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Bulletin No. 222 - A Quarter Century of Dry-Farm Experiments at Nephi, Utah

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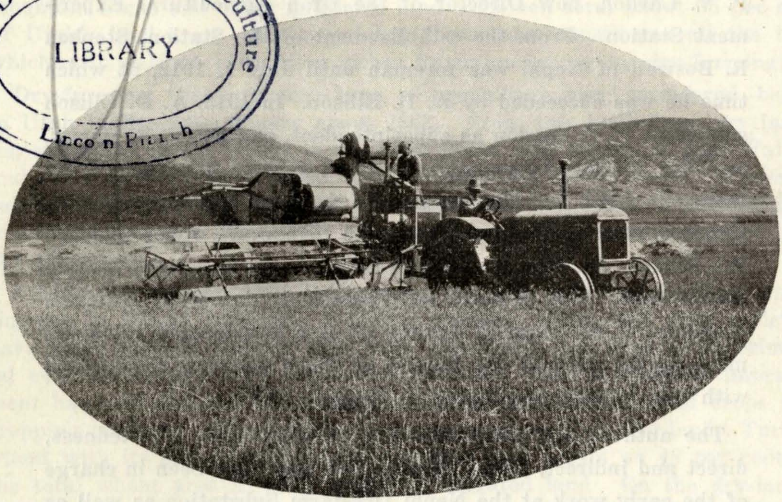

Utah Agricultural Experiment Station

Utah State Agricultural College

LOGAN, UTAH

FOREWORD

The Nephi Dry-farm Substation, together with five other farms, was established in 1903 by the Utah Agricultural Experiment Station. From 1903 to 1905 L. A. Merrill, Agronomist of the Utah Station, directed the work, followed by W. M. Jardine, who continued as Station Agronomist until 1907. In 1907 a cooperative agreement between the Bureau of Plant Industry of the U. S. Department of Agriculture and the Utah Agricultural Experiment Station was effected, followed by the appointment of F. D. Farrell as superintendent of the Nephi Dry-farm Substation. In March, 1910, F. D. Farrell was succeeded by P. V. Cardon, now Director of the Utah Agricultural Experiment Station. From the establishment of the Station, Stephen R. Boswell of Nephi was foreman until July 1, 1912, at which time he was succeeded by A. D. Ellison. In 1913, A. D. Ellison succeeded P. V. Cardon as superintendent, and Dr. F. S. Harris, as Utah Station Agronomist, assumed general direction of the farm. In 1918, I. J. Jensen became the farm foreman and continued in this position until 1920. In 1915, J. W. Jones replaced Mr. Ellison. In 1922, Dr. George Stewart was appointed Station Agronomist. The present superintendent, Aaron F. Bracken, succeeded J. W. Jones in April 1918. Due to necessary retrenchment on the part of the Bureau of Plant Industry cooperation with this Bureau terminated in October, 1920.

The authors are pleased to acknowledge their indebtedness, direct and indirect, to the several men who have been in charge of the early work at the Nephi Dry-farm Substation as well as to Dr. John A. Widtsoe, who, through many years of effort, lent enthusiastic encouragement to so many phases of dry-farming, both scientific and practical.

A Quarter Century of Dry-Farm Experiments at Nephi, Utah[1]

A. F. BRACKEN AND GEORGE STEWART[2]

IMPORTANCE OF DRY-LAND CROPS IN UTAH

Utah is naturally an arid state with precipitation varying from 3.71 inches at Wendover, located in the vast desert region on the western border, to more than 40 inches on some of the mountain ranges. Desert and mountain areas and other untillable land combined total about 95 per cent of Utah's land area. The remaining 5 per cent constitutes all the land which will yield to cultivation either by irrigation or by dry-farming.

Dry-farming, the particular type of agriculture here considered, began in Utah in Boxelder County about 1863. From this birthplace, dry-farming spread to Cache Valley, to the Sand Ridge near Ogden, to Juab Valley, and more recently has spread to practically the entire state. Wherever rainfall is sufficient and where topography and soil allow, dry-farming is practiced, with few places left unoccupied where transportation facilities are adequate.

