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RESULTS OF FIELD CROP, SHELTERBELT, AND ORCHARD INVESTIGATIONS AT THE UNITED STATES DRY LAND FIELD STATION, ARDMORE, S. DAK., 1911–32

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INTRODUCTION

The United States Dry Land Field Station at Ardmore, S. Dak., was established for the purpose of studying the possibilities and the limitations of crop production in the area that it represented. This area includes southwestern South Dakota, northwestern Nebraska, and east-central Wyoming. Ardmore is one of a group of 24 stations at which the Division of Dry Land Agriculture of the Bureau of Plant Industry has studied crop production in the Great Plains.

Work started at the station in 1911 with the breaking of prairie sod. Crop-rotation work was continuous from 1912 to 1932, inclusive. Work with dairy cattle, beef cattle, and hogs was inaugurated in 1917 for the purpose of determining the best methods of utilizing home-grown feeds. Shelterbelt investigations for the purpose of determining the species of trees and methods of planting and care suitable for the section were started in 1917. Fruit trees were planted at different times from 1917 on, to determine varieties that were suited to the conditions they must endure. Cooperative work with other divisions of the Bureau of Plant Industry was carried on for the purpose of determining the varieties of grains and forage crops best adapted to the section.

The results of all the work at the station to and including the year 1925 appear in an earlier publication.[1]

[1] COLE, J. S., KELSO, F. L., RUSSELL, E. Z., SHEPHERD, J. B., STUART, D., and GRAVES, R. R. WORK OF THE UNITED STATES DRY-LAND FIELD STATION, ARDMORE, S. DAK., 1912 TO 1925. U. S. Dept. Agr. Tech. Bull. 17. 68 p., illus. 1927. For sale by Superintendent of Documents, Washington, D. C., price 15 cents.

Reduced appropriations compelled the Bureaus of Plant Industry and Dairy Industry to close their work at the station in 1932. The present circular gives the results of the investigations of the Bureau of Plant Industry from the time they began in 1912, to the time they were discontinued in 1932.

AGRICULTURAL HISTORY OF THE SECTION

This section was first settled by large cattle companies whose business was growing beef cattle on the open range. Later, settlers and squatters took up favored locations along streams and watercourses. Some of these settlers produced crops in a small way, but cattle production on the open range remained the chief source of income.

The building of railroads into the section in the eighties brought about a great increase in homesteading and resulted in the breaking up of the large cattle companies. Many of the original homesteaders had no intention of remaining permanently in the country and confined their cultivation to the acreage necessary to obtain title to the land. Many of those who intended to remain were unfitted both by temperament and training for the life of a homesteader. As a result, much land passed into the hands of loan companies and nonresident owners. Settlement of the country was greatly stimulated during a series of years of good production. A series of bad years had the effect of depopulating the section, as very few of the settlers were financially situated to withstand successive years of crop failure. The last great wave of settlement was in the years 1905–12. During this period practically all the remaining land fitted for cultivation was settled and taken out of the public domain.

Crop production on a large scale was not practiced before 1912. During the period 1911–15 acreages under the plow were gradually increased. The stimulation of wartime prices greatly increased production during the next few years. The acreage continued to increase during the period 1918–29. The improvement of the farm tractor and other implements adapted to large-scale production was responsible for much of the increase. From 1929 to 1932 the acreage of land under cultivation remained almost stationary. Very little new land was brought under cultivation, but practically all that had been broken was planted to crops.

TYPE OF AGRICULTURE PRACTICED

The past 25 years have witnessed a change from livestock production on the open range, with a minimum amount of farming, to a type of farming wherein crop production plays an important part both as a method of providing feed for livestock and as a source of cash income. Beef cattle remain the principal item of livestock production, but hogs and sheep are grown to a lesser extent, and the majority of farmers milk cows. Dairying as a specialized industry is carried on by very few individuals.

The present tendency appears to be the consolidation of small holdings into relatively large farm units, with pasture land and plow land both contributing to the production of livestock. On nearly all farms wheat is grown as a cash crop, and in good years an important part of the farm income is obtained from it.

SOIL CONDITIONS

The soil at the Ardmore station is a heavy clay loam that remains fairly uniform to a depth of about 15 inches. Below that depth there is a zone of lime carbonate accumulation that extends to a depth of about 2 feet. Below that depth the soil remains fairly uniform clay or gravelly clay until the undecomposed shale is reached, except where sand or gravel deposits occur. The crop-rotation field is underlain with a layer of sand and gravel that generally lies at a depth of between 4 and 5 feet but comes closer to the surface in a few places. Where the layer of sand is within 2 feet of the surface, the producing capacity of the soil is drastically lowered. The color and profile correspond closely to that of the Rosebud series as mapped by the Bureau of Soils, and so far as essential characteristics are concerned it can be designated the Rosebud clay loam. The experimental plots are located on an upland terrace on which the soil material had accumulated by deposition from river water. The terrace is more than 100 feet above the level of Hat Creek. There is no ground water. The plots do not receive run-off from adjoining areas, and the nearly level surface does not especially favor run-off.

The surface soil is tenacious when wet, and when wet or dry, requires considerable power for cultural operations. The expense of working the soil makes it necessary to restrict the number of field operations as much as possible without sacrificing the crop.

CLIMATIC CONDITIONS

The average annual precipitation at Ardmore during the period covered by these investigations was 15.90 inches (table 1). Of this amount, 9.81 inches fell during the 4 months April–July and 12.44 inches during the 6 months April–September.

TABLE 1.—*Precipitation*[1] *at the Ardmore station for the 21 years, 1912–32*

Year	January	February	March	April	May	June	July	August	September	October	November	December	Seasonal, April–September	Annual
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1912	1.12	0.30	1.35	2.15	0.80	1.87	1.97	0.83	1.68	0.55	0.27	T	9.30	12.89
1913	.03	.40	.50	1.52	2.04	1.59	1.78	1.23	1.50	1.59	.15	0.90	9.66	13.23
1914	.02	.45	.28	3.27	1.24	3.24	.49	1.79	.75	1.51	T	.43	10.78	13.47
1915	.50	.64	.86	4.26	3.40	6.67	6.01	1.37	4.70	.81	.11	1.08	26.41	30.41
1916	.25	.35	.54	1.04	3.61	2.58	1.80	1.90	.02	.85	.39	.20	10.95	13.53
1917	.47	.09	1.02	2.74	5.34	1.71	.47	1.99	.43	.67	.18	.70	12.68	15.81
1918	.48	.29	.60	2.85	5.99	1.75	3.49	.44	3.01	.45	.25	.66	17.53	20.26
1919	T	.76	.93	2.52	2.65	1.50	3.05	.47	.38	2.10	.78	.14	10.57	15.28
1920	.15	.55	.92	3.78	5.20	3.10	.77	1.59	.29	1.48	.29	.31	14.73	18.43
1921	1.15	.18	.07	.52	2.41	4.54	1.26	.55	.46	.66	.68	.30	9.74	12.78
1922	.55	.14	T	3.23	2.56	2.59	4.07	.78	.15	.83	2.19	.41	13.38	17.50
1923	.05	.30	.40	.98	3.80	5.93	.67	3.09	1.52	1.48	.13	.25	15.99	18.60
1924	.02	.75	.70	.69	.75	1.95	2.61	.23	1.24	1.79	.57	.44	7.47	11.74
1925	.29	.45	.42	1.34	2.02	4.02	2.55	.72	.70	2.45	.32	.65	11.35	15.93
1926	.69	.12	.40	.49	2.53	1.80	3.55	2.94	1.09	1.26	1.70	.09	12.40	16.66
1927	.22	.34	1.14	4.06	3.26	3.28	3.33	2.25	1.01	1.16	.75	.27	17.19	21.07
1928	.28	.28	.49	.27	1.52	3.67	3.63	.76	.30	.55	.14	.16	10.15	12.05
1929	.09	.17	1.31	1.41	2.18	2.21	2.90	1.49	2.71	.74	.20	.05	12.90	15.46
1930	.36	.18	.37	1.93	2.89	1.24	.70	3.01	1.10	3.58	.34	.01	10.87	15.71
1931	.02	.36	.73	.19	1.13	1.89	.79	1.34	.44	1.71	.31	.33	5.78	9.24
1932	.39	.07	.71	4.17	2.73	.69	1.01	2.63	.19	.95	.09	.14	11.42	13.77
Average	.34	.34	.66	2.07	2.76	2.75	2.23	1.50	1.13	1.29	.47	.36	12.44	15.90

[1] T=trace.

The highest precipitation was 30.41 inches in 1915; the lowest was 9.24 inches in 1931. In only one year, 1915, was the moisture supply sufficient to mature all crops without drought damage. In several other years the damage was small, but in the majority of years yields were sharply reduced by drought, and in a number near failure resulted from severe drought. The normal expectation is for drought injury at some time during the growing season.

The fact that the average precipitation is 15.90 inches does not mean that this is the most probable amount. In 13 out of 21 years the rainfall was below the average. In other words, the normal expectation is for a less-than-average precipitation approximately 60 percent of the time.

Hail played an important part in determining crop yields. Hailstorms are frequent, but the injured areas are not usually large, and it is likely that the 15-percent average hail damage at the station is not far from the average for the section as a whole. At any rate, the probability of hail damage is a factor that must be taken into consideration in farming operations in this section.

The average evaporation for the 6 summer months April–September, was 38.206 inches during the 20 years that observations were taken. The highest evaporation was 51.760 inches in 1931, the year with the lowest precipitation. The lowest evaporation was 28.908 inches in 1915, the year with the highest precipitation. In general, low precipitation is associated with high evaporation, and high precipitation with low evaporation.

The temperature at Ardmore is characteristic of the northern Great Plains. Extremes of temperature are reached, both in summer and in winter. The lowest temperature recorded at the field station was −34° F. on January 17, 1916. The highest was 109° on July 25, 1931. In most winters temperatures of −20° or lower are recorded, but the minimum temperature reached −30° only seven times in 20 years. Temperatures of 100° are reached nearly every year, but temperatures of 105° or more were recorded on only 13 days in 20 years. Eight of these days were in the exceedingly hot and dry year of 1931.

In the 21-year period, 1912–32, the average date of the last killing frost in spring was May 10 and of the first in autumn September 27. The average frost-free period was 140 days. Frost-free periods in individual years ranged from 120 days in 1916 to 179 days in 1930.

FIELD CROP INVESTIGATIONS

Crop investigations at Ardmore were divided into three principal lines: (1) The production of crops in rotation plots for the purpose of determining the sequences and cultural methods under which the staple crops of the section should be grown; (2) growth of crops on a field scale as a feed-producing enterprise; and (3) tests of varieties of grain and forage crops. These three lines of endeavor will be discussed separately.

CROP ROTATIONS AND CULTURAL METHODS

The crop rotations comprise a study of the effects of different cultural methods and sequences on the yields of crops. They also show the effect of hay crops in rotations and the results that may be expected from the use of summer-fallow and green-manure crops. Most of the rotations have been carried on continuously from 1912, but some rotations were added as the need of studying particular problems became evident. A few rotations were discontinued after time had demonstrated their lack of adaptation to the locality. In 1932 there were in operation twelve 2-year, fifteen 3-year, nineteen 4-year, three 5-year, and three 6-year rotations. In addition there were continuously cropped plots of spring wheat, winter wheat, oats, barley, corn, and sorgo grown under widely different methods of soil preparation. Alternately fallowed and cropped plots were also devoted to these same crops. On one set of six plots the effect of delayed seeding of wheat as a means of weed control was studied. Eight plots were devoted to a study of the effects of different methods of fallowing. Two plots, one each of spring wheat and winter wheat, showed the results from continuous disking.

AVERAGE YIELDS

While the results from crop rotations are intended primarily to show yields of given crops under given cultural methods, the average yields of all plots of each crop grown each year give useful information on the adaptation of the several crops to the section. Exact comparisons cannot be made with such averages, because the relative numbers of good and poor methods of production that enter into them are not the same with all crops. With crops like wheat, oats, corn, and winter wheat the number of plots is large enough so that the average yields are fairly accurate measures of the production that may be expected. With crops occupying a smaller number of plots the measure is not so accurate, but in most cases they occupied a smaller number of plots because they were thought to be relatively less important, at least in rotations. In some cases, however, crops occupying a lesser number of plots are important.

The number of plots of the different crops grown in 1932 was as follows: Spring wheat, 50; delayed-seeding spring wheat, 5; winter wheat, 17; oats, 40; barley, 10; flax, 4; corn, 44; sorgo, 8; alfalfa, 3; bromegrass, 5; sweetclover, 4; winter rye, 6; peas, 4; potatoes, 2; and beans, 2. Twenty-seven plots were fallowed.

The 20-year average yields of the different crops are shown in table 2. With most crops all the plots are included in the average. Only one plot of winter rye was harvested for grain. The other plots do not appear in the average. No peas were harvested. With hay crops the yield does not include the first year. For example, with alfalfa the yield given is for second-year and third-year plots, and does not include the year in which the plot was planted. Only one plot of sweetclover appears in the average yields, as there was only one rotation in which a second-year hay crop of sweetclover was harvested.

