Sanborn Field
Historical Perspective

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Columbia, Missouri
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ACKNOWLEDGMENT

Memorial funds in tribute to Dr. William A. Albrecht have made
possible the publication of this bulletin. The broad influence of Dr.
Albrecht on soil science was enjoyed personally by many but now is
historical to others. During and beyond a tenure of 43 years at the
University of Missouri, he shared with all a vision encompassing the
whole biological dependence of higher organisms upon plants which
grow from the soil. Sanborn Field was one resource which allowed
Albrecht to examine plants in relation to a wide range of soil nutritional
levels.
INTRODUCTION

When J. W. Sanborn established the Rotation Field at the University of Missouri-Columbia in 1888, Missouri still was a young state. Her people, like most throughout the nation, led lives centered around agriculture. Their livelihood depended upon good crop returns and healthy, productive livestock. Industry employed but a fraction of the state’s people. And science was ever widening its scope of questions and answers on the laws of nature.

The Rotation Field, renamed Sanborn Field in 1924 by the University Board of Curators, was developed as a research tool. Sanborn undertook to utilize the field by studying the values of crop rotations, continuous cropping, manure and chemicals for maintaining soil fertility. In his field notebook, Sanborn wrote that the field was

"designed to show the value of various rotations; of constant tillage crops on soil fertility; of chemicals fed according to crop analysis to the necessity of rotation; and of various crops manured to soil fertility, etc.; etc."

From his experiments, he hoped to obtain practical answers to questions farmers were asking about using different cropping systems on the land.

The significance of the field never would have been realized, however, without the foresight of educational pioneers in the mid 1800s.

In the developing years of the state, people were voicing a need for colleges specializing in agriculture. Many saw the significance that such a practical education would have. From this need arose two major events: the Morrill (Land-Grant) Act and the Hatch Act.

The Morrill Act resulted from combined efforts of two people. Jonathan Turner, a school teacher in Illinois, crystallized the ideas of many men into the basic plan for a College of Agriculture. But it took Justin Morrill, a congressman from Vermont, to gain approval of the plan in Congress.
In 1862, Congress passed the Morrill Act which granted 30,000 acres of land to each state for every representative and senator. The states, in return, were required to construct and maintain a college that would emphasize technical training in agriculture and mechanic arts. Provisions of the Act were accepted by the twenty-second Missouri General Assembly in March 1863. But the College of Agriculture and Mechanic Arts was not established until 1870. Obstructing its development was the nation's slow recovery from the Civil War and disagreements over the school's location. Gov. Joseph McClurg authorized the establishment of the College as a division of the University of Missouri in Columbia on Feb. 24, 1870. George C. Swallow, professor of agriculture, was the first appointed dean.

Before long, however, faculty members' enthusiasm waned. Though the College was a reality, it lacked classrooms and laboratories, farm buildings and equipment. More than anything, it lacked appropriate subject matter. Faculty members agreed that research programs were necessary to build a foundation for college courses. The same information could be supplied to farmers to help them improve their productivity.

For 17 years the college faculty struggled to maintain its classes. Then in 1887, the establishment of the Hatch Act by Congress provided funds for agricultural experiment stations. Subject matter for classes was in reach at last.

The Act appropriated $15,000 in federal funds to each state annually. In turn, the state utilized the money to pay part of the costs of establishing and operating the experiment stations. One year later, Sanborn designed and laid-out the Rotation Field.

Sanborn, who replaced Swallow as dean in 1882, was a native of New Hampshire and a graduate of the New Hampshire College of Agriculture. He arrived in Missouri in the face of controversy that had flared over the location of the College. In him, the Board of Curators found a man of intellectual prowess as well as one with practical experience. A man ideally trained to represent the agricultural interests of the College and state, Sanborn was both a teacher and scientific investigator. He seemed to be the calming, unifying effect the school needed. But too much was expected of Sanborn, and his administration was marked by storms, bitterness and turmoil. After seven years, in 1889, Sanborn received an ultimatum from the Board of Curators: resign or be dismissed. He resigned.
INITIAL APPEARANCE AND SOIL CHARACTERIZATION OF SANBORN FIELD

By 1889, the Rotation Field had completed its first year, and Sanborn collected data from the 39 plots shortly before he resigned. When drawing the original chart of the field, Sanborn had planned 46 plots. For reasons unknown, only 39 were included in the experimental plan in those early years (Figure 1). Some people have speculated that the remaining seven were not included because of poor drainage conditions in that part of the field or because Sanborn anticipated the future need for additional rotations and soil treatments.

At the time of its origin, Sanborn Field became the third experimental field of its type to be established in the United States. The Morrow Plots, established on the University of Illinois campus in 1876, and the Jordan Plots, begun in 1881 at Pennsylvania State College, preceded Sanborn Field. Of these two, the Morrow Plots remain but on a reduced scale. The Jordan Plots were discontinued in 1958.

M. F. Miller described the Rotation Field as it appeared when Sanborn started his research:

"The land on which Sanborn Field was laid out was originally a tract of pasture with scattered elm trees and with buck brush interspersed. When Sanborn wished more crop land near the farmstead, he had this land cleared and put into cultivation. The records aren't clear, but no doubt it was planted to corn for one or more years after which he laid out the more or less permanent plots with different cropping systems and soil treatments of the original plots."

Miller and R. R. Hudelson in 1920 classified the soil on Sanborn Field as a Putnam silt loam recognizing that it differed slightly from the typical areas of Putnam. They described it as a dark, brownish-gray soil with a silt loam texture 9 to 12 inches deep. This top layer graded into gray silt subsurface soil 4 to 6 inches thick. The subsoil was described as a brown heavy clay loam rather imperious in character. Soil fertility appeared to be uniform throughout the field. Surface drainage was described as good, but plots 1 through 7, 23 through 26 and 29 through 33 were subject to slight erosion.

Refinement of recent times suggests that soil on Sanborn Field is more correctly classified as a Mexico silt loam (Udollic Ochraqualf, fine, montmorillonitic mesic).

Each plot was designed as one-tenth of an acre separated by 3-foot side borders. In 1904, plot 8 was eliminated when Bouchelle Avenue, north of the field was constructed. The remaining 38 plots were then
**FIGURE 1.**

<table>
<thead>
<tr>
<th>Plot</th>
<th>Cropping System</th>
<th>Annual Treatment per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wheat-tempery-tempery-corn-oats-clover</td>
<td>7 tons barnyard manure</td>
</tr>
<tr>
<td>2</td>
<td>Continuous Wheat</td>
<td>Chemicals - 40 bushels</td>
</tr>
<tr>
<td>3</td>
<td>Wheat-tempery-tempery-corn-oats-clover</td>
<td>Chemicals for full crop</td>
</tr>
<tr>
<td>4</td>
<td>Wheat-tempery-tempery-corn-oats-clover</td>
<td>7% chemicals for full crop</td>
</tr>
<tr>
<td>5</td>
<td>Continuous Wheat</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>6</td>
<td>Continuous Clover</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>7</td>
<td>Continuous Clover</td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>Wheat-tempery-tempery-corn-oats-clover</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>9</td>
<td>Continuous Wheat</td>
<td>None</td>
</tr>
<tr>
<td>10</td>
<td>Continuous Wheat</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>11</td>
<td>Wheat-tempery-tempery-corn-oats-clover</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>12</td>
<td>Wheat-tempery-tempery-corn-oats-clover</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>13</td>
<td>Wheat-tempery-tempery-corn-oats-clover</td>
<td>None</td>
</tr>
<tr>
<td>14</td>
<td>Wheat-tempery-tempery-corn-oats-clover</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>15</td>
<td>Continuous Oats</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>16</td>
<td>Continuous Oats</td>
<td>None</td>
</tr>
<tr>
<td>17</td>
<td>Continuous Corn</td>
<td>None</td>
</tr>
<tr>
<td>18</td>
<td>Continuous Corn</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>19</td>
<td>Wheat-tempery-tempery-corn-oats-clover</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>20</td>
<td>Wheat-tempery-tempery-corn-oats-clover</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>21</td>
<td>Continuous Wheat</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>22</td>
<td>Continuous Timothy</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>23</td>
<td>Continuous Timothy</td>
<td>None</td>
</tr>
<tr>
<td>24</td>
<td>Continuous Wheat</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>25</td>
<td>Corn-Clover-Wheat</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>26</td>
<td>Corn-Clover-Wheat</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>27</td>
<td>Corn-Clover-Wheat</td>
<td>None</td>
</tr>
<tr>
<td>28</td>
<td>Corn-Clover-Wheat</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>29</td>
<td>Continuous Wheat</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>30</td>
<td>Continuous Wheat</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>31</td>
<td>Wheat-Clover</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>32</td>
<td>Wheat-Clover</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>Plot</td>
<td>Cropping System</td>
<td>Fertilizer Treatment per Acre</td>
</tr>
<tr>
<td>------</td>
<td>-----------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>33</td>
<td>Wheat - Clover</td>
<td>None</td>
</tr>
<tr>
<td>34</td>
<td>Corn - Oats - Clover - Wheat</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>35</td>
<td>Corn - Oats - Clover - Wheat</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>36</td>
<td>Continuous Wheat</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>37</td>
<td>Corn - Oats - Clover - Wheat</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>38</td>
<td>Corn - Oats - Clover - Wheat</td>
<td>6 tons barnyard manure</td>
</tr>
<tr>
<td>39</td>
<td>Corn - Oats - Clover - Wheat</td>
<td>None</td>
</tr>
</tbody>
</table>

**Rotation Map:**

- 1 to 17
- 18 to 39
reduced to one-thirteenth of an acre while retaining the 3-foot wide borders between plots and decreasing the length of the plots to 101.5 feet. The width of the borders was changed from 3 feet to 5 feet in 1914 which reduced the plots to their present size, one-fourteenth of an acre.

In 1913, under Miller’s direction, a small area west of plot 28 was tile-drained. In 1915, this area was bulk-cropped with soybeans and later included in plot experiments that became a part of the Sanborn Field plan incorporating additional plots which are now number 40-45.

INFLUENCES ON SANBORN FIELD BY H. J. WATERS AND M. F. MILLER

Following Sanborn’s resignation, Edward Porter was appointed dean, but his time in office followed the pattern Sanborn had cut. He left the College in 1895 and was replaced by Henry J. Waters.

Waters, an 1886 graduate of the Missouri College of Agriculture, was born on a Missouri farm and had good insight into the state’s people. He had to bring order out of chaos, and at the same time develop the College in the face of skepticism. Fortunately, he succeeded. In the process, however, Sanborn Field was nearly discontinued.

By 1904, the plots were managed by the farm foreman under the general direction of Waters. Each plot had to be handled like a separate field because the array of crops and cropping systems made the operation complex and difficult. Waters considered the difficulties of this management and decided to discontinue the field.

But a young professor from Ohio convinced the dean that the plots were valuable and agreed to assume responsibility for the field. That professor was Merritt Finley Miller.

Miller came to the University as the first professor and chairman of the Department of Agronomy before the parent department was divided into two: Farm Crops and Soils. After the division in 1914, Miller was associated with the Soils Department and Sanborn Field continued under his leadership. He advanced through departmental ranks until, at the time of his retirement in 1945, he was dean of the College of Agriculture.

From interpreting soil analyses made after the initial 25 years of experiments on Sanborn Field, Miller determined that the most important factor in soil exhaustion was the loss of nitrogen and organic matter. His early studies suggested that crop rotations without manure were as effective in maintaining average yields of corn and wheat as
were large amounts of manure on crops grown continuously."

In 1921, Miller and R. R. Hudelson compiled data on the plot treatments, yields, soil management and maintenance of Sanborn Field. This information was recorded in the Agricultural Experiment Station Research Bulletin 182, *Thirty Years of Field Experiment with Crop Rotation, Manure and Fertilizers*.