During the 76 years that dry-farming has been practiced in Utah, many changes in tillage practices, cropping systems, crops, and crop varieties have taken place in keeping with early experience, and later as experimental evidence coupled with experience directed. This progressive improvement has now resulted in a nearly complete standardization of crops and cropping methods. Wheat is the dominant crop on Utah dry-lands. Turkey wheat with its strains and related varieties was grown on 48 per cent of the total wheat area in 1924 including irrigated land. On the dry-lands, Turkey together with Kanred winter wheat produces more than 95 per cent. Cropping and tillage methods now consist of alternate crop and fallow, fall or early spring plowing, rigid weed control, and seeding of 5 to 6 pecks of clean treated seed to the acre on clay loams with somewhat less on sandy soils.

While Utah is not an important wheat state as compared to some of the adjacent states and some of the states of the Middle West, yet the returns from this crop are highly important to certain towns and counties of Utah, in providing income for a number of families and work for many laborers.

[1]Contribution from Department of Agronomy, Utah Agricultural Experiment Station.
[2]Assistant Agronomist and Superintendent Nephi Dry-farm Substation, and Agronomist, respectively.
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The data given in Table 1 indicate that wheat was an important crop for the pioneers of Utah and that each decade has brought an increased wheat production.

Table 1. Total production of wheat in Utah for 1849, 1859 and 1869, and by 10-year periods from 1881 to 1929.

Period	Production (Bushels)
1849	107,708
1859	384,892
1869	558,473
1881—1890	1,783,000
1891—1900	2,997,000
1901—1910	4,826,000
1911—1920	6,106,000
1921—1929	5,822,000

The total wheat production for Utah for the years 1924 to 1928, inclusive, indicated in Table 2, divides the production and acreage into winter wheat and spring wheat. The spring wheat is produced almost wholly on the irrigated farms while the winter wheat is closely limited to the dry-lands. The 1928 acreage for winter wheat shows a 22 per cent increase over the acreage for 1924 and the spring wheat a 40 per cent increase for the same period. Of the average total production of 6,100,000 bushels, approximately 2,500,000 bushels are consumed in the state with the remaining 3,600,000 bushels being marketed elsewhere.

Table 2. Total acreage and production of winter and spring wheat for the period from 1924 to 1928, inclusive, for Utah.

CROP	1924		1925		1926		1927		1928	
	Acreage	Production	Acreage	Production	Acreage	Production	Acreage	Production	Acreage	Production
Winter Wheat...	133,000	1,769,000	145,000	3,190,000	149,000	3,129,000	152,000	2,888,000	162,000	3,726,000
Spring Wheat...	68,000	1,544,000	88,000	2,904,000	88,000	2,376,000	90,000	2,790,000	95,000	3,135,000
All Wheat......	201,000	3,313,000	233,000	6,094,000	237,000	5,505,000	242,000	5,678,000	257,000	6,861,000

In addition to wheat, other crops such as alfalfa, corn, peas, and potatoes are grown to a limited extent on the dry-lands where soil conditions and precipitation are favorable. Winter wheat, however, is, and will always remain, the dominant crop.

LOCATION OF NEPHI DRY-FARM SUBSTATION

The Nephi Dry-farm Substation is located 5.5 miles south of Nephi, in the eastern part of Juab County, Utah, somewhat west of the geographical center of the state. The farm comprises 103 acres of land near the top of the north slope of the Levan Ridge which crosses the Juab Valley from east to west. The spot at which the station is located is approximately 5600 feet above sea level and about 500 feet higher than the bottom of the valley. When the farm was established in 1903 a large part of the land surrounding the station, now annually producing from 250,000 to 350,000 bushels of wheat, was covered with a dense growth of sagebrush.

SOIL OF SUBSTATION

The soil of the Nephi Substation is a clay loam, derived from the weatherings of adjacent mountain ranges, reddish-brown in color and uniformly 10 feet or more in depth. Below the third foot the percentage of silt and sand increases, and at about the seventh foot there is a stratum of heavy blue clay with high moisture-holding capacity. In the spring, after being fallowed during the previous summer, the average moisture content of the first 6 feet varies from 18 to 22 per cent. A crop of winter wheat usually reduces the moisture content of this layer of soil to 8 per cent.

CLIMATOLOGICAL DATA

Precipitation

Of all the climatic factors concerned in crop production on the dry-lands, precipitation and its distribution throughout the year is most important. Since the bulk of the rainfall at Nephi comes during the winter and early spring months, which is characteristic of the Great Basin, the moisture must be stored and conserved in the soil if it is to be of use to growing plants.