TABLE 2.—*Average annual acre yields from all plots in the crop-rotation field at the Ardmore station for the 20 years, 1913–32*

Year	Spring wheat	Winter wheat	Oats	Barley	Flax	Corn		Sorgo	Alfalfa	Medium red clover	Brome-grass	Sweet-clover	Potatoes	Spring wheat (delayed seeding)	Winter rye	Beans
						Grain	Stover									
	Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
1913	2.0	1.4	2.3	1.4	1.0	0	927		0	0	0		14.4			
1914	[1] 0	0	0	0	0	0	1,018		480	0	443		24.9			
1915	46.8	33.2	77.2	52.9	13.8	38.8	3,669		4,725	2,100	3,900		94.5			
1916	21.1	31.3	39.8	23.4	6.4	22.1	3,025	6,240	2,525	2,700	2,967		149.6			
1917	9.2	7.2	15.2	5.3	3.0	13.9	1,410	3,100	1,900	0	1,483		109.6			
1918	35.0	19.4	65.1	39.9	6.7	22.2	2,110	6,700	4,150	4,700	2,033		126.5			
1919	11.6	18.3	22.4	8.6	2.7	9.2	1,524	3,964	1,125	850	1,433		47.9			
1920	28.1	25.7	56.8	35.1	6.8	19.3	1,660	4,040	2,125		2,333	0	0			
1921	18.6	16.0	42.5	14.4	5.3	7.9	1,976	4,290	1,900		1,450	4,700	39.7			
1922	[1] 0	0	0	0	0	14.8	1,386	4,300	1,200		1,533	0	83.8			
1923	24.4	17.4	59.1	43.5	11.1	29.5	2,607	7,180	2,250		1,750	3,450	71.9			
1924	11.9	9.3	13.3	11.2	0	2.4	1,978	2,090	500		440	2,040	45.0			
1925	17.1	10.2	33.6	32.3	2.4	13.0	2,013	3,940	450		850	0	111.2			
1926	7.2	4.4	24.8	18.6	1.2	11.5	1,931	3,900	200		233	0	175.6			
1927	32.6	18.6	66.8	50.8	9.5	36.5	3,442	9,350	3,525		2,217	3,300	190.6			
1928	25.5	20.5	46.1	27.7	4.8	20.4	1,930	3,240	1,400		700	2,900	134.3	7.9	8.8	
1929	13.4	9.4	25.1	17.9	1.2	10.1	2,562	2,560	1,350		1,000	1,600	117.9	.9	7.3	
1930	10.2	9.7	23.1	23.7	1.3	3.6	1,105	3,400	400		1,067	2,350	94.2	2.9	15.2	6.6
1931	2.9	2.4	5.0	5.5	0	.2	935	1,680	50		317	950	30.4	0	1.4	0
1932	10.8	4.8	18.0	18.3	.9	10.5	309	730	75		1,283	0	0	2.5	8.6	0
Average	16.4	13.0	31.8	21.5	3.9	14.3	1,876	4,159	1,517	1,479	1,372	1,638	83.1	2.8	8.3	2.2

[1] The failure of grain crops in 1914 and 1922 was due to hail.

The average yield of spring wheat was 3.4 bushels per acre higher than that of winter wheat. In only 2 years out of 20 did the yield of winter wheat exceed that of spring wheat. In the fall preceding each of these years the September precipitation was exceptionally high. This indicates that if winter wheat is to be grown, it is likely to be superior to spring wheat only in years following heavy fall precipitation.

Loss of stand of winter wheat is much more frequently due to soil blowing in the early spring than to winter-killing. Wheat does not make enough growth in the fall to form a cover for the soil. Freezing and thawing during the winter put plowed and cultivated soil in a friable condition that is almost certain to blow enough in the spring to injure winter wheat in its then weakened state. Winter wheat offers the greatest chance of success when planted in standing cornstalks or in clean grain stubble.

The yields of spring wheat and oats in pounds of grain per acre do not differ materially. Wheat averaged 984 pounds per acre and oats 1,018 pounds. As wheat usually is more valuable, pound for pound, than oats, it is a better crop to grow for sale.

The average acre yield of barley was 1,032 pounds. This is a little higher than that of oats, but does not represent the true difference in yield between the two crops. A greater proportion of the barley plots than of the other principal grain crops were grown under poor methods of cultivation, and other varieties of barley have been found to yield more than the ones used in the rotations from 1913 to 1921. A comparison of crops by cultural methods, which appears in later pages, shows the relative yields of the two crops under comparable conditions.

The importance of the choice of varieties is shown by a comparison of barley and oats. The same variety of oats was used throughout the 20 years. During the period 1913–21 six-rowed barleys of the Manchuria type were grown. During this period the average yields per acre were 1,142 pounds of oats and 965 pounds of barley. White Smyrna barley was used from 1922 to 1932. During this period oats produced an average yield of 915 pounds per acre and barley 1,090 pounds. The relative producing power of barley as compared to oats was increased approximately 350 pounds per acre through the use of a better adapted variety.

Flax produced an average yield of only 3.9 bushels per acre. As a speculative crop on new breaking, flax sometimes may be very profitable. It does not seem to be adapted to a regular place in a permanent farming system in this section.

As only one plot of winter rye was harvested, it must be compared with other grains on the basis of plots grown under the same type of soil treatment. The 5-year average yield of rye was 8.3 bushels per acre. Winter wheat grown under the same preparation during the same period of years averaged 7.3 bushels per acre. The yield of winter rye did not exceed that of winter wheat enough to make up for the usual difference in price.

The delayed-seeding wheat was produced on a group of plots handled in exactly the same way as a group of plots on which seeding was done at the normal date, except that seeding was delayed 1 month and the plots were cultivated to destroy weeds before seeding. The average 5-year yield of the delayed-seeding wheat was 2.8 bushels per acre. The corresponding group of plots seeded at the normal time produced 7.0 bushels per acre. The destruction of a crop of weeds did not compensate for the lower yield resulting from later seeding.

Corn produced an average yield of 14.3 bushels of grain per acre. This is lower than the yields of small grains. However, in most years corn produced a fair yield of stover, which gives it a value beyond its grain production. Corn fits into rotation practice well, and yields of grain following corn are generally above the average.

Sorgo produced an average yield of 4,159 pounds per acre. This is far above the yield of any other forage crop. Sorgo has proved to be a valuable feed for beef cattle and an excellent feed for horses and other livestock. It apparently deserves a place of much higher importance in the agriculture of the section than it now occupies. The factors that seem to limit the acreage in this section are the necessity for careful cultivation of land to eliminate weeds before planting and the danger of livestock being poisoned by pasturing on the stubble in the fall. In spite of these drawbacks, the acreage of sorgo, the most productive feed crop, could be increased materially to the advantage of the country.

Experiments described on other pages show that the yields of grain following sorgo are nearly as high as those following corn. The value of sorgo as a crop not relished by grasshoppers was demonstrated in some sections of western South Dakota in 1931.

The average yield of second-year and third-year alfalfa was 1,517 pounds per acre. The yield of third-year alfalfa was higher than that of second-year. The average second-year and third-year yield of bromegrass was 1,372 pounds per acre. The yield of third-year bromegrass was sharply lower than that of second-year bromegrass. Neither alfalfa nor bromegrass proved adapted to short rotations, but alfalfa appears to be much better fitted for use in permanent fields.

Growth of medium red clover was discontinued in 1922, after it had clearly demonstrated its lack of adaptation to the section.

Second-year sweetclover averaged 1,638 pounds of hay per acre during the period 1920–32. During the same period alfalfa averaged 1,187 pounds per acre. Sweetclover is not adapted to growth in permanent fields as a hay crop, because it is a biennial. It fits into rotation practice much better than alfalfa. Its chief value in this section, particularly on lighter soils, is as a pasture crop in the same field with native grasses. At certain stages of growth the sweetclover is readily eaten by livestock, but sweetclover alone does not make a desirable pasture for dairy cows.

Potatoes produced an average yield of 83.1 bushels per acre. The average percentage of marketable tubers did not exceed 70. In heavy soil, like that at the Ardmore station, the growth of potatoes beyond the quantity needed for home use is not justified. On lighter soils potatoes have been much more productive.

Great Northern beans were grown only 3 years. In one of these years a fair yield was obtained. The other 2 years beans were a failure, but yields of other crops were also low. Further trials are necessary to determine if bean production offers a possibility of success.

COMPARISON OF FOUR TILLAGE METHODS FOR CROPS GROWN CONTINUOUSLY

Spring wheat, winter wheat, oats, barley, corn, sorgo, and flax were grown continuously under different methods of cultivation from 1913 to 1932. The four methods used were spring plowing, fall plowing, subsoiling, and listing. All plots of a crop were seeded on the same date with seed of the same variety. The average yields of each of the crops grown by the different cultivation methods are shown in table 3.

TABLE 3.—*Average acre yields of 7 crops grown continuously under 4 different methods of cultivation at the Ardmore station for the 20 years, 1913–32*

Crop	Spring plowed		Fall plowed		Subsoiled		Listed	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
	Bushels	*Pounds*	*Bushels*	*Pounds*	*Bushels*	*Pounds*	*Bushels*	*Pounds*
Spring wheat	11.8		11.0		10.3		11.1	
Winter wheat	[1] 8.2		[2] 7.9		9.1		8.3	
Oats	23.6		24.2		21.8		22.2	
Barley	16.8		19.0		17.4		20.8	
Flax	3.3		3.6		4.3		3.6	
Corn	15.2	1,624	15.5	1,630	14.2	1,694	14.0	1,378
Sorgo		3,832		3,598		4,414		4,478

[1] Late-fall plowed.
[2] Early-fall plowed.

The most notable feature of these yields is the comparatively small differences that resulted from major differences in cultivation methods. Differences in individual years were sometimes high, but on the average these differences balanced each other so that, with a few exceptions, variations in yield in most cases represent no more than the experimental error.

Since average yields were not materially influenced by the cultivation method used, it follows that the selection of method may be based largely on factors other than yield. The amount of labor involved, the distribution of labor, and the timeliness of operations should be the bases for determining the cultivation to be given land.

For example, spring plowing and fall plowing are about equally productive. There is, however, a limit to the amount of spring plowing that can be done without unduly delaying seeding, and delayed seeding almost invariably results in reduced yields. To determine between spring and fall plowing one should decide whether the lesser amount of power usually required for spring plowing compensates for the possible loss of yield through later seeding. The fact that the two methods produce nearly equal average yields permits a wide latitude in choice. Fall plowing can be done in years when moisture conditions are such that plowing is not too difficult. If a dry, hard soil in the fall makes plowing difficult, plowing can be postponed until spring, with the assurance that no loss in yield will be experienced, if unfavorable weather does not too long delay seeding.

The fact that subsoiling increases costs without increasing yields eliminates this method of cultivation.

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Listing or "busting out" with a lister in the fall for small grains lessens the expense of fall work but increases the amount of work necessary to prepare a seedbed in the spring. Listing for corn or sorgo, where no fall work is done and when the crop is planted with a lister planter, is much less expensive than plowing. Observations on corn show a smaller growth of stalks and a lower yield of grain from listing in good years. The difference in size of stalk is reflected in the yield of stover. In dry years listed corn generally remains green longer than surface-planted corn. Listing is not to be recommended on very heavy soils, as the surface is very likely to crust badly and prevent emergence.

Prior to 1926 the listed sorgo plot was blank-listed in the fall, and the sorgo was planted in the partly filled furrows the following spring. From 1926 on listing and planting were done as a single operation. Observations on listed sorgo since 1926 show less tillering and a slower growth than for surface planting. Listing for sorgo is not recommended as far north as Ardmore.

It appears certain that sequence plays a more important part in the production of most crops at Ardmore than does the cultural treatment under which they are grown. When only slight differences in yield follow such major differences in cultural methods as those under trial, it seems certain that small differences in cultivation such as disking after harvest and other similar cultural refinements cannot materially affect the yields of grain crops.

Continuous cropping to grain for so long a period has been possible only because certain noxious weeds, such as wild oats, have never become established in the plots. The continuously cropped flax plots were discontinued in 1928 because redroot amaranth (*Amaranthus retroflexus* L.), which does not come up until after the flax has emerged, had become so prevalent that flax yields on these plots were near failures. Continuously cropped winter wheat suffered a reduction in yield in the later years from the prevalence of cornbind (*Polygonum convolvulus* L.).

During the first few years, grain grown under a continuous-cropping system produced yields approximately equal to those of grain following grain in rotations containing a cultivated crop, but later the yields from continuous cropping were distinctly lower. However, in the year 1927, when soil moisture was ample throughout the season, the yields of most grain crops grown continuously were higher than the average yields of all plots, indicating that the ability of the soil to produce good yields of these crops had not been permanently impaired.

COMPARISON OF DIFFERENT METHODS OF PREPARING CORN GROUND FOR SMALL GRAINS

Wheat was grown during the 20-year period on disked corn ground, fall-plowed corn ground, and spring-plowed corn ground. The average difference in yield between these methods was less than half a bushel per acre. This is less than the experimental error. Disking is the cheapest method of preparing corn ground for a crop, and there appears to be no reason for plowing corn ground as a preparation for wheat.

No oats were grown on fall-plowed corn ground. The average difference between oats grown on spring-plowed corn ground and oats on disked corn ground was less than a bushel per acre. As with wheat, the preceding crop and not the cultural treatment seemed to determine the yield.

No barley or winter wheat was grown on plowed corn ground.

The average yield of flax was less than a bushel higher on spring-plowed corn ground than on disked corn ground. This is not enough to pay the cost of plowing.

It appears that for all grain crops tested, where corn has been kept clean, disking for grain is preferable to plowing.

COMPARISON OF DISKING AND PLOWING GRAIN STUBBLE FOR SMALL GRAINS

The expense of plowing the heavy soil at Ardmore makes it undesirable to plow more frequently than is necessary. The practice of disking in wheat on wheat stubble is common in the section. Three rotations were started in 1927 to determine the effect of disking stubble. Wheat was grown on all plots each year. The essential difference between the rotations was that in one, plowing was done every second year; in another, plowing was performed every third year; and on one plot plowing was eliminated entirely, the wheat being grown continuously on disked land. For 5 years the average yield of wheat on continuously disked land was 7.1 bushels per acre. Where plowing was done every second year, the yield was 8.3 bushels per acre following plowing and 8.7 bushels on disked land. Where plowing was done every third year, the yield was 8 bushels per acre following plowing, 8.5 bushels on first-year disking, and 8.1 bushels on second-year disking.

The results show that where noxious weeds do not constitute a problem, disking for at least 2 years may be practiced without material loss of yield. On land continuously disked the yields were lower in the fourth and fifth years than those on plowed land. The series of years during which these rotations were conducted was much below the average in precipitation and crop yields.

A rotation in which corn took the place of the plowed plot in the 3-year rotation was started in 1928 to determine whether one cultivated crop in 3 years is sufficient to control weeds. This rotation was not used long enough for results to be conclusive, but it appears likely that the method will control weeds fairly well and that the aggregate yield of the three crops will be higher than in a 3-year rotation of small grains only.