Miller continued in the leadership role for Sanborn Field until the latter part of the 1930s. In 1937, George E. Smith was appointed assistant professor in the department and at that time Miller delegated management responsibility for the field to him. Smith was author of the second major published summary of results from Sanborn Field. This appeared in 1942 as Agricultural Experiment Station Bulletin 458, *Sanborn Field: Fifty Years of Field Experiments with Crop Rotations, Manure and Fertilizers*.

Smith’s leadership was particularly decisive in 1940 when significant changes were made in the management of a number of the plots. Management changes had been subject to seminar consideration by the Soils faculty. However, when Smith presented recommendations, faculty agreement could not be reached. Miller subsequently advised Smith to proceed with changes based on his own judgement. Additional changes in Sanborn Field under Smith’s leadership came in 1950. The detail and rationale behind changes made at these two times will be described later in this bulletin.

**OBJECTIVES OF SANBORN FIELD**

Since World War II, justification of the plots has not been based on their convenience to the campus nor their significance as a modern experimental field with the purpose of testing and developing new innovations in soil management and cropping practices. Justification has been based on the historical dimensions of the field relative to developed and developing soil conditions under the different systems of management over extended periods of time.

Specific objectives for Sanborn Field were written in 1979 by William Upchurch, who had leadership responsibility for the field during the period 1977 through 1984. Since 1888, directors of the field have kept the general focus of guidelines Sanborn established even though formal objectives had not been written. During the history of the field, research results and new technologies have dictated that changes be made in management systems of some plots. Persons responsible for the field have initiated these changes after considering
the historical dimensions of the plots. As a result, management systems have been maintained which have been judged to be of historical, practical or scientific value. Upchurch’s goal in formalizing objectives for the field was to guarantee the integrity of the plots by insuring the continuity of cropping systems and soil treatments. There are four basic objectives for the field:

1. To maintain Sanborn Field as a research field laboratory for determining long-term effects of crop and soil management upon chemical, physical and biological properties of soil.

2. To display the effects on soil productivity, of historical and modern methods of soil management applied to various cropping systems. The effects will be documented by crop yield and composition relative to crop performance in relation to growing conditions, and by measures of chemical, physical and biological soil conditions.

3. To maintain a historical field for collecting soil and plant samples systematically to relate to soil and environmental conditions.

4. To maintain the vitality of management systems by initiating at appropriate times, practices that have long-range implications relative to soil changes.

SOIL TREATMENTS AND CROPPING PRACTICES

Emphasis in the initial experiment was given to practical approaches in crop production that could be adopted readily by the farmers of the state without the need of off-farm inputs which were not available to them. All farms had an array of horses, mules, cattle, hogs and chickens that required feed and were sources of manure.

Nine cropping practices, using five crops (corn, oats, wheat, red clover and timothy) and four soil treatments, were originally used in the experiment (Table 1)\(^9\). The practices were continuous cropping systems of each of the five crops and rotational cropping sequences of two, three, four and six years.

Soil treatments consisting of no treatment and six tons of barnyard manure per acre annually (plot 1 received 7 tons of manure) were used with each of the nine cropping systems\(^9\). The continuation of these systems and treatments was to enable the determination of the comparative effects of continuous versus rotational cropping practices, the value of manure in maintaining soil productivity and the merits of different lengths of rotations. Red clover was included in all of the
TABLE 1.
Initial Cropping Practices and Soil Treatments on Sanborn Field (Rotation Field) 1888.

<table>
<thead>
<tr>
<th>CROPPING PRACTICE</th>
<th>PLOT NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Corn</td>
<td></td>
</tr>
<tr>
<td>untreated</td>
<td>17</td>
</tr>
<tr>
<td>manured</td>
<td>18</td>
</tr>
<tr>
<td>Continuous Oats</td>
<td></td>
</tr>
<tr>
<td>untreated</td>
<td>16</td>
</tr>
<tr>
<td>manured</td>
<td>15</td>
</tr>
<tr>
<td>Continuous Wheat</td>
<td></td>
</tr>
<tr>
<td>untreated</td>
<td>9, 29</td>
</tr>
<tr>
<td>manured</td>
<td>5, 10, 21, 24, 30, 36</td>
</tr>
<tr>
<td>fertilizer</td>
<td>2</td>
</tr>
<tr>
<td>Continuous Clover</td>
<td></td>
</tr>
<tr>
<td>untreated</td>
<td>7</td>
</tr>
<tr>
<td>manured</td>
<td>6</td>
</tr>
<tr>
<td>Continuous Timothy</td>
<td></td>
</tr>
<tr>
<td>untreated</td>
<td>23</td>
</tr>
<tr>
<td>manured</td>
<td>22</td>
</tr>
<tr>
<td>Two-Year Rotation: Wheat, Clover</td>
<td></td>
</tr>
<tr>
<td>untreated</td>
<td>33</td>
</tr>
<tr>
<td>manured</td>
<td>31, 32</td>
</tr>
<tr>
<td>Three-Year Rotation: Corn, Wheat, Clover</td>
<td></td>
</tr>
<tr>
<td>untreated</td>
<td>27</td>
</tr>
<tr>
<td>manured</td>
<td>25, 26, 28</td>
</tr>
<tr>
<td>Four-Year Rotation: Corn, Oats, Wheat, Clover</td>
<td></td>
</tr>
<tr>
<td>untreated</td>
<td>39</td>
</tr>
<tr>
<td>manured</td>
<td>34, 35, 37, 38</td>
</tr>
<tr>
<td>Six-Year Rotation: Corn, Oats, Wheat, Clover, Timothy, Timothy</td>
<td></td>
</tr>
<tr>
<td>untreated</td>
<td>13</td>
</tr>
<tr>
<td>manured</td>
<td>1, 11, 12, 14, 19, 20</td>
</tr>
<tr>
<td>fertilizer</td>
<td>3</td>
</tr>
<tr>
<td>one-half application each of manure &amp; fertilizer</td>
<td>4</td>
</tr>
</tbody>
</table>
rotations as a hay crop, but it was also a means of adding symbiotically fixed nitrogen to the soil.

From two to six replications of the manured plots were made in each rotation enabling each crop to be grown annually through 1913. Untreated plots involving rotations and fertilizer plots were not duplicated nor were continuously cropped plots except for continuous wheat which had six replications of the manure treatment at initiation of the field. In 1914, duplicate plots of manure treated rotation or continuous wheat were used to initiate additional soil treatment variables.

Only three original plots on Sanborn Field were planned to receive chemicals. Plots 2 and 3 received nitrogen, phosphorus and potassium for a full crop (i.e. high yield). Plot 4 received three tons of manure and half the amount of chemicals applied to plot 3.

As crops were harvested from Sanborn Field, records of straw and grain yields were made by field managers. In the rotation experiments, timothy was cut once and clover twice or more per season. Any late fall growth of clover was left on the plot as a source of nitrogen.

The quality of manure applied to the plots varied from year to year depending upon from where it was secured. Prior to World War II, all fertilizers were home-mixed using sodium nitrate, acid phosphate and potassium chloride. In the early 1950’s, commercial fertilizers of varied formulations became available and their use was incorporated into management changes on those plots that were modified to conform to then current practices.

A PROGRESSION OF IDEAS IN SOIL MANAGEMENT

During the history of Sanborn Field, a number of revisions were made in the experimental plan on some plots. The changes were prompted by a lack of practicality of some systems of management, by a desire to include new crops and cropping practices, and to add more variation of fertilization in the experiment. Evaluations of management of the field that led to revisions were made in 1914, 1928, 1940 and 1950. A brief tabulation of the original management of each plot and the changes made at the four mentioned dates is presented in Table 2. A few changes were made at other times. Historically the changes in Sanborn Field management paralleled the development of understanding of the nature and properties of soils and particularly its translation into practical approaches of liming and fertilization. Advances in technology that made agricultural limestone and fertilizer materials
TABLE 2.  
An Outline of the Cropping Systems and Treatments on Sanborn Field from 1888 to 1985  
Organized According to Original Cropping System.

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>System</th>
<th>1888 Treatment</th>
<th>1914 System</th>
<th>1914 Treatment</th>
<th>1928 System</th>
<th>1928 Treatment</th>
<th>1940 System</th>
<th>1940 Treatment</th>
<th>1950 System</th>
<th>1950 Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Wheat</td>
<td>Chemicals</td>
<td>Wheat</td>
<td>No change</td>
<td>Wheat</td>
<td>1/3 N Fall</td>
<td>Wheat</td>
<td>No change</td>
<td>Wheat</td>
<td>Full treat</td>
</tr>
<tr>
<td>5</td>
<td>Wheat</td>
<td>6t manure</td>
<td>Wheat</td>
<td>3t manure</td>
<td>Wheat</td>
<td>No change</td>
<td>Wheat</td>
<td>No change</td>
<td>Wheat</td>
<td>No change</td>
</tr>
<tr>
<td>9</td>
<td>Wheat</td>
<td>None</td>
<td>Wheat</td>
<td>No change</td>
<td>Wheat</td>
<td>No change</td>
<td>Wheat</td>
<td>No change</td>
<td>Wheat</td>
<td>No change</td>
</tr>
<tr>
<td>10</td>
<td>Wheat</td>
<td>6t manure</td>
<td>Wheat</td>
<td>No change</td>
<td>Wheat</td>
<td>No change</td>
<td>Wheat</td>
<td>No change</td>
<td>Wheat</td>
<td>No change</td>
</tr>
<tr>
<td>21</td>
<td>Wheat</td>
<td>6t manure</td>
<td>Wheat</td>
<td>200# acid phosphate</td>
<td>Wheat</td>
<td>No change</td>
<td>2-yr R</td>
<td>Lime; C&amp;W 8-24-8</td>
<td>Alf-brome</td>
<td>Full treat</td>
</tr>
<tr>
<td>24</td>
<td>Wheat</td>
<td>6t manure</td>
<td>Wheat</td>
<td>None</td>
<td>Wheat</td>
<td>No change</td>
<td>2-yr R</td>
<td>Lime pH &lt;6 0-40-0</td>
<td>Alfalfa</td>
<td>Full treat</td>
</tr>
<tr>
<td>29</td>
<td>Wheat</td>
<td>None</td>
<td>Wheat</td>
<td>50# (NH₄)₂SO₄</td>
<td>Wheat</td>
<td>100# (NH₄)₂SO₄</td>
<td>W-lesp</td>
<td>0-38-0</td>
<td>3-yr R</td>
<td>Corn 72-24-24</td>
</tr>
<tr>
<td>30</td>
<td>Wheat</td>
<td>6t manure</td>
<td>Wheat</td>
<td>60# NaNO₃</td>
<td>Wheat</td>
<td>120# NaNO₃</td>
<td>W-lesp</td>
<td>0-38-0</td>
<td>Timothy (1952+)</td>
<td>Full treat</td>
</tr>
<tr>
<td>36</td>
<td>Wheat</td>
<td>6t manure</td>
<td>Wheat</td>
<td>150# 3-10-4</td>
<td>Wheat</td>
<td>200# 4-12-4</td>
<td>4-yr R</td>
<td>Lime; C&amp;W 8-24-8</td>
<td>Full treat</td>
<td>dolomitic lime</td>
</tr>
<tr>
<td>15</td>
<td>Oats</td>
<td>6t manure</td>
<td>Oats</td>
<td>No change</td>
<td>No change</td>
<td>W-lesp</td>
<td>0-38-0</td>
<td>3-yr R</td>
<td>Samp as plot 29</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Oats</td>
<td>None</td>
<td>Oats</td>
<td>No change</td>
<td>Oats</td>
<td>No change</td>
<td>W-lesp</td>
<td>0-38-0</td>
<td>3-yr R</td>
<td>Same as plot 29</td>
</tr>
<tr>
<td>17</td>
<td>Corn</td>
<td>None</td>
<td>Corn</td>
<td>No change</td>
<td>Corn</td>
<td>No change</td>
<td>Corn</td>
<td>No change</td>
<td>Corn</td>
<td>No change</td>
</tr>
<tr>
<td>18</td>
<td>Corn</td>
<td>6t manure</td>
<td>Corn</td>
<td>No change</td>
<td>Corn</td>
<td>No change</td>
<td>Corn</td>
<td>No change</td>
<td>Corn</td>
<td>No change</td>
</tr>
</tbody>
</table>

