Research

For Better Farm Living

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
J. H. LONGWELL, DIRECTOR
BULLETIN 619 MARCH, 1954

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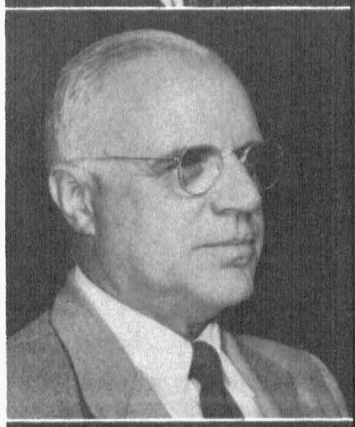

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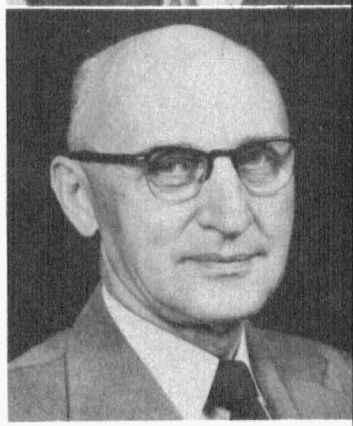

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INTRODUCTION

This brochure is a brief outline of the organization of the University of Missouri Division of Agricultural Sciences: The College of Agriculture and its sub-divisions, and the School of Veterinary Medicine. A statement of some of the accomplishments of the College and their estimated values to Missouri agriculture is included. Charts show the total income to individuals of all the states, value of agricultural products for all states, the position of Missouri with reference to state appropriations for support of Missouri's Agricultural Experiment Station, (research) and average salaries of county agricultural extension agents.

It is hoped that this report will inform Missouri citizens of the work which the College of Agriculture is doing to assist in the development of Missouri's greatest industry, Agriculture. Some of the problems and financial needs for this program also are stated. It is indeed a privilege to serve Missouri's agriculture. We believe that an enlightened farm people will actively support wise research and extension programs. Advisory Council members are now developing a plan to carry on this work until 1964.

J. H. Longwell
Director

Research—For Better Farm Living

Report of the

UNIVERSITY OF MISSOURI
DIVISION OF AGRICULTURAL SCIENCES

The Division of Agricultural Sciences of the University of Missouri include:

1. College of Agriculture with its three subdivisions:
   - Experiment Station
   - Resident Teaching
   - Extension Service
2. School of Veterinary Medicine.

COLLEGE OF AGRICULTURE

The research, teaching, and extension programs of the College of Agriculture are carried on through the thirteen departments:

- Agricultural Chemistry
- Agricultural Economics
- Agricultural Engineering
- Animal Husbandry
- Dairy Husbandry
- Entomology
- Field Crops
- Forestry
- Home Economics
- Horticulture
- Poultry
- Rural Sociology
- Soils

Research in Botany, Plant Pathology and Veterinary Medicine is included in the Experiment Station program.

Research and resident teaching programs are carried on by the resident staff. The distribution of time of resident staff members varies from full-time research to full-time teaching, with many combinations between these extremes. On the average, about one-half of the time of the resident staff is occupied with research and one-half with teaching. The salary of each staff member is paid from funds budgeted for research and for teaching in proportion to the distribution of time between these two activities. Extension staff members devote all their time to the extension program and receive all their salary from funds allocated to the Extension Service. Resident staff members occasionally assist with the extension program and extension staff members sometimes help with the resident teaching or research programs.

SCHOOL OF VETERINARY MEDICINE

The school of Veterinary Medicine includes five departments:

- Anatomy and Histology
- Bacteriology and Parasitology
- Pathology
- Physiology and Pharmacology
- Surgery and Medicine

Several staff members divide their time between resident teaching and research. The staff of this school also assists with the extension program when the occasion demands.

The Veterinary staff also teaches several courses which are open only to students in the College of Agriculture.

AGRICULTURAL EXPERIMENT STATION

The research program of the Experiment Station is basic to the resident teaching and extension programs. No substantial amount of agricultural information was available until 1888 when the Experiment Station was organized and conducting a number of investigations that provided information which was available to farmers. The Extension Service was organized in 1914, to provide an effective means of getting the information to farmers.

Research may be divided generally into two broad classes. The first is known as basic or fundamental research and consists of investigation which will discover new knowledge. The second class makes use of the knowledge previously accumulated, through basic research, to solve practical problems and is known as applied research. This kind of research leads to immediate economic rewards, often quite spectacular.

The larger part of the program of the Experiment Station involves applied research, but at times the research worker must conduct investigations to discover basic principles before the applied research can proceed. The application on Misouri farms of information developed by the research program of the University of Missouri Agricultural Experiment Station has increased farm income tremendously. Still greater income increases are quite possible if the information will be applied on more farms.

Research Is an Investment

Agricultural research is an investment, not an expense. Agricultural research creates new wealth, new industries, new jobs and new products. It pays its own way many times over, not only to farmers but to the whole state community. A few examples will show that research yields monetary returns worth many times the cost. Agricultural research raises both the quantity and quality of farm products, thereby improving the living standard of all our people. Large industrial concerns consider research to be the lifeblood of their business. Since at least sixty percent of the income received by Missourians is from agriculture or agriculture-related industry, is it not clear that the people of Missouri have a vital interest in advancing agricultural research?

In the pages that follow many illustrations of the importance of investment in agricultural research are given.

Agricultural research has been barely holding its own in monetary expenditures while industrial research has steadily marched forward. Why? Because industry's research and development programs have yielded products which, though unknown twenty years ago, today make up over fifty percent of their sales. Research is vital to industry's existence, Agricultural research, though utilized to a much less degree, has made possible a similar growth in agriculture. Fifty years ago one farm worker produced enough for himself and seven others; today he produces enough for himself and fourteen others, thereby freeing the fourteen other for industrial pursuits. This is the basis for the high standard of living now enjoyed by Americans.

Research Increases Farm Income

Agricultural research, by increasing productivity and cutting losses from insects and diseases, has made possible a greatly increased Missouri farm income. The increased returns resulting from one or two of the best Missouri Agricultural Experiment Station research projects easily made up for all the State money spent on research since the inception of the Experiment Station program in 1888. Clearly agricultural research has never cost the people of Missouri a penny. In fact, the increase in farm income that can be assigned to increased productivity from research will yield more in tax revenue than the total appropriation for agricultural research. Agricultural research creates new wealth, new industries, new jobs, and new products for consumer health and enjoyment.

The "wonder drugs" penicillin, aureomycin, chloromycetin, streptomycin, and terramycin are examples of the products of agricultural research. Therefore, it is obvious that farmers are not alone the benefactors of agricultural research. This is truly a sound investment.

Specifically, Missourians have appropriated $3,012,723 for expenditure by the Agricultural Experiment Station since it was organized under provisions of the Hatch Act in 1888. Federal funds have provided an additional $5,194,995. Funds other than those appropriated from state or federal sources have provided $5,686,819. These figures give a total of $13, 894,538 that has been expended by the Missouri Agricultural Experiment Station for research. This sum compares to an estimated $1,250,000,000 income to Missouri farmers during the last 21 years from results of one research project—the development of Lespedeza.

Other projects are almost as spectacular. Hybrid seed corn has added more than 500 million bushels to Missouri corn harvests. Soybeans, at first unpopular in Missouri, now add $100 million to the state's farm income in favorable seasons. Fertilizers have doubled yield in numerous instances. The amount of feed required to fatten animals has been halved. Researchers say that possible discoveries in rumenology may revolutionize cattle and sheep feeding.

Expenditures for agricultural research clearly are an investment that brings huge returns. The following history of the station reveals that other states are taking fuller advantage of this investment opportunity.

Missouri Station History

During the early years when all experiment stations were equally endowed by federal funds, the Mis-

souri station ranked favorably in funds for agricultural research. June 30, 1901, the Missouri General Assembly appropriated its first state grant of $3,500 to the Agricultural Experiment Station. In 1909 the State Board of Agriculture reported: "Missouri has not been as liberal with its College of Agriculture as it should have been. The last Illinois legislature appropriated nearly four times as much money for its College of Agriculture as Missouri has given hers since it was formed."

Dean F. B. Mumford, commenting on the turbulent infancy of the College in his "History of the College of Agriculture," stated: "The kind of college of agriculture demanded by the public could not be realized with funds available." He added, "As a result of the work of the Experiment Station and the rapid improvement in the practical instruction offered by the College, the attitude of farmers, generally, toward the institution was greatly improved." Dean Mumford was writing of the period 1909-10. It was during this period that Missourians began to take cognizance of the value of research to its greatest industry, agriculture.

It was about this time that they began to fully realize the vision of our forefathers when they passed the first Morrill or Land Grant College act of 1862. First the colleges were created for the express purpose of training young men and young women for practical phases of life, colleges that were to be open to all people who desired to seek knowledge. For the first time in history many who worked with their hands, people with little cash income, were able to obtain an education. A new, a democratized system of higher learning had come into being.

Source of New Knowledge Is Born

Being new, these Land Grant colleges experienced growing pains. The first great need of the colleges was for subject matter for a course in agriculture. Thus the agricultural experiment stations were initiated by Act of Congress in 1887.

The Missouri General Assembly accepted the provisions of the act in 1888, making possible the acquiring of competently trained scientists who were willing and eager to devote their energy to solving problems of every day life. New knowledge produced by this group served as a basis for courses in resident teaching.

No job in research is done until the facts are put to work by potential users in practical living. This pointed to another great need—a means to disseminate the new knowledge to farmers. In 1914 Congress passed the Smith-Lever Act establishing the Agricultural Extension Service and completing the linkage in the chain of education. The job of the Extension Service was to bring the University's knowledge to the citizen. Thus the American research and education system provides for pursuit of new knowledge by all citizens; both those who attend college and those who do not.

It is through this system of constant search for new facts, the prompt and wide dissemination of these facts, and the application of the facts by American farmers that our efficiency as producers of agricultural products is attained. In 1790, the efforts of 95 farm people were required to feed 5 city cousins. Today the effort of 16 farm people provides the raw materials required to feed, shelter, and clothe 84 city dwellers. Had our forefathers not established a system for discovery (research) and dissemination (resident and extension teaching) of new knowledge, Americans might be far short of their present standard of living.

Missouri Leads the Way

Solving problems of importance to all agricultural interests of the state always has been an objective of the Missouri Experiment Station. The vision of its directors has been broad and inspired. In 1908 Dean Waters recognized the potential of catching water run-off in farm ponds and utilizing it to ease droughts in crop production for livestock water supply. The Experiment Station had the responsibility of developing the technical knowledge necessary to put water storage construction on a practical basis. This has been accomplished. The use of stored water to supplement rainfall in growing crops is now being studied.

As head of the soils department in 1917, Dean M. F. Miller designed experiments under field conditions which determined for the first time the real losses of soil by erosion. Discoveries in this important investigation later led the federal government to undertake a vast program of soil conservation throughout the United States.

Missouri's Agricultural Experiment Station is charged with the task of supplying farmers with the knowledge needed for the most economical and efficient methods of improving their soil, selecting seed, planting, preventing plant and animal diseases, and feeding livestock. This knowledge is made widely available by Station field days, 114 county agents and the press. At present, Station personnel are pursuing more than 170 investigations. Annual costs of these tasks total a little more than $900,000.

Comparing Missouri's agricultural worth and investments with other states, Missouri ranked sixth in cash value of farm products in 1951. The State's total receipts of $1,263,334,000 ranked it fourth among

the midwestern states. In total income received by all individuals, Missouri ranked 11th in 1952, receiving $6,420,000,000.

Ranks Low in Research Funds

While Missouri ranks high in volume of agricultural business, the state invests comparatively little in the future of this business. Missouri ranked 23rd among the 48 states in funds available for agricultural research in 1952, and more than half of this amount came from endowments, grants, sales and fees. In state appropriations, Missouri ranks 41st, appropriating $238,041.61 in 1951 for agricultural research. State legislators in 14 states appropriated in excess of $1,000,000 for research in 1951. To take her place as sixth in state appropriations for agricultural research, the Missouri Legislature would need to provide $1,500,000 annually for this purpose.

Misouri also ranks 41st in average salaries paid to county agents. The average in this state is $4,444 per year, compared with the national average of $5,130. Yet Missouri's agents are recognized internationally as doing an excellent job.

It is hoped that these comparisons will cause Missourians to help the College of Agriculture achieve the following goals first recommended in 1929:

(A) Salaries for key men comparable with salaries in similar institutions.

(B) Recognition of the longer (11 months) service in the College of Agriculture, compared to the usual 9 months term of the University.

(C) Building space adequate for the teaching and research needs of a greatly increased student enrollment.

(D) Larger state appropriation for the Agricultural Experiment Station.

An enrollment surpassing the 2,200 peak following World War II is anticipated for the biennium 1959-61. If this estimate is correct, it is essential that we build the buildings and train the staff now. Present enrollment is 1,420, ranking the college sixth among agricultural colleges in number of students.

Agriculture is America's only renewable resource. It supplies the vast agricultural industry with a constant flow of raw materials to be processed into food, clothing and shelter. Agriculture no longer stops at the farm boundary. Extensive transporting, marketing, processing, and storage facilities have been developed to serve agriculture. Research has made possible this agricultural production-industry team.

Planning 10-Year Program

The College of Agriculture Advisory Council and staff are working out a 10-year program for the College. Much is expected from this effort.

The increasingly complex "business of farming" that is being carried on by a continually decreasing part of the total population demands answers to a greater variety of problems than ever before. These answers are obtained principally through the research programs of agricultural experiment stations.

This report includes information regarding the work of the University of Missouri Division of Agricultural Sciences, with emphasis on the value to Missouri farmers of some of the results obtained from the research program of the Agricultural Experiment Station.

The Agricultural Experiment Station was organized and began operating in 1888. The total cost of operating the station from that date through June 30, 1953, is shown in the following table.

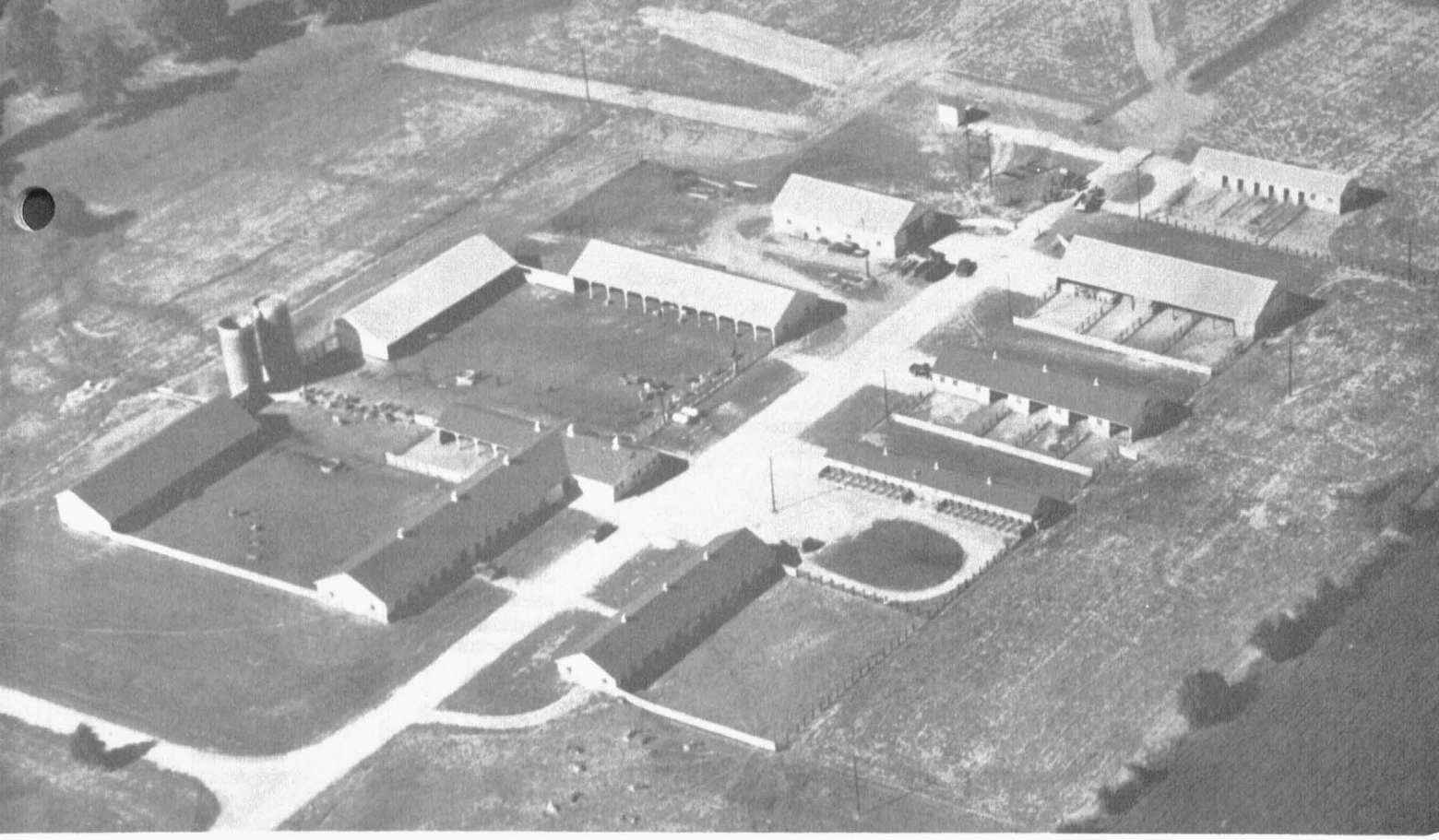
Funds from federal sources	$5,194,995.56
Funds appropriated by Missouri Legislature	3,012,723.52
Funds from other sources (grants, sales, endowments, fertilizer fees, etc.)	5,686,819.27
Total	13,894,538.35

Around $5,126,000 or 37 percent of the total has been spent during the last 10 years.