Table 3. Monthly, average monthly, yearly, and average yearly precipitation at Nephi, Utah, for the years stated.

YEAR	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Total 1898–1919*......	25.78	27.23	35.66	28.34	37.92	12.54	14.76	19.08	22.69	25.63	20.17	21.90	291.70
1920............	.73	1.21	2.34	2.38	1.21	.63	.81	2.14	.59	2.80	.40	.71	15.95
1921............	1.57	1.27	.71	2.25	2.41	.24	1.03	.75	.56	.75	.32	1.88	13.74
1922............	1.77	1.18	1.59	1.40	.88	.55	.82	2.05	.19	.48	1.14	1.85	13.90
1923............	1.69	.82	.75	1.32	1.33	.66	1.96	.60	.61	.94	.15	.53	11.36
1924............	.39	.10	1.28	.06	1.84	.05	.37	1.05	.88	1.29	.68	1.63	9.62
1925............	.54	1.48	1.31	1.61	.60	1.72	1.03	1.18	.74	1.57	.46	.85	13.09
1926............	.45	1.26	.75	1.78	1.65	.18	1.31	.48	.42	.00	2.17	1.22	11.67
1927............	.97	1.99	1.44	1.37	.52	.44	.48	.48	1.52	1.84	1.54	.82	13.41
1928............	.41	.68	1.56	.77	1.52	.41	.79	.20	.16	.84	1.64	.59	9.57
1929............	.79	.91	1.44	1.22	.85	.85	3.46	1.80	.85	.81	.26	.45	13.69
Total	35.09	38.13	48.83	42.50	50.73	18.27	26.82	29.81	29.21	36.95	28.93	32.43	417.70
Average	1.09	1.19	1.53	1.33	1.56	.57	.84	.93	.91	1.15	.90	1.02	13.05

*Up to 1903 precipitation measurements were taken from the data accumulated at Levan, Utah, which is 6 miles south of the farm. From 1903 on, readings were made at the Station.

The precipitation data, given in Table 3 by month from 1920 to 1929, inclusive, with averages extending back to 1898, show the yearly average to be 13.05 inches. In the 10-year period, given in detail, the greater amount of rainfall, 15.95 inches, came in 1920, with the lowest, 9.57 inches, occurring in 1928.

Table 4. Five-year averages for precipitation at Nephi, Utah, from 1898 to 1927, inclusive.

	1898–1902	1903–1907	1908–1912	1913–1917	1918–1922	1923–1927	1928–1929
Average Precipitation (Inches)	13.85	14.07	12.69	12.98	13.35	11.82	11.63

Dividing the 32-year period over which precipitation measurements have been made in Juab Valley into six 5-year periods, as given in Table 4, it is observed that the highest average rainfall of 14.07 inches occurred from 1903 to 1907 with the lowest, 11.82 inches, over the period from 1923 to 1927.

The relationship of yield of winter wheat to rainfall is given in Figure 1. Upon examination of this graph the interesting fact is brought out that of the fourteen years, results of five of the seasons producing near average and better than average yields were below normal in rainfall but were preceded by higher than usual precipitation the previous year. The season of 1926 is a striking example of the relation of yield to rainfall.

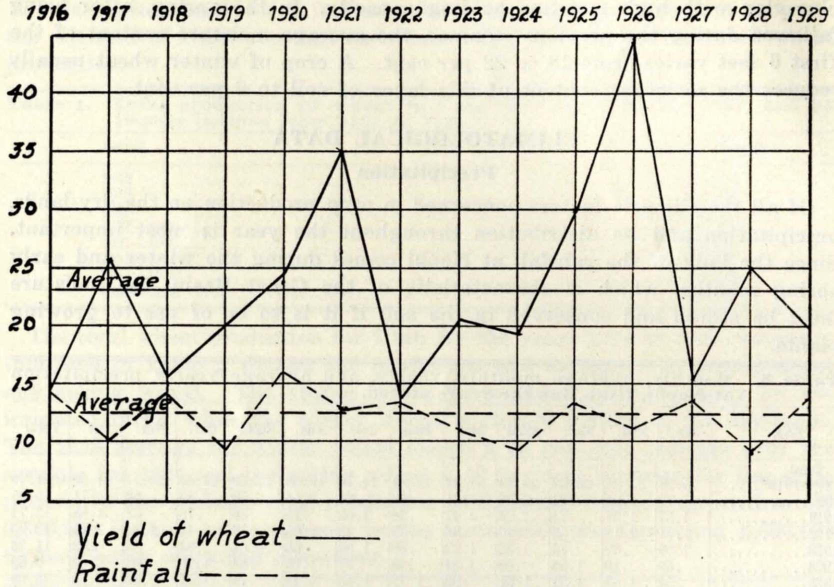

Figure 1—Annual and average acre-yields of wheat in bushels as related to the annual and average rainfall over the 14-year period from 1916 to 1929, inclusive.