(Continued)
<table>
<thead>
<tr>
<th>Plot</th>
<th>Clover/Manure</th>
<th>Cowpeas/Manure</th>
<th>Crop</th>
<th>Rotation</th>
<th>Manure/Phos/Lime</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>R Clover</td>
<td>6t manure</td>
<td>3t manure</td>
<td>4-yr R</td>
<td>Corn 34-36-18</td>
<td>Special study of P, K &amp; lime on grasses.</td>
</tr>
<tr>
<td>7</td>
<td>R Clover</td>
<td>None</td>
<td>Cowpeas</td>
<td>4-yr R</td>
<td>Same as plot 6</td>
<td>Corn Full treat</td>
</tr>
<tr>
<td>22</td>
<td>Timothy</td>
<td>6t manure</td>
<td>Timothy</td>
<td>4-yr R</td>
<td>No change</td>
<td>Timothy No change</td>
</tr>
<tr>
<td>23</td>
<td>Timothy</td>
<td>None</td>
<td>Timothy</td>
<td>4-yr R</td>
<td>No change</td>
<td>Timothy No change</td>
</tr>
<tr>
<td>31</td>
<td>2-yr R W,ScCl</td>
<td>6t manure</td>
<td>2-yr R No change</td>
<td>3-yr R</td>
<td>Lime, 0-50-50</td>
<td>3-yr R No change</td>
</tr>
<tr>
<td>32</td>
<td>2-yr R</td>
<td>6t manure wheat only</td>
<td>3-yr R</td>
<td>Lime, 0-50-0</td>
<td>3-yr R No change</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>2-yr R</td>
<td>None</td>
<td>2-yr R No change</td>
<td>3-yr R</td>
<td>Lime 0-0-50</td>
<td>3-yr R No change</td>
</tr>
<tr>
<td>25</td>
<td>3-yr R CWCi</td>
<td>6t manure</td>
<td>3-yr R No change</td>
<td>3-yr R</td>
<td>Lime, 0-38-0</td>
<td>3-yr R No change</td>
</tr>
<tr>
<td>26</td>
<td>3-yr R</td>
<td>6t manure</td>
<td>3-yr R</td>
<td>Lime, 0-38-0</td>
<td>3-yr R No change</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>3-yr R</td>
<td>None</td>
<td>3-yr R No change</td>
<td>3-yr R</td>
<td>Lime C&amp;W 8-24-8</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>3-yr R</td>
<td>6t manure</td>
<td>3-yr R None</td>
<td>3-yr R</td>
<td>Lime C&amp;W 8-24-8</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>4-yr R CWCi</td>
<td>6t manure</td>
<td>4-yr R No change</td>
<td>4-yr R</td>
<td>No change</td>
<td>4-yr R No change</td>
</tr>
<tr>
<td>35</td>
<td>4-yr R</td>
<td>6t manure</td>
<td>4-yr R None</td>
<td>4-yr R</td>
<td>No change</td>
<td>4-yr R No change</td>
</tr>
<tr>
<td>37</td>
<td>4-yr R</td>
<td>6t manure</td>
<td>4-yr R 3-10-4</td>
<td>4-yr R</td>
<td>C&amp;W 8-24-8</td>
<td>4-yr R No change</td>
</tr>
<tr>
<td>38</td>
<td>4-yr R</td>
<td>6t manure</td>
<td>4-yr R</td>
<td>Lime, fert. as plot 37</td>
<td>4-yr R No change</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>4-yr R</td>
<td>None</td>
<td>4-yr R No change</td>
<td>4-yr R</td>
<td>No change</td>
<td>4-yr R No change</td>
</tr>
<tr>
<td>1</td>
<td>6-yr R CONCIT</td>
<td>7t manure</td>
<td>6 t manure</td>
<td>6-yr R</td>
<td>No change</td>
<td>6-yr R No change</td>
</tr>
</tbody>
</table>

(Continued)
<table>
<thead>
<tr>
<th>Plot</th>
<th>Years</th>
<th>Manure</th>
<th>Chemicals</th>
<th>Treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>6-yr</td>
<td>R</td>
<td>No change</td>
<td>Same except 1/3N f, 2/3N sp</td>
</tr>
<tr>
<td>4</td>
<td>6-yr</td>
<td>R</td>
<td>1/2 Chemicals</td>
<td>Same except manure reduced 1/3N f &amp; 2/3 sp</td>
</tr>
<tr>
<td>5</td>
<td>6-yr</td>
<td>R</td>
<td>3t manure</td>
<td>Lime, W O-30-15, N 0-25-12, on C</td>
</tr>
<tr>
<td>6</td>
<td>6-yr</td>
<td>R</td>
<td>Lost in 1903 with the construction of Bouchelle Avenue.</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>6-yr</td>
<td>R</td>
<td>No change</td>
<td>No change ex. omit manure on 2nd timothy</td>
</tr>
<tr>
<td>8</td>
<td>6-yr</td>
<td>R</td>
<td>Manure as plot 4</td>
<td>Manure as plot 11 C&amp;W 20% super phos</td>
</tr>
<tr>
<td>9</td>
<td>6-yr</td>
<td>R</td>
<td>Manure as plot 4 bone meal</td>
<td>Manure as plot 11 20% super phosphate Red clover Full treat</td>
</tr>
<tr>
<td>10</td>
<td>6-yr</td>
<td>R</td>
<td>None</td>
<td>No change</td>
</tr>
<tr>
<td>11</td>
<td>6-yr</td>
<td>R</td>
<td>Manure as plot 4</td>
<td>No change</td>
</tr>
<tr>
<td>12</td>
<td>6-yr</td>
<td>R</td>
<td>Manure as plot 4 20% super phosphate</td>
<td>No change</td>
</tr>
<tr>
<td>13</td>
<td>6-yr</td>
<td>R</td>
<td>Manure as plot 4</td>
<td>No change</td>
</tr>
<tr>
<td>14</td>
<td>6-yr</td>
<td>R</td>
<td>Manure as plot 4</td>
<td>No change</td>
</tr>
<tr>
<td>15</td>
<td>6-yr</td>
<td>R</td>
<td>Manure as plot 4</td>
<td>No change</td>
</tr>
<tr>
<td>16</td>
<td>6-yr</td>
<td>R</td>
<td>Manure as plot 4</td>
<td>No change</td>
</tr>
<tr>
<td>17</td>
<td>6-yr</td>
<td>R</td>
<td>Manure as plot 4</td>
<td>No change</td>
</tr>
<tr>
<td>18</td>
<td>6-yr</td>
<td>R</td>
<td>Manure as plot 4</td>
<td>No change</td>
</tr>
<tr>
<td>19</td>
<td>6-yr</td>
<td>R</td>
<td>Manure as plot 4</td>
<td>No change</td>
</tr>
<tr>
<td>20</td>
<td>6-yr</td>
<td>R</td>
<td>Manure as plot 4</td>
<td>No change</td>
</tr>
<tr>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Plots No.</td>
<td>System</td>
<td>Treatment</td>
<td>System</td>
<td>Treatment</td>
</tr>
<tr>
<td>21 plots</td>
<td>3-yr R</td>
<td>C,W ,Rcl</td>
<td>2-yr R</td>
<td>C,W ,SwCl</td>
</tr>
<tr>
<td>11 x 101' control plots alternating with sources</td>
<td>A</td>
<td>No treat</td>
<td>W</td>
<td>no treat</td>
</tr>
<tr>
<td>of phosphate: rock phos, acid phos, bone meal, basic slag, calcine phos</td>
<td>B</td>
<td>C 8 t manure</td>
<td>W</td>
<td>No fert.</td>
</tr>
<tr>
<td>1923</td>
<td>1-yr R</td>
<td>C,W,SwCl</td>
<td>2 yr R</td>
<td>C,W,SwCl</td>
</tr>
<tr>
<td>1930</td>
<td>2-yr R</td>
<td>C,W,SwCl</td>
<td>2-yr R</td>
<td>C,W,SwCl</td>
</tr>
<tr>
<td>1940</td>
<td>2-yr R</td>
<td>C,W,SwCl</td>
<td>2-yr R</td>
<td>C,W,SwCl</td>
</tr>
<tr>
<td>1950</td>
<td>2-yr R</td>
<td>C,W,SwCl</td>
<td>2-yr R</td>
<td>C,W,SwCl</td>
</tr>
<tr>
<td>1967</td>
<td>2-yr R</td>
<td>C,W,SwCl</td>
<td>2-yr R</td>
<td>C,W,SwCl</td>
</tr>
<tr>
<td>1973</td>
<td>2-yr R</td>
<td>C,W,SwCl</td>
<td>2-yr R</td>
<td>C,W,SwCl</td>
</tr>
</tbody>
</table>

* 3-yr rotation 1973 - Corn, soybean, wheat-soybeans (corn and soybeans planted in standing wheat, wheat mowed for mulch, double crop bean planted in wheat stubble.
available at a favorable benefit/cost relation were equally important in effecting change.

The original experimental plan was conducted for 25 years without modification except that one cropping system, continuous red clover, both with and without manure began to fail after 10 to 15 years due to soil depletion. Continuous cowpea was used as a replacement crop beginning in 1909. After the completion of the first 25 years, soils of all plots were sampled to a depth of four feet. The soil samples were analyzed by the Station Chemist. Similar samplings and analyses have been made every subsequent 25 years. Results of these analyses and accumulated records on crop performance are kept in log books in the Departmental Files and they provided a basis for alterations in some management systems during the course of the field's history.

**Soil Treatment Changes in 1914**

The revisions made in 1914 dealt only with soil treatment. The rationale had to do with impracticality of the manure application rate, the indicated need for liming, the desire to evaluate different sources of phosphate and chemical nitrogen, and to explore a complete fertilizer that included N, P, K at a grade of 3-10-4 which was applied in quantities of 150, 200, and 300 pounds per acre.

Originally six tons of manure per acre annually was considered to be the quantity needed for production of a full crop. By 1914, that quantity was thought to be impractical relative to the amount of manure available on farms for fertilization of cropland. The manure on some plots was discontinued at that time, and cropping was continued to evaluate the residual effect of 25 years of manuring. On other plots, the manure treatment was reduced to three tons annually and in the case of rotations this three ton rate was the average treatment over the rotation cycle with a liberal rate preceding grain crops known to have a high nitrogen requirement.

The acid nature of the soil dictated the necessity of introducing liming into the experiment. Only one plot was limed beginning in 1914. The plot chosen for this new treatment was one in a four year rotation that had previously received an annual treatment of manure. This plot is thought to be the first soil to be limed in the state.

A need for extensive evaluation of phosphorus fertilization was indicated by the relative low inherent level of available phosphorus of the soil on Sanborn Field. This need was augmented by the observation that wheat headed and matured earlier on plots that received phosphate
as part of the soil treatment. New phosphorus treatments introduced in 1914 included rock phosphate in the 6 year rotation before corn and bone meal and acid phosphate each before corn and wheat. Rates of application were determined by the cost of the materials rather than quantity of available nutrient.

Additional new approaches to fertilization of wheat included annual treatments of ammonium sulfate, sodium nitrate, acid phosphate and a complete fertilizer with a grade of 3-10-4. Complete fertilizer also was employed with the four year rotation as a treatment for corn and for wheat combined both with and without lime.

The reserve area of the field (plots 40-45) was brought under experimentation in 1916 after improvement in soil drainage of the area and bulk cropping for one year with soybeans. A three year rotation of corn, wheat, red clover was used to evaluate various phosphorus fertilizers but the study was terminated in 1923 due to lack of any significant response to any of the treatments. The plots then were used to see if yields could be increased materially by use of a green manure crop. Sweet clover was the green manure in a two year rotation with wheat and corn. The clover seeded in wheat was harvested for hay in September and the subsequent spring growth plowed under for corn. When excessive stalk lodging occurred for corn and wheat it was found to be associated with a marginal level of potassium. This was regarded as the first observation of potassium limitation and need on the field.