COMPARISON OF CROPS GROWN UNDER ALTERNATE FALLOW AND CROP SYSTEMS WITH SAME CROP GROWN CONTINUOUSLY

Yields on fallowed land were obtained during the 20-year period. With each crop two plots were used, one of which was fallowed through the season and the other planted to crop. The yields of grains grown continuously and the yields of the cropped plots in the alternate fallow and crop series are given in table 4.

TABLE 4.—*Average acre yields of crops grown continuously and under an alternate fallow and crop system at the Ardmore station for the 20-year period, 1913–32*

Crop	Average yield on fallow [1]	Continuously cropped		Increased yield on fallow	Crop	Average yield on fallow [1]	Continuously cropped		Increased yield on fallow
		Plots	Average yield				Plots	Average yield	
	Bushels	*Number*	*Bushels*	*Percent*		*Bushels*	*Number*	*Bushels*	*Percent*
Spring wheat	17.2	4	11.1	55	Corn	20.2	5	14.6	38
Winter wheat	17.4	4	8.6	102					
Oats	38.3	4	23.2	65		*Pounds*		*Pounds*	
Barley	31.7	4	18.5	71	Sorgo [3]	4,502	4	4,082	10
Flax [2]	5.3	4	3.7	43					

[1] 1 plot in each case.
[2] Yields of flax are for the years 1916–27.
[3] Yields of sorgo are for the years 1916–32.

The yields of spring wheat, oats, and barley averaged from 55 to 71 percent higher when grown on summer-fallowed land than when continuously cropped. Winter wheat showed a much higher percentage increase, but the actual yield on fallowed land was approximately the same as that of spring wheat. Under continuous cropping the yields of winter wheat were much lower than those of spring wheat. The yields of flax were so low that the percentage increase in yield has little significance. The actual increase was less than 2 bushels per acre. Cultivated crops showed materially lower response to fallow than grain crops.

The response of small grains to fallow is as great at Ardmore as in many sections where summer fallowing is a common practice. The possibilities of fallow in the agriculture of the section have been discussed in detail in an earlier publication.[2]

COMPARISON OF YIELDS OF SMALL GRAINS IN DIFFERENT SEQUENCES

It has been shown that with a few exceptions only minor differences in average yields were obtained through differences in cultivation, where the crop sequence was the same. The effect of crop sequence in determining yields is shown in table 5. To reduce the experimental error due to soil differences, as many plots as possible were used in determining the averages. The yield of a grain crop on fallow represents the average yield of all plots of that crop grown on fallowed land, regardless of whether the fallow appeared in 2-, 3-, or 4-year rotations. In like manner, the yields on corn ground include all plots planted on corn ground, regardless of the length of the rotation or the method of cultivation used. Yields after small grains include all plots grown after oats, spring wheat; winter wheat, barley, and flax.

[2] MATHEWS, O. R., and CLARK, V. I. SUMMER FALLOW AT ARDMORE, S. DAK. U. S. Dept. Agr. Circ. 213, 15 p. 1932. For sale by the Superintendent of Documents, Washington, D. C. Price 5 cents.

TABLE 5.—*Acre yields of various crops following small grains, cultivated crop, and fallow at the Ardmore station for the 20 years, 1913–32*[1]

Crop	Previous crop, if any, and treatment	Plots	1913	1915	1916	1917	1918	1919	1920	1921	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	20-year average
		No.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Spring wheat	Small grains	8	0.6	40.2	16.4	7.2	25.9	6.7	22.5	9.7	19.1	6.1	12.8	5.1	29.4	15.2	6.5	6.0	2.3	8.5	12.0
	Cultivated crop	18	.2	48.6	23.6	9.6	35.2	10.7	30.5	19.1	25.5	8.9	17.4	6.3	33.8	22.3	11.5	12.6	2.4	12.3	16.5
	Fallow	10	7.2	50.6	18.5	9.7	37.1	14.7	26.3	22.8	25.7	18.3	18.7	10.3	33.4	36.8	23.6	11.9	4.2	12.2	19.1
Winter wheat	Small grains	4	0	29.4	31.3	4.7	15.4	7.5	21.3	4.3	15.2	1.7	7.4	5.0	14.7	11.2	1.1	2.3	1.8	2.4	8.8
	Cultivated crop	3	0	36.4	30.1	8.5	25.8	18.9	25.2	15.8	15.4	5.5	12.6	1.2	23.6	14.8	4.5	14.0	.2	6.1	12.9
	Fallow	3	8.0	37.0	31.6	10.8	21.2	32.5	31.9	32.4	21.6	19.7	12.4	7.2	18.3	34.0	22.6	15.5	3.8	7.0	18.4
Oats	Small grains	14	1.0	72.4	36.9	14.1	58.7	15.8	57.6	29.8	55.9	10.6	20.1	19.9	62.7	33.6	19.6	15.1	7.7	15.9	27.4
	Cultivated crop	13	.4	81.4	45.4	14.6	66.9	23.9	51.4	47.5	59.8	13.2	39.4	27.3	61.6	40.1	22.2	30.1	3.1	18.3	32.3
	Fallow	6	12.1	82.6	40.7	18.4	77.9	36.2	65.3	60.0	68.9	22.0	46.2	33.2	79.6	76.5	47.0	29.5	6.1	24.4	41.3
Barley	Small grains	7	0	51.3	24.9	5.0	36.9	7.2	36.2	11.2	40.0	8.8	27.3	15.4	47.9	22.9	12.6	18.1	4.5	14.8	19.3
	Cultivated crop	1	0	49.0	25.4	5.6	60.6	7.7	24.1	20.6	55.0	16.3	42.5	27.1	56.5	29.8	22.9	39.4	6.4	28.5	25.9
	Fallow	1	10.0	68.0	11.3	7.2	38.2	18.9	37.9	30.2	56.3	22.5	57.5	32.5	65.2	59.0	50.6	36.9	10.4	22.3	31.7

[1] Crops destroyed by hail in 1914 and 1922.

The average yield of spring wheat after a cultivated crop was 38 percent higher than following a small-grain crop. This illustrates the value of a cultivated crop in a rotation, above its value as a crop. The yield of spring wheat averaged 59 percent higher on fallow than it did following small grains. The total production of a farm all planted to small grain would be higher than that of the same farm if half of it were planted to grain on fallow and half of it kept fallow. The value of the fallow lies in the fact that the yield is better distributed between years, and that the distribution of labor would enable one man to handle a larger acreage of land with the same equipment.

The effectiveness of fallowing in overcoming drought is shown in the yields by individual years. Not counting the 2 years when hail totally destroyed crops, spring wheat on fallow produced 10 bushels or more of grain per acre in all except 3 of the 18 years. During the same period spring wheat after small grains produced less than 10 bushels per acre in 10 of the years.

The average yield of winter wheat was 47 percent greater on corn ground and 109 percent greater on summer fallow than it was following small grain. The apparently greater response of winter wheat than spring wheat to corn ground and fallow was not due to larger yields following those preparations but to lower yields following small grain.

The yield of oats following a cultivated crop exceeded that of oats after small grains by 18 percent, and the yield on fallow exceeded that following small grains by 51 percent. The response of oats to a cultivated crop in the rotation was lower than that of spring wheat. The response to fallow was nearly the same. The yield of barley was 34 percent higher after a cultivated crop and 64 percent higher after fallow than it was after small grains.

The influence of the type of season on crop production is shown by the production in different crop sequences during different periods of years. For the purpose of study, the records were divided into two 10-year periods. During the first period the increase for grain on fallowed land above that of grain after grain was 45 percent for spring wheat, 80 percent for winter wheat, 37 percent for oats, and 28 percent for barley. The increase during the second 10-year period was 76 percent for spring wheat, 158 percent for winter wheat, 66 percent for oats, and 95 percent for barley. The percentage increase due to fallow during the second 10-year period was double the increase during the first 10-year period. This illustrates the value of long-time determinations of results. Had the experiments been conducted during only the first 10 years, the results would have been relatively unfavorable to fallow. Records kept during only the second 10 years would have given fallow an importance above its average deserts. Some of the increase during the last period may have been due to better management of the fallow, but the major part must be attributed to seasonal conditions.

A comparison of crops in terms of pounds per acre instead of by bushels is made in table 6.

TABLE 6.—*Average annual acre yields (pounds) of crops under 3 different sequences at the Ardmore station for the 20-year period, 1913–32*

Crop	Average acre yields		
	After small grains	After cultivated crops	After fallow
	Pounds	*Pounds*	*Pounds*
Spring wheat	720	990	1,146
Winter wheat	528	774	1,104
Oats	877	1,034	1,322
Barley	926	1,243	1,522

With all crops and for all sequences winter wheat made the lowest yields per acre, spring wheat the second lowest, oats next, and barley the highest. The yield of spring wheat was much higher than that of winter wheat on soil preparations other than fallow. This indicates that if winter wheat is to be grown at all it should be grown under the best possible conditions. When grown under ordinary methods, spring wheat is much more productive than winter wheat.

The relatively low yield of winter wheat on corn stubble is due partly to soil blowing. Recognition of this fact led to the addition of a rotation in which winter wheat was planted in standing cornstalks. Five years' results are available from this rotation. During this period the yield of winter wheat in this rotation was materially higher than that of winter wheat following harvested corn, and slightly higher than that of spring wheat on corn ground.

For the period for which records are available, seeding winter wheat in standing cornstalks offered the greatest possibility of success with that crop of any method under trial. All the years in which this rotation was used were years of drought injury, in which the snow held by the cornstalks was of material benefit. Without exception, the stands of wheat in this rotation were better than those on corn ground from which the corn was harvested with a binder, the difference in stand being due to lack of injury by soil blowing in the plot protected by stalks.

Oats were more productive than spring wheat in all three sequences, the smallest difference being shown on corn ground. The differences in yield on other methods of cultivation are not great enough to make up for the difference in price, if grown for sale. The results clearly indicate that if oats and wheat are both grown, the corn ground should be planted to wheat.

Barley was more productive than oats in all three sequences. The difference was much greater after corn and fallow than after small grain, which indicates that barley should be given the preference in the better crop sequences. For the 11-year period in which White Smyrna was used, barley on fallowed land and on corn ground produced over 500 pounds per acre more than oats on corresponding methods of cultivation.

Barley is the most productive small-grain crop. The growth of an adapted variety of barley and the selection of a livestock-production program that will permit the best use of barley as a feed are steps forward in establishing a well-balanced farm program.

COMPARISON OF SMALL GRAINS GROWN CONTINUOUSLY WITH SMALL GRAINS FOLLOWING SMALL GRAIN IN 3-YEAR ROTATIONS CONTAINING A CULTIVATED CROP

The 20-year average yields of grains following grains in 3-year rotations containing a cultivated crop were more than 20 percent higher than those of grains produced under continuous cropping. This difference did not appear during the early years of the experiments, but was in evidence from 1916 to 1932. The extent of the difference varied with the character of the season. In the productive year of 1927, the yields of grains grown continuously on the same land were materially higher than those of grains after grain in the 3-year rotations. The same relation appeared for some crops in 1915 and 1918, but the differences were smaller. In general, the yield of grain after grain in the 3-year rotations showed the greatest increase over continuous cropping in years in which drought injury was above the average but not severe enough to cause a nearly complete failure. In productive years the difference was generally small.

The fact that the same condition was true for all crops makes it appear positive that the benefit derived from growing a cultivated crop extends to the second crop following. The carry-over is sufficient to increase yields materially in years of drought injury.

COMPARISON OF YIELDS OF CORN AND SORGO IN DIFFERENT CROP SEQUENCES

The effect of sequence on the yields of corn and sorgo is shown in table 7. As with small grains, the effect of plot variation is reduced by the inclusion of as many plots as possible. For example, the yield of corn after small grain represents the average yield obtained from all plots where corn followed small grain, regardless of the length of the rotation, the grain crop, or the method of cultivation under which the corn was grown. Corn was grown after corn only under a continuous cropping system, and only one plot was grown on fallowed land. Sorgo was grown after sorgo only under a continuous cropping system. Only one plot of sorgo was grown on fallowed land.

TABLE 7.—*Average annual acre yields of corn and sorgo following small grains, continuously cropped, and on fallow at the Ardmore station for the 20 years, 1913–32*

Crop	Previous crop, if any, and tillage method	Plots	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	Average
		No.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Corn (grain)	Small grains	38	0	0	39.2	21.4	13.7	22.2	9.3	18.7	8.4	14.8	29.2	2.2	12.3	11.9	38.1	20.5	9.9	1.6	0	10.2	14.2
	Corn	5	0	0	35.0	25.6	15.1	22.1	6.1	22.7	11.8	13.3	31.4	1.7	15.9	7.7	28.3	18.7	9.8	14.3	0	11.8	14.6
	Fallow	1	0	0	43.3	30.9	16.8	29.6	19.2	27.7	15.3	20.1	31.7	11.5	26.7	17.7	19.7	25.1	18.4	25.0	6.9	18.6	20.2
			Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Corn (stover)	Small grains	38	887	945	3,666	3,042	1,424	2,137	1,507	1,676	1,943	1,413	2,649	2,043	2,069	2,084	3,695	2,068	2,698	1,090	991	345	1,919
	Corn	5	886	1,244	3,630	2,980	1,310	1,940	1,380	1,500	2,180	1,320	2,320	1,376	1,548	1,450	1,900	1,014	1,662	1,192	580	140	1,578
	Fallow	1	1,780	1,130	4,000	2,500	1,400	2,000	2,900	1,850	2,200	1,700	2,450	2,530	2,450	1,680	1,550	1,940	2,160	1,230	650	150	1,913
Sorgo	Small grains	3	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	3,353	2,217	3,200	1,867	780	2,283
	Sorgo	4	------	------	------	6,150	3,275	6,825	3,705	4,138	4,275	4,300	7,375	2,000	3,913	3,840	9,175	2,775	2,450	3,300	1,238	653	[1] 4,082
	Fallow	1	------	------	------	6,600	2,400	6,200	5,000	3,650	4,350	4,300	6,400	2,450	4,050	4,160	10,050	4,750	4,000	4,400	2,900	870	[2] 4,502

[1] 5-year average, 2,083 pounds.
[2] 5-year average, 3,384 pounds.

Results from the 20-year test show that the average yield of ear corn where corn followed a small grain crop was only a little lower than where corn followed corn, and the yield of stover was materially higher. The fact that corn stover has some value as a feed makes it apparent that corn following small grain is at least as valuable as corn after corn.