These are substantial sums of money. They are not outright expenditures that bring no return. The increased incomes obtained from the sale of greater production by Missouri farmers who used the information and materials developed by the research show a high rate of return from the money spent on research.

Farmers demand the knowledge and materials obtained by research on a steadily widening front. The research program of the Experiment Station must be extended in scope and accelerated in rate to meet these demands.

Costs of conducting research are considerably higher than they were in past years. These higher costs and the demand for expanded research require considerable increases in funds available for this purpose.



University of Missouri Foremost Guernsey Farm, home of the University's 280-head purebred Guernsey herd. The farm and herd were given to the University by J. C. Penney for improvement of Guernsey breeding cattle of the state. The farmstead represents an ideal layout for maximum efficiency in dairy herd management. Visitors are welcome to stop in when passing through Columbia.

MISSOURI INCOME AND INVESTMENTS IN RESEARCH COMPARED WITH OTHER MID-WEST STATES

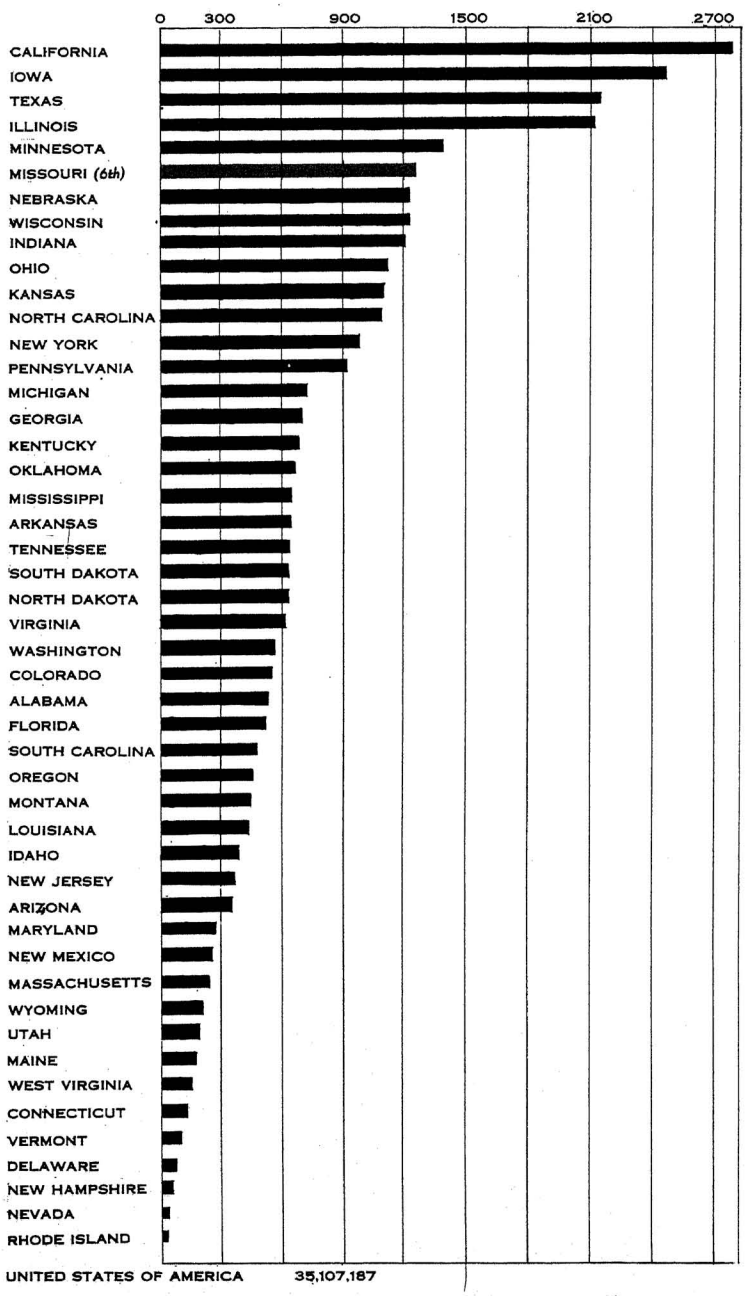
States	Cash Value Farm Products 1951 ($000)	State Appropriations 1951 ($)	Total Funds Available for Exp. Sta. ($)	Avg. salary for Co. Agt. ($)	Total Income received by Individuals ($000)
Iowa	2,456,031	1,080,000.00	2,572,684.14	5271	4,087,000
Illinois	2,109,121	1,510,468.68	2,438,251.27	5979	17,681,000
Minnesota	1,362,137	1,412,843.83	2,368,668.17	5051	4,505,000
MISSOURI	1,263,334	238,041.61	1,256,069.41	4444	6,420,000
Nebraska	1,202,721	567,685.44	1,385,962.23	4820	2,147,000
Wisconsin	1,202,095	1,448,547.00	2,869,169.02	5112	5,837,000
Indiana	1,201,849	979,042.50	2,289,552.95	5210	6,917,000
Ohio	1,152,400	1,211,844.12	1,867,630.25	5133	15,378,000
Kansas	1,100,670	805,570.00	1,369,370.05	4745	3,400,000
Michigan	785,847	1,048,245.49	1,686,882.64	5566	12,172,000
Arkansas	644,470	361,236.45	903,566.24	4607	1,785,000

MISSOURI

high in income

CASH RECEIPTS FROM FARMING BY STATES, 1951 (1)

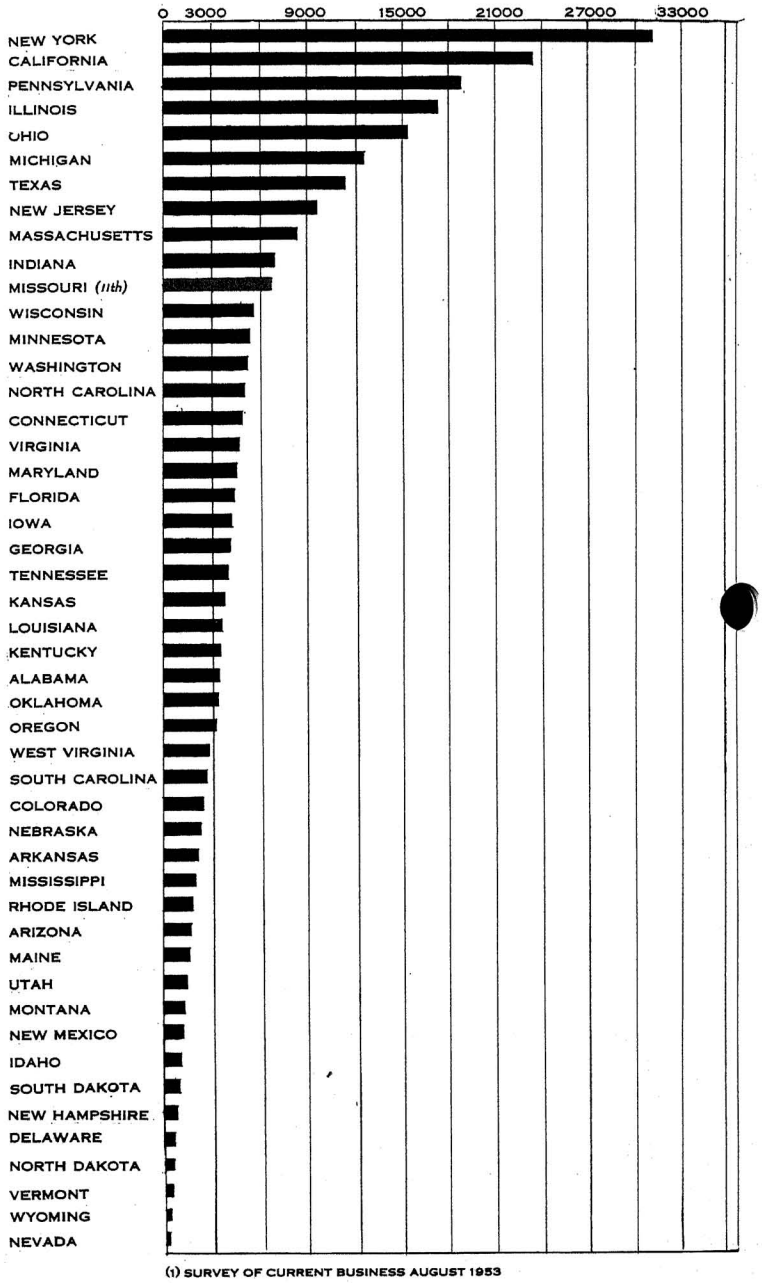
IN MILLIONS OF DOLLARS



(1) AGRICULTURAL STATISTICS 1952, UNITED STATES DEPARTMENT OF AGRICULTURE

INCOME PAYMENTS TO INDIVIDUALS FOR 1952 (1)

IN MILLIONS OF DOLLARS

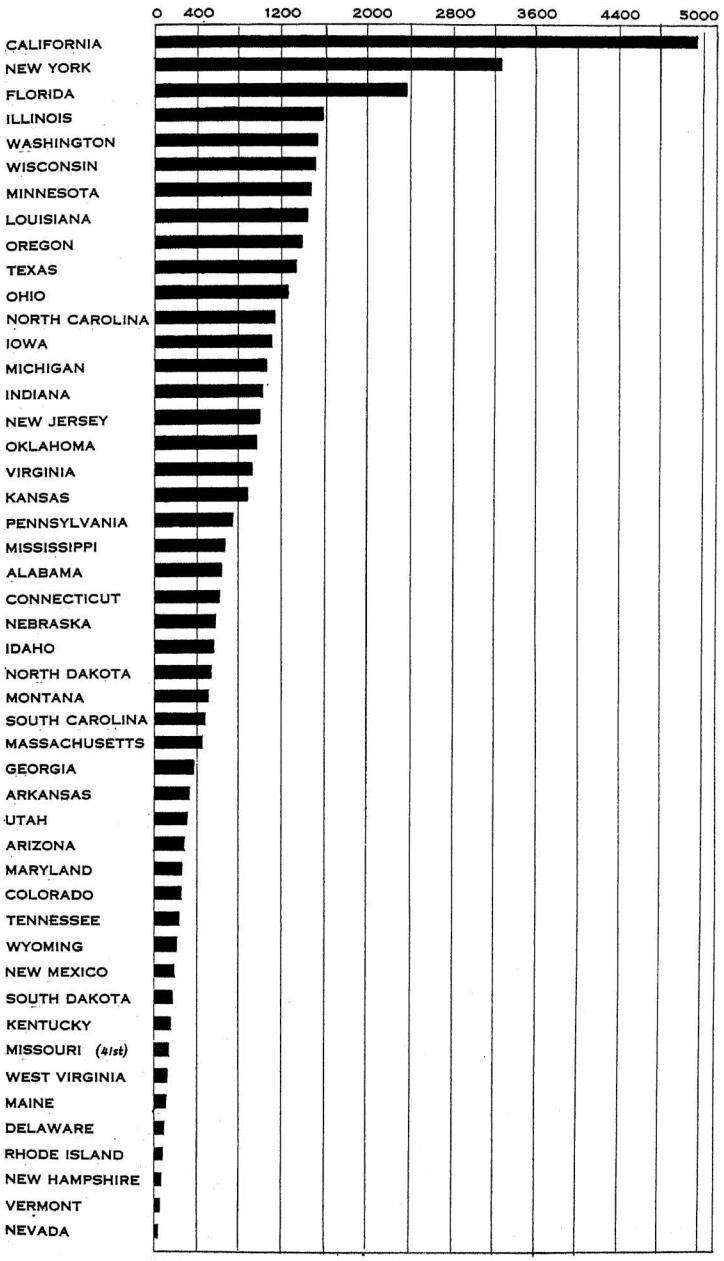


(1) SURVEY OF CURRENT BUSINESS AUGUST 1953

RANKS . . .

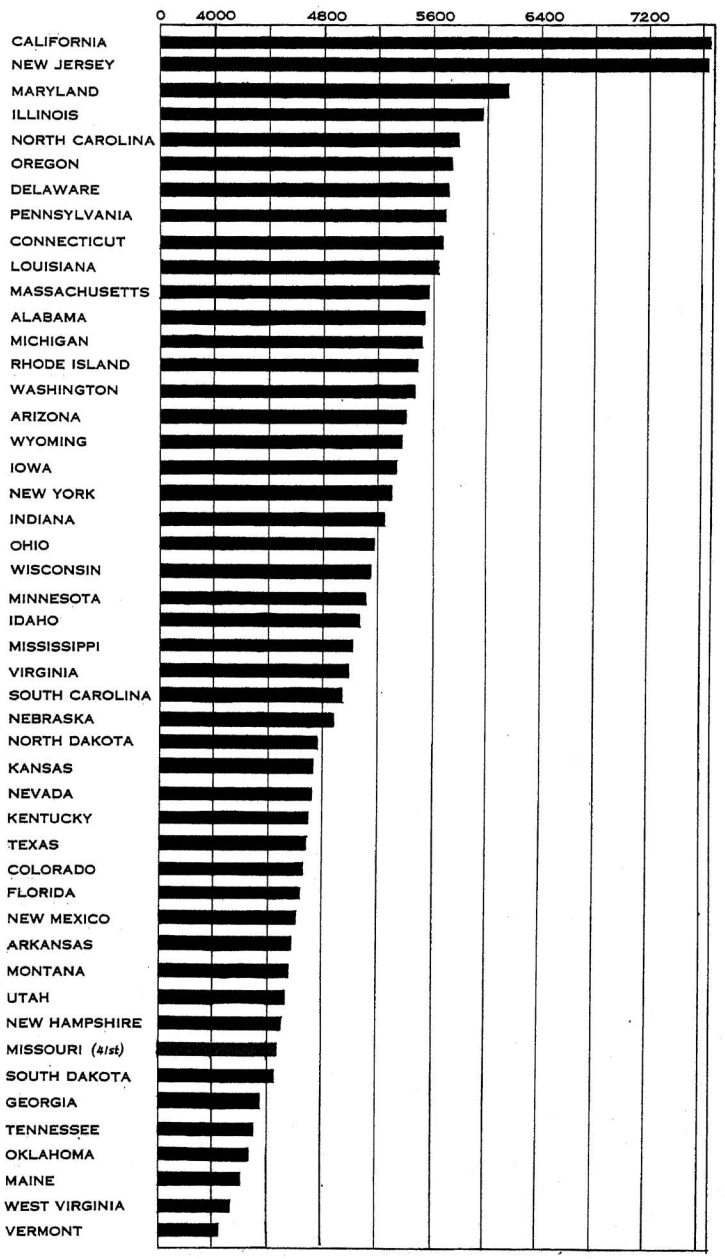
low in appropriations

STATE APPROPRIATIONS FOR AGRICULTURAL RESEARCH FOR JULY 1, 1951 TO JUNE 30, 1952 (1)
IN THOUSANDS OF DOLLARS



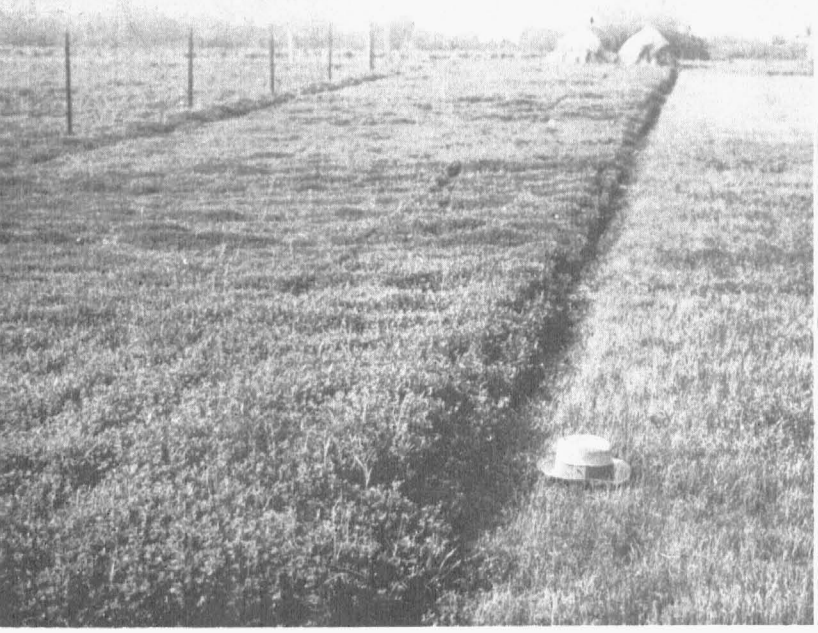
(1) REPORT ON THE AGRICULTURAL EXPERIMENT STATIONS, 1952
OES JANUARY 1953

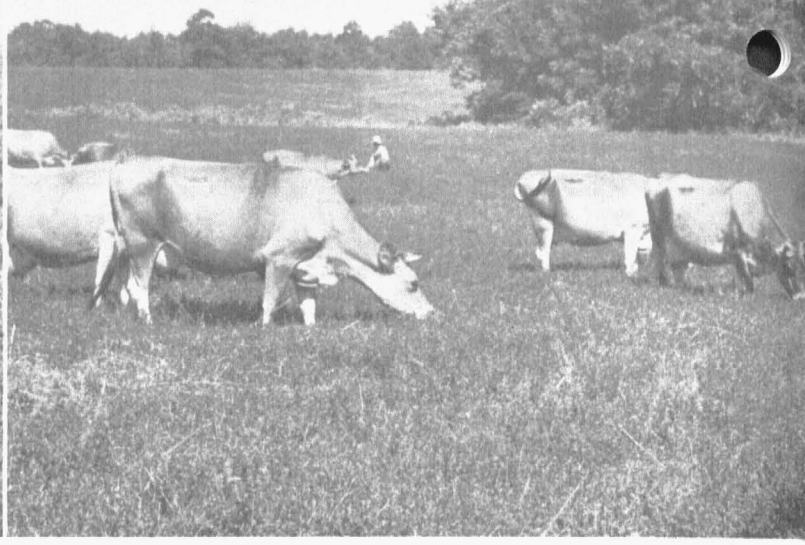
AVERAGE ANNUAL SALARIES FOR COUNTY AGENTS
SEPTEMBER, 1952



UNITED STATES OF AMERICA 5130

Lespedeza . . . Missouri's Leading LEGUME





From this first mass planting of Korean Lespedeza (left) in 1926 at the University Experiment Station, came a legume that has been established on 10,000,000 Missouri farm acres. It brings more than $90,000,000 annually to farmers of the State. Many producers seed small grain in Lespedeza, harvest a grain crop, then let cattle, like the Jerseys at right, harvest the legume. Lespedeza is at its best when other pastures are dry.

