is the determining factor, then a lifeline tariff that reduces the electric bills of many customers may actually promote increased overall use of electricity.

Lifeline critics also question whether such tariffs would really provide financial assistance to the poor. While low-income groups in general use little electricity, some low-income customers use relatively large amounts. Conversely, some high-income customers consume relatively low volumes of
Involves renters whose electric block of electricity requires an increase (PURPA) and some low-income customers may actually receive electricity. Utilities block has not been authorized. Hence, customers may decrease while those of commercial users or are billed under a residential tariff for which a lifeline block was not included in their rental payments. Landlords are often classified as commercial users or are billed under a residential tariff for which a lifeline block has not been authorized. Hence, their renters will not receive the benefits of the lifeline tariff. In fact, since the rates to other user classes must be increased to recover the lifeline-induced deficiency, these renters may find their monthly rental rates increased as landlords pass on the increase in electricity costs. Unfortunately, the proportion of low-income households occupying rental units is considerably greater than in other types of housing. Lifeline rates thus could be detrimental to many of those in greatest need.

A related problem with lifeline rates involves renters whose electric bills are included in their rental payments. In 1978, Congress passed the Public Utilities Regulatory Policies Act (PURPA). This legislation required state regulatory commissions to hold hearings to evaluate the desirability of lifeline rates. In July of 1981, the Utah Public Service Commission held its PURPA-mandated hearings. The Commission has yet to announce its findings. For several years, however, the Commission has allowed Utah Power and Light (UP&L) to offer a special rate to senior citizens. Under this tariff, the first 400 KWH of electricity were billed at a rate about 30 percent below that charged to other customers. In September 1981, this tariff was ruled by the Utah Supreme Court to be discriminatory and therefore unlawful. The relevance of this decision to the legal status of lifeline rates is still unclear.

**USU ENERGY SURVEY**

A survey conducted by the authors in the spring of 1980 provided information which can be used to evaluate the impact of lifeline proposals in Utah. A mail questionnaire was sent to a random sample of 2,150 UP&L customers. The head of the household was asked to provide information on home conservation practices, the nature of the dwelling unit, and demographic characteristics of the inhabitants. Completed questionnaires were received from over 70 percent of those receiving the mailing. In addition, UP&L provided the number of KWH of electricity used by each respondent during the first three months of 1980. The confidentiality of consumption data for individual respondents was preserved by merging the consumption and questionnaire data without using the name of the respondent. In no case did the researchers know the electricity consumption of any named individual in the sample.

The questionnaire also requested that the respondents indicate total family income for 1979. Most of those completing the questionnaire provided this information. The income and consumption data obtained from the study are the basis for the analysis of lifeline rates which follows.

**EVALUATING LIFELINE RATES**

To evaluate potential impacts of lifeline tariffs in Utah, a hypothetical, but typical, lifeline tariff was used. Specifically, it was assumed that the first 300 KWH per month were priced at 6¢/KWH. Then the sample data were used to calculate the revenue deficiency that would result if the theorized lifeline tariff was applied instead of the present rate structure. The calculated deficiency represents the total amount that must be recovered from other electricity sales. It was assumed that the revenue loss was to be made up solely by increasing the charge to residential customers for electricity they used beyond the lifeline block. Using the sample data, the KWH charge necessary to recoup this deficiency was determined. The calculated price per KWH for monthly consumption in excess of 300 KWH was 8.2¢/KWH.

Next, bills for various levels of consumption were computed under the existing tariff and for the lifeline proposal (Table 1). This calculation revealed the break even point beyond which lifeline bills would be higher than those under the existing rate.

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1. The UP&L tariff used in the analysis prices the first 60 KWH per month at 10.9256¢/KWH, the next 140 at 8.6846¢/KWH, and all additional consumption at 6.3251¢/KWH.

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All consumers using more than the breakeven amount (about 675 KWH/month) would be worse off under lifeline than under the present rate structure.

Finally, the proportion of consumers in different income categories that would benefit from or be hurt by the hypothetical lifeline rate were determined. Of particular interest are the percentage of sampled customers in the lowest income group who had monthly electric consumptions in excess of the breakeven point and the percentage of consumers in the high-income group whose consumption was below the breakeven point (Figure 1).

FINDINGS

Using the breakeven point of 675 KWH per month and Figure 1, the proportion of gainers and losers under lifeline tariffs can be estimated. Approximately 66 percent of the total sample used less than 675 KWH per month. Hence, the hypothesized lifeline rate would provide at least some benefits to about two-thirds of the sampled electricity users.

Focusing on the low-income group, about 90 percent of the responding families with incomes less than or equal to $10,000 per year would be better off under the lifeline proposal. About 10 percent, however, would find themselves paying higher electric bills. Of families with incomes of $30,000 or more, about one-third would benefit from a proposal which is designed to provide assistance to the poor.

CONCLUSIONS

The data suggest that lifeline rates are a relatively inefficient method for redistributing income. Ten percent of low-income families are actually made worse off under lifeline rates and about one-third of high-income families are made better off. The problem is that

| TABLE 1. Hypothetical Lifeline vs. Actual Electricity Bills |
|-------------------------------------------------|-----------------|---------------|
| KWH/Month | Lifeline Bill | Actual Bill | Lifeline Savings |
| 100       | $6.00         | $10.03       | $4.03          |
| 200       | 12.00         | 18.71        | 6.71           |
| 300       | 18.00         | 25.04        | 7.04           |
| 400       | 26.20         | 31.36        | 5.16           |
| 500       | 34.40         | 37.69        | 3.29           |
| 600       | 42.60         | 44.01        | 1.41           |
| 700       | 50.80         | 50.34        | -0.46          |
| 800       | 59.00         | 56.66        | -2.34          |
| 900       | 67.20         | 62.99        | -4.21          |
| 1000      | 75.40         | 69.31        | -6.09          |
| 1100      | 83.60         | 75.64        | -7.96          |
| 1200      | 91.80         | 81.96        | -9.84          |
conventional lifeline proposals are not targeted specifically at those who are in greatest need of help. An improved lifeline concept would establish some kind of need criteria for eligibility. One possibility would be to require customers to certify that their incomes were below a certain level. Another approach would tie eligibility to other forms of welfare assistance. For example, in North Carolina an experimental lifeline rate was limited to families who were receiving supplemental social security benefits. In this way, high-income, low-volume families were not allowed to benefit.

Although basic lifeline proposals can be refined and improved, it is not clear that lifeline electricity rates are the best method of providing assistance to the poor. It is possible to achieve the same results at a lower cost by providing direct subsidies to low-income groups. The advantage of subsidies is two-fold. First, a general subsidy does not distort relative prices. In contrast, lifeline rates may make some uses of electricity more attractive in comparison to other energy forms and, hence, alter patterns of consumer choice. Second, the subsidy decision is traditionally a prerogative of the legislature. It is probably preferable that an elected body make decisions relating to the redistribution of income and that the appointed members of the Public Service Commission interpret their rate-setting function more narrowly.

ABOUT THE AUTHORS

LaRae B. Chatelain, as an Assistant Professor in the Department of Home Economics and Consumer Education, has research interests which include housing and energy.

H. Craig Petersen is an Associate Professor in the Department of Economics. He has been on the faculty at Utah State University since 1973. His recent research activities have focused on government regulation of business and on energy problems.
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