With a total precipitation of 11.67 inches preceded by 13.09 the previous season, the average yield of all check plats on the station was 39.4 bushels, as shown in Table 5, with some acre-yields as high as 55 bushels. Normal and better than normal precipitation during the fallow year is of great benefit to the crop which follows not only from the standpoint of moisture stored for use of the plants but also because the extra moisture brings about a condition which is favorable for the liberation of plant-food elements such as potassium, phosphorus, and especially for the liberation and accumulation of available nitrogen, thus increasing the efficiency of the stored moisture in producing a unit of growth.

Table 5. Average yield of winter wheat, percentage of average normal crop, amount of precipitation and percentage of normal precipitation, percentage of normal precipitation of two years preceding each crop, and average mean temperature, all for each year from 1916 to 1929, inclusive, at the Nephi Dry-farm Substation.

	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Yield of winter wheat in bushels..	14.6	26.1	16.4	20.6	24.4	35.4	13.6	21.8	19.3	30.3	39.4	15.7	25.6	19.7	23.1
Percentage of average normal crop	63	113	71	89	106	153	59	94	83	131	171	68	111	85	100
Amount of precipitation in inches....	14.32	10.16	13.49	9.68	15.95	13.74	13.90	11.36	9.62	13.09	11.67	13.41	9.57	13.69	12.48
Percentage of normal precipitation	115	81	108	78	113	110	111	91	77	105	94	107	76	109	100
Percentage of normal precipitation for two years preceding each crop ...	112	98	95	93	103	119	111	101	84	91	100	100	92	93	99.4
Average mean temperature for April.	48	42	43	48	39	41	37	43	44	47	45	42	43	43	44

High yields of winter wheat in the Great Basin are usually associated with fall emergence of the crop, whereas low yields are invariably connected with emergence under winter snow, provided poor tillage is not a factor causing reduction. The yields of 1917, 1920, 1921, 1925, 1926, and 1928, as given in Table 5, are examples of fall emergence, whereas the low yields of 1916, 1918, 1922, 1927, and 1929 can be traced to winter emergence. April temperature also has a direct influence on yield. If the crop has emerged in the fall early enough to have established permanent roots, below-normal temperature for April has no noticeable effect on yield. The season of 1921 is an example of this. The average mean temperature for April was 41 degrees, as given in Table 5, as compared to a normal mean of 44 degrees (Table 6). The seasons of 1917 and 1928, both

Table 6. Average mean temperature by months at Nephi, Utah, over a 22-year period from 1908 to 1929, inclusive.

	April	May	June	July	Aug.	Sept.	Oct.
Average mean temperature	44	53	63	71	70	61	48

with a low rainfall and lower than normal April temperature, are similar examples. The season of 1919 with a low rainfall of 9.68 (78 per cent normal) but with a mean April temperature of 48 degrees produced a crop which was 89 per cent normal. On the other hand, 1922 with a rainfall which was 111 per cent normal and with a mean April temperature of 37 degrees gave yields which were only 59 per cent normal, due largely to delayed emergence followed by the low April temperature. The low yields for 1918, 1923, 1927, and 1929 can be traced partly to the same depressing factors, such as winter emergence and low April temperature. When wheat is forced to tiller in the spring, producing the crown and permanent root system, April needs to be a month of growing temperature if anywhere