**Cropping Practices and Soil Treatment Revisions of 1928**

At the completion of the 40th year (1928), revisions were made in the field plan to address matters raised by experimental results that had been accumulated, primarily since 1914. A beneficial effect of liming had been demonstrated, need for phosphate fertilizer established, adequacy of soil potassium with some management systems was found questionable, and an adverse effect of soluble fertilizer materials at seeding had been observed. Two cropping practices, continuous cowpeas and the two year rotation of wheat and red clover, were judged to be unsatisfactory practices relative to crop performances with the soil treatments used. Interest in soybeans suggested that it should be included among crops of the field. Soybeans had only been grown on the field in 1915 as a bulk crop of the unplotted area and during the 1920's, planted occasionally in some rotations when a failure in the stand of clover following wheat occurred.

Beginning in 1928, the two year rotation of wheat and red clover
was changed to a three year rotation of corn, soybeans, wheat-sweet clover. The soybeans were harvested as a forage crop and the sweet clover plowed under for green manure. Modifications in soil treatment involved expanded use of agricultural limestone and commercial fertilizer. The quantities of fertilizers continued to be modest, with the exception of plots 2 and 3 which were Sanborn's original fertilized plots based on crop composition and yield goals. The implemented changes explored four aspects of fertilizer usage; quantities, balance of nutrients, placement, and time of application. There was an increased emphasis on liming including variables such as lime plus phosphorus, lime plus potassium, lime plus phosphorus and potassium, and lime plus a complete fertilizer. The grade of complete fertilizer was changed from 3-10-4 to 4-12-4. The nitrogen treatment of wheat on some plots was doubled to 20 pounds per acre. All nitrogen treatments for wheat were changed to split applications with $\frac{1}{3}$ to $\frac{1}{2}$ at seeding and the remainder in early spring as a topdressing.

**Major Changes - 1940**

The year 1940 was pivotal in the history of Sanborn Field. The field had completed its 50th year (1938) and the results of a half century of experiments with crop rotation, manure and fertilizers had been evaluated and summarized. Developments and progress had been made not only in the experimental work on Sanborn Field but in other experimental fields of the college and significant advancement in soil science had occurred. During the latter part of the twenties and the decade of the thirties, basic research efforts in the fields of geology and soil science established the chemical structure and composition of clay minerals. This led to the unraveling of the mystery of cation exchange phenomenon in soils and the development of the knowledge of how the proportion of cations associated with the exchange complex controlled their availability to plants. New concepts in soil management on the farm had occurred as well. Mechanization had replaced draft animals reducing the amount of manure available and the importance of crops grown formerly for feeding draft animals. Commercial fertilizer had come into common use in crop production.

In consideration of the developments that had occurred throughout the years including the expansion of the campus, the old experimental field appeared to some to be of decreased value. The faculty of the Department of Soils considered the future of the field at that time and attention was directed to recommendations for change offered by Dr.
George E. Smith who had been given responsibility for management of the field beginning three years earlier. It was agreed that Sanborn Field provided laboratory material, yield records, a collection of soil samples and demonstrational use that made it of inestimable value. It was conceded however, that plots with antiquated cropping systems and impractical soil treatments resulted in crop yield data of little value relative to recommended practices of that day. Such plots, however, provided an excellent resource of material for studying soil conditions and change.

A general consideration used in revising the field plan in 1940 was to continue systems of management that could possibly contribute information either of practical or scientific value. Elimination of excessive duplication in systems retained purely for technical value was balanced with development of more comparable series of treatments. Soil conditions which developed under any antiquated system of management were recognized as having value in reference to new concepts and approaches in cropping and fertilization practices.

The past continuous cropping ceased on five of the original nine plots of wheat and the two plots of oats. Lespedeza was added as a new crop on the field in an annual system of wheat-lespedeza and as a catch legume when red clover failed in any rotation as was often the case for soil not treated with limestone. Lespedeza had become widely accepted over the state for soils of low fertility that had failed to support good stands of red clover. The new work examined the accumulated diversity in fertility level combined with soil treatments of phosphate fertilizer and limestone. Plots 15, 16, 29 and 30, with widely different histories of management and soil conditions were used in this evaluation.

Plots 15 and 16 were the former continuous oats plots (with and without manure) and were terminated because spring oats was considered to be a poor indicator of soil fertility. High temperatures occurring during the fruiting period of oats was thought to be the most significant factor in controlling yield. Plots 29 and 30 had been cropped with continuous wheat for fifty years but reflected primarily the effects on the soil of 26 years of fertilization with ammonium sulfate and sodium nitrate respectively. The yields of wheat were very low due to lodging and poor crop performance from the long and continuous use of only nitrogen. Relative to the treatments, the yields were in agreement with those obtained at Rothamsted and on the Jordan Plots in Pennsylvania. Soil samples had been collected and were available for study in the laboratory and continuation of the plots under the then current management was judged impractical. An interpretation of the fertility
level of four plots that were shifted to an annual cropping system of wheat-lespedeza is given in Table 3. Plot 15 had a relatively high fertility level while plot 29 was one of the most infertile plots in the field.

TABLE 3.
Treatment History and Fertility Level on Four Plots Selected in 1940 to Evaluate Lespedeza on Soils of Differing Fertility.

<table>
<thead>
<tr>
<th>PLOT</th>
<th>1888</th>
<th>CROPPING &amp; TREATMENT</th>
<th>1914</th>
<th>1940</th>
<th>FERTILITY N CONTENT LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>6 tons manure</td>
<td>No change</td>
<td>E+ time + 100# 0-38-0</td>
<td>W+ 100# 0-38-0</td>
<td>Wheat-lespedeza</td>
</tr>
<tr>
<td>16</td>
<td>None</td>
<td>No change</td>
<td>Same as plot 15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>6 tons manure wheat</td>
<td>Ammonium sulfate</td>
<td>Same as plot 15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>None wheat</td>
<td>Sodium nitrate</td>
<td>Same as plot 15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Additional revisions in soil treatment in 1940 included discontinuance of some manure treatments with six and three rotations and discontinuance of the use of bone meal and acid phosphate, both classical sources of phosphorus no longer in common use at that time. Limestone was added to thirteen more plots generally as a basic soil treatment because its benefit had become well established. Its addition as a new treatment to some plots with a long history of manure and to others in combination with various chemical fertilizers, set a basis for more appropriate evaluation of the benefit of nutrients in soil amendments. New fertilizer treatments were included for corn and wheat in rotations with quantities of nutrients comparable to those initiated in 1928.

Three new concerns were addressed in the 1940 revisions. One aimed at determining the availability of phosphorus from treatment with rock phosphate. A second sought to determine whether P and K for corn in rotation would be better applied directly to corn or as fertilizer for clover. The third was to determine effects of removing or returning to the soil crop residues including red clover growth after the first cutting, in order to provide available nutrients as the residues were mineralized in the soil. Previous management history of the field followed the practice of removing straw and stover from all of the plots.
Recognition of other modern concepts in soil management were expressed in the revisions adopted. The added use of limestone and its influence on availability of potassium recognized new knowledge of soil chemistry including an understanding of cation exchange capacity and the proportional composition of exchangeable cations. Limestone applications were in relation to the amount of 'exchangeable hydrogen'. Variations in potassium fertilization dealt with its percentage saturation.

Plots 6 and 7 which historically had been in continuous clover and after its failure in continuous cowpeas were selected for special work to develop a better understanding of the implications of soil chemistry in soil-plant relations. Detailed plans involving nitrogen, phosphorus, calcium and potassium were drawn up but never carried out because George E. Smith who was the principal investigator departed in early 1943 for the armed forces. During the period 1940-1949, these plots were kept in a mixed bluegrass sod.

**Soils Faculty Influences in Sanborn Field**

Among the faculty of the Department of Soils whose work and thinking influenced management of Sanborn Field over many years was William A. Albrecht, Professor of Soil Microbiology and beginning in 1938, Chairman of the Department. For 43 years Albrecht taught at the University and championed his convictions on the importance of relationships between soils, plant composition and animal health.

From research on soil conditions of Sanborn Field, Albrecht gained understanding of the relationship of organic matter to soil acidity and fertility as they apply to plants and to the animals that consume them. Albrecht perceived that soil is the key to the health and nutrition of all animals, including man.

One Albrecht theory was that a soil high in acid does not necessarily denote a soil low in minerals. To support his theory, he often would compare plots 34 and 38. Plot 34 was manured and relatively acid in pH, yet it produced good clover stands. Plot 38 had been limed since 1914 and had a near neutral pH. Clover yields on it were comparable to those on plot 34. Albrecht often would even argue that a certain level of acid in soil is necessary to maintain proper plant nutrition.

The discovery of aureomycin, an early, well-known antibiotic, is attributed partly to Albrecht. In 1945, he collected soil samples from Sanborn Field plots and sent them to Dr. Benjamin M. Duggar working in mycological research and production for American Cyanamid's Lederle Laboratories. Duggar, formerly a faculty member at the...
University in biological sciences, discovered the microorganisms *Streptomyces aureofaciens* in a soil sample taken from plot 23 cultivated to continuous timothy with no treatment and one of the most infertile and unproductive plots on the field. From the isolated microorganism came aureomycin. In 1958, the soil sample from which the isolate was obtained was placed in the Smithsonian Institute.

During the decade of the 1940’s, soil science was undergoing rapid expansion in knowledge in the area of soil chemistry and fertility. Faculty of the Department of Soils were among national leaders in the development of concepts that related cation exchange composition to the soil solution and to nutrient availability. The understanding of cation exchange and the importance of the balance among exchangeable cations on their availability to plants provided the foundation for establishing chemical soil tests to assess the fertility level of soils and to determine fertilizer and limestone needs. By the late 1940’s, E. R. Graham, the Missouri pioneer in this field, had developed a soil testing scheme for Missouri soils. Soil material and related crop performance on plots of Sanborn were used extensively by Graham in perfecting his system of analyses.

**New Thinking Prompts 1950 Changes**

In 1949, soil tests were made of the plow layer of all plots on the field. These provided the basis for modern soil treatments which were included in the management schemes on a number of plots modified in 195017, again under George E. Smith who had recently returned to the University. New thinking suggested that many of the soil treatments previously used were inadequate to replace the nutrients removed by cropping. On some plots certain nutrients were present in sufficient quantities while other nutrients were low, resulting in improper nutritive balance.

Acceptance and use of soil testing by Missouri farmers was accompanied by a marked increase in use of fertilizers. The availability of cheap forms of fertilizer nitrogen had de-emphasized the value of animal and green manures. The more progressive farmers were using management systems that were widely different from any of the practices followed on the plots of Sanborn Field.

The primary objective of the revised plan of 1950 was to introduce modern approaches to fertilization. Fertilization of the soil at a level termed ‘full treatment’17 was introduced into each of the historical continuous and rotational cropping systems and this provided compari-
son among no treatment, manure only, and modern fertilizer practices as well as other variations in the use of lime and fertilizer. The full treatment involved use of limestone, potassium, and phosphorus to upgrade and then maintain levels of K, P, Ca and Mg at appropriate soil test values and to use chemical nitrogen in accordance with the then current recommendations.

Cropping practices on some plots were changed in 1950 to accommodate modern fertilization of continuous cropping systems for corn, red clover, alfalfa, alfalfa-bromeegrass, and timothy. The introduction of continuous corn with full treatment on plots 6 and 7 was a forward-looking change and provided much value as data accumulated over many subsequent years during which there was no diminution in soil productivity. Plot 6 was managed under conventional cultivation and plot 7 under the then new wheel track planting system.

Additional revision in the field plan included dropping the annual wheat-lespedeza system to be replaced with a three year rotation of corn, oats-lespedeza, wheat-lespedeza. Plots 1, 3 and 4 were changed from a six to a three year rotation of corn, wheat, red clover with full soil treatment and with each crop grown yearly. Plots 11 and 14 were shifted from a six to a four year rotation by omitting the two crops of timothy.