Corn on fallowed land produced 42 percent more grain than corn following small grains. The yield of stover was not increased through fallowing. It is apparent that fallowing has no place in the production of corn.

The average yield of sorgo on fallowed land for 17 years was only a little higher than that of sorgo grown continuously. Sorgo was grown following small grains for only 5 years. During this period the average yield exceeded that of sorgo after sorgo. Sorgo should be grown on land where small grains have been grown, and sorgo ground should be planted to small grains rather than to grow each continuously.

The value of long-time records in determining the response to cultural methods is again demonstrated in table 7. During the last 5 years of the experiment both corn and sorgo showed a response to fallow much higher than for the entire period. Experiments conducted during only the last 5 years would be very misleading.

EFFECT OF SOD CROPS ON YIELDS OF SUCCEEDING CROPS

Only two grain crops, oats and flax, were grown on sod land in the rotations. For the 20-year period oats following alfalfa produced a yield of 20.3 bushels, oats after bromegrass 23 bushels, and oats after clover or sweetclover 27.1 bushels per acre. The average yield of oats following any sod crop was less than the yield of oats following small grain, the reduction in yield being especially sharp following alfalfa and bromegrass. These two crops leave the soil so extremely dry that the succeeding crop is likely to suffer from drought. Sweetclover, a biennial, usually makes little or no growth following cutting in its second year, and consequently does not dry the soil so completely. Yields of oats after sweetclover were substantially the same as after small grains.

A depressing effect on crops following sod sometimes extends into the second and even the third year. In the sod rotations the oats were followed by corn. Volunteer alfalfa and bromegrass sometimes persisted in the corn crop and increased the cultivation necessary to keep the corn clean. In some cases the volunteer growth was sufficient to reduce the yield of corn. In all rotations containing sod crops the yield of corn was lower than the average yield in rotations not containing sod crops.

Flax after sod was nearly as productive as in other sequences, but flax as a sod crop in a regular rotation was not a success. Good yields were occasionally obtained, but many years of failure or nearly complete failure were recorded. Flax on sod was a complete failure in the 4 years, 1929–32.

Low yields of crops following sod crops, and the fact that a year is lost in securing a productive stand of the sod crop, make it apparent that these crops have no place in short rotations.

COMPARISON OF YIELDS ON MANURED AND UNMANURED FALLOW

One of the major fields of rotation studies is the cumulative effect of continuing cultural practices over a long period of years. Involved in this is the possibility that rotations in which no fertilizing material is added to the soil will eventually decrease in yield. For this reason rotations receiving barnyard manure and rotations including winter rye, peas, and sweetclover to be plowed under for green manure were grown in comparison with rotations in which no such material was added. In the rotations where manure was used, it was applied at the beginning of the fallow period to the plot to be fallowed. This was for the purpose of permitting the manure to rot and become thoroughly incorporated with the soil before a crop was grown.

The 20-year average yield of wheat grown on manured fallow was 1.3 bushels per acre more than that on fallow not manured. The number of plots entering into the comparison was small, and original differences in soil may account for much of the difference in yield. The principal value in manure should be in maintaining or increasing the fertility of the soil. A study was made of the yields during the whole period to determine whether the difference in favor of the manured rotations was greater during the last few years than it was earlier in the course of the experiments. Results showed no cumulative effect in favor of the manured rotations. There were differences from year to year, but as a whole there was no measurable increase in the differences between the manured and the unmanured wheat plots during the 20-year period. Results from individual years indicated that the greatest returns from manure were obtained in years of good production. In the 11 years when the yields of wheat were above 20 bushels per acre, the wheat on manured fallow produced 2.5 bushels more per acre than wheat on unmanured fallow. In the years when yields were below 20 bushels per acre, the yields on manured fallow were 0.2 bushel lower than on unmanured fallow. It appears that the increase in vegetative growth brought about through the use of manure may be detrimental in years of low precipitation.

Oats on manured fallow yielded 2.3 bushels per acre more than on unmanured fallow. No increase in the difference appeared during the 20 years. In fact, there appeared to be a tendency for the difference to become less rather than greater. It is safe to say that no cumulative benefit from manure appeared during the 20 years of the experiment.

In years when oats produced more than 40 bushels per acre the yield was 5 bushels higher on manured than on unmanured fallow. In years when production was less than 40 bushels per acre, oats on manured fallow yielded 0.4 bushel per acre less than on unmanured fallow. These differences are almost exactly the same in pounds per acre as those for wheat. They show that the benefit from manure is obtained largely in years of good production, and that manure may lower the yields in dry years.

This conclusion is borne out by observations of other fields where applications of manure were much heavier than in the rotations. In these fields there was a stimulation of growth that resulted in high yields in favorable years. In years when the moisture supply was insufficient to maintain this growth, these fields suffered more severely from drought than fields in which no manure was used.

COMPARISON OF YIELDS ON FALLOW WITH YIELDS FOLLOWING A GREEN-MANURE CROP

Yields of wheat obtained from plowing under rye, peas, and sweetclover for green manure may be compared to those obtained on summer-fallowed land in comparable rotations during the 20-year period. The yields following both rye and peas plowed under approached but did not quite equal those on fallowed land. The yield after sweetclover plowed under was materially lower than that on fallowed land. It is apparent that any increase in fertility brought about through plowing under a green-manure crop was counterbalanced by the loss of moisture used in producing the green manure.

The lower yield after sweetclover was undoubtedly due to a deficiency in moisture. Sweetclover is plowed under later than other green-manure crops, and when opportunities for moisture storage are low after the sweetclover has been plowed under, yields the following year are likely to be lowered, particularly in dry years. Yields following sweetclover were fully as high as following other green-manure crops in years when the lower moisture storage was not a limiting factor.

The results of the 20 years indicate that no appreciable benefit had been derived from plowing under green-manure crops. Fertility in the plots not receiving manure was still high enough to produce good yields under favorable conditions. Moisture rather than fertility was the limiting factor in crop production, and the limits set by the relatively low precipitation were such that other factors had little chance to show their effect.

The difference in favor of bare fallow over green-manure crops was more pronounced with oats than with wheat. As with wheat the number of plots that could be compared was small, and experimental error caused by original differences in productivity of the plots may account for much of the difference. A study of the 20-years' record makes it appear certain that no measurable increases in yields on green-manured land over those on fallowed land took place during the progress of the experiment.

Summing up the results of the 20-years' experiment, it may be stated that cumulative benefits from adding humus to the soil were not a factor during the course of these experiments. Any beneficial effect was upon the crop immediately following. Factors other than fertility played a more important part in determining the yield.

Reduction in yield from practices that tend to deplete the fertility of the soil were not noticeable where weeds and similar factors not associated with fertility were kept under control. It may be said that the effect of any particular crop or method of production did not make itself evident for a period of more than 3 years, and that in most cases little effect was noted beyond the first year.

APPLICATION OF RESULTS FROM ROTATIONS

Average results from rotation experiments indicate what may be expected from the use of certain crop combinations in field practice. Average yields may not represent the utmost that may be obtained but are sufficient to establish what may reasonably be expected from different cropping practices.

The choice of crops that a farmer makes depends upon the livestock that he raises. The farmer or rancher with a large number of stock to be wintered should have a considerable acreage of corn or sorgo, and he may find that a 2-year rotation of a cultivated crop followed by small grain will about meet his requirements. In such a rotation the grower could reasonably expect an average yield of approximately 14 bushels of ear corn and 1,900 pounds of stover or 2 tons of sorgo fodder on land that had produced grain the year before. On the land that had been in corn or sorgo the year before, the average production should be about 16 bushels of wheat, 32 of oats, or 26 of barley.

A grower with less need for cultivated crops might plant only one-third of his acreage to them and two-thirds to small grains. In this case the expected yield per acre of cultivated crops would be the same as where half the cropped acreage is in cultivated crops. Half of the small grain could be expected to yield at the rate following cultivated crops, the other half at the rate following small grains, or 12 bushels for wheat, 27 for oats, and 19 for barley. This is actually the minimum expectation, as some effect of the cultivated crop would extend into the second year.

The choice of small grains would depend on the use to which they are to be put. Wheat normally commands the best price on the market, and should be the choice when a crop is grown for sale. Barley is the most productive grain crop and can be depended on to produce the most feed, and should be grown to the extent that it can be utilized. Oats can be grown to the extent of their use for specialized classes of livestock.

Modification of the system can be made as required. Sharp reduction of the livestock may make it desirable to replace part of the acreage of cultivated crops with fallow. Regardless of the combination, probable average crop yields, as shown in the sequence studies, should be easily determined.

Wheat, as the cash crop, should be planted where it will have the least chance of becoming mixed with other crops. Mechanical mixture with other grains is less important with feed crops than with cash crops.

Alfalfa and similar hay crops are not adapted to growth in rotations, but nearly every farm has favorably situated land on which they may be grown in comparatively permanent fields.

The first consideration in a farming system should be the production of feed suited to the needs of the livestock to be grown. Secondary consideration should be given to the production of grain for sale. During years of good prices, returns from grain farming may be attractive, but very few farmers not producing livestock have been able to continue through successive years of drought or low prices.

FIELD TRIALS

AVERAGE YIELDS FROM FIELD TRIALS COMPARED WITH AVERAGE YIELDS FROM ROTATIONS

Crops were grown on a field scale from 1917 to 1932. Production of crops was for the purpose of furnishing feed for the livestock on the farm. A few fields were divided into the required units, and crops were grown on them in definite rotation. These fields give continuous records of different crops and can be studied as rotations. By far the most fields were used as units, and the crops grown were changed from year to year according to the needs of the livestock. Corn was grown largely for silage, but in many years some of the corn was husked. Sorgo was grown both for fodder and silage. In nearly every year, however, some corn was husked for grain and some sorgo was grown for fodder.

In most years all the staple crops were grown on some field or other. While the individual fields do not furnish much in the line of comparable information, the average yields from all fields are valuable.

The yields from fields were averaged in order to obtain representative figures for the different crops. For example, the yield for ear corn given in any particular year is the average production from all fields where the corn was husked. The average yield of sorgo fodder for any given year is the average of all fields on which sorgo was harvested for fodder, except field 13, which was located on soil much less productive than that of any other field and where difficulty was experienced in obtaining a good stand of sorgo. In some years only one or two fields were planted to a certain crop. In another year it may have been grown on 8 or 10 fields. Exactly the same fields may not appear in the average in any 2 years. As a whole, the averages give very good indications of the yields that may be expected over a number of years by farmers using good production methods.

Since the purpose was the production of feed for livestock, it follows that the fields were devoted to five principal crops—corn, sorgo, oats, barley, and alfalfa. All the yields of these field tests are shown in comparison with the averages of all plots in table 8.

TABLE 8.—*Average annual acre yields of all field tests compared with average annual acre yields of all plots at the Ardmore station for the 18 years, 1915–32*

Crop	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	Average
Corn:	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
Field	26.5	22.0	--------	21.2	12.9	24.2	6.9	12.5	24.8	0	7.6	10.1	26.6	15.6	4.7	0	0	7.2	13.1
Plot	38.8	22.1	--------	22.2	9.2	19.3	7.9	14.8	29.5	2.4	13.0	11.5	36.5	20.4	10.1	3.6	.2	10.5	16.0
Barley:																			
Field	--------	--------	--------	--------	--------	--------	--------	--------	36.1	13.0	30.3	19.7	57.7	61.6	31.7	29.3	6.6	20.4	30.6
Plot	--------	--------	--------	--------	--------	--------	--------	--------	43.5	11.2	32.3	18.6	50.8	27.7	17.9	23.7	5.5	18.3	25.0
Oats:																			
Field	71.0	43.0	19.9	50.9	17.3	41.3	36.7	0	56.2	13.2	39.6	24.6	57.6	40.9	24.6	18.8	6.0	23.5	32.5
Plot	77.2	39.8	15.2	65.1	22.4	56.8	42.5	0	59.1	13.3	33.6	24.8	66.8	46.1	25.1	23.1	5.0	18.0	35.2
Sorgo:	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Field	5,616	7,204	--------	5,763	5,035	5,035	3,619	3,498	--------	1,334	2,702	3,788	6,320	3,370	2,357	3,863	1,744	711	3,872
Plot	6,240	3,100	--------	6,700	3,964	4,040	4,290	4,300	--------	2,090	3,940	3,900	9,350	3,240	2,560	3,400	1,680	730	3,970
Alfalfa:																			
Field	--------	--------	872	1,553	--------	1,750	1,820	3,464	2,394	220	829	718	4,059	552	851	778	15	1,120	1,400
Plot	--------	--------	1,900	4,150	--------	2,125	1,900	1,200	2,250	500	450	200	3,525	1,400	1,350	400	50	75	1,432

The average yield of all plots as given here is not exactly the same as given in table 2, as all years are not included in the average. For example, barley represents an average of the last 9 years only, because barley was not grown on a field scale prior to 1923. With corn the year 1917 is omitted, because no field was harvested as ear corn in that year. In other words, average yields of plots appear for only those years in which comparable fields were harvested.

The most striking feature of the results is the fact that crops grown on a field scale produced yields nearly as high as and in some cases higher than those obtained on the plots. This result was hardly expected as the rotations were on land slightly above the average of the whole farm in general productiveness.

The greatest difference in favor of the plot yields was with corn. Part of the difference was real, but part of it was due to the fact that corn was grown largely for silage, and the most productive fields were generally put in the silo. Corn harvested for grain, except for one or two fields, was the portion of the crop not needed for silage.

The average yields of sorgo on plots and on fields were nearly equal although much variation between plots and fields was shown in individual years. In 1917 and 1923 all fields of sorgo were harvested as silage, and no yields of air-dry fodder were obtained.

The yield of oats on plots exceeded that of oats in fields, but the difference was not great.

Barley in fields produced a higher yield than barley in plots. This is accounted for by the fact that a proportionately high number of barley plots was grown under poor conditions. In the fields barley was generally grown after a cultivated crop or on fallowed land.