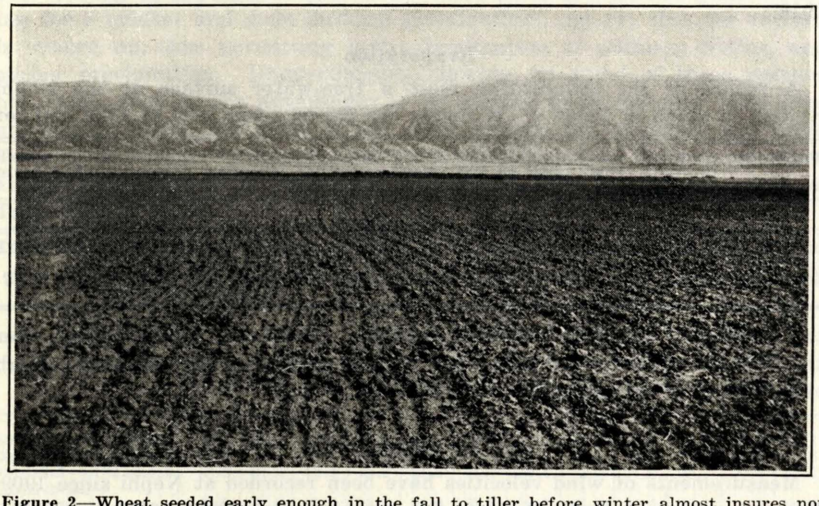

Figure 2—Wheat seeded early enough in the fall to tiller before winter almost insures normal or better than normal yields the following season.

near normal yields are produced. If the reverse happens, untillered wheat makes little growth. This forces all vegetative production into the longer, hot, drying days of late spring and early summer with the consequence that yields are usually materially reduced.

Aside from the effect of April temperature, another retarding factor has been observed where wheat has failed to tiller before April 1. In some seasons, especially in 1922, the nitrates are almost completely leached out of the surface 15 inches, that layer of soil in which they are formed, to lower depths much beyond the reach of temporary roots. As a result, the wheat is noticeably yellow in color and unthrifty in growth. Then, if this condition is coupled with low temperatures which are as unproductive of nitrate accumulation as of wheat growth, yields suffer measurably. On the other hand, when the plants emerge in the fall, thus insuring a wide feeding range, even nitrate deficiency in the surface soil fails to be a retarding influence on yield.

Temperature

Table 6 shows the mean monthly temperatures at Nephi over a 22-year period recorded for the months of April to October, inclusive.

Table 7. Frost-free period at Nephi, Utah, for the years specified from 1920 to 1929, inclusive.

	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.	Avg. 1910–1929
Frost-free period in days........	115	81	126	87	153	112	136	126	88	120	114	112

The average frost-free period of 112 days at the Nephi Substation is shown in Table 7. Frosts in late spring and early summer have at times injured heading grain; however, most of the damage is limited to the low places in the floor of Juab Valley. During the 22-year period over which temperatures have been recorded the latest spring frost recorded was 30 degrees on July 2, 1921, and the earliest autumn frost on September 4, 1912.

Evaporation

A record of the evaporation from a free-water surface at the Nephi Station is given in Table 8. It covers the period from 1908 to 1929 and for

Table 8. Average monthly evaporation from a free-water surface in the seven months from April to October, inclusive, over the 22-year period from 1908 to 1929, inclusive.

	April	May	June	July	Aug.	Sept.	Oct.	Total
Evaporation in inches	3.898	6.545	8.730	9.547	8.733	6.367	3.532	47.352

the months of April to October, inclusive. The total, 47.352 inches, over the 7-month period is 3.6 times the total precipitation for the year. High evaporation is characteristic of arid areas.

Wind

Measurements of wind velocities have been recorded at Nephi since 1909. The data given in Table 9 cover the period from 1909 to 1929, inclusive.

Table 9. Average hourly wind velocity at Nephi, Utah, covering a 21-year period from 1909 to 1929, inclusive.

	April	May	June	July	Aug.	Sept.	Oct.
Hourly wind velocity....	4.1	3.9	3.8	3.3	3.2	3.2	3.1

Wind rarely does damage to wheat in the Great Basin, except as it may be accompanied by high temperatures during the fruiting period of wheat and heavy precipitation after the grain is ripe. Velocities as high as 30 miles an hour have been measured at times for only a small part of a day.

TILLAGE EXPERIMENTS

Treatment of Land before Plowing

After harvesting a crop of wheat, often for some particular reason farmers deviate from the general practice of just normal fall or spring plowing of the stubble land. In 1916 the Nephi Station began a set of experiments covering most of the possibilities which include (1) disking of the wheat land immediately after harvest followed by fall or spring plowing, (2) burning of all or a part of the straw left after the use of a combine harvester-thresher, and (3) leaving the stubble to stand followed by normal fall or spring plowing.