Recent Modifications

Modifications made in Sanborn Field since 1950 involved the introduction of supplemental irrigation and the shifts of some plots to no-till cropping. In 1967, supplemental irrigation was included in the management of plots 40-45 under the direction of C. M. Woodruff who had assumed responsibility for the field at that time. Cropping of these plots was shifted from the two-year rotation of corn and wheat-sweet clover to a rotation of corn and soybeans and again modified in 1973 to a three year rotation of corn and soybeans each planted into wheat mulch and wheat-soybeans with the double cropped soybeans no-till planted into wheat stubble. Supplemental irrigation also was practiced on the full treatment, continuous corn plots, where from 1970 through 1979 plot 6 was irrigated in even years and plot 7 in odd years. Modification in culture practices on the two corn plots, beginning in 1972, was a shift to no-till planting in a mulch of wheat that had been sown the previous fall. In 1980, plot 6 was returned to conventional cultivation and plot 7 managed as no-tillage. This appropriately followed earlier comparative history between the two plots with plot 6 conventional and plot 7 of
wheel track planted as a form of minimum tillage, the fore-runner of current no-tillage practices.

**Current Perspective**

As was stated earlier, Table 2 is presented as an abbreviated tabulation of changes in field management in order to allow one to visualize over time the cropping and fertilization protocol of the plots. More detail is given in the appendix. The revisions made in the experimental plan during the ninety-seven year history of the field were deemed appropriate and necessary by the researchers who were looking to the future but in each case a continuing effort was made to maintain, without alteration, the management system of a number of plots judged to be of historical significance relative to soil conditions which had developed.

Currently the management systems of the 44 plots include 13 different cropping practices and 20 variations in soil treatment. Dates of initiation of the various management schemes range from 1888 to 1973. During the history of the field, cropping systems and soil treatments have not been altered on nine of the original plots (Table 4). Five

**TABLE 4.**
**Management Description of Nine Plots on Sanborn Field Which Have Continued Without Alteration Since 1888.**

<table>
<thead>
<tr>
<th>PLOT</th>
<th>CROPPING SYSTEM</th>
<th>SOIL TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>continuous wheat</td>
<td>no treatment</td>
</tr>
<tr>
<td>10</td>
<td>continuous wheat</td>
<td>six tons manure annually</td>
</tr>
<tr>
<td>17</td>
<td>continuous corn</td>
<td>no treatment</td>
</tr>
<tr>
<td>18</td>
<td>continuous corn</td>
<td>six tons manure annually</td>
</tr>
<tr>
<td>22</td>
<td>continuous timothy</td>
<td>six tons manure annually</td>
</tr>
<tr>
<td>23</td>
<td>continuous timothy</td>
<td>no treatment</td>
</tr>
<tr>
<td>27</td>
<td>three-year rot. of corn, wheat, red clover</td>
<td>no treatment</td>
</tr>
<tr>
<td>34</td>
<td>four-year rot. of corn, wheat, oats red clover</td>
<td>six tons manure annually</td>
</tr>
<tr>
<td>13</td>
<td>six-year rot. of corn, oats, wheat, red clover, timothy</td>
<td>no treatment</td>
</tr>
</tbody>
</table>
additional plots have had only minor modification since 1888 (Table 5).
The original cropping practices have been followed on 20 of the original 38 plots but in many cases there have been revisions in soil treatment to adapt more appropriate, modern practices.

**TABLE 5.**
Management Description of 5 Plots on Sanborn Field Which Have Continued Since 1888 with Minor Soil Treatment Modifications.

<table>
<thead>
<tr>
<th>PLOT</th>
<th>CROPPING SYSTEM 1888-1984</th>
<th>SOIL TREATMENT IN 1888</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Wheat</td>
<td>Chemicals for a **full crop</td>
</tr>
<tr>
<td>5</td>
<td>Wheat</td>
<td>6 t. manure annually</td>
</tr>
<tr>
<td>35</td>
<td>*4-year rotation</td>
<td>6 t. manure annually</td>
</tr>
<tr>
<td>3</td>
<td>*6-year rotation</td>
<td>Chemicals for a **full crop</td>
</tr>
<tr>
<td></td>
<td>(change to 3-year rotation in 1950)</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>6-year rotation</td>
<td>6 t. manure annually</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PLOT</th>
<th>SOIL TREATMENT IN 1914</th>
<th>SOIL TREATMENT IN 1928</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>No change since 1888</td>
<td>No change since 1888</td>
</tr>
<tr>
<td>5</td>
<td>3 t. manure</td>
<td>No change since 1914</td>
</tr>
<tr>
<td>35</td>
<td>No manure</td>
<td>No change since 1914</td>
</tr>
<tr>
<td>3</td>
<td>No change since 1888</td>
<td>Split application of N</td>
</tr>
<tr>
<td>19</td>
<td>Reduce manure to 8 t.</td>
<td>No change since 1914</td>
</tr>
<tr>
<td></td>
<td>on corn, 5 t. on wheat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 t. on second timothy crop</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PLOT</th>
<th>SOIL TREATMENT IN 1940</th>
<th>SOIL TREATMENT IN 1950</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>No change since 1888</td>
<td>Full treatment</td>
</tr>
<tr>
<td>5</td>
<td>No change since 1914</td>
<td>No change since 1914</td>
</tr>
<tr>
<td>35</td>
<td>No change since 1914</td>
<td>No change since 1914</td>
</tr>
<tr>
<td>3</td>
<td>Line, chemicals for</td>
<td>*** full treatment</td>
</tr>
<tr>
<td></td>
<td>full crop</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Omit 5 t. manure for</td>
<td>8 t. manure on corn and</td>
</tr>
<tr>
<td></td>
<td>second timothy crop</td>
<td>5 t. manure on wheat</td>
</tr>
</tbody>
</table>

* 4-year rotation: corn, oats, wheat, clover
6-year rotation: corn, oats, wheat, clover, timothy, timothy
3-year rotation: corn, wheat, clover

** high yielding crop

*** full treatment: calcium, magnesium, potassium and phosphorus are maintained in accordance with soil test recommendations. Corn: 6-24-24 (starter), 100 lbs N plowed-down and 33 lbs N side-dress. Wheat & Red clover, alfalfa/brome grass and timothy: are top-dressed annually with P & K relative to crop removal plus 66 lbs N for timothy. All treatment rates are given pounds per acre.
CROP ROTATIONS AND THEIR VALUES

Crops in sequence called crop rotations, were introduced on the field as an attempt to compare their value to that of continuous cropping. Simultaneously, the practice of rotating crops was promoted among Missouri farmers. Prior to 1888, rotating crops was rare in Missouri but was common in the northeastern United States and in Europe.

Four rotations were established in 1888: a two-year rotation of wheat and red clover; a three-year rotation of corn, wheat and clover; a four-year rotation of corn, oats, wheat and clover; and a six-year rotation of corn, oats, wheat, clover, timothy, timothy\(^9\).

Though some rotation plots have been discontinued, the six-year rotation on plots 13, 19 and 20 has been maintained for historical reasons. Similarly, plots 25 through 28 have been in a three-year rotation since 1888. The four-year rotation on plots 34 through 39 also has continued since 1888.

The two-year rotation of wheat and red clover on plots 31 through 33 was changed to a three-year rotation of corn, soybeans, wheat/sweet clover in 1928. This change was made when managers of Sanborn Field foresaw soybeans as the premiere crop in Missouri. Two years prior to 1928, soybeans were substituted whenever clover failed. The soybean crop was utilized as a forage\(^{13}\) until 1950 when it was first harvested as a grain crop.

Recognition of the value associated with crop rotation has come from evidence that crop yields are better when long periods of time elapse between exhaustive crops. The 50-year summation of field experiments in 1942, showed that yields from crops on most rotation plots without treatment were as high as yields from the comparable crop under continuous culture with six tons of manure applied annually\(^{15}\).

One of the topics that dominated any discussion of rotations in the late 19th and early 20th centuries was the possibility that this management practice could increase organic matter and nitrogen and thereby increase yields. When first implemented, rotations did increase yields. But any increases in the land’s productivity without replacement of those nutrients removed in the harvested crop resulted in soil depletion. Miller and Duley concluded in 1921 that rotation alone could not put plant nutrients other than nitrogen back into the soil\(^8\). They recognized that a proper rotation could contribute nitrogen through legumes if only the seed was harvested but that it would reduce the amount of other elements as they were taken from the land in the harvested crops.
Plot 13, in a six-year rotation with no treatment, is one of the best examples on Sanborn Field of progressive fertility reduction under rotations. Since the late 1940s, it has been practically incapable of sustaining even timothy. In its second year, after seeding, timothy has been repeatedly choked by competitive wild grasses which establish themselves on nearly 100 percent of the plot. The remaining plots in this six-year rotation series do not display the same pattern since they receive manure or fertilizer. Plot 13 simply is not fertile enough to sustain timothy but contains adequate minerals for the invasion of weeds.

In 1950, the six-year rotation on plots 11 and 14 was changed to a four-year rotation of corn, oats, wheat and clover to follow a more current emphasis on grain crops in a system appropriate to Missouri agriculture. Modern fertilizer treatments were included in the revisions made at that time and nutrients were applied according to soil tests.

THE VALUE OF USING MANURE

When first established, the principal treatment on Sanborn Field was six tons of manure applied annually. In subsequent years, this amount was considered to be larger than was practical. For crop varieties used in the early period of Sanborn experiments, such large applications of manure prompted lodging in wheat and oat crops and injured clover stands either through smothering or through microbial competition for plant nutrients.

During the plots’ first 25 years, manure had the most beneficially noticeable effect on timothy. When continuous timothy was not manured, it was overrun by wild grasses and weeds and frequently had to be reseeded. Manured plots of timothy grew vigorously.

In 1913, the manure applications on some plots were reduced to three tons and on others were omitted. Data collected from 1914-38 and analyzed by G. E. Smith showed that the return from continuous wheat with three tons of manure annually was only 1.4 bushels less than where six tons of manure had been applied annually.

On plots where manure was discontinued after 25 years of use, its residual effect on crop yields decreased rapidly. Crops sustained by any residual nutrients from manure produced yields that within a few years were no better than yields from plots that had not received manure treatments. The study on carry-over value of manure confirmed the importance of regularly repeated additions of fertility for short-term effects as opposed to large, single additions.
Comparisons made between the use of manure and commercial fertilizers on rotation plots during the period of 1888-1942, showed that fertilizer produced higher yields for wheat, oats and timothy. It must be recognized, however, that no data were available to show that the quantity of added nutrients was the same for the two treatments.

Corn and clover production, in contrast, was higher on manured plots. The modest response of corn to commercial fertilizers in comparison to that for small grains was due to the effect of drought, insufficient nutrients, and shallow placement of fertilizer on corn.

Where three tons of manure were applied and only half the usual amount of fertilizer, the yields of oats and wheat were higher than where either manure or fertilizer was used alone.

Early thinking on the value of crop rotation and of manure had its focus on soil organic matter and the nitrogen it contained. Research in the early years of the century to identify management systems that would result in an accumulation of nitrogen and soil organic matter did not achieve practical success. After 1928 when researchers had measured nitrogen losses on nearly all plots of Sanborn Field, the philosophy shifted to a consideration of nitrogen turnover and its relationship to productivity of the soil. A major advancement in the understanding of soils developed about that time from results which showed that cultivation decreased soil productivity. This work by Hans Jenny, then a member of the Missouri soils faculty, showed a loss in soil nitrogen of 35% from a virgin prairie soil over a period of 60 years of cultivation. Jenny's examination of data from Sanborn Field led to the conclusion that this decline does not continue indefinitely, but tends to reach a minimum level where it is again stabilized in accord with the cropping system and soil management being practiced.

Annual applications of manure provide an additional input of organic material to the soil beyond that provided by the crop residues. Analyses of periodically collected samples of the soil over the history of Sanborn Field from 25 to 75 years showed that the level of carbon in soil treated annually with 6 tons of manure per acre was about one-half percentage unit higher than the level for an equivalent cropping system without manure.
THE INTRODUCTION OF FERTILIZERS TO MISSOURI

Missouri was without agricultural limestone supplies and commercial fertilizer manufacturers in 1888 because need for them had not been established. Nor had many technological innovations, associated with development and growth of these industries, yet occurred.