AN IMMIGRANT TO MISSOURI

W. C. Etheridge, C. A. Helm, and M. S. Offutt[1]

From two ounces of seed obtained by the Missouri Agricultural Experiment Station from the U. S. Department of Agriculture in 1921, Lespedeza has now spread to 10 million acres, or nearly one-third of Missouri's total farmland. No other legume grown in Missouri approaches Lespedeza in total acreage.

Although several species of Lespedeza are found growing wild over much of Missouri, the two species of major economic importance, common Lespedeza (Lespedeza striata) and Korean Lespedeza (Lespedeza stipulacea), were introduced from the Orient.

The first record of lespedeza in this country was that of common Lespedeza, first called Japan clover, which appeared in 1846 at Monticello, Ga. Presumably it first came to this country through the sea port of Charleston, S. C., in tea packing from the Orient. From there the plant spread rapidly through the South. This Japan clover is thought to have reached Missouri during the Civil War, entering in forage carried by southern troups for their horses. *Kobe,* a large variety of common Lespedeza, was introduced in 1919 from Kobe, Japan, by J. B. Norton, a U. S. Department of Agriculture explorer.

Korean Lespedeza arrived in the United States in 1917 as an introduction from Korea. This introduction, named Korean Lespedeza, was destined to become widely used in the lower half of the Corn Belt and in much of the Cotton Belt.

Dr. Ralph Mills, an American Medical Missionary in Seoul, Korea, found Korean Lespedeza at the edge of a salt marsh along a cove of the Yellow Sea, near Seoul, in 1916. One of these plants he sent to the U. S. Department of Agriculture in 1917. At this point an oversight almost cost this country the discovery of a valuable crop, because the plant was labeled by workers in the department as "alfalfa" and as such remained practically unnoticed in the departmental collection for two years.

In 1919, A. J. Pieters of the department observed the specimen and discovered that it had been mislabeled. Dr. Pieters removed the seed from this plant and planted it at the Arlington, Virginia experimental grounds in 1920. After the 1921 season enough seed was available to distribute a two ounce packet to each of the half-dozen experimental stations.

The Missouri Agricultural Experiment Station received one of the two ounce packets in the fall of 1921, and it was planted the following spring on the site where Crowder Hall now stands. It did surprisingly well, making excellent growth, and a heavy seed crop was harvested in the fall of 1922. The next spring the plot was green with volunteer seedlings.

[1]E. Marion Brown and Joe D. Baldridge have been untiring researchers in the uses and improvements of the lespedeza crop.

Interest in the new crop mounted quickly as its possibilities were envisioned. Korean had much to offer over the old Common or Japan clover. It grew taller, making a more dependable and more productive hay crop. It was superior in setting seed and the seed crop was earlier to mature and easier to harvest. Furthermore, it was easier to establish, quicker to come into production, and somewhat more hardy in drouth periods. It was Korean that made practicable the one-year rotation of small grain and Lespedeza.

Under the direction of Field Crops Chairman, W. C. Etheridge and Field Crops Professor, C. A. Helm, Korean Lespedeza became the subject of many carefully planned experiments covering the essential phases of its production, management, and utilization. The results of these experiments confirmed the belief of the investigators that the Far Eastern legume had possibilities for widespread use on Missouri farms.

The time had now arrived for multiplication of seed and distribution to farmers.

In the winter of 1927 seed was sent in 5-pound lots to 30 Missouri farmers who had been recommended by county agents. Almost without exceptition, reports from the farmers were enthusiastic. During the next three years similar lots were distributed through county agents and teachers of vocational agriculture to farmers in all counties of the State. By 1930 farmers were able to secure seed from commercial sources, and in 1932 nearly one-half million acres of Missouri farmland was devoted to this crop.

Lespedeza Filled A Need

The full significance of so vast an increase in the State's acreage of legumes in so short a time is difficult to grasp. Lespedeza's entrance upon the scene was the more dramatic because of desperate problems arising from soil depletion, financial distress, and frequent summer drouths. Here, suddenly, was a legume easily and cheaply established, reseeding itself, resistant to drouth, producing forage at the season of greatest need, tolerant of low fertility but responsive to soil treatments. And it provided good soil cover, a starter of soil improvement, and a key crop in quick turnover crop rotations. Here was a legume adapted for pasture, for hay, or for seed; adapted for growing in small grain stubble, in meadows, in permanent pastures, or in short-term pastures. Here was a crop with a variety of uses and with the ability to thrive in a variety of situations. Lespedeza wrought a profound change in the whole forage productive system of Missouri.

This annual herbaceous legume, Korean Lespedeza, is especially well adapted to soils of low fertility and those inclined to be acid, which are unadapted to such crops as red clover and alfalfa. It is particularly good for improving such soils and for utilizing them to good advantage. It also does well on the more fertile soils. It is upright to spreading in habit of growth and lends itself well to use as either hay or pasturage. The plant produces a good seed crop that is easy to harvest.

As a summer hay and pasture crop, Lespedeza achieved remarkable popularity. In 1951, for example, 43 percent of the hay produced in Missouri was classed as lespedeza hay. It is equally important for summer grazing. Until the introduction of Lespedeza, Missouri farmers had no widely adapted crop that was cheap, easy to grow, and in peak production when permanent pastures became dormant in July, August, and September. During these months livestock gains had been small or non-existent, and in some years supplementary feed was necessary even to maintain the animals. But, with the coming of Lespedeza, a great change took place. Lespedeza and a small grain seeded together furnished a cash crop or feed crop from the small grain and three months of excellent pasture from the Lespedeza. And these three months coincided almost exactly with the low production months of permanent pastures. Also, Lespedeza in the aftermath of grass meadows and pastures produced grazing in this same period.

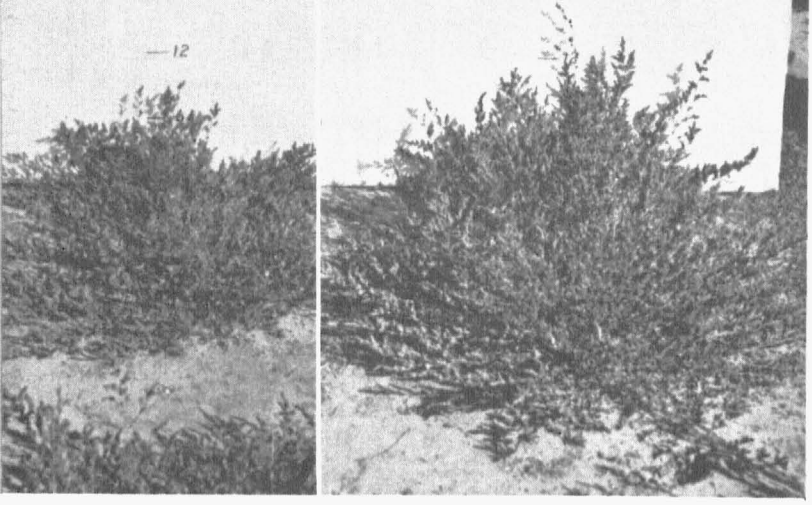
In addition to the timeliness of its growth, Lespedeza has shown remarkable fattening qualities. In fact, year in and year out, no other pasture crop has produced the daily rate of gain and the finish of steers and lambs that Lespedeza has. Furthermore, no reports have been received of bloat. It is a small wonder that over three-fourths of Missouri's ten million acres of Lespedeza is utilized for pasture.

PRINCIPAL STATES GROWING LESPEDEZA FOR HAY AND SEED

Rank	Hay 1933-48 (acres)	Seed 1938-48 (acres)
1. Missouri	1,281,000	259,000
2. Tennessee	1,155,000	103,000
3. Kentucky	686,000	83,000
4. North Carolina	450,000	156,000

Poor Land Has Future

The combined effects of the depression following the first world war and the severe drougths in 1934 and 1936 left Missouri farmers and farmland in a critical condition economically. Land had been mined to pay interest and taxes. Fertilizer and lime had been used only in very limited amounts. Money was not available for costly soil treatments to restore the soil to higher productivity. What could be done? To answer this question, a research program was initiated by the Field Crops and Animal Husbandry Departments.



Great strides in increasing forage of Lespedeza through plant breeding are illustrated by comparison of a new hybrid (right) with the original imported strain.

The results of this research are told in the story of a farm which was purchased by the University in 1938. This story described the causes of decay and the means of regeneration. This land had never been good soil—never had contained the basic components of a fertility better than medium, and for many years before the University's purchase of the farm a long succession of tenants and share croppers had "picked it to the bone." Upon exploring the field, only a natural growth of poor land plants such as tickle grass and dwarf plantain were found. Some of the surface was raw and barren; much of it was broken by small gullies; all of it had been badly washed. The last year it had been cultivated it had produced a meager 15 bushels of corn to the acre. Here, then, was a situation typical of hundreds of Missouri farms.

If this research was to be practicable, cost must be guarded. Time and management for natural adjustment were of equal importance with money in the reviving process. It was here that Lespedeza came into its own; for here was a legume made to order for these conditions. Since earlier research had shown that Lespedeza grew well in a small grain, wheat was planted with it to give the land cover over the entire year. Wheat was seeded each fall with moderate applications of fertilizer and the Lespedeza was allowed to reseed itself each time. Both the wheat and the Lespedeza were grazed in order to return as much of the fertility to the soil as possible, and at the same time receive maximum returns from the land. The live weight gains of the cattle averaged approximately 250 pounds of beef per acre from six months of continuous grazing at the rate of two-thirds of an animal unit per acre without supplementary feed. The annual cost of producing the pasture feed at that time averaged $5.00 per acre, counting all charges that might be laid against similar land. Here, then, was 15-bushel-per-acre corn land giving returns comparable to good land under normal conditions.

If this land was once impoverished it is no longer in that low state. Though not yet good land, it has been raised to a condition of moderate productivity for small grains and legumes which are to be harvested by grazing. Erosion has been stopped and gullies healed by the all-year protective cover of wheat-Lespedeza. Special evidence of total improvement is found in the natural growth of bluegrass in the wheat-Lespedeza rotation.

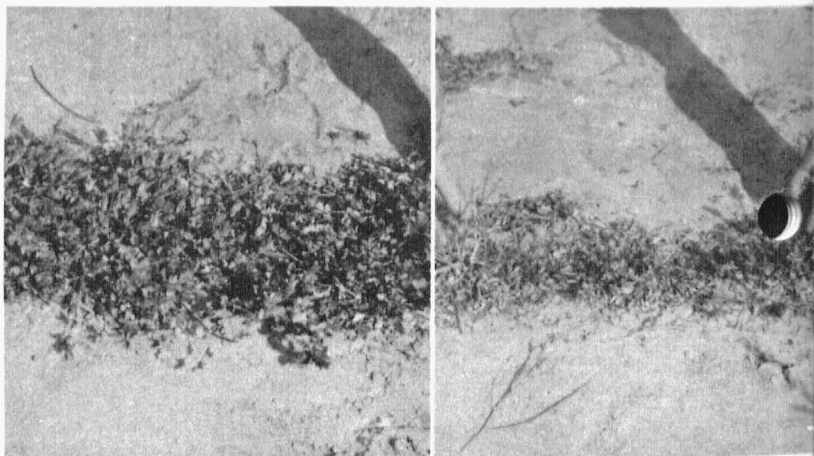
This farm has been a continuing demonstration for many years, visited by thousands of Missouri farmers who have come to the annual soils and crops field days held at the University farms, as well as by hundreds of students attending the Missouri College of Agriculture each year. In this way practical research has been presented to farm people, thereby helping to encourage the widespread use of Lespedeza in Missouri.

Continuing Research

The widely used Korean and the less widely used common Lespedeza have been called varieties, but actually they are not highly bred varieties. They are merely multiplications of the original unselected material introduced from Asia. Sensing that these varieties could be improved, the Missouri Experiment Station in cooperation with the U. S. Department of Agriculture has sought to develop superior new varieties. Much progress has been made in adjusting the maturity of the crop to the length of the growing season in different sections of the State. Early maturing, medium maturing, and late maturing varieties of *Lespedeza stipulacea* (Korean) and also of *Lespedeza striata* (common) have been obtained and can be made available to fill demands for varieties of different maturity.

In recent years a new breeding problem, namely that of disease, has been recognized. Like many other newly introduced crops, Lespedeza was relatively free from disease at first, but as its use increased, diseases increased. This was to be expected. Bacterial wilt was the first disease to attract attention in Missouri. It was recognized as early as 1937, but not until re-

Here the new and old Lespedeza varieties pictured at top of page are contrasted for wilt resistance. The new hybrid (left) shows vigorous regrowth after cutting while the old strain has barely recovered.



cently has serious study been given to the importance of the problem. Ordinary strains of Lespedeza are known to be susceptible to the wilt disease, which damages them severely under some conditions. In tests at the Missouri Experiment Station currently grown varieties have been reduced from 30 to 50 percent in forage yield, and lowered in quality where wilt was severe. Other diseases also are present and await thorough study.

Continued breeding is needed to safeguard this important hay and pasture crop for Missouri farmers. A small start has been made toward the breeding of wilt resistant varieties. The first step was to find a source of resistant material. Scores of different strains were obtained from foreign countries as well as those that were available here in this country, and were carefully screened and tested for their resistance to wilt, as well as for their forage quality and yield. A few of the strains have shown promise as a source of breeding material, but the long process of making crosses, selecting, and testing is still ahead. Breeding requires large amounts of tedious, time consuming hand labor, and large amounts of land and greenhouse space. It is costly and little money is available for the job. A carefully planned, well supported program of research is necessary if disease resistant varieties are to be developed in a reasonable length of time.

In addition to the breeding of new varieties, research must continue on the production management and utilization of Lespedeza. We must learn better grazing practices for maintaining Lespedeza in permanent pastures. We must learn how Lespedeza is adapted for growing with newly introduced grasses, such as tall fescue, and how it fits into newly developing practices such as the heavy fertilization of small grains and grasses, or the use of weed killing chemicals in small grain fields and in weed infested grasslands.

"But why," you may ask, "must we fight continually to hold the gains from earlier research?" For it often seems that we work long and hard to develop a new crop and get it into wide use only to have some new pest move in to take it away from us.

As a matter of fact this is no new thing in human experience, nor is it peculiar to field crops research. To hold our gains from any enterprise we must rate it high, watch it close and work at it hard. The ancient Greeks had a proverb for it, "For painstaking labor on our part the gods sell us all good things." The Bible words it: "In the sweat of thy brow shalt thou eat bread."

Lespedeza's Trial Balance

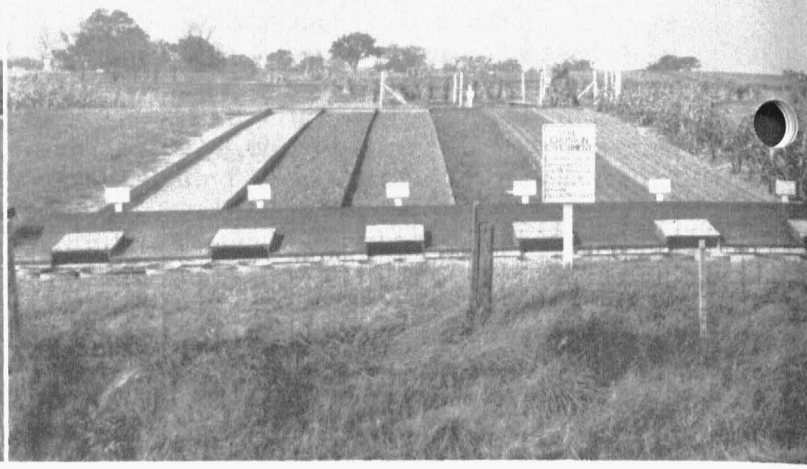
And in the case of Lespedeza, a simple trial balance (on this crop) to date will show that our investment in research with this crop has paid immense dividends and still is a rich field for further development. The U. S. Department of Agriculture has estimated that the total cost of the discovery and early testing of Korean Lespedeza was only $75,000, while in Missouri alone, the annual worth of Lespedeza is estimated at much more than $90,000,000. In 1952, a drought year, especially in South Missouri, $6,000,000 worth of seed and 2,000,000 tons of Lespedeza hay worth $40,000,000 were harvested. In addition, most of the roughage-consuming animals in Missouri regularly depend on Lespedeza to furnish much of their summer diet. The value of this pasturage is estimated to be at least $47,850,000.

Furthermore, if a value could be placed on the soil conserving effects of Lespedeza, a much higher figure than the one given above would be in order. If we assume that each acre of Lespedeza in Missouri fixes 10 pounds of nitrogen annually, and this is probably a low estimate, it would be the equivalent of about 150,000 tons of ammonium nitrate, which at present prices would cost roughly $12,000,000 or each year about 160 times the total cost of discovering and adapting the crop. Lespedeza is an annual crop especially adapted to reseeding itself. When we total the annual acreages from 1931 to 1952 inclusive, we find that a sum total of 131,395,000 acres of Lespedeza has been grown on Missouri farms. Assuming a very low value of $10.00 per acre, the total value to Missouri farmers of the Lespedeza crop would be in excess of one billion dollars. The eleven year average in beef production for Lespedeza following small grains is 103 pounds. Most farmers would value 103 pounds of beef at somewhat more than $10.00, once it had been converted.