The average yields of alfalfa from fields and plots were practically equal, although there were material differences in individual years. The yields of alfalfa on plots were the yields obtained the second and third years after planting. The yields from fields generally represent those of established fields that were kept in alfalfa for longer periods of time. Yields from plots are sometimes much higher, but this is balanced by the fact that failure to obtain a good stand sometimes reduced the yields of plots.

Alfalfa in fields was usually stacked in the field and weighed when hauled. There was always a certain amount of loss from weathering. If the weights had been obtained when the alfalfa was stacked, the field yields would have exceeded the plot yields, which averaged nearly three-fourths of a ton per acre.

The comparative figures as a whole indicate that farmers should be able to obtain average yields at least as high as the averages of all plots.

Figures on crops harvested for silage are not given in table 8, because none of the rotation plots were harvested for silage, but it can be stated that there never was a total failure of corn or sorgo for silage in the 20 years that the station operated. In such years as 1917, 1930, and 1931 the silo utilized a crop of corn that would have been worthless for husking.

Results of fields also show the possibility of successive years of low yields and the desirability of carrying over grain reserves from years of good production.

COMPARISON OF CORN AND SORGO AS PREPARATIONS FOR WHEAT AND OATS

The value of a cultivated crop in rotations is determined to a considerable extent by the yields of grains following it. Results show that sorgo as a crop is well adapted to the section. The question arises whether yields of grain crops following sorgo are likely to be lower than following corn. For the purpose of determining the fact, four 2-year rotations were established in small fields in 1916. In all of these rotations the grain was grown on disked corn or sorgo stubble and the cultivated crop on fall-plowed grain land. The rotations were as follows: Corn and wheat, sorgo and wheat, corn and oats, and sorgo and oats.

The yields of grain in these rotations are given in table 9. The year 1916 is not included, because the preceding crop and preparation were uniform.

TABLE 9.—*Annual and average acre yields of wheat and oats following corn and sorgo at the Ardmore station for the 16 years, 1917–32*

Crop	1917	1918	1919	1920	1921	1922[1]	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	Average
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Wheat following corn	6.8	35.2	15.9	18.5	17.7	0	23.9	7.1	20.0	10.2	23.6	17.5	11.9	11.9	4.5	7.2	14.5
Wheat following sorgo	4.8	24.6	14.5	28.6	13.1	0	22.4	10.0	15.7	13.0	19.8	17.9	12.6	11.4	2.6	10.7	13.9
Oats following corn	24.3	57.2	19.3	43.9	41.1	0	63.8	12.8	32.4	22.7	39.9	37.9	17.5	30.8	10.7	22.5	29.8
Oats following sorgo	26.0	61.1	20.4	58.7	24.4	0	60.2	16.0	37.7	22.5	55.6	39.2	18.0	27.8	2.8	24.8	31.0

[1] Crops destroyed by hail.

The averages indicate that the yields of grain following sorgo may be expected to equal or nearly equal those obtained on corn ground. The relative acreages of corn and sorgo should be determined from the value of the crops themselves, without reference to the yield of grain that may be grown following them.

FEED-CROP ROTATIONS

A rotation to determine whether a more certain production of feed could be assured through a definite rotation was started in 1916. This rotation contained sorgo, corn, oats, and fallow, the fallow being heavily manured. The heavy application of manure was designed not only to show the effect of manure on crop production, but to determine whether it would correct a bad physical condition of the soil.

The soil at the time the experiment was started contained many alkalied or slick spots that crusted badly on drying and prevented emergence of crops. The quantity of manure added to this field was sufficient to correct this condition, and when the work ended in 1932 the soil appeared to be as mellow and to cultivate as readily as that of some of the more favorably situated fields. The manure induced a heavier vegetative growth of grains than was noted on fields not receiving manure. In good years this resulted in increased yields, but in some adverse years it reduced them. In 1927, when moisture for small-grain production was ample, the yield of oats from this rotation was very high. In 1930, overstimulation of the oats in its early stages of growth resulted in a complete failure to produce grain when severe drought checked the growth of the crop before grain had started to form.

The yields of oats, corn, and sorgo in this field for 16 years are given in table 10. The sorgo was harvested for fodder in 1930 and 1931. Green weights for those years were computed from the dry weight.

TABLE 10.—*Acre yields of crops in a 4-year field rotation at the Ardmore station for the 16 years, 1917–32*

Crop	1917	1918	1919	1920	1921	1922	1923	1924	1925
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Corn [1]	5,097	15,741	4,441	7,567	4,390	3,915	11,689	5,622	4,460
Sorgo [1]	10,799	17,693	10,661	11,841	7,695	10,451	17,213	8,271	13,003
	Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
Oats	16.7	70.2	22.5	35.2	47.2	[2] 0	65.1	15.2	59.6

Crop	1926	1927	1928	1929	1930	1931	1932	Average
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Corn [1]	9,418	10,175	8,766	4,433	3,902	2,000	1,500	6,445
Sorgo [1]	17,075	25,497	14,115	9,555	14,375	8,060	1,762	12,379
	Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
Oats	34.0	85.7	57.0	37.5	[3] 0	9.5	25.9	36.3

[1] Total green weight.
[2] Crop destroyed by hail.
[3] No grain produced because of drought.

Corn and sorgo were harvested for silage. The sorgo was grown on manured fallow in this rotation. However, the yield of sorgo in this rotation was not materially higher than the yields in other fields. The air-dry weight of sorgo mature enough for silage is approximately one-third of the green weight. On this basis, the average yield of air-dry stover was approximately 2 tons per acre.

The results indicate that dependable yields of feed crops can be obtained throughout a period of years. Oats failed to produce grain in 2 years. In one of these, 1922, hail destroyed the crop. In 1930 no grain was produced because of drought following a period of heavy early growth. In that year the oats were cut for hay after it appeared certain that no grain would be produced, and a hay yield of more than 1.5 tons per acre was obtained. In some of the years when the yields of grain were low, good farming practice would have dictated cutting the crop for hay. Yields of grain are so varied that a carry-over from years of good production is necessary.

Sorgo and corn never were complete failures during the 16-year period. In 1922, when small-grain crops were a total loss, sorgo recovered sufficiently to produce a yield of over 5 tons, green weight, per acre. The value of a crop like sorgo in such years cannot be overestimated. In only one year after this rotation was started was the yield of sorgo for silage less than 7,500 pounds per acre. Calculated as dry fodder, the average yield of sorgo was nearly 2 tons per acre, and only once was the yield less than 1 ton. In feeding tests with steers conducted at the station, sorgo closely approached alfalfa in feeding value. The dependable production of nearly 2 tons of feed per acre is of great value in a livestock-production program.

No total failure of the corn crop occurred during the period of the experiments, but there were several years when little or no ear corn was produced. The silage production of corn was only about half as high as that of sorgo, and the difference in favor of sorgo was greater in poor than in good years. Sorgo is the more productive feed crop, but corn is more valuable in years when a good crop of ear corn is produced. The greater ease of handling a corn crop and the need for ear corn for feed make corn the preferred cultivated crop. It is believed, however, that part of the corn acreage could be advantageously planted to sorgo.

In the field rotation just described, the sorgo was grown on fallowed land and the corn or sorgo land. Since its yields are increased by the use of fallow, sorgo had the preferred place in the rotation. In 1924 a new field rotation was started in which the corn followed manured fallow and the sorgo was grown on corn ground. In this rotation the sorgo was planted with a lister from 1927 to 1932. The yield of corn was proportionately greater than on the rotation previously described, and the yield of sorgo was smaller. The production of sorgo, however, remained higher than that of corn, in spite of the fact that sorgo does not do its best in this locality when planted with a lister.

Both of these rotations show that a fairly dependable production of feed may be obtained from corn and sorgo, and that good grain yields can be produced in most years. Neither of the rotations is the best that could be selected for general farm use. One cannot afford to grow corn after sorgo or sorgo after corn. Yields of small-grain crops are higher after a cultivated crop than after small grain. On the other hand corn and sorgo yield no more after cultivated crops than they do following small grain. Results obtained from rotations indicate that both corn and sorgo should be followed by small grain, the kind to be grown depending on the disposal to be made of the crop.

The need for barley for feed led to the establishment of a field of alternate barley and manured fallow in 1926. In this rotation the fields were 10 acres in size. The yield was below 25 bushels per acre in only 1 of the 6 years, 1927–32, and averaged 37.7 bushels. During the same years the average yield of barley from all plots was 24 bushels per acre. The average yield of all plots was below 25 bushels in 3 of the 6 years. Yields indicate that the same surety of production may be expected from fields as from plots. They also show that in years of exceedingly severe drought, such as 1931, even grain on fallowed land may fail to produce a crop worth harvesting.

VARIETAL TESTS

Varietal tests with grasses and forage crops were started in 1914. Forage-crop tests were carried on consistently, except for 3 years when no variety tests were conducted. Grain variety tests were continuous from 1923 to 1932. The number of varieties was increased in 1926. From 1929 to 1932 the 10 varieties of wheat included in the uniform variety test conducted by the Division of Cereal Crops and Diseases were grown in cooperation with that Division. Wheat varieties in other years, and other crops in all years, were grown under informal cooperation with divisions of the Bureau of Plant Industry.

The extreme importance of selection of varieties of grain to be grown in this section is shown by the tables for wheat, oats, and barley. Differences in yield between varieties of the same crop grown under identical conditions frequently exceed differences obtained under different crop sequences. For example, the difference in yield between White Smyrna and Coast barley, a variety of the type most widely grown, is greater than the difference between barley grown on corn ground and that grown on summer fallow. Poorly adapted varieties, like Hannchen, may yield only about half as much as better adapted varieties. No variety of oats is so outstanding as White Smyrna is among the barleys, but the loss in yield that could be experienced through the selection of a midseason variety like Swedish Select is clearly apparent.

With both barley and oats, earliness is an important factor. No late variety of either oats or barley produced yields comparable with those of earlier varieties. The early varieties are comparatively more productive in dry years than later varieties. Selection of the variety to be grown plays an important part in distributing production between years.

The wheat varieties tested were more uniform in yield than other grains, but even with wheat the selection of a good or a poorly adapted variety may change the yield 20 percent or more.

Variety tests of small grains were generally conducted on corn ground under uniform conditions. Comparison of the best varieties can be made to determine the relative productive capacity of the different crops. Kubanka wheat, Brunker oats, and White Smyrna barley were the most productive varieties during the period 1926–32. In pounds per acre the comparative yields of crops as represented by these varieties were 852 pounds for wheat, 986 pounds for oats, and 1,243 pounds for barley. These results are in harmony with those obtained in rotation studies.

WHEAT VARIETIES

Table 11 gives the annual and average yields of wheat varieties from 1923 to 1932. With each variety, the yield for each year is the average of three plots.

TABLE 11.—*Annual and average acre yields of wheat varieties at the Ardmore station for the 10 years, 1923–32*

Class and variety	C. I. no.	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	Average		
												1923–32	1926–32	In percentage of Marquis during comparable years
Hard red spring:		*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	
Reward	8182	-----	-----	-----	-----	-----	-----	6.7	11.7	2.8	5.3	-----	-----	173
Double Cross II-21-47 (Minn. 2305)	10005	-----	-----	-----	-----	-----	-----	-----	7.8	1.1	6.4	-----	-----	161
Marquillo	6887	-----	-----	-----	-----	-----	-----	7.0	9.3	.8	3.6	-----	-----	135
Hope	8178	-----	-----	-----	-----	-----	-----	10.3	7.5	.6	.7	-----	-----	125
Reliance	7370	-----	-----	-----	7.0	38.6	22.5	9.2	10.3	1.1	1.9	-----	12.9	119
Ceres	6900	-----	-----	-----	6.5	39.2	20.0	6.9	11.4	1.7	3.2	-----	12.7	117
Marquis	3641	27.8	1.7	22.7	8.5	32.2	20.0	5.8	7.5	.6	1.4	12.8	10.9	100
Supreme	8026	-----	-----	-----	-----	28.1	18.0	8.1	9.5	.8	2.1	-----	-----	99
Kota	5878	20.7	4.5	13.0	7.5	24.5	18.9	8.3	8.6	.8	4.5	11.1	10.4	87
Durum:														
Nodak	6519	-----	-----	-----	8.5	47.0	18.1	8.3	9.2	1.7	-----	-----	-----	124
Kubanka	1440	24.4	4.7	18.3	11.2	40.0	21.1	10.3	8.6	2.2	5.7	14.7	14.2	114
Acme	5284	25.9	4.1	18.7	11.8	43.9	19.5	7.8	8.7	-----	-----	-----	-----	111
Peliss	1584	27.0	3.4	18.3	5.2	40.3	16.9	10.3	10.1	1.4	3.5	13.6	12.5	106
Mindum	5296	-----	-----	-----	-----	-----	14.8	6.9	9.4	.8	4.6	-----	-----	103

Marquis wheat was grown continuously in these trials and affords a standard by which to measure other varieties. It is the variety of wheat most commonly grown in the section, and a new variety must be superior to Marquis to warrant a place in the crop program.

Kota proved to be less productive than Marquis over the 10-year period. There were no years of heavy stem rust infection, so rust resistance was not an important factor in determining yields. It is noteworthy that Kota produced higher yields than Marquis in dry years when there was little or no rust infection, and produced lower yields in years more favorable to stem rust. For the period as a whole, Marquis was distinctly superior to Kota.

Ceres and Reliance were practically equal in yield, and both were more productive than Marquis during the 7 years that they were under trial. As stated before, there were no years when yields were noticeably lowered by stem rust, so the difference was not due to rust resistance. In 6 of the 7 years both of these varieties equaled or exceeded Marquis in yield.

The varieties grown only since 1929 had no opportunity to show their production in favorable seasons. Yields of all varieties were so low that large percentage gains mean little, and none of these varieties can be recommended without being tried in years of good production. Reward appears to be the most promising. During 1931 and 1932 its earliness was the principal factor in producing yields above the average. Hope lacks heat resistance and produced lower yields and a poorer quality of grain during the time it was grown than Ceres, Reliance, Marquillo, or Reward. All the hard red spring varieties grown from 1930 to 1932, except Hope and Supreme, are worthy of further trial in the section.

Kubanka wheat was one of the best yielding durum wheats. Its quality for the manufacture of semolina and macaroni and its wide distribution make it the best variety. Kubanka exceeded all durum varieties except Nodak in yield. Its much better qualities make it more valuable than Nodak.