In designing the field experiments, Sanborn was not indifferent to the potential role and need of chemical fertilizers in maintaining the productivity of Missouri soils. He simply used fertilizers to a limited extent but in a measured way. Presumably he wished to demonstrate that chemical fertilizers could be used successfully in crop production in lieu of crop rotations.

An annual application of chemicals, for what then was considered a high yielding crop, served as a soil treatment with only two cropping systems: continuous wheat and the six-year rotation. Crop analyses were used as the basis for determining the quantities of chemicals (N, P and K) to be applied in relation to defined yield goals.

Plot 2 in continuous wheat received amounts of nitrogen, phosphate and potash equivalent to nutrients removed by a 40-bushel crop of wheat (grain plus 2 tons of straw). Plot 3, in a six-year rotation, received nitrogen, phosphorus and potassium in amounts equivalent to nutrients removed by 80 bushels of corn plus 2.4 tons of stover, 60-bushels of oats and 1.5 tons of straw, 40-bushels of wheat and 2 tons of straw and three tons each of clover and timothy. Plot 4, also in a six-year rotation, received half the amount of chemicals applied on plot 3 plus manure at three tons per acre.

For nearly the first 40 years of this century, people groped for a better understanding of fertilizers and their use. On Sanborn Field, the development of proper methods of fertilization was determined through trial and error. One wheat failure in 1920, F. L. Duley wrote, was caused by applying too much sodium nitrate and potassium sulfate at the time of seeding:

"On account of a practical failure of the wheat on plot 2 during the season of 1920 it was decided to change the time of application of part of the fertilizer. The only way we were able to account for the very poor stand of wheat was because of the large amount of sodium nitrate and sulfate of potash that was sown with the wheat last year. The amount of these materials to be applied in the fall was therefore cut down and the remainder will be applied as a top dressing in the spring of 1921."
In the origin of the field plans, limestone treatment was not included. Beginning in 1914, the four-year rotation on plot 38 received lime making it one of the first if not the first limed soil in Missouri.

In 1930, comparisons were made between clover stands with lime and those without lime and were recorded in the Sanborn Fieldbook.

"Clover—a generally thin stand and poor growth account for the small clover yield. Much of the injury attributed to severe winter. Plot 25, 26 and 28 were about alike—all had good stands and few weeds. Plot 27 had very little clover. Hay yield, largely wire grass. Plots 34, 35, 37 and 39 had less than one-fourth stand. Many weeds. Clover on plot 38 fine stand, clean and fair growth. It pays to lime."

By 1942, it was nearly impossible to obtain clover stands on any unlimed plot in the four-year rotation. The average yields of other crops, however, did not show as much benefit from lime as was normally obtained on other fields located on the Putnam-Mexico soil. It was speculated that the unlimed plots in this series may have been contaminated somewhat by lime blown from the nearby street.

Total soil nitrogen in the plow layer to a depth of 7 inches on Sanborn Field in 1888 was estimated to be 3,400 pounds per acre. For most plots there was a progressive decline in the nitrogen level over time due to cultivation which aerated the soil. The increased oxidation in turn, accelerated mineralization of organic matter. Progressive decline in productivity also resulted in a decreased quantity of residue returned annually. It must be recognized that during the first 61 years of managing the field, the straw and stover were removed. All but one of the initial soil management systems, where six tons of manure were added annually to timothy, experienced a loss of soil humus and nitrogen.

Until phosphate fertilizers were added to plots receiving only manure, wheat yields and possibly those of oats were limited by a lack of available phosphorus. Miller and Duley observed that, when wheat was manured, a good growth of straw was made but the beginning of head emergence was spotty and the crop ripened unevenly. By contrast, wheat fertilized with a material high in available phosphorus usually matured evenly and several days earlier. It was concluded after the first 30 years of experimental results, that the only element of fertility that must be purchased in a system of general farming, livestock farming or grain farming was phosphorus.

In 1928, it was observed that, in spite of abundant moisture, corn on the sweet clover plot of the two year rotation ‘fired’ and lodged during
the latter part of August. According to plan, sweet clover seeded in wheat was cut for hay in early September and the subsequent spring growth was turned under for corn. The continued lodging of corn and of wheat as well, and the firing of corn leaves lead to the conclusion that the soil was deficient in potassium. A treatment of 400 pounds per acre of 0-12-12 was begun in 1932 to determine the effects of potash in counteracting the tendency of crops to lodge. Chemical analysis of soils in prior years indicated abundant total potassium but its availability had not been defined.

For over a half century, the original soil treatments of nitrogen, phosphorus and potassium (Table 6) applied on the basis of crop composition and specific yield goals were considered impractical due to cost of the quantities of nitrogen used. The general conclusion was that manure or rotation with legumes were better and more economical alternative sources of nitrogen. If nitrogen fertilizer was used in the fertilization of field crops it was accepted that it should be applied in small quantities due to the expense. It should be pointed out that even in the revised plan of 1940, the chemical nitrogen applied was that included in Sanborn's original plan by which plots 2, 3, and 4 were treated with chemicals on the basis of crop composition, and that initiated in 1914 and subsequently, involving use of complete fertilizer containing 9 pounds of nitrogen per acre applied to corn and 6 pounds for wheat. Revisions of 1928 showed no further increase in nitrogen

### TABLE 6.
**Chemicals Applied for Full Crops on Basis of Crop Composition (1914 Calculations).**

<table>
<thead>
<tr>
<th>Crop and Yield Goal/Acre</th>
<th>N</th>
<th>P₂O₅</th>
<th>K₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat 40 bu + 2 ton straw</td>
<td>72</td>
<td>29</td>
<td>56</td>
</tr>
<tr>
<td>Oats 60 bu + 1.5 tons straw</td>
<td>56</td>
<td>23</td>
<td>49</td>
</tr>
<tr>
<td>Corn 80 bu + 2.4 tons stover</td>
<td>115</td>
<td>42</td>
<td>68</td>
</tr>
<tr>
<td>Red Clover 3 ton</td>
<td>116</td>
<td>34</td>
<td>108</td>
</tr>
<tr>
<td>Timothy 3 ton</td>
<td>70</td>
<td>21</td>
<td>85</td>
</tr>
</tbody>
</table>
rate. The continued long use of Sanborn’s uneconomical fertilizer treatments did serve an important purpose. It aided in dispelling misconceptions about any detrimental effects of chemical fertilizers on the soil. The only unfavorable factor verified was a greater decline in soil organic matter when compared with plots treated with manure.

Investigators throughout the history of Sanborn Field were well aware of the implications of nitrogen in crop production. The total nitrogen content of the soil was considered the most important characterization to be made in evaluating the effects of the different management systems on soil productivity. Crop production in Missouri by the start of World War II was based on management practices which generally included use of available manure, a legume in the rotation, and appropriate amounts of lime, phosphorus, and potassium conforming to the then best available recommendation for this soil. Clearly, however, these soils required more nitrogen.

Many of the synthetic nitrogen plants constructed in the war effort to supply ammunition, were left standing idle at the end of the war. These plants then turned to producing synthetic nitrogen fertilizers. As a result, nitrogen became available for general farm use. Yields often were phenomenal when the synthetic nitrogen was combined with already developed systems of soil management.

One man partly responsible for the dramatic increase in fertilizer usage in Missouri during the 1950s was George E. Smith, then a professor in the University Soils Department. Smith was an aggressive leader in soil fertility investigations. He promoted the use of liberal quantities of nitrogen in grain production based on two prior years of research with corn by C. M. Woodruff. At two different experimental fields, Woodruff had applied 120 pounds of nitrogen each year and obtained corn yields in excess of 100 bushels per acre. The calculated need for a higher rate of nitrogen fertilizer and the yield response that Woodruff expected, came from his research on the rate of release of nitrogen from organic matter for soils on Sanborn Field.

Smith was recognized as a catalyst behind the development of fertilizer usage in the state and region. Most farmers in Missouri, as well as in the rest of the nation, had been minimizing their use of fertilizer. Smith changed their philosophy. His experiments on Sanborn Field and elsewhere in the state, revealed the important relationship between fertilizers used, quantities applied and crop yields.

The impact of Smith’s new approach in crop fertilization may be illustrated by plans formulated in 1950 for plots 6 and 7 and the subsequent crop performance. Smith decided to initiate a management
system for continuous corn that included soil treatment to provide the crop with optimum levels of the plant nutrients. There was some sentiment among the soils faculty to split the two historical continuous corn plots (17 with no treatment and 18 with manure) and use the full fertilizer treatment on one half of each plot while continuing the historical management practice on the other half. Instead, Smith selected plots 6 and 7 for the new work with corn. Neither of these two plots which were the old clover then cowpea plots had been very productive throughout the history of the field and according to soil tests were comparable to plots 17 and 18 in available nutrients. Soils tests were made of samples taken from the two plots in the summer of 1949 and subsequently basic soil treatments of agricultural lime, phosphorus and potassium were applied in quantities to raise the pH of the soil and the amounts of available P, K, Ca, and Mg to the desired soil test level.

One hundred pounds of N, as ammonium nitrate were plowed down in the spring and the plots planted to corn using starter fertilizer as well. Subsequently, a sidedressing of 33 pounds of N was applied when the corn was knee high. The 1950 growing season was reasonable and the plots averaged 126 bushels per acre which was the first corn yield on Sanborn Field that exceeded 100 bushels per acre. The yield on plot 17 (no treatment) and 18 (6t manure) were 22 and 55 bushels per acre respectively.

In formulating the new plans in 1950, plots with the most historical laboratory value were retained. Additions and changes were made in accordance with modern concepts of soil fertility. The changes were intended to develop soil differences that would serve in laboratory studies and to demonstrate the importance of fertilizing the soil for optimum crop production. The historic value of the field was clearly recognized in developing comparisons between past practices and modern innovations.

An important milestone in the history of Sanborn Field for which Dr. Smith carried the principal initiative involved its designation as a Registered National Historic Landmark by the U.S. Department of Interior. This designation came in 1965 and was highlighted in a ceremony on June 10th that included unveiling of an appropriate bronze plaque affixed to the limestone post of the main gate.

At the historic landmark designation ceremony, Smith pointed out that much remained to be learned from Sanborn Field. He noted that chemical and biological analyses were showing differences that specific management programs had developed through the years. Attention was
called to the fact that the field had provided clear demonstration of practices that are soil conserving and soil depleting. Emphasis was made of the changed philosophy in soil science, that 'worn out' soil can be made productive.

**EROSION ON SANBORN FIELD**

Erosion has long been a threat to Missouri soils. Only Tennessee surpasses the state in soil losses.

On Sanborn Field, much of the erosion is attributed to traditional farming methods. The majority of the field is farmed conventionally with primary tillage by moldboard plow and secondary tillage consisting of tandem disking and harrowing. Seeding is done with conventional machinery as is cultivation and harvesting.

After nearly 100 years of producing crops, some of the primary values of Sanborn Field are reflected in the long-term changes of its soils' physical, chemical and biological characteristics. Erosion is expressive in many of the changes. In 1961, an evaluation of these changes was undertaken and variations in the plow layer of the soil as it existed then were determined. These evaluations followed the suggestion of M. F. Miller, then Dean emeritus whose pioneer work much earlier was in developing a quantitative approach for measuring run off and sediment loss with different types of cropping systems.

Plots selected for the 1961 evaluation were plots 9 and 10 in continuous wheat, plots 22 and 23 in continuous timothy, and plots 13 and 19 in the six year rotation. Each pair includes no treatment and that receiving six tons of manure per acre annually. Samples were limited to four locations on each plot. The horizon characterizations are reported in Table 7 and indicate the variation in top soil losses.