Lespedeza's Future Threatened

The history of Missouri agriculture contains no development more remarkable than the coming of Korean Lespedeza from the other side of the world to take a dominant place in the cropping systems of the entire State, in a period of only three decades. A scant handful of seed in 1921, tested and multiplied through scientific procedures and distributed to every soil type and county, became Missouri's most widely grown legume crop by the late 1930's. Truly, the performance of Lespedeza in Missouri in the past has been remarkable; at present, Lespedeza is still a great crop; but the future of Lespedeza well may rest in the hands of those who are responsible for the appropriation of funds to enable research workers to develop new, disease-resistant varieties to meet the ever-increasing need. What will the picture of Lespedeza be in Missouri 30 years from now?

Sanborn Field, established in 1888, now has wider soil differences available for study than can be found at any other place. Many of the leading soil scientists in this country learned their fundamentals through studies of these plots.



The first systematic measurements of soil and water losses in cropping systems were made on these Missouri Station plots by Dean M. F. Miller and F. L. Duley in 1917. They have been widely copied. Results now serve as basis for erosion control throughout the world.

Soil Research . . .

The Basis for Abundant Food

by W. A. Albrecht, C. M. Marshall and G. E. Smith

HEY-DAY OF SOD BUSTER OVER

The great era of soil exploitation has passed. No longer is new land available to feed growing population. We cannot consider our soils as mines with minerals to be removed. All too long we have taken soil for granted and have disregarded the gradual exhaustion of soil fertility as an item in cost of production. Agricultural land must be considered as a production facility where raw mineral materials (plant nutrients) are processed and regularly replaced in the soil for making more finished feed and food products.

Developments in soil fertility and plant nutrition during the past decade have been little short of revolutionary. Research information on the nutrient requirements of crops, the better understanding of soil chemistry, and the production of lower cost fertilizer materials have been in a large part responsible for changing an era of possible food shortage to one of surpluses.

From another point of view, advancement in soil management has almost eliminated the wide difference between rich, virgin soils and depleted land in productive capacity in favorable seasons. People living on many soils of low fertility need no longer be held down to sub-standard living based on nutrient delivery of low producing fields. They can enjoy the same advantages as neighbors who possess better land.

PIONEER IN RESEARCH

Missouri soil scientists pioneered experimental work in the measurement of soil erosion and water loss and suggesting preventive means. After more than 35 years of experimenting, evidence is accumulating that many devastated and abandoned lands can be brought back to productivity. This restorative procedure may be costly and unprofitable in competition with others who continue to follow a "mining management," but we possess much of the knowledge necessary when the land is needed.

DEVELOP ACCURATE SOIL TESTS

A better understanding of the nutrient requirements of crops and the behavior of these nutrients in the soil has been responsible for increased yields on Missouri farms in recent years. A change from the practice of applying small quantities of fertilizer which furnished only a fraction of the crops' requirements to one where soil fertility is restored has given spectacular improvements. Previously, despite better varieties, improved machinery and more efficient control of diseases and insects, the average Missouri crop yields had increased little because the removal of soil fertility offset these improvements. The development

of reliable soil tests has enabled farmers to apply the deficient elements without expenditure for unneeded soil treatments. The number of soil analyses being made and the quantity of fertilizer being used by Missouri farmers attests to the practicability of this approach. In 1946, with only three soil testing laboratories, 221,753 tons of fertilizer, containing an average of 21 percent of plant nutrients, were applied. In 1952 there were 85 soil testing laboratories and the fertilizer tonage mounted to 847,284 tons containing 29.5 percent plant nutrients. This is nearly a seven-fold increase in the replacement of plant nutrients on Missouri farms in six years.

Results of many Station experiments, as well as tests on many farms, show that one dollar invested in needed fertilizers will return three dollars. On this basis the increased use of fertilizer in 1952 over that applied in 1946 netted Missouri farmers over 100 million dollars. One-fourth of the crop production in Missouri is conservatively estimated to be the direct result of proper use of nutrients applied as fertilizers.

Corn production has undergone radical changes in recent years. This crop, which will produce more feed units per acre than any other, fell from favor because of high nutrient requirements, soil depletion, and excessive erosion. Recent experiments show that it is the methods of management that have been responsible rather than the corn plant. Research has developed methods of continuous corn production where erosion is no greater than that following inadequately fertilized sod crops.

Recent research also indicates that properly fertilized corn can be less soil-depleting than legumes. Corn has a high nitrogen requirement. It removes almost one pound of nitrogen in each bushel. However, when the stalks are returned to the soil, corn removes less phosphorus, less potassium, less calcium, less magnesium, and less of other minerals than do legumes when cut for hay. In the long-time experiments on Sanborn Field, the soil growing corn for a high percentage of the time with no fertilization is low in nitrogen. Where legumes have been included in the cropping sequences and have been removed for hay, the soil is at a much lower level of minerals. Legumes are excellent livestock feeds, not only because of their nitrogen but also because of their high mineral content, which could come only from the soil.

Where corn has been planted thickly and ample nutrients have been supplied on once depleted soils, the yields have been increased sufficiently in one year to pay the entire cost of initial treatments. The quantity of organic material in stalks added to the soil has been greater than that returned by any other crop. It appears, then, that corn, instead of being our most soil-depleting crop, may be the means of rejuvenating depleted lands and of paying for this soil restoration.

Small grains are produced on most Missouri farms. Fall-seeded small grains were the first crops

Corn is regaining a dominant place in Missouri agriculture. The corn at left, supplied with adequate nutrients, produced 75 bushels per acre in the dry year 1953 while the unfertilized area at right produced only 15 bushels of inferior grain.

Proper soil treatment meant the difference between profit and loss on this farm. Wheat at left, receiving adequate starter fertilizer and a top dressing of 33 pounds nitrogen produced 40 bushels per acre. That at right without soil treatment produced 10 bushels per acre.

Legumes do not furnish sufficient nitrogen for maximum crop yields in a cropping system. Application of chemical nitrogen with legumes before corn has increased grain yields more than 30 bushels per acre.

Pasture at right, treated according to soil test produced more than 300 pounds of beef per acre from a tall fescue-Ladino clover mixture. Land thought limited to forestry offers new possibilities.

that were extensively fertilized. In many counties the acreage now seeded annually without commercial plant nutrients is very small. The place of these crops in soil management systems has undergone radical changes in recent years. Emphasis on livestock production has shifted much wheat acreage from cash grain to supplemental pasture crops. Heavy fertilization and thick planting of corn, with little of it being cut and shocked, has made difficult the practice of planting wheat after the late corn harvest. The introduction of lespedeza and the increased production of soybeans have resulted in much wheat being planted after these crops. The consequent late seedbed preparation for wheat has completely changed fertilization practices from those used in older cropping systems where the small grain stubble was plowed in in July and fallowed until fall planting time.

Average small grain yields have been much higher in Missouri during the past five years than in the previous ten. Much of this increase can be attributed to a better understanding of the nutrient requirements of these crops and the proper use of soil treatments. Without use of proper fertilizers, the production of wheat and barley on most Missouri farms would not be profitable.

Soybeans have become a major source of income on Missouri farms. Better yields in recent years have resulted in a steadily increasing acreage. Soybeans have a high nutrient requirement. Consequently, the fertility treatments designed to build up the soil's nutrient reserves have improved yields so that this legume crop is grown extensively on many soils which were formerly considered unadapted. Soybeans have not given spectacular response to row application of fertilizers in small amounts. Information on their response to added nutrients is much less extensive than that for some other crops. Additional research is required before this crop will produce maximum yields regularly.

Pastures are basic when livestock and livestock products are considered the principal sources of income on Missouri farms. Pasture land is no longer limited to that which is considered unsuited for other crops. The realization that nutritious forage crops have a higher nutrient requirement than grain crops has resulted in the extensive use of soil treatments. Pastures have been rejuvenated with the seeding of more nutritious plant species. After proper soil treatment, much land once abandoned and producing little livestock feed or considered suited only for forestry now is producing more income as pasture harvested by livestock than land on the same farms that is classified much higher in the scale of capabilities.

Less than a decade ago it was difficult to secure stands of nutritious species as red clover, alfalfa, brome or orchard grass. These choice forages were being replaced by other plants of lower nutrient requirements—and correspondingly lower feed value. The fact that most plants which will grow on soils of low fertility are also inferior feed is gaining recognition.

Cotton is the principal crop in the lowland country of Southeast Missouri. Much of the land in that section of the state has been cultivated for a relatively short time. Soils there are highly variable. In many sections the virgin fertility has been adequate to maintain high yields to date. However, the soil organic matter is being depleted rapidly under intensive cultivation. Soils are becoming more difficult to till and their productivity is declining. Results from field experiments and the soil tests are showing ways of increasing yields and of improving the general farm efficiency.

The relationship of crop quality and the well-being of people and animals to soil fertility has been shown more by Missouri's research than by work in any other state. As the nutrient content of soil declines, the shift to crops that will produce satisfactory yields on these poor soils has resulted in feed of inferior nutritional value. Protein supplements are being

required in ever increasing quantities to balance the livestock rations. Experimental evidence shows that soil treatment can alter the species that will dominate in pasture mixtures. In many cases, the chemical composition of individual crops can be changed. Indiscriminate additions of plant nutrients, however, can result in a lowering in feed values.

This is a phase of soil research that is still in its infancy. Nevertheless, many farmers have observed that after initiating a soil-building program, their animals have shown preference for feeds grown on treated soils. Livestock which feed on well nourished pastures generally are better doers than those on unimproved pastures. These are benefits of soil research that cannot be measured in yields per acre, but may have greater value in animal and human welfare, when additional experimental work has revealed these soil-plant-animal relationships.

Soil surveys show that Missouri has a wide variety of soils that differ greatly in their properties and productive capacities. The information furnished by these surveys has pointed out the desirable properties and shortcomings of land on individual farms. A study of soil survey maps has become a regular practice by people purchasing farm land. This information has permitted the sale and purchase of land at proper values. It is the most reliable and unbiased guide to land values.

FUTURE RESEARCH AIMS

Despite recent spectacular findings in soil fertility and plant nutrition, there are ever-increasing questions of observant farmers for which there are as yet no answers. Good experiments conducted by qualified investigators usually raise more questions than they answer.

We have an ever-mounting population that could tax the production facilities of our agricultural land. Present food surpluses could rapidly diminish with unfavorable seasons or with changes in international responsibilities. Research to be applied must therefore always be ahead of the need for it.

Among the current problems in soils that are being studied, or will be investigated when qualified personnel and funds are available, are the following:

1. The nature and properties of the clays, minerals, and humus.

Clays and humus are the active portions of soils, while the silt minerals are the reserve supplies of fertility to be acted upon by them. The amounts and properties of these soil components differ widely and influence the use and availability of nutrients applied in fertilizers. Although the detail varies from soil to soil, and from crop to crop, certain general features shared by all enable planning a research program directed at the heart of this problem. The passage of plant nutrients from the silt and sand to the clay and humus is a slowly continuing process. Clay and humus, then, provide most of the immediate source for the plants. But this source does not serve the plant root merely as a passive recipient. Plant roots, like clay and humus, are colloidal systems; they enter actively into competition with the clay and humus for calcium, potassium, and magnesium, for example. Hence, we need to understand both the individual soil colloids and the individual plant roots in order to predict what the outcome of the competition will be in practical cases. Soil tests cannot be intelligently interpreted nor fertilizer efficiently used without this fundamental information on soil chemistry.

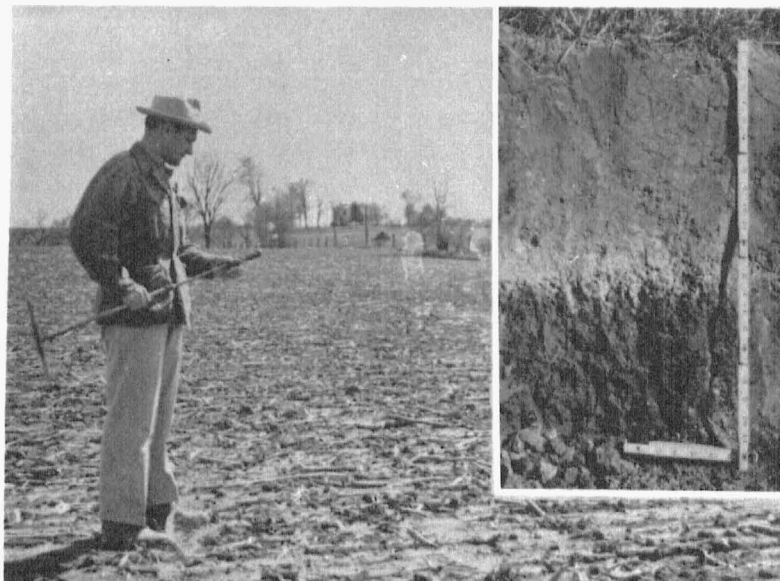
2. Soil test correlations.

Past management practices and soil treatments have altered the needs of the individual fields. Soil tests are being used widely to measure nutrient reserves. Extensive field trials are needed to correlate yield response with added treatments. Variable seasonal conditions complicate results. Findings may not be spectacular and they require some years, but this type of investigation is a necessity if we are to obtain the most efficient use of fertilizers and most efficient production from our highly variable soils.

3. Continuous corn versus rotations.

Much has been learned regarding nutrient balance and corn production. Availability of reasonably priced chemical nitrogen has lessened our dependence on legumes for soil improvement. Crop sequences to include legumes and grasses may not be as important as formerly believed. This new concept could completely nullify soil conservation practices that have been followed traditionally in the past. It could be more desirable to grow cultivated crops continuously on some land and other crops on more erosive fields, rather than to install water management systems and crop rotations based on over-all land capabilities. This

When the soil surveyor pulls up a sample he gets a mental picture (insert) of the cross section. Here he finds 12 inches of silty surface soil, part forming a gray layer. Below 12 inches he hit clay subsoil. Surveying provides useful guide for land buyers.



is a field of investigation of much current interest and one in which research is needed.

4. Erosion control and crop management under high fertility levels.

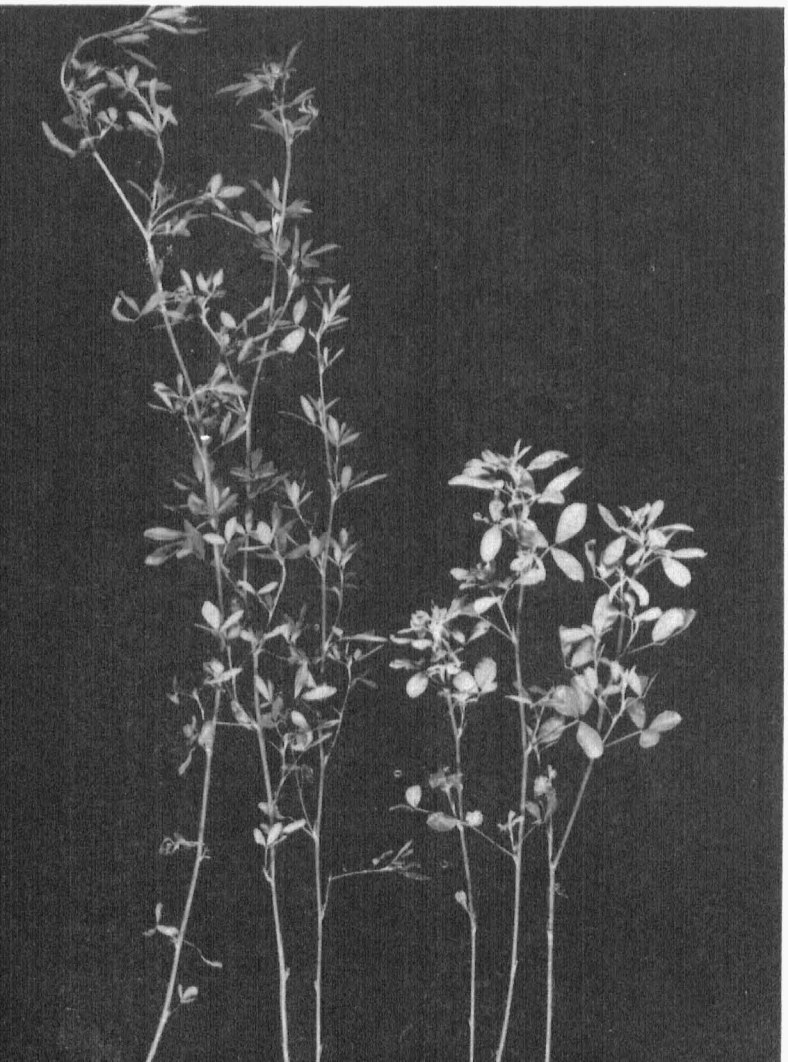
Most soil conservation now practiced is based on investigations where the nutrient additions and returns are less than those removed in the crops. There is abundant evidence that management practices which correct soil fertility and remove this limiting factor in production increase crop growth and reduce erosion and runoff. It is even probable that additional research will show that some established practices in soil conservation can be greatly modified to give lower costs and greater farm efficiency.

5. Pastures and forages.

We are just beginning to appreciate pasture as a crop. Missouri has over ten million acres where proper soil treatment could increase the amount of livestock feed decidedly. This potential can be wisely developed only through systematic investigatons.

Alfalfa and some other legumes have high nutrient requirements and do best on deep soils. There is evidence that alfalfa can be grown on many soils heretofore considered unadapted to it, when rejuvenating practices currently being developed are applied to soils.

In a field where trace element boron was deficient, application of borax, costing $1.00 per acre doubled this alfalfa hay yield over check (right).



6. Deep tillage.

Shallow soils with infertile subsoils represent extensive areas in Missouri. These properties make them subject to drought and limit the kinds of crops they can produce. Deep tillage and addition of nutrients thereby may offer opportunities for increased production.

7. Maximum fertilizer use.

The addition of larger quantities of plant nutrients has produced substantial increases in crop yields. However, the application of some chemicals in excessive or unbalanced quantities has developed complications and in some cases reduced yields and crop quality. Studies in soil chemistry are needed to understand the interrelationship of plant nutrients in the soil and their limitations and possibilities toward increased production.

8. Soybeans.

Less is known about the growth and nutrient absorption by soybeans than about any of our other principal crops. Research is urgently needed on the use of soil treatments for optimum production on Missouri's expanding soybean acreage.