During the period 1926–32 Reliance, the best yielding variety of hard red spring wheat, produced an average yield of 12.9 bushels per acre. During the same period Kubanka, the highest yielding durum wheat, produced an average yield of 14.2 bushels per acre. The difference in yield in favor of Kubanka was not proportionately so high as the price difference in favor of hard red spring wheat. When any great margin in price exists, it more than makes up for the higher yield of durum wheat.

OAT VARIETIES

Comparative yields of oats are shown in table 12. Sixty-Day was used as a standard for measuring other varieties.

TABLE 12.—*Annual and average acre yields of oat varieties at the Ardmore station for the 10 years, 1923–32*

Group and variety	C. I. no.	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	Average		
												1923–32	1926–32	In percentage of Sixty-Day during comparable years
Early white:		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	
Gopher	2027	-----	-----	-----	18.1	85.9	35.4	9.9	23.7	1.1	25.3	-----	28.5	107
Iowa	847	-----	-----	-----	18.1	88.5	31.8	7.8	15.1	1.1	21.1	-----	26.2	98
Nebraska No. 21	841	52.0	-----	40.6	0	74.0	31.3	17.2	16.9	-----	-----	-----	-----	92
Early yellow:														
Richland	787	-----	-----	-----	-----	-----	-----	-----	-----	2.6	21.6	-----	-----	106
Sixty-Day	165	52.9	4.2	36.9	21.6	75.0	34.9	16.7	15.4	.5	22.4	28.1	26.6	100
Burt × Sixty-Day	727	-----	-----	-----	21.3	67.7	29.2	10.4	24.5	1.0	26.6	-----	25.8	97
Early red: Brunker	2054	-----	-----	-----	21.3	80.2	33.8	19.3	27.1	2.6	31.1	-----	30.8	115
Midseason white:														
Swedish Select	134	41.3	1.5	20.0	0	64.0	25.5	4.2	5.2	2.1	12.5	17.6	16.2	63
Midseason yellow:														
Markton	2053	-----	-----	-----	26.3	70.7	33.3	5.7	15.4	5.7	20.6	-----	25.4	95
Golden Rain	493	45.2	3.1	35.0	0	66.0	26.6	5.2	2.6	-----	-----	-----	-----	71
Hull-less:[1] Fowlds	1996	-----	4.2	40.0	9.4	60.9	26.6	8.8	9.4	-----	-----	-----	-----	78

[1] Calculated at 32 pounds to the bushel.

Brunker was the outstanding variety of oats. During the 6-year period this variety produced an average yield 4.2 bushels per acre higher than Sixty-Day, and in dry years the grain was generally of better quality. In the very dry years, 1931 and 1932, Brunker was the only variety of oats that produced grain weighing more than 32 pounds per bushel.

Gopher oats were less productive than Brunker but were considerably better than other varieties. During the 6-year period they produced an average yield of 28.5 bushels per acre. Three other varieties of oats, Iowar, Burt × Sixty-Day, and Markton, produced yields closely approaching each other but all lower than Gopher. Very little oat smut appeared during the variety test, and the smut resistance of Markton was not a factor in influencing yield.

Midseason varieties were uniformly unproductive. Swedish Select, the only midseason variety grown continuously, produced 17.6 bushels per acre during the 10-year period as compared with 28.1 bushels for Sixty-Day over the same period.

Brunker appears to be the variety best suited to this section, and its increase is recommended.

BARLEY VARIETIES

The yields of barley varieties during the period 1923–32 are shown in table 13.

TABLE 13.—*Annual and average acre yields of barley varieties at the Ardmore station for the 10 years, 1923–32*

Variety	C. I. no.	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	Average		
												1923–32	1926–32	In percentage of White Smyrna during comparable years
		Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Percent*
Ace	1853	-----	-----	-----	-----	-----	24.6	17.7	26.8	5.2	15.5	-----	-----	104
White Smyrna	658	38.0	2.8	44.2	27.7	67.0	25.3	18.4	24.1	0	18.9	26.6	25.9	100
Vaughn	1367	-----	-----	-----	-----	-----	-----	11.5	25.3	5.2	13.2	-----	-----	90
Trebi	936	52.6	3.3	31.3	10.6	68.1	19.4	12.8	16.3	2.8	9.0	22.6	19.9	85
Horn	926	-----	-----	-----	16.3	76.0	25.7	12.5	10.7	2.1	8.5	-----	21.7	84
Odessa	182	47.4	1.8	23.3	11.5	73.3	20.5	4.2	16.9	2.8	5.7	20.7	19.3	78
Coast	690	-----	-----	-----	16.5	50.0	21.2	17.0	17.0	0	12.9	-----	19.2	74
White Gatami	920	34.6	1.8	23.3	9.4	49.0	17.0	11.1	-----	-----	-----	-----	-----	65
Glabron	4577	-----	-----	-----	-----	-----	-----	10.1	13.9	2.8	10.7	-----	-----	61
Horsford	507	-----	-----	22.5	6.5	52.4	16.3	7.0	15.1	-----	-----	-----	-----	58
Hannchen	531	24.3	2.8	27.6	0	64.9	17.7	3.5	3.1	0	0	14.4	12.7	54
Velvet	4252	-----	-----	-----	-----	-----	-----	-----	7.8	1.0	4.5	-----	-----	31

White Smyrna (C. I. 658) was outstandingly more productive than other varieties. During the period 1926–32, its average yield was 4.2 bushels per acre higher than that of any other variety. Ace, a variety grown from 1928 to 1932, equalled White Smyrna in yield. This variety is a selection of White Smyrna and was grown under the impression that it was taller, but it proved to be shorter than White Smyrna. As one of the principal objections to White Smyrna is its short straw, Ace appears to be no improvement.

Vaughn barley, a short, stiff-strawed, six-rowed variety, produced yields approaching those of White Smyrna during the 4 years it was grown. It may be valuable for replacing White Smyrna on soils where that variety lodges. Without production data during good years, it is impossible to tell to what extent Vaughn will respond to more favorable conditions.

In nearly all years a good quality of grain was obtained from White Smyrna, even in years when many other varieties produced shriveled grain. The dependable production and good quality of grain produced by White Smyrna make it the variety best adapted to this section of those under trial. In spite of this fact, the acreage of White Smyrna has not increased rapidly. Its ragged appearance in the field creates a prejudice against it.

FLAX VARIETIES

Flax varieties were grown in 1930 and 1931. The crop was a complete failure in 1931. In 1930 yields were too low to be significant.

CORN VARIETIES GROWN FOR GRAIN

Corn varieties were grown for grain production during the years 1923–32. There was little to choose from in yield between several of the early varieties of dent corn and some of the flint corns. Northwestern Dent, Payne White Dent, Falconer, Alta, Gehu Flint, Mercer Flint, and White Flour corn may be depended on to mature every year. Later varieties do not mature on heavy soil like that at Ardmore but do mature on lighter soils within the section.

Corn varieties do not have the fixed characteristics of small-grain varieties. The date of ripening, height of ear, and many other characteristics may be greatly changed by selection. Two strains of the same variety from different localities may exhibit markedly different characteristics. The source of the seed used in a variety test is often a stronger factor than the variety in determining yield, and the results of variety tests may be misleading.

For this reason no table of corn yields is included. Adapted strains that have been produced locally for a number of years are likely to be more productive than corn brought in from a distance. Since maturity is an important factor, if corn seed is introduced an effort should be made to procure it from a source where the season is as short as or shorter than the season where the crop is to be grown.

CORN VARIETIES GROWN FOR SILAGE

Varietal tests of corn for silage were conducted from 1923 to 1931. Results are given in table 14. In most years sunflowers and Dakota Amber sorgo were grown for comparison. Sunflowers were discontinued after 1929. They were less productive than some varieties of corn and contained much less dry matter. In some years they were too immature to make silage of good quality.

TABLE 14.—*Annual and average acre yields (green weight) of corn, sunflowers, and sorgo harvested for silage at the Ardmore station for the 10 years, 1922–31*

Crop and variety	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	Average for years tested	Years grown	Average yield in percentage of Rainbow Flint during comparable years
Corn:	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Number*	
Rainbow Flint	5, 180	9, 575	10, 500	6, 075	12, 750	23, 715	9, 638	6, 167	8, 750	3, 602	9, 595	10	100
Calico Dent				7, 400	9, 175	18, 950					11, 842	3	84
Minnesota 13	4, 270	10, 100	7, 200	9, 950	8, 850	13, 640	8, 138	6, 452	5, 250	2, 738	7, 659	10	80
Fulton Yellow Dent			8, 475	7, 750	9, 250	15, 215	8, 552				9, 848	5	79
Akron Yellow	4, 920		7, 100	7, 725	6, 725	18, 120					8, 918	5	77
Mercer Flint		11, 300	8, 450	7, 500	7, 175	13, 715	8, 588	5, 083	4, 625	2, 888	7, 703	9	76
Akron White		3, 825	7, 650	10, 800	8, 800	11, 810	8, 890	7, 250	7, 125		8, 269	8	76
U. S. Selection 133	2, 090	9, 550	5, 500	6, 525							5, 916	4	76
Martin White	3, 050	7, 450	5, 650	7, 000							5, 788	4	74
Northwestern Dent	2, 000	11, 450	6, 175	6, 975	7, 375	12, 760	7, 088	5, 208	4, 625	3, 188	6, 684	10	70
Payne White Dent	4, 470	7, 350	7, 700	6, 325	5, 125	10, 690	7, 838	6, 875	4, 790	3, 188	6, 435	10	67
Gehu Flint					4, 625	10, 380	7, 200	5, 667	2, 500	2, 777	5, 525	6	51
Sunflowers	2, 030	7, 950	8, 320	6, 600	11, 850	25, 645	11, 025	6, 708			10, 016	8	96
Sorgo: Dakota Amber		12, 100	7, 700		14, 950	19, 095	15, 075	5, 208	4, 960	2, 738	10, 228	8	97

Rainbow Flint produced by far the highest yield of any variety of corn tested. This variety does not mature grain regularly at Ardmore, but acclimated strains mature sufficiently to make a good quality of silage. Of the varieties of corn that mature, Northwestern Dent, Mercer Flint, and Payne White Dent were about equally productive. These earlier maturing varieties contained a slightly higher proportion of dry matter than Rainbow Flint, and probably contained a higher percentage of grain. The much higher yield of Rainbow Flint more than compensates for this difference.

Minnesota 13 produced yields of silage somewhat higher than those of the early varieties, but it always was immature when harvested.

The air-dry matter present in the corn when harvested for silage was determined during the 6 years, 1926–31. While the green weight of Rainbow Flint was 44 percent higher than that of Northwestern Dent the air-dry matter was 39 percent higher.

MILLET VARIETIES

Millet varietal tests were conducted from 1915 to 1931 with the exception of 3 years. Sorgo and Sudan grass in 7-inch drills, the planting method used for the millet varieties, were grown in comparison with the millets. During the period 1915–20 these tests were conducted by the Office of Alkali and Drought Resistant Plant Breeding Investigations. Results are shown in table 15.

TABLE 15.—*Annual and average acre yields of millet varieties, sorgo, and Sudan grass at the Ardmore station during certain years from 1915 to 1931*

Crop and variety	1915	1916	1918	1919	1920	1923	1924	1925	1926	1927	1928	1929	1930	1931	Average	In percentage of Dakota Kursk during comparable years
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	
Millet:																
Dakota Kursk	4,670	3,240	4,330	3,870	4,370	4,700	0	3,890	3,400	5,750	6,250	2,867	3,665	1,080	3,720	100
Siberian	5,030	3,970	4,170	3,630	4,180	4,970	0	3,520	2,780	4,583	6,000	1,967	4,165	1,330	3,593	97
Gold Mine	4,630	3,350	3,780	2,770	5,670	5,020	0	4,800	3,370	4,667	5,750	2,567	2,625	1,080	3,577	96
Kursk No. 5	4,870	2,950	4,270	3,470	3,970											95
German	5,230	2,730	3,250	2,120	4,480	4,070	0	2,450	3,020	9,167	5,250	2,050		1,170	3,461	93
Common	3,630	3,200	4,270	3,330	3,970											90
Hungarian	3,800	3,270	3,970	2,830	4,170	4,930	0	3,050	3,050	4,583	5,083	2,200	2,915	500	3,168	85
Sorgo: Dakota Amber	7,470	7,830	4,170	4,870	8,880	5,100	0	1,160	5,920	14,833	5,333	6,333	5,000	1,750	5,618	151
Sudan grass	6,800	3,980	3,670	1,880	5,830	3,400	0	4,400	2,900	8,167	4,500	2,667	4,875	1,500	3,898	105

Both sorgo and Sudan grass were more productive than the millets, but the difference in yield between Sudan grass and the more productive varieties of millet was small. Dakota Kursk was the highest yielding millet. This variety has fine leaves and a relatively fine stem. As it excels the other varieties not only in yield but in quality, it can be recommended as a catch crop.

Sudan grass produced slightly higher yields than millets, and its feeding value is at least as high.

Neither millet nor Sudan grass approached sorgo in yield, but sorgo produced in drilled plots is difficult to handle. It dries very slowly and is subject to damage by rain while curing. Sorgo is a recommended forage crop, but for convenience in handling it should be grown in cultivated rows.

SORGO VARIETIES AND SUDAN GRASS

Sudan grass and three varieties of sorgo were grown continuously in 42-inch rows from 1923 to 1932 and one additional variety from 1925 to 1932. The yields are given in table 16. Some variety testing was done prior to 1923, but the records were not continuous and are not given. During the period 1923–32 Red Amber sorgo produced the highest yield and Black Amber only slightly less. All the sorgos exceeded Sudan grass in yield. Of the sorgos Dakota Amber produced the lowest yield but the highest quality of feed. It matured fully every year, and there always was a considerable amount of ripe seed in the forage, which increased its feeding value. Sorgos appear to increase both in feeding value and in palatability as they approach maturity, and Dakota Amber is recommended because it matures. Red Amber and Black Amber matured in some years, but in other years they were far from mature when harvested. Black Amber appears to be a little earlier than Red Amber and produced a greater percentage of matured grain. It is a more valuable crop to grow than Red Amber. Leoti Red produced good yields during the period it was grown, but it is the latest of the varieties under trial and never approached maturity when harvested.