On the continuous timothy plots, the original horizons were in place showing a deep A₁ layer of 12 inches and a distinct A₂ of nearly 5 additional inches. On plot 9, the plow layer of 7 inches in depth lay immediately above the B horizon. It was made-up of the remaining original A₁ and the A₂ horizons that gradually mixed as plowing proceeded through the years. Erosion depleted the A₁ progressively until plowing began to reach into the A₂.

Some of the important differences among the diverse plots since 1888 are the losses of parts or all of surface horizons by erosion. Soil erosion losses in these cases constitute the dominant factor responsible for the current conditions.
TABLE 7.
Study of Horizon Depths of Select Plots on Sanborn Field in 1961.

<table>
<thead>
<tr>
<th>Plot</th>
<th>Continuous Timothy, No Treatment</th>
<th>Continuous Timothy, Manured</th>
<th>Continuous Wheat, No Treatment</th>
<th>Continuous Wheat, Manured</th>
<th>Six-Year Rotation, No Treatment</th>
<th>Six-Year Rotation, Manured</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLOT 23</td>
<td>0-7 inches Plow layer. Part of A₁</td>
<td>0-7 inches Plow layer, upper part of A₁</td>
<td>0-7 inches Plow layer. Erosion that has taken place over the years, has resulted in a mixing A₁ and A₂ and this is resting on the upper B horizon.</td>
<td>0-7 inches Plow layer plus. Includes A₁ and A₂ materials combined by plowing.</td>
<td>0-7 inches Plow Layer. A₁ horizon</td>
<td>0-8 inches Plow layer plus. A₁ horizon</td>
</tr>
<tr>
<td></td>
<td>7-10 inches Lower part of A₁</td>
<td>7-12 inches Lower part of A₁</td>
<td>7-19 inches Upper B horizon</td>
<td>9-19 inches Upper B horizon</td>
<td>7-13 inches The A₂ horizon</td>
<td>8-12 inches The A₂ horizon</td>
</tr>
<tr>
<td></td>
<td>11-17 inches The A₂ horizon</td>
<td>12-19 inches The A₂ horizon</td>
<td>13-23 inches The B horizon</td>
<td>12-22 inches The B horizon. This plot is better drained than Plot 13 and does not have as well developed, light color for A₂.</td>
<td>17-27 inches The B horizon - clay accumulation</td>
<td>12-22 inches The B horizon</td>
</tr>
<tr>
<td></td>
<td>17-27 inches The B horizon - clay accumulation</td>
<td>19-34 inches The B horizon (No attempt was made to subdivide the B horizon.)</td>
<td>19-34 inches The B horizon</td>
<td>19-34 inches The B horizon</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No erosion prevention methods were introduced onto Sanborn Field for row crops until the early 1970s. Until then all plots, prior to planting corn or soybeans, were fall plowed subjecting them to erosion particularly in early spring. Fall plowing for many years has been recognized as an unacceptable practice on large, sloping fields unless the fields are protected by terraces. For plot length of 101 feet on Sanborn Field, rough tillage surfaces are assumed to have kept erosion at a minimum. Erosion that has occurred was from intense rains after row
crops had been planted or cultivated. On plots 1 through 7 which have 6% slope down the length of the plots to the east, it was recognized that tillage operations and erosion have resulted in transport and deposit of soil from the upper west end to the lower east end. An attempt to correct this was made in 1961 by moving several inches of the deposited soil material from the east end, back to the west end to restore uniformity of topsoil depth.

The current view that no-till is a reliable system of growing row crops has gained acceptance because the soils are not opened and exposed to erosion by plowing and tilling them. The first no-till planting on Sanborn Field was done in the fall of 1971\textsuperscript{25}. Plots 6 and 7 in continuous corn with full treatment utilized no-till cultivation beginning in 1971. Plot 7 had been under a reduced tillage management since 1950. In 1980, plot 6 was returned to conventional tillage.

Plots 40-45 in a rotation of corn, soybeans and wheat-soybeans have been managed under a conservation tillage system beginning in 1973. After harvesting the fall grain crops the residues were shredded and the plots disked. A winter cover crop of wheat was planted each fall after fertilizing. Each spring the corn and soybeans were no-tilled into the wheat\textsuperscript{25}. This wheat was mowed and left as a mulch on the soil. Both crops emerged through the mulch. Weed control measures included box spraying and using a rotary mower used between rows. Since 1979, appropriate herbicide tank mixes have been applied with corn and soybeans.

**INTRODUCTION OF IRRIGATION ON CLAYPAN SOILS**

Studies on irrigating crops, primarily corn, in Missouri began in the mid 1960s. A University student enrolled in a special problems course with C. M. Woodruff, measured the moisture levels on plot 7 of Sanborn Field throughout the growing season. Information he derived from the measurements became the basis for establishing irrigation on claypan soils.

From this study Dr. Woodruff, who carried leadership responsibility for Sanborn Field from 1967 to 1976 prepared these guidelines\textsuperscript{24}:

1. The moisture content of the surface soil should be kept sufficient to prevent development of water stress in plants especially during periods of pollination and grain formation.

2. The amounts of water applied should be so limited that developing plant roots will remove the available water from the deeper
layers of soil. The consequences are a more vigorous, higher yielding plant, a lessened requirement for added water, less runoff in the event of rain falling after irrigation, and an oxidized state of the claypan which will be reflected by better crop yields the succeeding year.

3. Rates of application of water should be low enough to permit the water to be drawn into the soil by capillarity so as to prevent structural breakdown and puddling of the surface soil that would occur if it became saturated with water.

The two latter considerations may be achieved best with sprinkler type irrigation. A fair compromise may be achieved with furrow type irrigation by running water between every other row.

Irrigation was first practiced in accord with these guidelines on plots 40-45 in 1967. Beginning in 1973 the irrigation was limited to plots 40-42 with the other three plots providing a non-irrigated comparison for each crop in the series. Plots 6 and 7 cultivated to continuous corn beginning in 1950 were brought under an irrigation variable in 1970. Each year, alternately, one of the two plots was irrigated (plot 6 in even years) until 1980. Future irrigation studies likely will be limited to plots 40-42 where 18 years of history involving irrigation has now been accumulated.

**CONCLUDING PERSPECTIVE**

Sanborn Field is an invaluable field laboratory. The cropping systems and fertility programs which have been used on the field have resulted in some very marked changes in soil properties. The surface soil samples taken in 1981 vividly demonstrate the influence of nearly a century of varied treatments as shown by the range in soil test results (Table 8).

The varied levels of nutrients reflects the changes in soil chemical properties. These existing soil properties which have resulted from man’s activities provides a resource for detailed laboratory studies. The differences among plots in crop response, especially yield, reflect the different chemical properties of the soil. There is no other location in the United States with this extensive resource.

The collective history of Sanborn Field to date when the field is three years from entering its centennial year is brought together in this bulletin. Cropping histories, soil treatment information and details of
TABLE 8. Analyses on Sanborn Field That Show Variations in the Composition of its Surface Soil in 1981.

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>organic matter</td>
<td>1.3 - 2.7%</td>
</tr>
<tr>
<td>pH&lt;sub&gt;s&lt;/sub&gt; (soil acidity)</td>
<td>4.3 - 6.8</td>
</tr>
<tr>
<td>acidity (neutralizable)</td>
<td>0-9 me/100g</td>
</tr>
<tr>
<td>calcium</td>
<td>1840 - 5560 lbs/A</td>
</tr>
<tr>
<td>magnesium</td>
<td>156-984 lbs/A</td>
</tr>
<tr>
<td>potassium</td>
<td>91-900 lbs/A</td>
</tr>
<tr>
<td>phosphorus</td>
<td>7-258 lbs/A</td>
</tr>
</tbody>
</table>

management practices included here are vital bits of information essential to interpretation of any soil characterization, plant analyses, or yield results published from the field.

At the conclusion of 75 years of existence of Sanborn Field, a major sampling of the soils on all plots was completed. Analytical work on these samples was carried out during subsequent years and the data awaits processing and publication. A detailed report of the 75 year results and appropriate conclusions will follow within the next year as a separate research bulletin. Already published are some recent microbiological characterizations of selected plots and a paper giving data on the progressive decline in soil organic carbon with cultivation. The latter is a report of periodic changes over time and it and future analytical work are made possible because samples collected first in 1914 and at subsequent occasions over the field's history are held in storage by the Department of Agronomy for just such purposes.

Planning has now begun for the 100th year sampling under the leadership of James R. Brown, who this year assumed responsibility for the Field. This will allow characterizations of many kinds to feature the centennial event.

The focus of the historical bulletin in hand will provide a valuable detailed background record for reference to past and future research reports developed from Sanborn Field.
REFERENCES


10. *Missouri Agricultural Experiment Station Records, Bound Field Notebook, 1888-1902; Rotation Series Notes*, pp. 30-79. UMC Agronomy Dept. Vault, 135 Mumford Hall.


APPENDIX

Detailed elaboration of the changes in plot treatments and cropping plans on Sanborn Field that have occurred since 1888. (1914, 1928, 1940 and 1950)

1888 Cropping Systems and Plot Treatments

Continuous Crops:

CORN PLOTS
17 - no treatment
18 - 6 tons barnyard manure annually

WHEAT PLOTS
2 - chemicals for 40 bushels
5 - 6 tons barnyard manure annually
9 - no treatment
10 - 6 tons barnyard manure annually
21 - 6 tons barnyard manure annually
24 - 6 tons barnyard manure annually
29 - no treatment until 1907 then, 6 tons barnyard manure annually
30 - 6 tons barnyard manure annually
36 - 6 tons barnyard manure annually

TIMOTHY PLOTS
22 - 6 tons barnyard manure annually
23 - no treatment

CLOVER PLOTS
6 - 6 tons barnyard manure annually
7 - no treatment

OATS PLOTS
15 - 6 tons barnyard manure annually
16 - no treatment

TWO-YEAR ROTATION PLOTS (wheat & red clover)
31 - 6 tons barnyard manure annually
32 - 6 tons barnyard manure annually
33 - no treatment

THREE-YEAR ROTATION PLOTS (corn, wheat, red clover)
25 - 6 tons barnyard manure annually
26 - 6 tons barnyard manure annually
27 - no treatment
28 - 6 tons barnyard manure annually
FOUR-YEAR ROTATION PLOTS (corn, oats, wheat, clover)
   34 - 6 tons barnyard manure annually
   35 - 6 tons barnyard manure annually
   37 - 6 tons barnyard manure annually
   38 - 6 tons barnyard manure annually
   39 - no treatment

SIX-YEAR ROTATION PLOTS (corn, oats, wheat, clover, timothy, timothy)
   1 - 7 tons barnyard manure annually
   3 - chemicals for a full crop
   4 - ½ chemicals for a full crop, plus 3 tons barnyard manure
   8 - 6 tons barnyard manure annually
   11 - 6 tons barnyard manure annually
   12 - 6 tons barnyard manure annually
   14 - 6 tons barnyard manure annually
   19 - 6 tons barnyard manure annually
   20 - 6 tons barnyard manure annually
   13 - no treatment

*Cropping Systems and Plot Treatments 1914-1927*

Continuous Crops:

CORN PLOTS
   no change from 1888 plan

WHEAT PLOTS
   2 - chemicals for 40 bushels
   5 - 3 tons barnyard manure annually
   9 - no treatment
   10 - 6 tons barnyard manure annually
   21 - acid phosphate, 200 lbs./acre annually
   24 - no treatment
   29 - ammonium sulfate, 50 lbs./acre annually
   30 - sodium nitrate, 60 lbs./acre annually
   36 - 150 lbs./acre 3-10-4, fertilizer annually

TIMOTHY PLOTS
   no change since 1888

COWPEAS
   6 - 3 tons barnyard manure annually
   7 - no treatment
OATS PLOTS
no change since 1888

TWO-YEAR ROTATION PLOTS (wheat & clover)
31 - 6 tons barnyard manure annually
32 - 6 tons barnyard manure, topdress before wheat
33 - no treatment

THREE-YEAR ROTATION PLOTS (corn, wheat, clover)
25 - 6 tons barnyard manure annually
26 - 9 tons barnyard manure before corn
27 - no treatment
28 - no treatment