9. Cotton.

Missouri is at the extreme northern end of the cotton-producing region. Many of the soils used for cotton have been cultivated only a relatively short time. There are soil problems in fertility for the production of this crop that cannot be answered from work of states farther south.

10. Crop quality.

While soil fertility levels can alter crop composition and nutrient values for animals and humans, little is known regarding these relationships. Probably no field of research in agriculture is of greater interest or offers more possibilities for public benefit.

11. Trace and secondary nutrients.

The increased use of synthetic fertilizers of higher concentrations and greater removal of nutrients in larger crop yields can make other elements become the limiting ones in crop growth. Evidence of magnesium, boron, and sulfur deficiencies is becoming more prevalent. Other essential trace elements are being found in decreasing quantities by chemical analyses. Information is needed on the levels of these elements required by plants and the quantity delivered by different soils.

12. Soil classification.

Soil surveys have been completed on less than half the counties in the state. Although soil tests have replaced some of the value of soil classification, soil classifications and surveys can be of much value in the interpretation of soil tests on a large scale. An up-to-date classification of all soils in the state could take much of the risk out of farm purchases.

Are you getting your return from investment in Missouri's Agricultural Experiment Station?

Do you consult your county agent on your farm problems? Do you regularly attend soils and crops conferences?. . .livestock days? Are you on the "Announcer" and "Outlook" mailing lists? Do you attend college field days and witness new findings for yourself?

These are returns from the Experiment Station to which each citizen is entitled. Results of research aid Missouri farmers in cutting costs while increasing both quantity and quality of farm products. Your county agent is your local contact with the Experiment Station. He is prepared to help you get the maximum benefit from Experiment Station discoveries. He can help you translate these findings into practical farm use. County agents are official representatives of the College of Agriculture and cooperate with the United States Department of Agriculture. If you are in doubt about the better way of doing a thing, a good rule is: "Ask your county agent."

Others who keep in close touch with results of the Experiment Station are the high school teachers of vocational agriculture, veterans on-the-job training instructors, soil conservation technicians; many fertilizer, feed, seed, and farm equipment dealers; and hatcherymen and bankers.

Field Days:

For a first hand look at discoveries from Station research, plan to attend annual Experiment Station field days. For the skeptic who says, "Believe half of what you see," we can promise a profitable experience with that half. You can observe the advantages of raising proven and acclimated crop varieties; you can get first hand results of all tests. Field days are held regularly at the University South Farms and other outlying Experimental Fields. County agents know the program and can arrange a visit, even an unscheduled one.

Publications:

Results of completed research are reported in Experiment Station Bulletins and Research Bulletins. The annual Experiment Station report summarizes the progress of each study, project by project. Agricultural Extension Service Circulars cover practical recommended practices based on research. These publications will be supplied free for the asking. For a list of available publications, write to: Mailing Room, 21 Mumford Hall, Columbia, Mo.

Press, Radio, and Television:

By special arrangements, radio and television stations report highlights of important research discoveries and newspapers and farm magazines devote much space to new developments announced by Agricultural Experiment Stations.

More than 2,500 Missourians attended the 1953 Crops and Soils Field Day, held at the University of Missouri South Farms. Visitors toured experimental plots where specialists explained objectives of the trials and new findings that could improve production and income on the farm.

Investments in Research

$245 per acre . . .

In a study of the use of supplemental water in the production of canning tomatoes, the use of 3½ inches of water increased the yield 8½ tons per acre. This was at a cost of $35. At $35 per ton, the value of 8 tons of tomatoes would be $280. Substracting the cost of irrigation leaves $245 additional profit per acre.

$50 per acre . . .

Through the use of chemical weed killers, strawberry growers have been able to eliminate two or three cultivations and two to three hand hoeings. This saving figures more than $50 per acre.

$455 per acre . . .

Assuming a natural rainfall, or at least a rainfall where water would not be a severely limiting factor, farmers using fertilizers according to soil tests and recommended practices on canning tomatoes could realize an additional $455 per acre. Experimental trials have produced increases of 13 tons per acre from investment of $70 in fertilizers. In checks where fertility was low, the tomatoes produced 3 tons per acre. Adequate fertility resulted in a yield of 16 tons per acre. We do not know whether supplemental water would have added to this yield. In this case, the fertilizer study was independent of moisture supply.

$5000 to one farmer

Experiment Station personnel recommended to one grower that he plant his entire bean acreage in the variety "Contender". The grower experienced a little difficulty in locating seed of this variety, therefore planted only part of his acreage in "Contender" and the remainder in the old standy-by "Tender Green". When the crops had been harvested, he calculated his returns and observed that he would have realized $5000 additional had he planted his entire acreage in the variety "Contender".

$2,000,000 per year . . .

By utilizing heifer rations developed by the Experiment Station to include a maximum amount of roughage, approximately 300 pounds of grain per animal can be saved. Missouri's dairy herds require 232,00 heifers annualy as replacement stock. A saving of 300 pounds of grain each would amount to a total saving of $2,088,000 for Missouri.

$97,500,000 . . .

Missouri Agricultural Experiment Station research in Entomology has been directed largely as a service to Missouri farmers in pest control. In 1953 army worms invaded the entire State. They were in sufficient numbers in the southern two-thirds of the State to warrant control. In all, some seven and one-half million acres of grain crops and pastures were sprayed at a cost of two dollars per acre. We can safely estimate that this insect pest reduced grain crop yields (wheat, barley, oats) by 25 percent where not treated. With a conservative estimate of 30 bushels per acre yield of grain and a two-dollar per bushel value for the grain protected by destroying the insect, the recommened practice of spraying for army worm control saved the State of Missouri $97,500,000 in 1953. Also, the new methods of chemical control are easy to apply and save money in labor required for application.

$1,700,000 . . .

Controlling hornflies on 850,000 head of cattle helped Missouri farmers to market an extra 8,500,000 pounds of meat valued in excess of $1,7000,000. Automatic sprayers for applying activated pyrethrins and back rubbers made from burlap bags soaked with insecticides were used to control this annoying pest. The burlap bags were wrapped around barbed wire and strung between two posts about twenty feet apart. Good hornfly control was achieved when the rubbers were located in loafing areas.

$1,000,000 . . .

A concerted war on rats has resulted in the death of one-fourth million of these destructive rodents. Each is estimated to destroy four dollars worth of feed annually. Killing 250,000 brought a one million-dollar saving. The tool—Warfarin.

Answer to Wool Problem

By simply separating and packaging fleeces by grades, Missouri wool producers could greatly increase returns, research studies reveal. In this manner domestic wool producers could approach the price paid for imported wool. Three basic principles involved would be (1) proper shearing, (2) proper packaging and (3) marketing on a graded basis. Missourians marketed $5,518,000 worth of wool in 1952. Improvements in this product are worthy of consideration.

Bring Big Returns

$50 per acre . . .

The thinning of apples with hormone sprays is a common practice which resulted from extensive Agricultural Experiment Station study. This enables (1) growth of larger, more desirable fruit and (2) control of alternate year production, to a certain extent. Less breakage of tree limbs is another advantage. The tremendous increase in charge for hand labor has resulted in abandonment of hand thinning of apples. At least $50 in these labor costs is saved per acre through hormone thinning. We cannot measure the increase in returns due to improvement in the market product, but the additional advantages likely save another $50 per acre.

Invaluable Service . . .

This past season and up to date, insect-pests survey was maintained. The survey provided information for county agents, newspapers, radios, teachers of vocational agriculture and other professional agriculturalists on the current prevalence of insect-pests. In this way, farmers could be warned to look for insects and warned of insect prevalence so that they could treat before crops were damaged. Farmers were kept advised within a few days of the economic prevalence of insects in their locality. In this manner, money was saved by avoiding unnecessary use of chemical sprays or insecticides as well as time and applications made for the control of certain insect-pests. Missouri is the only State furnishing this service. It is a cooperative effort including Missouri State Department of Agriculture, the Agricultural Experiment Station and the Agricultural Extension Service.

$750 per acre . . .

The Missouri Agricultural Experiment Station has been a leader in investigations on hormone sprays for apples. Outstanding among the hormone sprays are those designed to thin the apple population when applied during blossom time and those designed to prevent apple drop. Normally the drought and high temperatures of 1953 would have resulted in almost all apples dropping. Hormone sprays kept them on trees until harvest. Where they would have sold at $1.00 per bushel as windfalls, the crop averaged around $2.50 per bushel to the grower. Going by a conservative estimate of 500 bushels per acre, growers can realize an additional $750 per acre by applying this discovery.

$1,125,000 . . .

The control of strawberry insects and diseases, such as the tarnish plant bug, the bud weevil and leaf spot, has enabled strawberry growers to increase their yields 25 crates per acre. They not only increased their yields but also, by eliminating button berries, dead caps and similar deformities, improved the quality of their product. At $7.50 per crate the value of the additional 25 crates per acre would be $187.50. For Missouri's 6,000 acres of strawberries this means an increased return of $1,125,000.

$750 per acre . . .

Strawberry growers who have changed to the new variety, "Armore," recommended by Missouri Agricultural Experiment Station, have realized 50 to 100 crates per acre increase in yield. At $7.50 per crate, this would mean as much as $750 per acre increase in returns. This increase is over the next best variety now commonly grown in Missouri. The improvement over other varieties is even greater.

$250 per acre . . .

In fertility studies on sweet potatoes, the proper balance of fertilizers added according to soil tests resulted in a 100 bushels per acre increase in yield. This increased return was realized at a cost of $25 per acre for fertilizers. At $2.75 per bushel the return would mean an additional $275 gross per acre. Substracting the $25 for fertilizer leaves $250 net profit per acre from the soil testing practice.

$50,000,000 per year . . .

Missouri Agricultural Experiment Station has contributed materially to the development and use of hybrid seed corn. Most farmers recognize the value of planting adapted hybrid seed, but few stop to think of the immense amount of research that preceded its development. And that research in hybrid seed corn is a continuing process. Of Missouri's 1952 corn crop 97 percent, or 4,112,040 acres, was planted with hybrid seed. Planting hybrid seed corn will result in an estimated 20 percent increase in yield. Using the 1952 state average of 41 bushels per acre, 8 of these bushels could be attributed to use of hybrid seed. At $1.50 per bushel this amounts to $12 per acre or $49,344,480 in additional income to Missouri farmers.

$75,760,000 per year . . .

The use of proved sires through artificial insemination has increased milk production of daughters over dams by 1,770 pounds anually. If applied to Missouri's entire dairy industry, this practice could add 1,640,000,000 pounds of milk valued at $75,760,000. Another comparison of daughters of 1,163 sires used in artificial breeding revealed that they produced an average of 5,000 pounds more milk than the average cow in the United States.

New market for cream . . .

Through the "Cultured Cream Spread and Salad Dressing" developed by workers at the Missouri Agricultural Experiment Station a new market for several million pounds of milk, cream, and solids-not-fat has been found. This new product has many uses in preparation of various foods. Its development was to add to enjoyment of foods and add to their nutritive value, rather than to replace other food constituents.

$300 to $400 per acre . . .

A proper spray control program for the control of blackrot and other diseases and insects such as berry moth, has again made possible the production of grapes in Missouri. It now is possible to produce four tons of grapes per acre by following an adequate spray schedule. Those who have not sprayed have experienced total loss. Grapes are selling at $75 to $100 per ton. Growers realize from $300 to $400 per acre. Grapes return at least three quarters of a million dollars to Missouri growers.

Fat beef from less grain . .

In recent studies Station workers have produced 80 percent of total gains of two-year-old steers from roughage and pasture. Steers were bought as 650-pound yearlings and sold as 1,200-pound choice cattle. Only 10 to 15 bushels of corn were required to finish the steers. Under the old method 55 to 65 bushels of corn would have been required. Calves fattened and sold as 950- to 1,000-pound yearlings required 25 to 30 bushels of corn. By the old method, 45 bushels were used and only 60 percent of the calf came from roughage and pasture.

Pigs behind cattle can salvage corn at the rate of ¾ to 1½ pounds of pork per bushel of shelled corn fed to the cattle, bringing further cost reduction. This is especially true when cattle are fed on concrete or pasture. The price per bushel of corn thereby is reduced by the value of the pork.

Spectacular Advances In Weed Control

Many Sprays Have Emerged To Aid Farmers Since World War II

Grain Crops

Two, 4-D was not available for research until the end of World War II. Research began on the use of 2,4-D for weed control in corn and small grains in Missouri in 1945. As a result of this early work, it was recommended for use in 1949. As a testimonial of its value, Missouri farmers used 2,4-D on 359,000 acres of corn and 28,000 acres of small grains in 1952. In that year there were 8,000 power sprayers on Missouri farms (exclusive of those owned by commercial custom operators). Resulting increases in corn yields are not the only advantages of relatively weed-free corn. Many farmers report that the satisfaction and economy of harvesting clean corn is worth the cost of 2,4-D treatment. The greater assurance of success of crops, especially meadows and pastures planted after weed-free corn, has been a factor in stimulating the use of 2,4-D. The use of herbicides for weed control in grain crops is probably in its infancy, but already direct benefits have repaid the costs of research many times.

Brush

Since the clearing of the timber lands and the plowing of the prairies, the Missouri farmer, seldom aided with more than an axe, has been tussling with nature over the invasion of brush into his crop and pasture land. At great cost in time and effort he has only partially succeeded. As he has found ways to increase his efficiency in other fields, this periodic hand "sprouting" has become increasingly unattractive. Following research started in Missouri about 1944, farmers are now able to kill brush by aerial or surface applications. Where it is desirable to remove the growth from the land, cut stumps can be kept from resprouting by the use of chemicals. Pasture production has been increased by the use of chemical brush control on some Missouri farms.

Pastures

Weeds in pastures continue to take a large toll in productive capacity. Many pastures produce as little as 50 percent of their potential as a result of weed infestations. Mowing has been a recommended practice for combating the weed problem; now 2,4-D promises much greater efficiency in this battle.

Study Meat Products from Farm to Table

by D. E. Brady

Meat is much a part of our every conscious thought. It has been said so well, so many times that meat is a part of our way of living and that it is almost impossible to plan a meal without it. To the advertising man and the merchant who sells roasts, steaks, chops, and stew meat or the restaurant manager who uses the meat item for his main entree' there is little difference. Each capitalizes on the intrinsic qualities of the meat that appeal to the palate of his customer.

Perhaps to the busy housewife it means something in addition, particularly from the standpoint of the dollars and cents she must spend. Sometimes she can find what she wants and sometimes she cannot. Sometimes she finds meat low priced and abundant, sometimes high priced and scarce. In any case, her family meals are planned around the meat dish.

Food is America's biggest business. American farmers have the highest cash income among the world farmers. We process and eat more food than any nation in the world. Meat packing, the largest food industry, processes the most important single food product. Six percent of the disposable income or one-third of the average worker's food expenditure is normally spent for meat.

In Missouri, livestock ranks first in importance in farm income—over three-fourths (1951—77 percent) of the total farm income comes from the sale of livestock and livestock products. This source of income totaled 896 million dollars in 1951. Of this amount 616 million came from the marketing of meat animals. Missouri ranked tenth in cattle slaughter, 15th in calf slaughter, fourth in hog slaughter, and ninth in sheep and lamb slaughter.

Missouri is thus a very important meat producing state, in spite of the fact that 75 percent of the population is urban and 50 percent is in the four largest cities. Serving the people of Missouri are more than 12,000 food stores, and nearly 10,000 grocery stores. Approximately 450 frozen food locker plants and 168,000 food freezers also serve Missouri. This gives each family of four an average of about three and one-third cubic feet of frozen space. There is little zero storage space available in our large metropolitan centers. These areas are served by good frozen food distribution centers. It is in the outlying areas and rural districts, where people have the ability to buy frozen foods in quantity and store them, that better frozen food distribution is needed.

MORE RESEARCH NEEDED

There is a need for additional research to insure more effective use of our livestock and meat products, eliminate waste, and conserve the quality and nutritive value of these products thereby conserving the natural resources and taking care of the growing population.

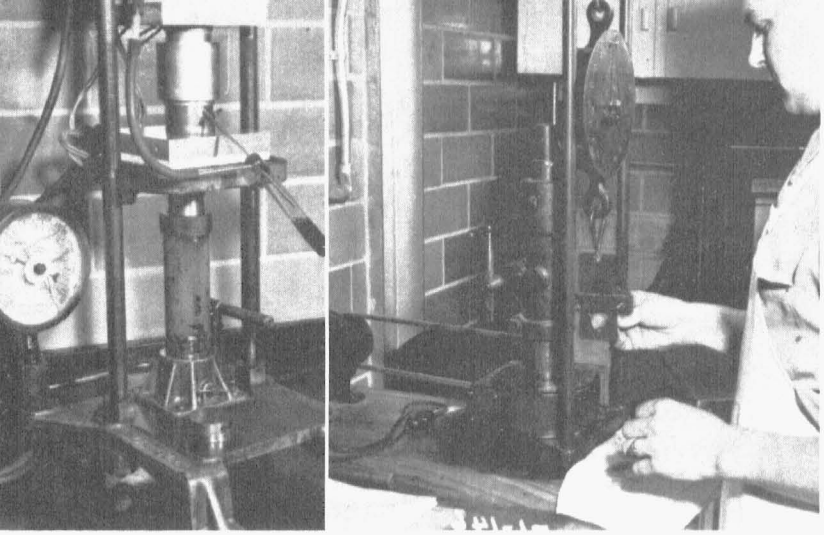
For thousands of years food was produced and consumed in the same community. Our ancestors spent most of their time seeking something to eat. Food was plain and in most cases there was seldom an abundance—when there was, little could be preserved. In the past fifty years, there has been a revolution in the handling and processing of meat and meat products. The big changes have been made in processing and distribution. Approximately two-thirds of the meat animals are produced west of the Mississippi, while more than two-thirds of the meat is consumed east of it. This picture is further complicated by the perishability of the product. Meat requires the use of extensive refrigeration facilities as well as speed in the delivery of tremendous tonnages.

Some meats are frozen, canned, and cured, yet the bulk must be sold fresh. Much of the cured product today is nearly as perishable as the fresh.