TABLE 16.—*Annual and average acre yields of sorgo varieties and Sudan grass at the Ardmore station for the 10 years, 1923–32*

Variety	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	Average	In percentage of Red Amber during comparable years
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	
Leoti Red	------	------	3, 050	6, 280	11, 035	4, 510	3, 250	5, 460	1, 150	2, 556	4, 661	106
Red Amber	6, 600	521	3, 040	3, 730	11, 310	5, 168	3, 042	5, 060	840	2, 926	4, 224	100
Black Amber	6, 520	1, 061	4, 210	4, 010	8, 440	5, 177	3, 208	5, 360	1, 177	2, 399	4, 156	98
Dakota Amber	4, 320	936	2, 433	4, 910	6, 988	4, 193	2, 917	3, 065	1, 268	1, 397	3, 243	77
Sudan grass	5, 090	628	2, 000	2, 450	3, 917	2, 070	1, 675	3, 415	872	935	2, 305	55

Sorgo and Sudan grass were grown in 42-inch rows in the sorgo variety test and in 7-inch drills in the millet variety test during certain years from 1915 to 1931. Comparison of the yields from the two methods of production is made in table 17. Both sorgo and Sudan grass produced higher yields in drilled plots than in rows.

TABLE 17.—*Acre yields of sorgo and Sudan grass grown in 7-inch drills and in 42-inch rows at the Ardmore station, during certain years from 1915 to 1931*

Crop	1915	1916	1918	1919	1920	1923	1924	1925	1926	1927	1928	1929	1930	1931	Average
	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
Sorgo: [1]															
Drilled	7,470	7,830	4,170	4,870	8,880	5,100	0	1,160	5,920	14,833	5,333	6,333	5,000	1,750	5,618
Rows	8,300	6,860	5,850	3,930	3,650	4,320	936	2,433	4,910	6,988	4,193	2,917	3,065	1,268	4,259
Sudan grass:															
Drilled	-----	3,980	3,670	1,880	5,830	3,400	0	4,400	2,900	8,167	4,500	2,667	4,875	1,500	3,675
Rows	-----	3,660	4,180	2,430	2,820	5,090	628	2,000	2,450	3,917	2,070	1,675	3,415	872	2,708

[1] Dakota Amber.

Sudan grass cures readily when cut and is easily handled as hay. It should be planted with a drill and handled like any other hay crop. Sorgo dries very slowly and is subject to injury by wet weather during the curing process. Sorgo in rows produces a much higher percentage of seed than that planted in drills, and is easily handled as a fodder crop. In spite of the lower yield, its production in cultivated rows is recommended. The better quality of feed and the greater ease of handling more than make up for the difference in tonnage.

ALFALFA, BROMEGRASS, AND CRESTED WHEATGRASS

Tests of alfalfa, bromegrass, and crested wheatgrass were conducted by the Office of Alkali and Drought Resistant Plant Breeding Investigations during the period 1917–22. No tests were conducted during the period 1923–25. Seedings of bromegrass, crested wheatgrass, and four varieties of alfalfa were made in 1926, from which yield data are available from 1927 to 1930.

Results given in table 18 show that crested wheatgrass and alfalfa approached each other very closely in yield during the entire period. In the early seeding crested wheatgrass was more productive, and during the later period alfalfa was more productive. Bromegrass was decidedly lower in yield than crested wheatgrass during both periods. Reduction in yield through becoming sod-bound was responsible for much of the lowered yield of bromegrass. In neither of the seedings that were made did crested wheatgrass become sod-bound.

TABLE 18.—*Annual and average acre yields of alfalfa, bromegrass, and crested wheatgrass hay at the Ardmore station, during certain years from 1917 to 1930*

Crop and variety	1917	1918	1919	1920	1921	1922	1927	1928	1929	1930	Average, 1927–30	Average, 1917–30
	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
Alfalfa:												
Grimm	1,800	5,570	1,170	550	1,600	2,000	4,567	1,150	1,160	350	1,807	1,992
S. Dak. No. 12	------	------	------	------	------	------	5,017	1,517	1,360	850	2,186	-------
Ladak	------	------	------	------	------	------	4,667	1,117	1,360	535	1,920	-------
Cossack	------	------	------	------	------	------	4,400	1,350	1,327	485	1,891	-------
Bromegrass	3,400	2,300	240	160	800	800	2,267	1,100	833	550	1,188	1,245
Crested wheatgrass	5,400	4,800	1,100	250	1,400	1,500	2,227	1,533	733	1,135	1,407	2,008

Native common, or South Dakota No. 12, alfalfa was more productive than any other variety under trial during the period 1927–30. This difference was consistent from year to year. For hay production there is no variety superior to the acclimated native alfalfa. For seed production, varieties whose seed commands a higher price are recommended.

SHELTERBELT INVESTIGATIONS

The need for trees to provide protection from wind and snow led to the planting of the first shelterbelt at the field station. Later Ardmore was selected by the United States Northern Great Plains Field Station, Mandan, N. Dak., as one of four stations where a definite set of uniform experimental plantings was made. These experimental plantings were made to study the species of trees adapted to shelterbelt use; the spacing of trees in the shelterbelt; the advantages and disadvantages of pruning; and the relative merits of mulching, clean cultivation, and lack of cultivation during the early years of a shelterbelt.

During the life of the experiments nearly all the trees used were shipped to the station from Mandan, N. Dak., and annual inspections of the shelterbelt were made by officials from that station.

The heavy soil and dry subsoil at Ardmore produce conditions of exceptional severity, under which only the hardiest species of trees were able to survive. The drought of 1931 was instrumental in completing the destruction of less hardy trees.

The first shelterbelt was planted along the west side of the buildings and grounds in 1917. This belt was divided into two blocks each 450 feet long, one block being spaced 4 by 4 feet and the other 4 by 8 feet. Siberian pea-tree in both blocks were spaced 2 feet apart in the row. Nine rows of trees were planted in each block in the following order from west to east:

(1) Laurel willow (*Salix pentandra* L.); (2) boxelder (*Acer negundo* L.); (3) green ash (*Fraxinus pennsylvanica lanceolata* (Borkh.) Sarg.); (4) boxelder; (5) and (6) Northwest poplar (*Populus* sp.); (7) American elm (*Ulmus americana* L.); (8) boxelder; and (9) Siberian pea-tree (*Caragana arborescens* Lam.).

All trees, except Siberian pea-tree, in the block spaced 4 by 8 feet were pruned. Ordinarily the low-growing, hedgelike type, in this case Siberian pea-tree, should be planted on the windward side, in this locality the west side, of the shelterbelt to trap snow in the belt itself, but in this planting it was placed on the east side. A good stand was obtained from all species planted.

The trees in the section spaced 4 by 4 feet did well until their spread prevented cultivation with available equipment. They reached that stage without shading the ground sufficiently to check weed growth, and the block became a breeding plot for weeds. Weed seeds produced in it were scattered to other parts of the farm. The poplars made good growth, and a loss of not over 20 percent was incurred prior to the winter of 1921. They had used up nearly all available moisture by autumn that year and went into the winter dry. The next spring about 80 percent of them were dead, and the remainder were weakened. By 1925 the only trees of this species remaining were those in favored locations at the end of the row.

Laurel willow and boxelder in the 4 by 4 foot planting suffered only partial winter killing until about 1929. From then on many trees died each year, and in the winter following the dry year 1931 these species were entirely eliminated. The American elm and ash survived fairly well, though they made little growth owing to their crowded and weedy condition. Ash proved to be more hardy than elm. In the spring of 1932 practically all the ash and about 60 percent of the elms in the original planting were still alive.

In the section spaced 4 by 8 feet cultivation was carried on for a longer period, and the trees grew more rapidly. The poplars and willows, however, commenced to die following the winter of 1921, and within the next few years were entirely eliminated. The boxelders survived fairly well until 1929, when they had exhausted the moisture in the wider area provided by the 8-foot planting. During the winter of 1929 portions of many of them died, but very few trees were entirely killed. During the winters of 1930 and 1931, practically all the boxelders were killed outright, and by the spring of 1932 the only trees left in this planting were the ash and the American elm. These two species were injured but not killed during the winter of 1931, and with favorable weather in the spring of 1932 seemed to be again in fair growing condition. The elms and ash in this planting averaged somewhat greater height and diameter growth than those in the planting spaced 4 by 4 feet. The elm and ash in both tests were injured by borers in 1932.

The single row of Siberian pea-tree survived during the entire period and in 1932 was one of the finest examples of a snow trap to be found. The trees make a practically solid row approximately 10 feet in height, and each winter collect a large drift of snow that not only holds much snow away from the buildings, but gives this row of trees and trees situated to the east of them a surplus supply of moisture. The species is perfectly hardy.

Differences in spacing distance had little effect on survival in this test. Qualities inherent in the species, rather than the closeness of planting, determined their ability to survive adverse conditions. Either rate of planting was thick enough to exhaust the available soil water.

Plantings of conifers were made from year to year in a strip of land east of the row of Siberian pea-tree. Conifers are much more difficult to transplant than deciduous trees, and only a small percentage of survival was obtained each year, but the trees seemed to be hardy after becoming established. Continued plantings in spaces where trees failed to survive were carried on until 1922. By that time there was a fair stand of conifers and the roots of the trees had become so well established that newly planted trees had little chance of surviving. For the first few years the growth of these conifers was slow, but during the later years they grew rapidly and in 1932 were the most showy part of the shelterbelt.

The species of conifers used in the test were jack pine (*Pinus banksiana* Lamb.), Scotch pine (*P. sylvestris* L.), and ponderosa, or western yellow pine (*P. ponderosa* Dougl.). Until the winter of 1930, the conifers, owing to a thinner stand and to water provided by trapped snow, did not experience a distinct water shortage. In the summer of 1931, the jack pine showed some evidence of drought damage, and a few of them died. The ponderosa pine and the Scotch pine were still in good condition in 1932. They have extended their branches enough to cover most of the space between them and have become very valuable, both for wind protection and as snow traps.

In the spring of 1917, three rows of Chinese elm were planted on the north side of the garden, and a row of Siberian pea-tree was planted between the north row of Chinese elm and a strip of sod bordering the cultivated land. The Chinese elm made a remarkable growth, and by 1925 they were the tallest trees on the station. Nearly all of these trees were still alive in 1932, though there was some killing of branches following the winters of 1930–31 and 1931–32. The row of trees next to the garden is several feet taller than the row next to it, and this row in turn is taller than the row bordering the Siberian pea-tree. This difference is accounted for by the fact that the trees on the side next to the garden are able to draw upon the cultivated soil in the garden for moisture. No doubt the second row also obtains some moisture from the garden. This has been a great benefit to the trees but not to the garden crops. Occupation of the soil by tree roots has made unproductive for garden crops a space approximately 40 feet wide bordering the Chinese elm.

The row of Siberian pea-tree between the Chinese elm and the sod is an example of survival under adverse conditions. This row is so overshadowed by the Chinese elm, and has such a small area of cultivated ground from which to draw moisture, that it has had a severe struggle for existence. In spite of the adverse conditions, practically all the trees have lived and there has been no killing of branches. Naturally these trees have grown very slowly, but their survival shows that they are able to withstand the most severe conditions.

PRUNING AND SPACING EXPERIMENT

In 1918 three blocks of trees were planted for a pruning demonstration. One of the blocks was to be pruned high, one medium, and one left unpruned. Each block was planted to 10 rows of trees arranged in the following order: (1) Buffaloberry (*Lepargyrea argentea* (Pursh) Greene); (2) willow (*Salix* sp.); (3) boxelder; (4) green ash; (5 boxelder; (6) Northwest poplar; (7) green ash; (8) boxelder; (9) laurel willow; and (10) Tatarian maple (*Acer tataricum* L.). The trees were spaced 4 by 4 feet in half of each block and 4 by 8 feet in the other half.

The evil effects of pruning were apparent as soon as the trees had reached a height of 7 or 8 feet. The pruned blocks of trees were entirely unsatisfactory for catching snow or providing protection from the wind. The ground in the pruned block was almost invariably blown free from snow, while drifts of snow collected in the unpruned block. Trees in the unpruned block were more vigorous than those in the pruned blocks, and the survival was better. A shelterbelt in this section should be left unpruned, in order that it may catch the snow that would otherwise drift around the farm buildings. The water from the melting snow furnishes a much needed supply for the trees.

The willows were the first to die, except for end trees which were able to send their roots into the cultivated area outside of the belt. The poplar became eliminated next, and these were followed by boxelder which have practically all died in recent years. The few surviving boxelder trees have suffered heavy killing back. Green ash were in the best condition of any species in 1932, though they showed some damage from borers. Buffaloberry had suffered very little loss, but the trees presented a very ragged appearance, chiefly as a result of top and side crowding by sharpleaf willow in the adjacent row. Tatarian maple seems to be semihardy. This tree appears to be especially palatable to rabbits, and until the shelterbelt was surrounded by rabbitproof fence in the fall of 1927, trees were killed nearly to the ground each year by rabbits. After 1927 these maples made fair growth, though portions of the trees were killed following the dry year 1931.

COMPARISON OF CULTIVATION, MULCHING, AND LACK OF CULTIVATION

Comparison was made of clean cultivation, lack of cultivation, and mulching in the care of a shelterbelt. The same species of trees and spacings were used as in the pruning test. The neglected or uncultivated block was a continual source of weed seed that blew over the adjoining fields. Losses of species were much the same as in the previous experiment. The willow, poplar, and boxelder, however, died out at an earlier age, and the more hardy species, green ash, buffaloberry, and Tatarian maple, made a slower growth in the noncultivated block than in the blocks of other cultural treatments.

The mulched block of trees was covered with straw to a depth of about 6 inches, and straw was added each year for several years to maintain this mulch. This block of trees did not grow so well as the clean cultivated block, and the less hardy species, willow, poplar, and boxelder, died out at an earlier age. In 1932 all except the hardiest species, ash, buffaloberry and Tatarian maple, were dead in both blocks. As in other tests the green ash proved hardiest.