FOUR-YEAR ROTATION PLOTS (corn, oats, wheat, clover)
34 - 6 tons barnyard manure annually
35 - no treatment
37 - complete fertilizer before wheat and corn 3-10-4. Fertilizer application before corn 300 lbs., before wheat 200 lbs. of a fertilizer containing 3% N - 10% available P₂O₅ - 4% K₂O made up from 375 lbs. NaNO₃, 1430 lbs. 14% acid phosphate, 160 lbs. KCl & 35 lbs. filler.
38 - complete fertilizer before corn & wheat, plus 2 tons lime every four years
39 - no treatment

SIX-YEAR ROTATION PLOTS (corn, oats, wheat, timothy, timothy, clover)
1 - 6 tons barnyard manure annually, 1000 lbs. rock phosphate before corn
3 - chemicals for a full crop
4 - ½ chemicals for a full crop, 8 tons manure before corn, 5 tons manure before wheat and second timothy crop
11 - manure: 8 tons before corn, 5 tons as topdressing on wheat and second timothy crop. 1000 lbs. rock phosphate with manure before corn
12 - manure: 8 tons before corn, 5 tons as topdressing on wheat and second timothy crop. 200 lbs. steam bonemeal before corn and wheat
14 - manure: 8 tons before corn, 5 tons as topdressing on wheat and second timothy crop. 300 lbs. acid phosphate before corn and wheat
19 - manure: 8 tons before corn, 5 tons as topdressing on wheat and second timothy crop
20 - 6 tons barnyard manure annually
13 - no treatment

_Cropping Systems and Plot Treatments 1928-1939_

**Continuous Crops:**

**CORN PLOTS**
no change since 1888

**WHEAT PLOTS**
2 - apply all phosphorus and potassium and 1/3 nitrogen at seeding; remainder of nitrogen applied in spring
5 - no change
9 - no change
10 - no change
21 - no change
24 - no change
29 - ammonium sulfate at 100 lbs.; apply half in fall, remainder in spring
30 - sodium nitrate at 125 lbs.; apply half in fall, remainder in spring
36 - 4-12-4 at 200 lbs.

**TIMOTHY PLOTS**
no change since 1888

**OATS PLOTS**
no change since 1888

**TWO-YEAR ROTATION PLOTS (wheat & clover)**
31 - changed to three-year rotation of corn, soybeans, wheat/sweet clover. Limestone when needed. Superphosphate 20% at 250 lbs. potash at 100 lbs.
32 - changed to three-year rotation of corn, soybeans, wheat/sweet clover. Limestone when needed. Superphosphate at 250 lbs.
33 - changed to three-year rotation of corn, soybeans, wheat/sweet clover. Limestone when needed. Potash at 100 lbs.

**THREE-YEAR ROTATION PLOTS (corn, wheat, clover)**
25 - no change
26 - limestone when needed, and acidphosphate 16% at 200 lbs. on corn and wheat
27 - no change
28 - limestone when needed, 4-12-4 at 200 lbs. on corn and wheat

**FOUR-YEAR ROTATION PLOTS** (changed from cowpeas to corn, oats, wheat, clover)

6 - 6-12-6 at 300 lbs. and NaNO₃ at 100 lbs. on corn. Superphosphate 20% at 150 lbs. on oats. 6-12-6 at 300 lbs. on wheat

7 - fertilizer treatment same as for 6

34 - no change

35 - no change

37 - 4-12-4 at 200 lbs. on corn and wheat

38 - 4-12-4 at 200 lbs. on corn and wheat, limestone when needed

39 - no change

**SIX-YEAR ROTATION PLOTS** (corn, oats, wheat, timothy, timothy, clover)

1 - no change since 1914

3 - same as 1914 except ½ N at seeding and remainder in spring

4 - same as 1914 except manure treatments reduced ½ and nitrogen split as plot 3

11 - no change since 1914

12 - no change since 1914

14 - no change since 1914

19 - no change since 1914

20 - no change since 1914

13 - no change since 1914

**Cropping Systems and Plot Treatments 1940-1949**

**Continuous Crops:**

**CORN PLOTS**

17 - no change since 1888

18 - no change since 1888

**WHEAT PLOTS**

2 - no change since 1928

5 - no change since 1888

9 - no change since 1888

10 - no change since 1888

**TIMOTHY PLOTS**

22 - no change since 1888

23 - no change since 1888
THREE-YEAR ROTATION PLOTS (corn, wheat, clover)
25 - reduce manure to 5 tons before corn. Seed mixture of red clover and lespedeza.
26 - no change except seed mixture of red clover and lespedeza
27 - no change except seed mixture of red clover and lespedeza
28 - no change except seed mixture of red clover and lespedeza

THREE-YEAR ROTATION PLOTS (corn, soybeans, wheat/sweet clover)
31 - no change since 1928
32 - no change since 1928
33 - no change since 1928

FOUR-YEAR ROTATION PLOTS (corn, oats, wheat, clover and lespedeza)
34 - no change except seed mixture of red clover and lespedeza
35 - no change except seed mixture of red clover and lespedeza
37 - no change except seed mixture of red clover and lespedeza
38 - no change except seed mixture of red clover and lespedeza
36 - changed to 4-year rotation with legume mixture of red clover and lespedeza lime, 4-12-4 at 200 lbs. annually. Corn stalks, wheat straw and all clover removed.
39 - seed mixture of clover and lespedeza. Lime, 4-12-4 at 200 lbs. on corn and wheat. Return corn stalks, wheat straw and second clover to soil.
4 - changed to 4-year rotation (C, O, W, Cl). Lime, 0-20-10 at 150 lbs. on wheat; N½ 0-20-10 at 125 lbs. on corn, and S½ 0-20-10 at 125 lbs. on clover. Harvest as two plots.

SIX-YEAR ROTATION PLOTS (corn, oats, wheat, timothy, timothy, clover)
1 - omit manure. Lime, 1000 lbs. rock phosphate on corn. 150 lbs. 20% superphosphate on north half in hill with corn and wheat. Seed lespedeza at 50 lbs./acre in spring of clover year if clover fails. Harvest as two plots.
3 - add limestone. Seed lespedeza at 50 lbs./acre in spring of clover year if clover fails.
11 - omit manure on second timothy crop. Seed lespedeza in spring of clover year if clover fails.
12 - limestone, 150 lbs. of 20% superphosphate on corn and wheat. Seed lespedeza in spring of clover year if clover fails.
13 - no change except seed - lespedeza in spring of clover year if clover fails.

14 - omit manure on second timothy crop. Use 150 lbs. of 20% superphosphate on corn and wheat. Seed lespedeza in spring of clover crop if clover fails.

19 - omit manure on second timothy crop. Seed lespedeza in spring of clover year if clover fails.

20 - lime. Change manure to 8 tons on corn, 5 tons on wheat. Seed lespedeza in spring of clover year if clover fails.

TWO-YEAR ROTATION (corn, wheat/sweet clover)

21 - lime equivalent to exchangeable H, 20% superphosphate at 200 lbs. on corn and wheat. E½ KCl equal to ½ exchangeable J. E½ band minor elements on plow sole, W½ on surface.

24 - lime to pH 5.5-6.0, 20% superphosphate at 200 lbs. on corn and wheat. E½ 100 lbs. of KCl on corn and wheat, W½ on wheat only. Minor elements as plot 21.

ONE-YEAR DOUBLE CROPPING (wheat/lespedeza)

15 - wheat for grain, lespedeza cut for hay. Lime E½, 0-38-0 at 100 lbs. over entire plot. Harvest each half plot separately.

16 - same as plot 15

29 - same as plot 15

30 - same as plot 15

BULK AREA PLOTTED IN 1923 (2-yr rotation: C, W/Sw Cl)


B - 8 ton manure on corn in 1923; split in 1930 with E½ 0-48-48. In 1940 W½ becomes plot 42, E½ plot 43.

C - spring sweet clover under for corn in 1923; split in 1930 with E½ 0-48-48. In 1940 W½ becomes plot 44, E½ plot 45.

Cropping Systems and Plot Treatments 1950-1984

Continuous Crops:

CORN PLOTS

17 - no treatment

18 - 6 tons manure annually

6 - full treatment*, 1950-71 and 1980-84 conventional tillage, 1970 and alternate years irrigated, 1972-79 conservation tillage

7 - full treatment, 1950-71 reduced tillage, 1971 and alternate years irrigated, 1972-84 conservation tillage
WHEAT PLOTS
  9 - no treatment
  5 - 3 tons manure annually
  10 - 6 tons manure annually
  2 - full treatment

TIMOTHY PLOTS
  23 - no treatment
  22 - 6 tons manure annually
  30 - full treatment

RED CLOVER PLOT
  12 - full treatment

ALFALFA PLOT
  24 - full treatment

ALFALFA-BROMEGRASS PLOT
  21 - full treatment

THREE-YEAR ROTATION PLOTS
corn, wheat, red clover (hay) . . . (All crops planted each year)
  1, 3, and 4 - Mg lime, rock phosphate, and muriate of potash
  applied according to soil test. Ammonium nitrate at
  300 lbs. under plus 100 lbs. side dressed for corn.
  Nitrogen topdressed on wheat when need is evident.
  6-24-24 at 100 lbs. in row with corn. 10-10-10 at 200
  lbs. with wheat. Minor element mix in starter ferti-
  lizers. Residues returned.

corn, oats-lespedeza, wheat-lespedeza
  15, 16, and 29 - E½ limed, W½ unlimed, corn 6-24-24 plus 66 lbs.
  N, oats and wheat 20-20-20, lespedeza cut as hay

corn, soybeans, wheat-red clover (under)
  31 - full treatment with the exception of 33 lbs. N plowed with
  soybean residue (only N applied for wheat other than starter)
  32 - same as 31 except no potassium
  33 - same as 31 except no phosphorus

corn, wheat, red clover (hay)
  25 - 6 tons manure annually plus 100 lbs. N plowed down for corn
  and wheat top dressed with 33 lbs. N
  26 - full treatment
  27 - no treatment
  28 - lime, P and K as needed according to soil tests, 8-24-8 on corn
  and wheat
corn, soybeans, wheat-soybeans (double crop) - all crops planted each year

The plotted area is seeded to wheat in the fall. Corn and soybeans are no-till planted in wheat which is mowed and/or killed with Paraquat when a tank mix is applied. Two plots of wheat are harvested for gain and soybeans are planted in the wheat stubble (no-till).

40, 41 and 42 - Full treatment; corn and soybeans irrigated, 200 lbs. N on corn and 50 lbs. N on wheat

43, 44 and 45 - Unirrigated with other treatments the same as plots 40-42

FOUR-YEAR ROTATION PLOTS

corn, oats, wheat, red clover (hay)

34 - 6 tons manure annually
35 - no treatment
36 - full treatment with dolomitic lime
37 - 8-24-8 on corn and wheat
38 - lime and 8-24-8 on corn and wheat
39 - full treatment with calcic lime

11 - Rock phosphate - 1000 lbs. each 8 years. Lime and potash according to soil tests. Manure - 8 tons on corn and 5 tons on wheat. One hundred pounds N on corn. E½ starter, corn 6-24-24, oats and wheat 20-20-20

14 - same as plot 11 except 200 lbs. 20 percent superphosphate is broadcast before corn, oats and wheat in lieu of the rock phosphate treatment

SIX-YEAR ROTATION PLOTS

corn, oats, wheat, red clover, timothy, timothy

13 - no treatment
19 - manure; corn 8 tons, wheat 5 tons
20 - full treatment

* Definition of full treatment: calcium, magnesium, potassium and phosphorus are maintained in accordance with soil test recommendations. Other fertilization practices unless specified

corn: 6-24-24 (starter) 100 lbs. N plowed down and 33 lbs. N side dress
wheat & oats: 20-20-20 (starter) and top dressed with N when need is evident
red clover, alfalfa, alfalfa-brome grass and timothy are top dressed annually with P and K relative to crop removal. Timothy top dressed with 66 lbs. N

All treatment rates given are pounds or tons per acre.
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