Consumer Preference Spurs Research

Consumer preference is another unstable characteristic. Changes in consumer taste and diet pre-

A valuable insight into consumer preference is developing from customer surveys. Results of one where consumers were invited to choose from this trimmed and unmarked display of commercial, good and prime beef cuts appear in an accompanying table.



University laboratory equipment for measuring juiciness (left) and tenderness (right) of meat. The latter almost duplicates chewing action when it tests the pounds required to shear cooked meat.

ference indicate the necessity of keeping pace. Thus the demand for lighter cuts of meat, and the practical disappearance of our export and retail outlets for lard have profoundly affected both the type of pork production and the method of processing.

From a long range point of view we are concerned with increasing production and efficiency of processing and distribution, but there are many short range effects that cannot be overlooked. The packer and others along the distribution line require a large volume of the product to insure adequate returns, while over-abundance has been a major worry for the farmer in the past and may well be so in the future. The search for ways to use this abundance through increased sales volume has been responsible for many revolutionary developments in the processing of meat. For example: There was no meat packing industry of any note prior to the Civil War. Demands of the armies changed this. Development of the refrigerator car made it possible to dress large quantities of meat in cities like Kansas City and St. Joseph and distribute it over a large area. Competition, sharpened by research and aggressive selling, has brought about marked improvements in processing and distribution methods, yet today the meat industry stands on the verge of a new revolution. Two wars have brought about significant changes in the eating habits of a great number of people. These changes, which have resulted in a better way of living, have come largely from the results of research at such institutions as Missouri College of Agriculture. They mean better ways of handling meat from slaughter to the table.

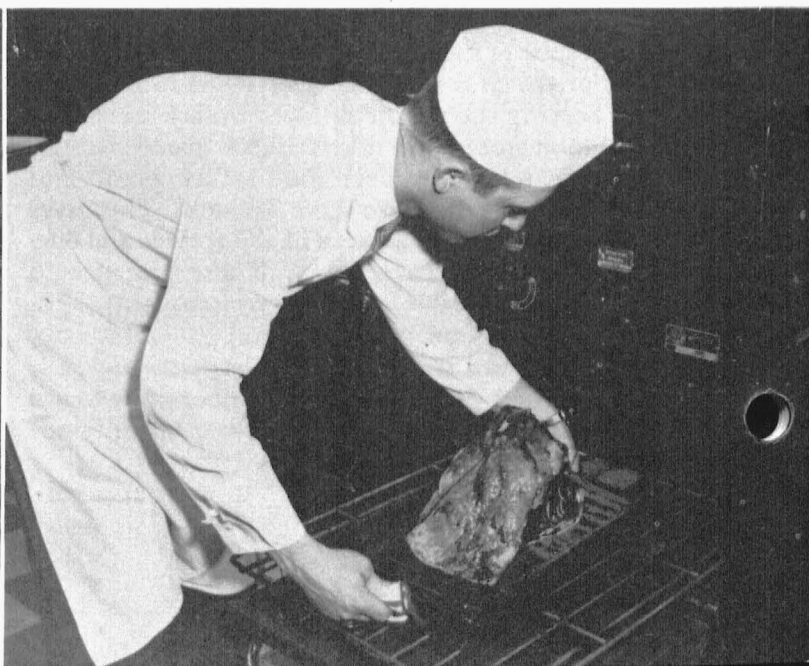
EFFICIENCY SOUGHT

Our sights must remain clearly on the future despite periodic distractions if we are to bring to the American table the quality, nutritive value, variety, and abundance which but a few decades ago were never thought possible. It has been repeatedly emphasized that the lack of a proper diet can be attributed primarily to low incomes and ignorance. Our objectives in the College of Agriculture, both from the standpoint of the Experiment Station and the Extension Service, are to find out facts on how we can more efficiently grow, process, and distribute meat and then make this information available to growers, processors, distributors, and consumers. We know, for example, that we must substantially reduce the amount of time spent in the kitchen. This means that the processor must perform many operations that have formerly been taken care of in the home.

The great problem of fatness continues to be with us. Just how fat should our cattle, hogs, and lambs be

Four cuts can be cooked simultaneously in this oven to obtain the same degree of doneness. Temperature at the center of the roast is recorded several times a minute by the apparatus at left.

A roast is shown coming out of one of the ovens ready to be subjected to other tests. Careful comparisons are kept of many University animals from feeding days until they are ready for the table.



when slaughtered to provide beef, pork, and lamb meat that is most generally acceptable? Moreover, does it suffice to view the problem as it relates to gross fatness? An experiment that was carried on by the University this past year uncovered some interesting facts about how housewives select beef roasts and steaks. Four grades of rib roasts and steaks were trimmed down to less than one-half inch of external fat, pre packaged, priced identically on a price per pound basis and placed in a self service display case. The purchasers were not informed as to what grades they were buying. Here are the results.

PERCENT OF EACH CUT SELECTED BY GRADE

GRADE	STEAKS	ROASTS
Prime	19	14
Choice	20	28
Good	28	31
Commercial	33	27

ANIMAL TYPE CHANGING

Some very significant changes have been made in hog-type, from the chuffy hog of the early 1900's and the long rangy-type of the 1920's. It is doubtful that either type met the needs of the consumer or was especially economical from the standpoint of production. We know that the consumer is interested in a minimum amount of fat—just enough to insure good eating quality—no more. This means that we must produce a type of hog with a high yield of lean meat and a minimum of fat. This is, in part, due to the fact that vegetable oils can be produced more economically than animal fats. Since 1910, when lard sold for approximately 40 percent more than the live hog, we have seen a steady decrease in the price of lard relative to the price of the market hog. On this basis, lard is worth but one-third as much today as it was in 1910 when the lard-type hog was profitable.

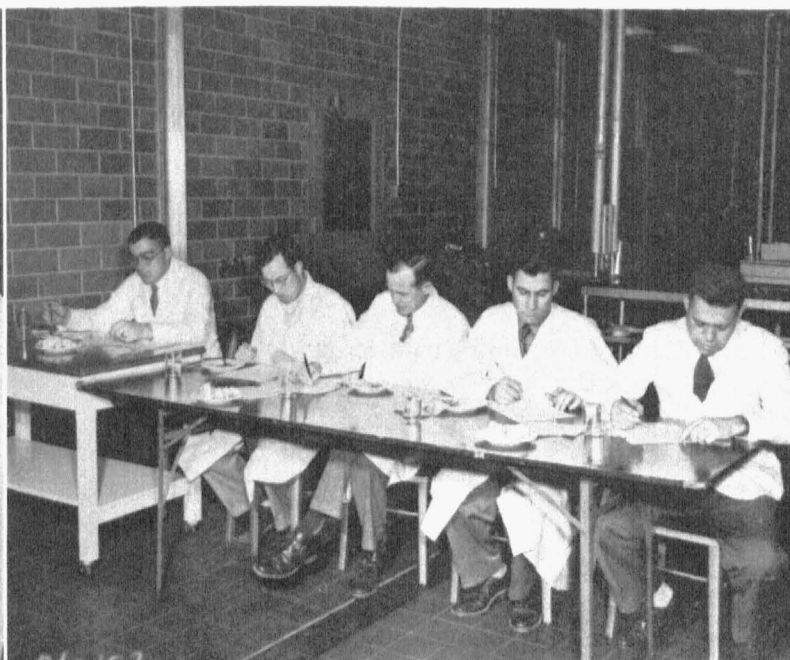
A great deal has been done in developing a leaner type hog; there is considerable more to be accomplished. From all evidence, the consumer will not compromise. The price she pays is tangible proof that cannot be overlooked. There is a type of hog that yields an end product which consumers prefer. This hog is perhaps a good deal leaner than the producer, the packer, or even the retailer may wish to believe. Just how lean, we are not prepared to state.

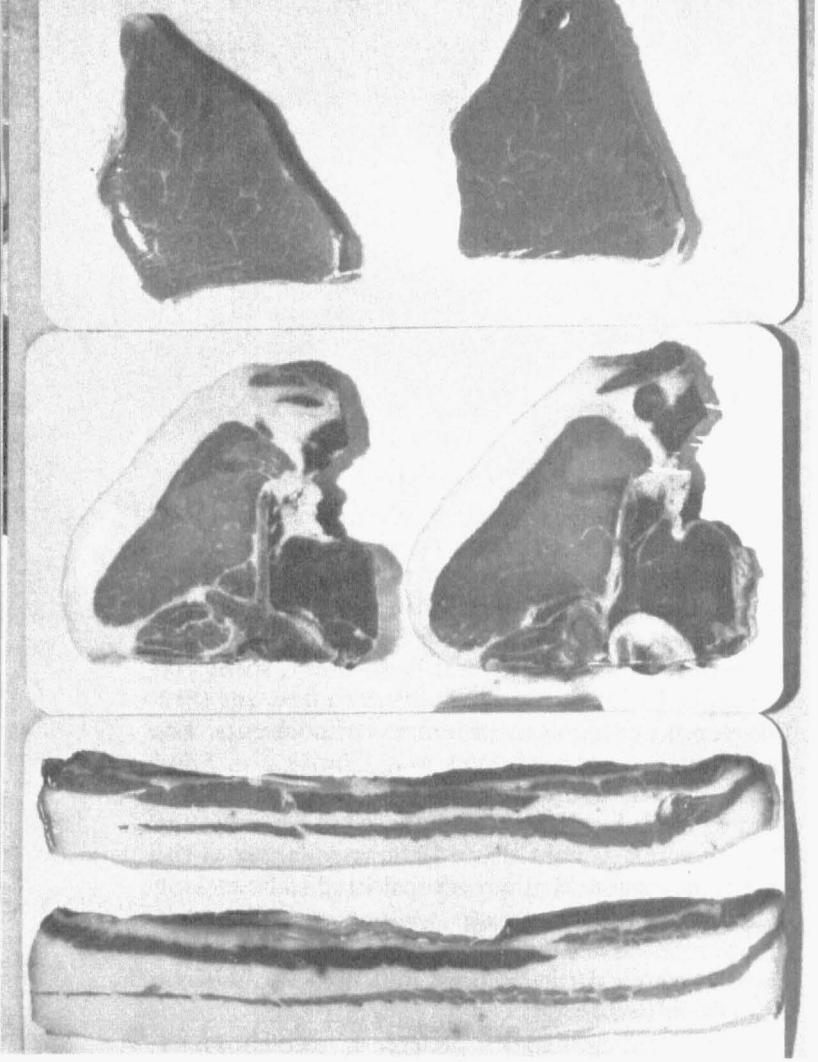
Perhaps it would be of interest to note a few of results from a survey in Columbia during the spring of 1953. From hogs produced on the University of Missouri Animal Husbandry farms, two grades of hogs were selected, slaughtered, and the meat processed. In cooperation with the departments of Home Economics and Agricultural Economics, some 400 homes in Columbia were surveyed to find out their preference in the matter of leanness of pork cuts. The two grades of pork carcasses were Choice No. 1 and Medium. The grades were determined by the thickness of back fat. It should be pointed out that the Choice No. 1 is considered to be the leanest of the three top grades. Medium is considered to be lacking in the required fatness necessary for top quality pork. Those interviewed were shown loin chops, cured and smoked center cut ham slices, and cured sliced bacon from these two groups.

After indicating their preference from the standpoint of appearance, they were given chops, ham, and bacon from each grade and asked to prepare them in their customary way and determine which of the two grades they felt tasted the best. They were not informed with regard to the grade and quality of the

Here a laboratory technician weighs a meat sample to determine the amount of shrinkage encountered in cooking. Various tests can sometimes be related back to known feeding methods and breeding.

Meat samples come up for a final test before a panel. This group is scoring beef from two systems of management involving maximum use of pasture and roughage in the fattening process.





Surprising results of a survey on preference between these Choice No. 1 and Medium pork cuts appear in the table below. Medium cuts are the ones with a hole punched in them. Fat was trimmed even so samplers could not identify grades by the fat covering.

meat except that it had not been experimented on in any way. Here is what they said.

PREFERENCE IN PERCENT

Preference based on Appearance	Choice No. 1	Medium	No Preference
Bacon	41	56	03
Chops	37	57	06
Ham	46	51	03
Preference based on Taste Test			
Bacon	41	48	11
Chops	40	44	16
Ham	33	52	15

It should be pointed out that the Medium carcasses referred to, while underfinished from the ordinary market standpoint, were not from "hard doers", but from hogs weighing 200 pounds alive that reached this weight on less than 350 pounds of feed per hundred pounds of live weight gain. In other words, these were hogs which, through improved breeding, feeding, and management, can with a minimum of fat satisfy the taste of today's meat eaters. It is true that many of the carcasses and cuts lacked the firmness which is generally considered to indicate the highest degree of quality. Some of the bellies also lacked the thickness which might be considered desirable. Nevertheless, they produced meat which was equal if not superior to that from the Choice No. 1 grade.

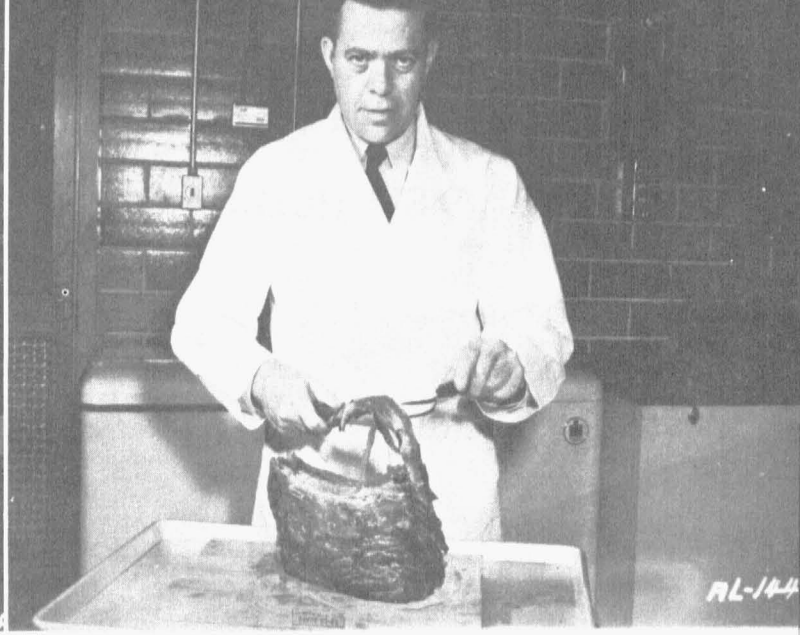
Additional information is needed on other economic considerations, such as cooler shrink, drip after defrosting, curing, and on smokehouse yields and other characteristics affecting processing before the whole story can be told. Plans include investigating this phase of the problem during the coming year. Information of this nature will be invaluable in arriving at a more adequate evaluation of carcasses of varying degrees of finish. In the final analysis the sales price of the live hog must be closely related to the yield, cut out, and adaptability of the cuts to various methods of handling.

Methods of feeding and management also have a pronounced effect on the quality of beef. The Missouri Agricultural Experiment Station has been concerned with improved pasture and forage utilization since this offers a means by which the total production of meat may be increased. We have been concerned lest the winter ration should be kept so low in nutrients in order to secure economical gains that the quality of the beef is adversely affected. Work now being completed indicates that the full potential quality of the beef may never be realized under some conditions.

There are other problems, related to the perishability of meat. They are more apparent with an increase in prepackaged meat sales. Twenty percent of the meat is estimated to be prepackaged. Work completed during the past two years indicates most products maintain a high degree of freshness, where reasonable precautions are used in obtaining a regular turnover and maintaining the desired temperatures. Occasional samples have been found which leave room for improvement. The maintenance of a high degree of sanitation with meat cutting tables, blocks, and other equipment is essential to low microbial counts. Improved methods of caring for this equipment have been developed at the Missouri Station during the last year.

Rancidity is a serious problem in frozen meats. This is especially true of pork. The packer freezes fresh bellies and hams during periods of heavy slaughter for later curing. Cured pork is susceptible to rancidity. Farm families also store much frozen pork in their

This is a view of the University of Missouri research laboratory where studies are conducted on factors causing meat spoilage. Work is done on fresh, frozen, cured and dehydrated meat.



Daniel E. Brady, professor of animal husbandry, who contributed this report, is shown carving one of his sample roasts. Prof. Brady heads carcass and meat phases of U. of M. livestock experiments.

freezer lockers and home freezers. This meat also is quite susceptible to rancidity. Work is under way to increase the storage life of this pork by the addition of suitable antioxidants. These materials, according to present indications, are effective to a limited extent in prolonging the storage life.

One research project, carried on cooperatively with the Agricultural Chemistry Department, is concerned with the fundamental changes which occur in dehydrated meat and with development of methods of controlling these undesirable changes. The immediate practical importance of this project is related to military needs. A solution to the problem would not only assist in the formulation of more suitable ration items, but would provide much useful information on the mechanism of "browning."

Study Three Meat Problems

Thus it can be said that the work of the meat section of the Animal Husbandry Department is concerned with the following problems of importance to Missouri Agriculture.

1. Determining consumer preferences for grades and weights of carcasses and cuts especially as they relate to the amount and distribution of fat.
2. Evaluating carcasses and cuts of beef, lamb, and pork as they are affected by various systems of feeding, breeding, and management.
3. Conserving the palatability of fresh, frozen, cured and dehydrated meats. This refers to the physical, chemical, and microbiological changes occuring in meat and meat products and methods for controlling these changes.

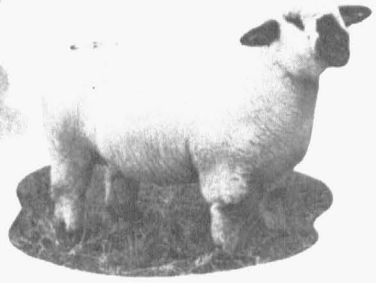
Research means little, however, if it is not made available to the public. In the main, the Missouri Agricultural Extension Service has this responsibility. During 1953 a number of new activities were initiated to aid in the dissemination of this information. These included meat merchandising schools for industrial groups, educational demonstrations on meat for consumer groups, training schools for trade groups and education work with such groups as 4-H Clubs and F. F. A.