SPECIES BLOCKS

Blocks of trees, each set in pure stands, were planted in 1918. The species used in this test were Northwest poplar, laurel willow, boxelder, and green ash. Each block was divided, one-half being spaced 4 by 4 feet and the other half 4 by 8 feet. Nearly all the poplar trees died following the winter of 1924–25. The willow trees did not entirely die, but killed back to the ground each winter, and new growth took place from the roots the next spring. These two blocks of trees were pulled in 1930. The boxelder trees grew with but little injury until about 1927. During the years 1930–32 nearly all the boxelders died either in whole or part, and the boxelder block then presented a very ragged appearance.

The block of ash trees has shown very little killing, although many of the trees appeared to be weakened in the spring of 1932. This was followed by a good recovery, and the trees were in good condition in the autumn except for borer injury. The trees have not made much growth the past few years, the block spaced 4 by 4 feet having an average height of 10 feet and a diameter of 1.5 to 3 inches, as compared with an average height of 9 feet and a diameter of 2.5 to 3 inches in the block spaced 4 by 8 feet. As in previous tests, this species has proved to be the most hardy of those tested.

HOG-HOUSE SHELTERBELT

The hog house at the field station was located to the north and west of the other buildings in a comparatively exposed position. To protect this house a shelterbelt consisting of three rows of Chinese elm, three rows of Russian-olive (*Elaeagnus angustifolia* L.), and one of honeylocust (*Gleditsia triacanthos* L.) was planted in 1925. A severe freeze in September 1926, before the trees had ceased growth for the season, caused partial killing of the young elm and Russian-olive trees. Conditions were favorable the next spring, and these trees made a rapid growth, but the character of the growth was bushy because of the killing of the top branches.

The killing back causing a bushy growth resulted in this becoming the best snow catcher of any belt on the farm, entirely eliminating snowdrifts from the hog house and farrowing pens. The large amount of snow held by the belt gave the trees additional moisture, which has been very clearly reflected in the resultant remarkable growth.

The Russian-olives, since 1926, have shown little winter injury, except for certain trees whose smaller branches have been killed. Chinese elms showed little winter injury from 1926 to 1931. In the spring of 1932 a few elms were found to be entirely dead, and many others had dead branches.

Honeylocusts have survived fairly well, but have been very poor trees for shelterbelt purposes. They have few branches near the ground, and as a result are valueless as snow catchers. This species should be planted in interior or leeward rows where it will serve for wind-protection purposes, rather than toward the windward side where the chief function would be to hold drifting snow. The use of the thornless variety is recommended for shelterbelts.

CONCLUSIONS FROM SHELTERBELT INVESTIGATIONS

The accumulated results to date indicate that shelterbelt plantings should be restricted to a few species of hardy trees. Low-growing bushy species to check snow should form the border rows on the north and west. Siberian pea-tree and Russian-olive are adapted to this purpose. Ash and American elm have proved to be the best adapted of the taller-growing species, with ash the most hardy of the two but having a slower growth rate. Chinese elm has also given good promise, and its rapid growth rate makes it a valuable species for use in a windbreak where quick protection is desired. They should be planted with full understanding that they may not be fully hardy, and that in time they may be eliminated. By the time the Chinese elm has killed out, the ash and American elm should have reached a height sufficient to check the wind in the immediate vicinity. Northwest poplar also has a rapid growth rate and can be used as a temporary tree on the more favorable sites. Where rapid growth and a good survival is desired over a period of years, the Chinese elm should be used in preference to Northwest poplar on all sites except those which are very favorably situated in relation to moisture.

In general it may be stated that many species of trees are hardy so long as available moisture is present in the soil. Going into the winter dry is the most severe test for a tree. Trees that can survive this condition are in a position to form part of a permanent shelterbelt. Moisture is so much of a factor in hardiness, that a shelterbelt holding snow has a great advantage over one not catching snow. The amount of moisture above the average precipitation obtained through retaining snow is a vital factor in the growth of shelterbelts.

The losses of less hardy species sustained in the shelterbelts at Ardmore might lead one to believe that shelterbelts are not a success. This is not true. The trees remaining in the shelterbelts at Ardmore serve their purpose in holding snow away from the buildings. The shelterbelt as a whole greatly improves the appearance of the farm and makes it a more pleasant place to live. For the sole purpose of catching snow, a shelterbelt pays for its upkeep. In adding to the appearance of a farm and as an aid in making a farm a real home, the shelterbelt has a value that cannot be measured. Results from experiments with shelterbelt plantings should enable farmers to avoid costly mistakes in establishing them.

FARM ORCHARD INVESTIGATIONS

Plantings of fruit trees were made at different times following the establishment of the shelterbelt. Severe rabbit injury caused the loss of many trees, and in the spring of 1927 not over a 15-percent stand of trees remained in the orchard. Replacements of all dead trees were made in the spring of 1927, and the orchard and shelterbelt were surrounded with a rabbit-proof fence. There was no further rabbit injury, as the few rabbits that made their way into the enclosure were easily removed. Some of the less hardy varieties of trees died each year, and replacements with hardier varieties were made each year until 1931. By 1931 the roots of the older trees occupied the soil so completely that newly planted trees had little chance of surviving.

The trees have not reached a condition where moisture shortage plays a part in determining hardiness. The wide spacing and clean cultivation practiced in the orchard should indefinitely postpone the reaching of such a condition. Fruit trees need moisture for the production of fruit, and ample room, combined with freedom from weed competition, appears to be essential to successful fruit growing.

The greater proportion of the fruit trees in the station orchard was procured from the United States Northern Great Plains Field Station, Mandan, N. Dak. Selection of varieties for Ardmore was based largely on results at Mandan. Detailed reports on the hardiness and quality of different species of fruit trees for the section are contained in Farmers' Bulletin 1522.[3] This bulletin also gives information on selection of site, care of trees, planting, spacing, and pruning.

No extensive variety test of fruit trees was made at Ardmore, but the varieties that are still growing well in the orchard appear to have the hardiness necessary in this section. The less adapted varie-

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[3] BAIRD, W. P. THE HOME FRUIT GARDEN ON THE NORTHERN GREAT PLAINS. U. S. Dept. Agr., Farmers' Bull. 1522, 49 pp., illus. 1927.

ties have died. The behavior of the different varieties of apples and plums in the station orchard will be briefly discussed.

APPLE VARIETIES

No standard variety of apples has yet borne much fruit, though some varieties have begun to bear. The Anoka produced fruit the earliest after setting out. It appears to be fully hardy and has ample foliage to protect the tree. The Hibernal is very hardy, but the foliage is too scant for sun protection, and the trees had not commenced to bear in 1932. Wealthy and Oldenburg (Duchess) appear to be hardy with adequate foliage and are beginning to bear.

The trees of all standard varieties of apples are still small, and it will be many years before they produce much fruit.

Crab apples made much more rapid growth than standard varieties, and many trees are now producing good crops of fruit. Dolgo is a consistent producer and the trees are thrifty. The fruit is small but of fairly good quality. Florence produces the heaviest crop of fruit, though the production from year to year is not so consistent as it is with Dolgo. The trees of this variety are strong growing and the foliage is ample. The fruit is above average size. Sylvia bears some fruit each year and the fruit is of better than average quality. The foliage is slightly sparse and does not fully protect the fruit. Transcendent and Siberian are hardy and the trees are vigorous in growth. Production of fruit is fair, but the quality is not equal to some of the other varieties, although the quality of Transcendent generally is considered good. Virginia is hardy and the fruit is of good quality, but the foliage is scanty and the fruit crops have been small. Whitney is hardy, and the fruit is of superior quality, but the tree is slower in reaching bearing age than some of the other crabs.

PLUM VARIETIES

Opata, Sapa, Compass, and Zumbra were the first varieties of plum-sand cherry hybrids to produce fruit. Sapa and Zumbra were very short lived, and portions of the trees began to die within a few years. Opata and Compass were longer-lived. They produced fair crops of fruit earlier than standard varieties. All trees of these two varieties are now dead or in very poor condition, but their loss is due more to location than to lack of hardiness. Both of these varieties were in the row bordering the shelterbelt and were unable to stand the competition of the larger trees in the shelterbelt. Opata and Compass are short-lived as compared with standard varieties, and the quality of fruit is not so good for eating out of hand, though they are acceptable for culinary uses. They are valuable in the early development of an orchard, because they produce fruit when better varieties have not commenced to bear.

Standard varieties of plums that have proved hardy and productive are Red Wing, Teton, Radisson, Mammoth, Emerald, and Cree. Teton, Mammoth, and Cree are not considered very good quality plums, but they are hardy and productive. The trees of Mandan Selection No. 73 grew more rapidly than those of any other variety and are fully hardy. The fruit is of medium size and average quality. The trees suffered more wind damage than those of any other variety, apparently because the wood is more brittle. This plum has not been so productive as the other varieties mentioned, but part of the lower production may be ascribed to the destruction of fruit buds by birds.

FRUIT PRODUCTION

Production of fruit in this section should be limited to production for home needs. There are some favored locations where commercial orcharding is feasible, and some locations in which unusually able fruit growers have made a success of commercial orcharding under ordinary conditions. For the average grower on the uplands, the production of more fruit than is needed for home use is an economic loss.

The orchard should be small enough so that its cultivation is not an undue burden. Such an orchard can be well taken care of without hindrance to field work. Larger plantings require more time for cultivation and other care, and are likely to be neglected when field work presses for time. Unless an orchard is well cared for it might better not be planted.

No detailed study of small fruits was made at the station, but several varieties of currants and gooseberries were found to be hardy and productive. These small fruits should be spaced wide enough to prevent crowding. Bushes 6 feet apart in the row and rows 8 feet apart is a suggested spacing.

Suggestions for a selection of trees for a home orchard are as follows: Some early bearing plums should be included, such as Opata or the Compass, that make up in earliness of bearing for what they lack in quality. Opata is considered good quality for cooking on account of thin skin, small pit, and flavor. These varieties appear to be short lived and can be removed when they become unthrifty. Selection of standard plums can be made from the varieties mentioned as hardy. These trees should be producing well by the time the Opata and Compass become unthrifty. Apples should be selected largely from the crab-apple group, because of earlier and more prolific bearing. Anoka and Wealthy appear to be the most desirable standard apples, though the Anoka may be short lived. Care should be taken not to attempt to grow too many varieties or too many trees of a variety. A small orchard, well kept, should produce fruit sufficient for the needs of a family. If the orchard is small enough so that its care is not a burden, it will be a source of satisfaction to the grower, and the fruit will provide a much desired addition to the regular diet throughout the year, either as fresh or canned fruit, or in jellies, pastries, and preserves.

SUMMARY

The Ardmore Field Station completed 20 years of experimental work in 1932. Crop rotations and cultural-method experiments were continuous during that period. Other lines of investigation were conducted for shorter periods.

The average precipitation at Ardmore was 15.90 inches for the 21-year period 1912–32. Normal expectation is for drought injury at some period of the crop year.

Crop-production work was conducted along three principal lines: (1) Crop rotations, (2) fields, and (3) variety tests.

Average yields of all crops grown in the rotations during the 20-year period give a fair index of the yields that may be expected under dry-land conditions in the section.

Methods of cultivation played a relatively unimportant role in determining crop yields. The preceding crop rather than the method of land preparation seemed to determine the yield, so long as the method of cultivation did not encourage weed growth or delay seeding.

Difference in crop sequence resulted in major differences in yield. Small grains grown after a cultivated crop produced yields approximately one-third higher than after small grain, and after fallow they produced yields approximately two-thirds higher than after small grain. Somewhat different responses were shown by the different grain crops.

The yields of cultivated crops were not appreciably higher when grown after cultivated crops than after small grains. Cultivated crops showed less response to fallow than small grain crops.

The effect of a cultivated crop in a rotation was evident the second year following. Yields of grain after grain in 3-year rotations containing a cultivated crop were approximately 20 percent higher than where grain was grown continuously.

Yields of grains following manured fallow were somewhat higher than following unmanured fallow. This difference was greatest in the most productive years. When yields were low, the yields following manured fallow were as low as or lower than yields following unmanured fallow. No cumulative benefit from the use of manure was evident during the life of the experiments.

Small-grain crops on green-manured land produced lower yields than on land that was bare fallowed. No cumulative benefit from plowing under green-manure crops was shown.

Crops were grown on fields for the purpose of producing feeds. Average yields from fields compared favorably with average yields from plots. Results from one field demonstrated that corn land and sorgo land are practically equal as preparations for small grains. Feed-crop rotations showed that dependable production of feed crops can be obtained over a series of years.

Variety tests with wheat demonstrated that both Ceres and Reliance were more productive than Marquis during the 7-year period 1926–32. Some varieties grown only after 1929 showed promise and should be tried further. Brunker oats were the most productive variety tested. Gopher oats were better than Sixty-Day but not so productive as Brunker. White Smyrna barley and Ace, a selection of White Smyrna, were outstandingly more productive than other varieties tested. Early varieties of both oats and barley were more productive than midseason or late varieties. Variations in yield between varieties were extreme, and sometimes accounted for greater differences in yield than resulted from major differences in crop sequence.

Rainbow Flint corn produced higher silage yields than any other corn variety grown. Yields of Dakota Amber sorgo were as high as those of Rainbow Flint in terms of dry matter per acre. Little difference was shown between several varieties of corn in grain production. Growth of acclimated strains that will mature is recommended.

Dakota Kursk millet produced the highest yield and the best quality of hay of any variety under trial. Red Amber and Black Amber sorgos produced the highest yields. Dakota Amber sorgo produced the lowest yield but the best quality of feed of any of the sorgo varieties. It was the only variety to mature regularly.

Both sorgo and Sudan grass were more productive in 7-inch drills than in 42-inch rows, but greater ease in curing and a higher production of grain make it advisable to grow sorgo in cultivated rows in spite of the lower yield.

Shelterbelt investigations demonstrated that shelterbelts can be grown successfully under the severe conditions at Ardmore. Selection of hardy species and arrangement so that snow is trapped and held in the shelterbelt are requisite to the successful growth of a shelterbelt. A good shelterbelt improves the appearance of a farm and is of great value in keeping snow away from the buildings and in checking winds.

Adapted varieties of apples, plums, and small fruits can be successfully grown. A home orchard is a farm asset.

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