RUMENOLOGY

THE FARM RUMINANTS.....

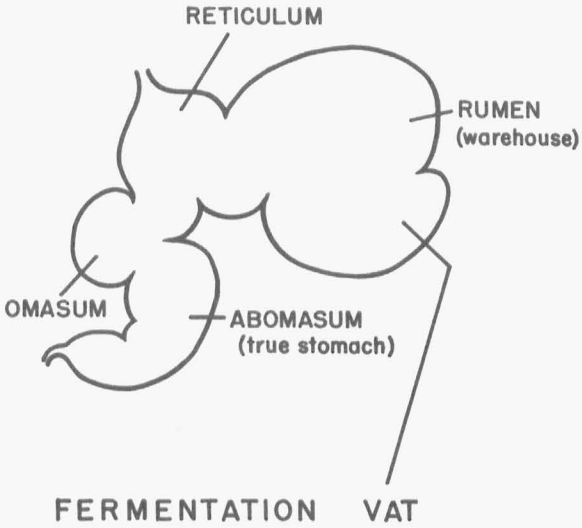
.....HAVE FOUR STOMACHS

BEEF CATTLE

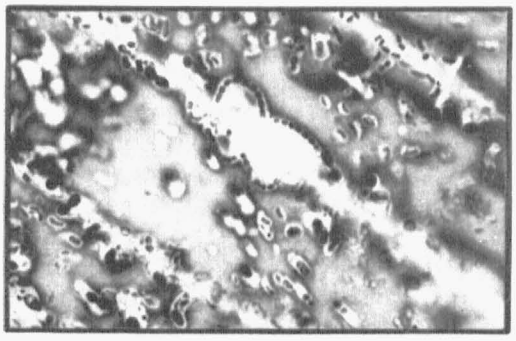


SHEEP

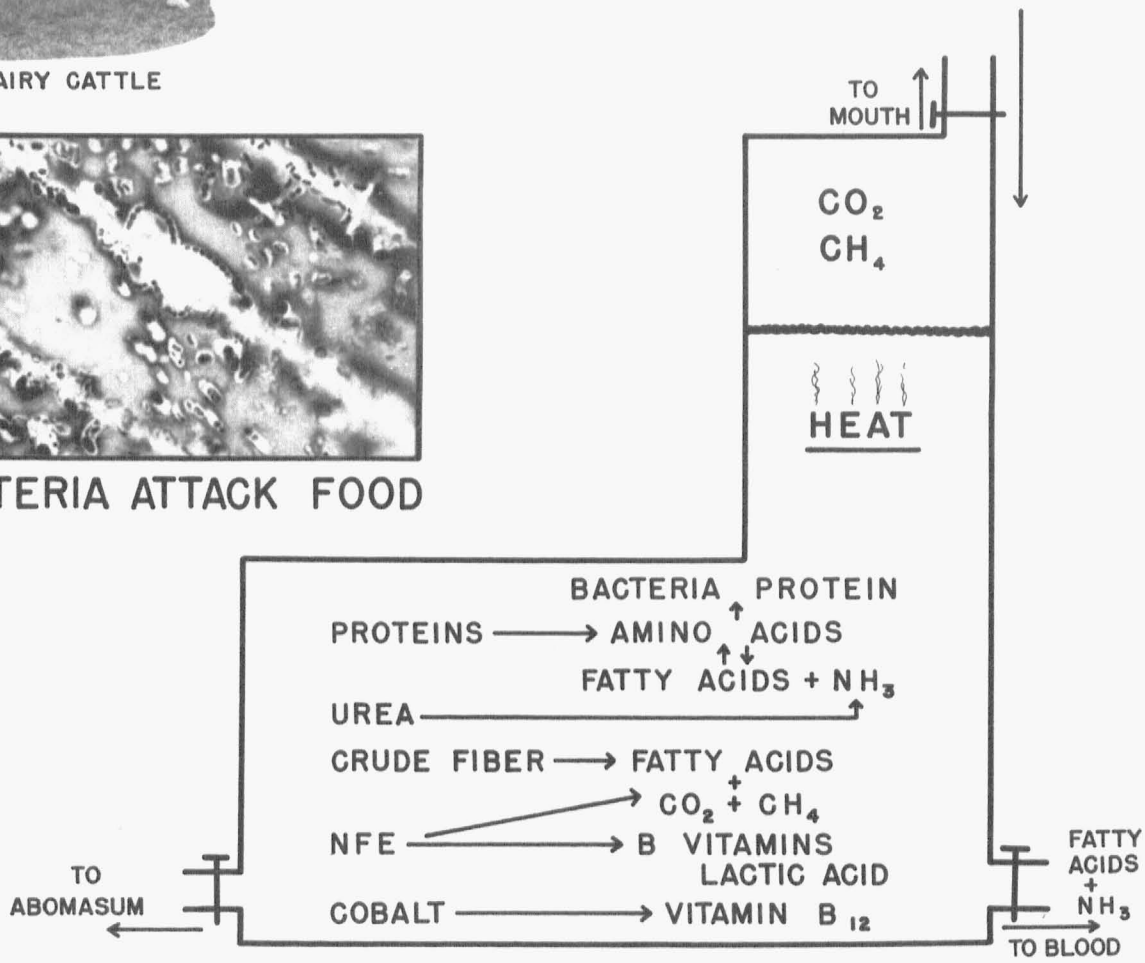
DAIRY CATTLE



FERMENTATION VAT



BACTERIA ATTACK FOOD



As farmers prepare to face the winter feeding period with a shortage of good feed, and in some cases with no feed, it is fortunate that research workers of the past have been able to lay down some basic principles concerning the utilization of roughages by ruminants.

Most of our present knowledge has been obtained because some investigator became interested in the life processes of ruminants and made further observations. Investigations in progress may appear to some people to be entirely useless and to represent the dreaming of an impractical doddler pondering away in his ivory tower at the University. But this generation may, and the next generation will, apply the results of current research. It should be remembered that any information which can be obtained about the basic nature of the life processes of ruminants (sheep, cattle) may some day be an important factor in increasing the efficiency of utilization of the products of American Agriculture. German workers in 1879 showed that ruminants could utilize non-protein nitrogen sources such as urea. It was not until the second World War reduced the supply of protein supplements that research workers in the United States and Great Britain made practical applications of this finding. They used urea to replace part of the protein in ruminant rations.

Ruminants often are the basis of important farm enterprises. Pasture farming is recognized as a must in efficient meat and milk production. Ruminants are ideally constructed for the utilization of the products of pasture farming. They carry in their first stomach or rumen the bacteria and chemicals needed to break down the complex carbohydrates found in coarse hays and fodders. Today most of our best farmers try to obtain maximum growth and production from their ruminants by feeding the best roughages and the best concentrates available. Many of these products could be used as food for man.

More Food From Fewer Acres

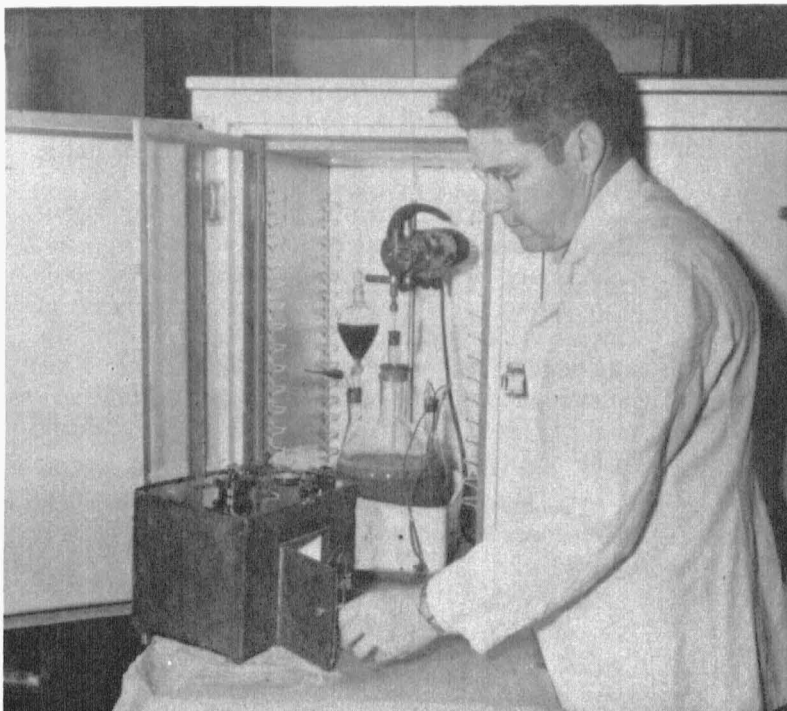
A 25 to 30 percent increase in population of the United States is expected within 20 years. A corresponding increase will occur in the requirements for food—food which will have to be produced on fewer acres. Land is being taken from agricultural production by the growth of suburban areas and by the dams which inundate fertile river valleys. Advances in technology, better varieties of crops, and heavy application of fertilizer will help meet the additional need for food. Each year, however, drought, insects and poor harvest weather combine to produce large amounts of low grade roughage. Eventually all of the United States may be faced with the problem of a roughage deficiency. It then will be necessary to determine ways to help ruminants utilize all the coarse materials which are higher in cellulose and are commonly referred to as "agricultural waste."

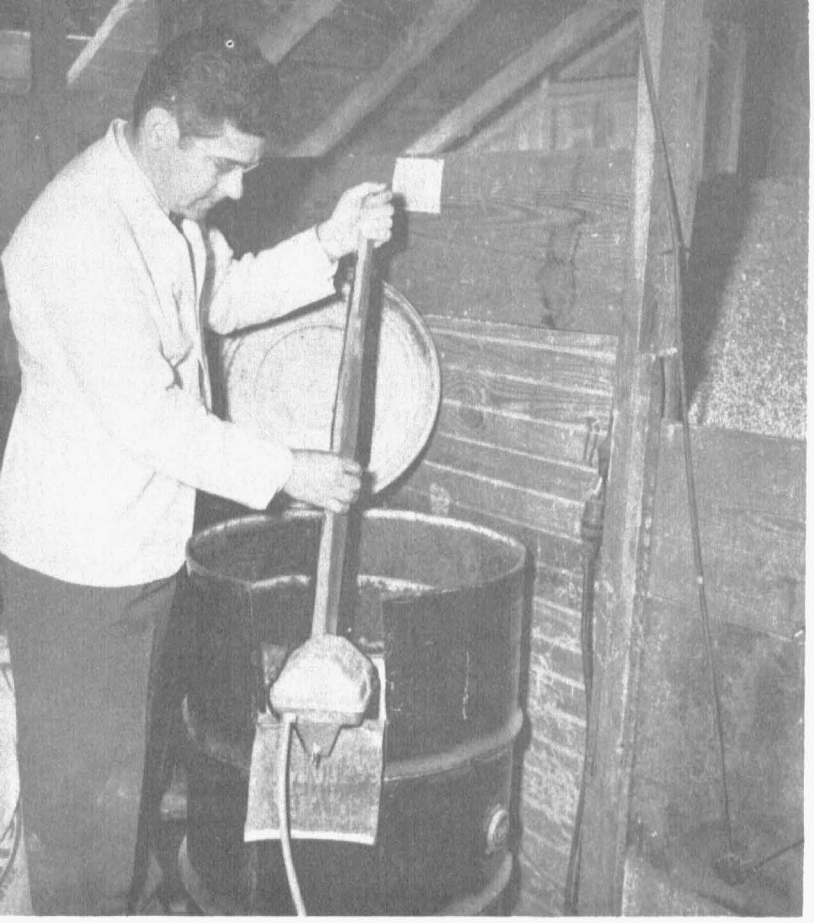
Thus, basic research on the ruminant is becoming increasingly important. Most of the principles which can be used in attacking a problem on ruminant nutrition are similar to those which have been laid down by nutritionists working in related fields. Usually the first step in a nutritional investigation is to purify the ingredients to be used in the study and to obtain as accurate an analysis as possible on the components of the ration. By feeding purified components it is possible to determine the requirements of the animal for individual nutrients. After the requirements for each individual nutrient are determined, rations which are believed to contain the correct proportions of each nutrient are formulated and the performance of animals fed these rations is compared to the performance of other animals fed good practical rations. The outstanding feature of such work is that the study goes from the simple or purified product to the complex product.

Use "Pilot" Artificial Rumen

Ruminants have one of the most complex ecological systems known. Any mammal is a complicated machine with many different types of cells and tissues and with several coordinating systems. As an added complication, ruminants contain large populations of micro-flora and micro-fauna in their rumens. Several hundred species of bacteria have been identified in the rumens of sheep and cattle. The investigation of

Merle E. Muhrer, professor of agricultural chemistry, checks the pH of a laboratory artificial rumen. Though results must be checked in animals, the artificial rumen often saves months of live testing.





This is a large artificial rumen designed to pre-digest feed before giving it to animals. Some advantage has been found on non-rumen test animals by furnishing them this artificial rumen processed feed.

nutritive requirements of ruminants is difficult. It takes large amounts of purified ingredients, costly feeds, and much labor to feed and care for the animals. However, we can borrow from the methods used by nutritionists and engineers and use pilot animals or pilot experiments.

Early German workers often used rabbits and guinea pigs as pilot animals for determining feeds to use in ruminants. While the guinea pig and rabbit are herbivorous animals they do not have a population of bacteria living in the foregut which will allow maximum fermentation of the ingested carbohydrates. Recently the artificial rumen has become a prominent "test pilot" for checking nutritional problems in the ruminant.

The artificial rumen has the great advantage of allowing an approximate duplication of the acid, air, light, water, heat and mixing conditions that occur in the rumen. It is simple to operate, inexpensive in comparison to studies on the ruminant, and results may be obtained much more rapidly. One can often get as much information in a week by using the artificial rumen as is possible to get in several months in the ruminant.

While the artificial rumen will often give clues or point the direction of future research, it is necessary to check in the ruminant those compounds which are found to produce favorable results in the artificial rumen. Some compounds which fail to work in the artificial rumen may work if supplied to the ruminant, and some compounds give the opposite results. Sheep are useful experimental animals because they do not require large amounts of feed and are easier to manage than cattle.

Put "Window" In Animals

Another useful technique is that of surgically opening certain parts of the digestive tract and inserting a fistula or window.[1] Through the fistula the investigator can introduce feed or chemicals, withdraw samples, or make direct observations. The accompanying pictures show a ewe which was fistulated in the fall of 1952.

There are many advantages of having an animal with a fistula in the rumen. Samples for analysis can be removed from the rumen without danger of contamination by saliva, and without greatly disturbing the sheep. It is possible to remove a sample from a fistulated cow while she goes right on chewing her cud. It often is desirable to introduce substances into the rumen which it might be difficult to get sheep to eat. It is easy to put any desired compound into the rumen by opening the fistula.

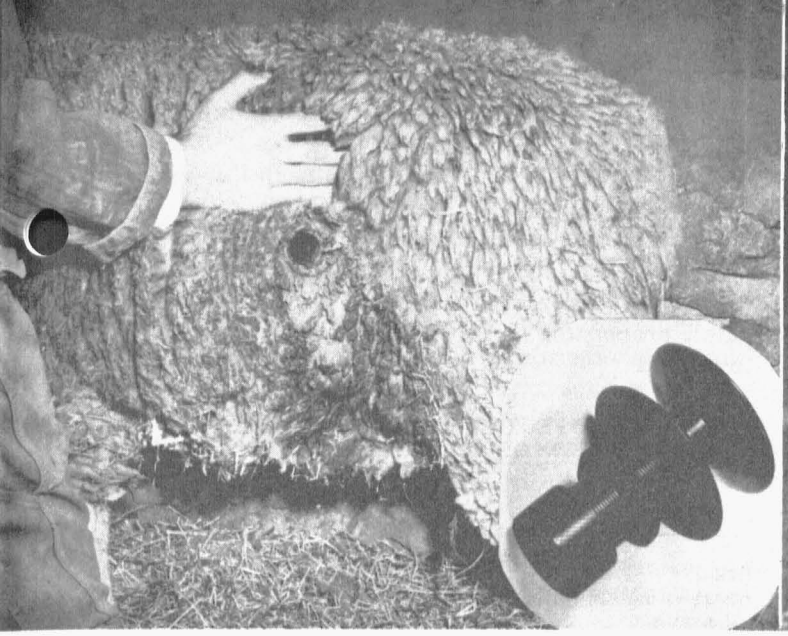
With several animals fitted with fistula into the digestion tract, we have studied cellulose digestion and the digestive disturbances bloat, ketosis and chronic digestion.

Another aid is inserting tubes into other parts of the digestive tract and into the blood stream to obtain samples of body fluids under different conditions.

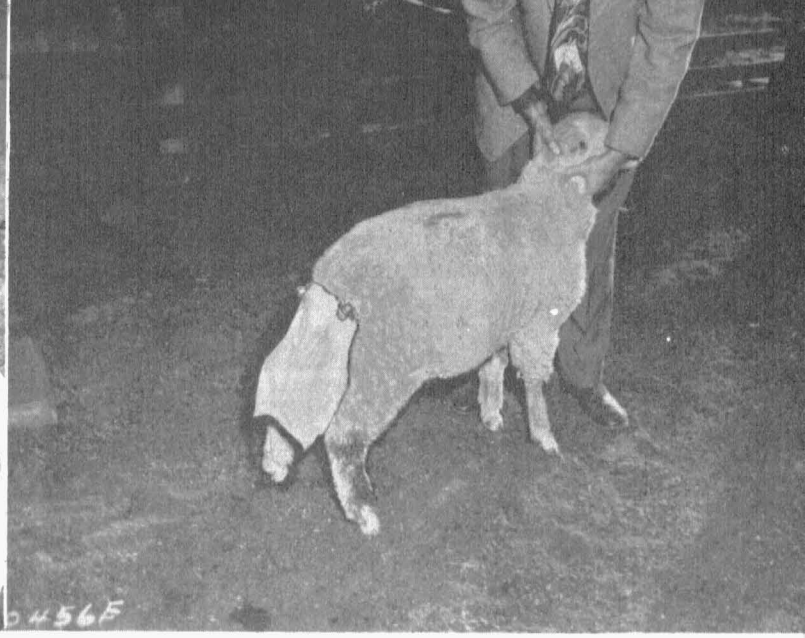
Past research, using some or all of the techniques outlined above, has revealed many interesting things about ruminant animals. It has been found: that bacteria living in the rumen ferment cellulose and produce fatty acids, methane and carbon dioxide; that the bacteria grow and use breakdown products from feed protein; and that they are able to get part of the nitrogen for growth from the non-protein nitrogen compounds of the feed. Common sources of non-protein nitrogen are *urea* and *ammoniated compounds.* The bacteria also produce B vitamins in adequate amounts to meet the requirements of the ruminant.

To obtain proper function in the rumen, the feed must contain, in balanced amounts, a quick source of energy; a readily available protein; and adequate minerals, especially phosphorus, iron, cobalt, potassium, sodium and chloride. Good legume pasture provides all the needs of the rumen bacteria. For winter feeding, efforts are made to duplicate the composition of pas-

[1]The fistula were installed by Dr. E. F. Ebert and associates in the School of Veterinary Medicine department of Veterinary Medicine and Surgery.



Feeds can be inserted directly into the rumen and samples extracted for bacteria digestion studies through opening made to the rumen of this sheep. The insert shows a close-up of the fistula seal.



A poultry freezer bag is being used here for fecal collection. Excreta as well as the intake must be analyzed in many feeding trials for complete interpretation of the results.

ture. The energy needs are supplied by grain, molasses, or sugar; the protein by good hay, oil meals or urea. Legume hay, bonemeal, and complex mineral mixtures supply the mineral. Our experiments are designed to determine the fundamental needs of rumen microorganisms living in the animal, in the test tube, or in pre-digesters.

Rumen Synthesizes Vitamins

The ruminant is superior to the non-ruminant with respect to digestion of high fiber feeds, utilization of non-protein nitrogen and synthesis of vitamins. In our research efforts we are attempting to find out how the ruminant and its symbiotic bacteria are able to perform these things so that we can establish conditions that will lead to maximum efficiency of physiological functions, for the benefit of the ruminant. Once we discover how the ruminant is able to digest cellulose as well as synthesize proteins and vitamins from less valuable substances, perhaps we can do these things in an artificial rumen for the benefit of other animals. It is possible that the products of the artificial rumen could be fed to the less efficient, non-ruminant. Thus, we could do for the pig and the chicken what the cow and sheep do for themselves.

An artificial rumen large enough to pre-ruminate feed for swine and chickens has been set up at the Missouri Agricultural Experiment Station. Feed high in fiber, low in proteins and B vitamins but containing urea has been fermented in this artificial rumen and fed to swine and chickens. In each case this fermented feed proved to be superior to the non-fermented ration.

TABLE 1 -- EFFECT OF FERMENTING RATION IN ARTIFICIAL RUMEN ON RATE AND EFFICIENCY OF GAIN IN SWINE

Treatment of Ration	No. of Pigs	Rate of Gain (lb./day)	Pounds of Feed (100 lb. gain)
No treatment	20	.91	507
Pre-ruminated	24	1.17	403

The results given in Table 1 were obtained over a period of two years, representing four separate feeding trials. In each trial the fermented feed was superior to the non-fermented feed. These results indicate that it is possible to improve a ration for a non-ruminant by predigesting it in an artificial rumen. Therefore, our knowledge of ruminant nutrition may some day be used to advantage in feeding non-ruminants more efficiently.

Recent investigations at the Missouri Agricultural Experiment Station have shown that cellulose digestion can be influenced by a number of compounds not previously known to influence the feed value of rations. A basal ration of cottonseed hulls, casein, and minerals which had been tested in an artificial rumen was supplemented with Vitamin A, and fed to sheep. After the sheep had been on the ration for 20 days, a four day collection period was used to determine the digestibility of cellulose and crude protein by the chromic oxide reference method. At the end of the period a sample of rumen contents was obtained and analyzed for the content of volatile fatty acids and the bacteria count.

Supplement Effects on Rumen

After studies on the basal ration were completed, groups of sheep were given supplements of (1) corn

oil, (2) lard, (3) ash from alfalfa grown on these types of soil, (4) molasses, and (5) Stilbestrol. The effect of the supplements on digestion of cellulose and protein, the volatile fatty acids produced, and the bacteria per gram of rumen contents is shown in Tables 2, 3, and 4.[2]

TABLE 2 -- EFFECT OF SOURCES AND LEVELS OF ENERGY SUPPLEMENTS ON THE DIGESTION OF CELLULOSE AND PROTEIN BY SHEEP; ON THE BACTERIA PRESENT AND THE VOLATILE FATTY ACIDS PRODUCED

	% Cellulose Digested	% Protein Digested	No. Bacteria Per Gm. x 109	Volatile Fatty Acids Produced
				Mg %
1. Basal ration	42.5	37.1	21	3.5
2. Basal + 3% corn oil	27.5	30.5	19	---
3. Basal + 6% corn oil	12.5	24.1	20	---
4. Basal + 3% lard	26.6	37.0	20	3.2
5. Basal + 6% lard	24.0	26.5	19	2.4
6. Basal + 6.3% molasses	46.6	37.7	24	3.8
7. Basal + 12% molasses	41.7	28.7	24	---

The addition of lard or corn oil to the basal ration depressed cellulose digestion and volatile fatty acid production. The rumen contents of the sheep fed 6 percent corn oil resembled calf scours. When allowed to stand in a graduate cylinder for 48 hours a layer of fat was observed. The fat did not cause a decrease in total bacteria, but there was a decrease in the number of small cocci (cellulose digesters) and an increase in the number of small rods.

When 6.3 percent molasses was added to the ration there was a slight increase in cellulose digested and in the bacteria present. Twelve percent of molasses lowered the digestibility of protein and did not increase the digestion of cellulose. Other workers have reported similar results.

Some presently unrecognized mineral or combination of minerals in the ash of alfalfa from fertile soil was found to increase the digestion of cellulose.

TABLE 3 -- EFFECT OF ASH OF ALFALFA FROM THREE TYPES OF SOIL ON DIGESTION OF CELLULOSE BY SHEEP

	% Cell Digested	Percent Protein Digested	No. Bacteria x 109	VFA Prod.
				Mg %
Basal Ration	42.5	37.1	21	3.5
Basal + ash from alfalfa grown on Sarpy fine sandy loam	46.4	39.2	29	5.7
Basal + ash from alfalfa grown on Knox silt loam-complete fert.	44.3	----	26	4.1
Basal + ash from alfalfa grown on Hagerstown silt loam treated with lime.	42.5	37.2	22	3.9

Apparently the same mineral or combination of minerals in ash from alfalfa grown on fertile soil stimulates the growth of rumen bacteria and causes them to digest more cellulose and produce more volatile fatty acids.

Stibestrol increased digestion of cellulose in the artificial rumen, and for a time in sheep, but the condition of the experimental sheep revealed that a compound may not be desirable in the ration just because it increases digestion. This sheep was close to death before proper treatment was used to bring him back to normal.

TABLE 4 -- EFFECT OF DIETHYL STILBESTROL ON DIGESTION OF CELLULOSE BY SHEEP

Ration	% Cellulose Digested	VFA Prod.
		Mg %
Basal	42.5	3.5
Basal + 10 PPM Stilbestrol 1 month	44.3	3.9
Basal + 20 PPM Stilbestrol 2 months	Sheep refused food	3.3

The study on factors which influence cellulose digestion can be summarized as follows:

(1) Corn oil or lard should not be added to high fiber maintenance rations of ruminants. It may be possible to feed fat to ruminants if it is not fed with the roughage or if it is fed to fattening animals.

(2) Diethyl stilbestrol (10 PPM) will increase cellulose digestion and overcome some of the depressing effects of fat, but cannot be tolerated by sheep for more than 4 to 6 weeks.

(3) The ash of alfalfa grown on fertile soil contains some substance or combination of substances which stimulate microorganisms to ferment cellulose and produce high levels of volatile fatty acids. The ash will prevent part of the depressing effect caused by 6 percent fat in the ration.

(4) The readily available energy requirement of the cellluose digesting organisms appears to be met by the addition of 6.3 percent molasses to a cottonseed hull ration.

(5) Factors which cause an increase in the number of rumen bacteria may not increase cellulose digestion.

One factor which often is overlooked in current ruminant feeding experiments is that readily available nutrients may be much more than total nutrients in establishing a good working group of bacteria for a ration. Research has shown that certain coarse hays may contain fairly satisfactory amounts of trace minerals and nitrogen but, due to their high degree of lignification, the bacteria are not able to utilize the compounds for their own growth and, as a result, cellulose is not well digested. On some of these coarse hays the animal actually may become deficient in some of the important minerals, although the roughage would appear to contain adequate amounts when considered in terms of chemical analyses.

[2]Chemical analyses for cellulose, protein, and chromic oxide were run in the Experiment Station analytical laboratory under the direction of Dr. C. W. Gehrke.

Investigations using the animals with fistulae revealed that when juice pressed from clover or alfalfa was placed in the rumen the animal bloated very rapidly. This suggested that the juices contained a material which prevented the proper functioning of the muscles of the wall of the rumen in forcing out excess gas or that some of the juice contained materials which caused very rapid fermentation, resulting in the production of a great excess of gas. A sample of rumen contents taken from a heifer with chronic bloat was found to contain an organism which rapidly produced a very foul smelling gas.

Two Phases Research Vital

One of the great needs of the United States is for more basic research. European countries have furnished a majority of the basic observations in the field of nutrition. Americans have been adept in applying the results of European research. It would seem very appropriate that America begin to build a stockpile of basic information and to train more agricultural scientists in the basic techniques which are needed for the complete study of ruminant physiology and nutrition.

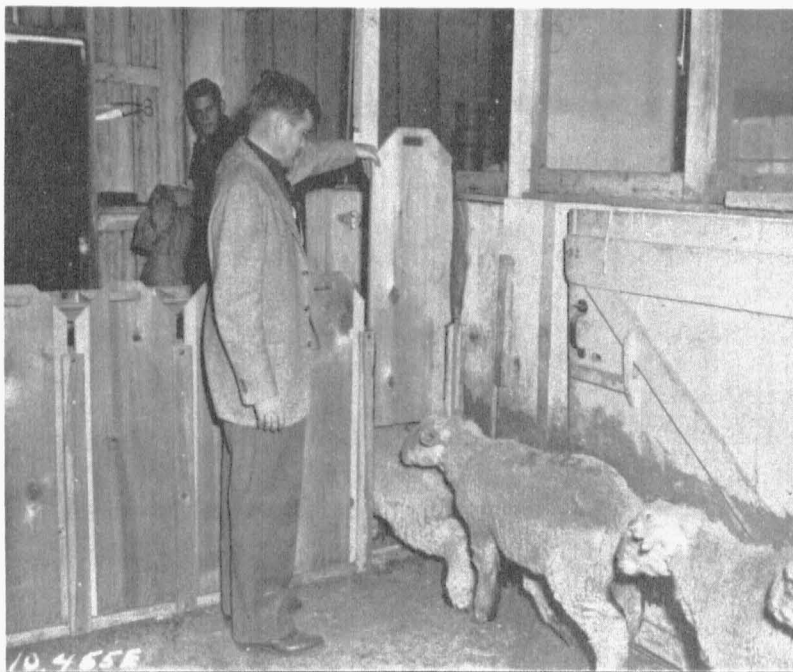
Attempting to forecast the trends of future work is always a difficult task. But a few signposts indicate that a great deal of research definitely needs to be done in at least two general areas.

1. Certainly, the artificial rumen will continue to be a very popular tool in studying micro-biological aspects of ruminology. We need to know which organisms are important; what they do; and how they are effected by various changes in rations. More pure cultures must be obtained and the behavior of each organism worked out. After the organization and behavior of the different organisms is known, mixed cultures can be prepared similar to those which exist in the rumen, and the associative effects of the various organisms can be determined.

Basic information obtained from the artificial rumen can be used to predict the changes which should take place when animal feeding is changed from grass to drylot or vice versa, and will allow us to control the desirable features of fermentation and to eliminate undesirable products which cause digestive disturbances.

2. Work on the ruminant itself must be directed toward determining the changes in the levels of various substances in the blood and tissues—changes which are brought about by changing the feed of the animal or by changing the microorganism population present in the rumen. It will be necessary to observe the physiological reaction of animals when they are given various substances which have produced an effect in the artificial rumen, and to identify and learn the physiology of the organisms that are found normally in the rumen. The results will be applied to establish production performance on winter feed at the same level as that obtained by grazing animals on the best pastures available. The final result should be an increase in efficiency and in the rate of gains in the ruminant fed coarse roughage—an increase in production which will result from the utilization of waste products changed into meat and other products by ruminant animals.

Fifty years ago, nutritionists were studying the performances of animals fed combination of minerals, protein, and fat, and investigating the value of feeds and seeds from different plants. They found that purified or single ingredient products could not support growth or, in most cases, life. Continued investigations, started about 1900, and spread over the past 50 years, have developed basic concepts, isolated and synthesized chemical compounds, and developed the vitamin story as we know it today. Knowledge of vitamin nutrition has been an important factor in obtaining increased efficiency and faster rates of gain in swine and broiler rations. It is possible that we are at the beginning of a period of rumen research that will revolutionize the feeding of ruminants, as vitamin research has changed poultry and swine feeding practices.



Sheep are pictured entering feeding crates on the Experiment Station feeding floor. Sheep are used on many of the rumen investigations because they are easier to handle than larger animals.

FUNDS AVAILABLE TO EXPERIMENT STATIONS FOR THE YEAR ENDED JUNE 30, 1952

State Appropriations, State Funds other than Appropriated, Federal Funds, and the Total Funds for Agricultural Experiment Stations, Fiscal Year 1951-52 (1)

	State Appropriations $	Endowments, Grants, Fees, Sales, Misc. $	Federal Funds * $	Total $	Rank
California	4,946,535.81	331,429.62	322,777.15	5,600,742.58	1
New York	3,212,932.52	452,646.50	390,225.23	4,055,804.25	2
Florida	2,307,021.00	749,643.93	226,728.98	3,283,393.91	3
Texas	1,230,010.00	1,397,684.62	505,589.70	3,133,284.32	4
Wisconsin	1,448,547.00	1,085,609.00	335,013.02	2,869,169.02	5
Iowa	1,080,000.00	1,152,703.85	339,980.29	2,572,684.14	6
Illinois	1,510,468.68	577,570.77	350,211.82	2,438,251.27	7
Minnesota	1,412,843.83	642,322.77	313,501.57	2,368,668.17	8
Indiana	979,042.50	1,310,510.45	345,333.02	2,289,552.95	9
Washington	1,501,279.41	357,345.12	279,985.46	2,138,609.99	10
Oregon	1,272,748.40	553,756.75	220,162.73	2,046,667.88	11
Ohio	1,211,844.12	242,766.83	413,019.30	1,867,630.25	12
North Carolina	1,168,731.51	241,350.79	424,200.46	1,834,282.76	13
Michigan	1,048,245.49	273,536.78	365,100.37	1,686,882.64	14
Alabama	673,385.00	672,896.35	340,159.12	1,686,440.47	15
Louisiana	1,297,464.59	105,645.51	268,493.96	1,671,604.06	16
Mississippi	673,916.70	606,311.46	373,117.57	1,653,345.73	17
Oklahoma	847,394.00	472,862.23	265,325.67	1,585,581.90	18
Pennsylvania	706,047.00	382,647.34	427,367.39	1,516,061.73	19
New Jersey	863,897.69	405,403.71	203,210.19	1,472,511.59	20
Nebraska	567,685.44	605,716.73	212,560.06	1,385,962.23	21
Kansas	805,570.00	318,778.50	245,021.55	1,369,370.05	22
MISSOURI	238,041.61	718,679.79	299,348.01	1,256,069.41	23
Virginia	806,552.74	92,634.12	315,912.57	1,215,099.43	24
South Carolina	449,394.80	279,686.74	285,890.88	1,014,972.42	25
Montana	458,300.87	362,330.70	184,086.68	1,004,718.25	26
Georgia	362,178.00	233,537.39	389,415.90	985,131.29	27
Tennessee	310,057.12	302,072.67	341,520.40	953,650.19	28
Connecticut	644,994.20	115,247.28	177,803.95	938,045.43	29
Arkansas	361,236.45	253,066.75	289,263.04	903,566.24	30
Kentucky	257,021.68	334,203.22	310,021.69	901,246.59	31
North Dakota	496,733.94	196,826.86	172,574.09	866,134.89	32
Colorado	316,073.19	298,777.88	212,128.71	826,979.78	33
Idaho	505,375.99	142,718.32	164,017.27	812,111.58	34
Utah	356,000.00	201,657.98	186,058.51	743,716.49	35
Maryland	330,932.27	204,344.10	205,696.85	740,973.22	36
West Virginia	227,812.00	193,385.91	293,691.08	714,888.99	37
Massachusetts	442,213.45	47,778.17	180,941.40	670,933.02	38
South Dakota	269,073.00	171,993.39	186,472.07	627,538.46	39
Arizona	333,626.41	89,230.76	164,665.08	585,522.25	40
Wyoming	308,623.36	121,680.96	147,340.12	577,644.44	41
New Mexico	290,950.00	65,881.46	165,693.00	522,524.46	42
Maine	215,707.00	44,514.54	185,348.03	445,569.57	43
Delaware	141,417.21	158,832.53	126,572.30	426,822.04	44
Rhode Island	60,208.07	39,348.08	151,370.99	250,927.14	45
Vermont	75,173.80	21,866.18	144,833.59	241,873.57	46
New Hampshire	59,512.56	6,381.97	135,533.11	201,327.64	47
Nevada	36,756.99	35,079.49	123,687.86	195,524.34	48

*Carry-over has been removed.

(1) Report on the Agricultural Experiment Stations, 1952 OES January 1953.