Fall Disking

In the earlier development of dry-farming disking of the stubble land immediately after harvest was advised, and in some sections the practice is still followed to a small extent. In giving reasons for such tillage the following claims are made for it: (1) That the straw left on the field is put into a more favorable environment for decomposition; (2) that Russian thistles, sunflowers, and other weeds which emerge in the stubble are killed, thus saving moisture and plant-food for the following crop; (3) that disking of the stubble land covers weed seeds and shelled grain allowing for a quicker and more uniform germination; and (4) that the surface is opened up, thus permitting better penetration of autumn, winter, and spring precipitation. Unquestionably, disking for some of these reasons has value, such as the advantages to be derived from covering weed seed and shelled grain, but some of the other reasons are probably not valid. Tests to determine the comparative value of disking have been in operation at the Nephi Dry-farm Substation since 1916. The results are given in Table 10.

Table 10. Annual and average yields of winter wheat produced on land disked after harvest, with one plat later fall plowed and the other left for spring plowing as compared to normal fall and spring plowing with no disking.

TREATMENT	YIELD IN BUSHELS PER ACRE											
	Total 1916–19	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Not Disked—fall plowed	82.6	27.1	48.0	15.7	23.0	23.8	30.2	52.7	18.5	26.8	16.8	26.1
Disked & later fall plowed	77.0	30.5	40.2	15.5	20.7	22.8	28.7	51.5	16.3	26.2	15.7	24.6
Not disked—spring plowed	88.3	27.5	38.4	12.8	24.5	21.7	30.4	42.0	17.0	28.8	20.0	25.1
Disked in fall—spring plowed........	69.2	28.0	36.9	13.8	21.0	22.8	23.7	45.8	14.5	27.8	11.3	22.5

When compared to land not disked in the fall but fall plowed with land disked and later fall plowed, the advantage lies with the single operation of fall plowing by 1.5 bushels. The same comparison for spring plowing shows an acre loss of 2.6 bushels due to disking. This test was conducted on single tenth-acre plats.

Disposal of the Stubble

Burning of the stubble either in fall or spring is not a common practice on the dry-lands of the Great Basin, but in certain areas of the Northwest (Oregon and Washington) the heavy crop of straw left after the combine harvester-thresher is difficult to plow into the soil without seriously interfering with subsequent tillage operations. The problem has been solved by burning. This practice has been followed for a period of more than forty years in a few of the sections and such lands are now showing serious effects from the deficiency of organic matter. In areas where winter winds sweep the snow into the low places in addition to piling it up behind various obstructions, standing stubble has a decided advantage in catching and holding the snow and when plowed into the soil the benefits of the organic matter are of great importance in maintaining maximum production. An experiment covering this problem has been conducted at Nephi since 1916. The results are given in Table 11.

Table 11. Annual and average yields of winter wheat after ordinary fall plowing, and fall plowing following application to the land of all of the straw, all of the straw followed by burning, high stubble left, and high stubble burned over the 14-year period from 1916 to 1929.

TREATMENT OF STUBBLE	ANNUAL AND AVERAGE YIELDS PER ACRE IN BUSHELS														
	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Ordinary fallow	20.0	23.6	17.4	21.9	25.5	38.9	14.1	21.0	17.6	29.7	44.0	15.2	20.9	18.3	23.3
All straw plowed under	11.1	22.7	20.2	20.7	28.6	39.2	14.2	19.2	20.4	30.4	44.9	16.0	22.0	19.1	23.4
All straw burned	12.6	24.4	20.5	21.7	29.0	40.8	16.3	22.0	20.2	30.3	46.1	17.6	24.9	18.7	24.7
High stubble plowed under	10.8	25.6	18.2	23.4	27.6	40.9	14.7	21.3	19.7	32.7	48.3	17.1	22.8	20.1	24.5
High stubble burned	10.9	26.1	17.1	25.3	26.1	42.7	15.1	25.0	19.8	32.7	49.3	18.3	24.2	21.1	25.2

An examination of the data in Table 11 shows that burning all or a part of the stubble gives slightly higher yields than the corresponding treatment of plowing all or a part of the stubble under in the fall. The differences, while not great enough to be significantly favorable to burning, are rather consistent over the entire 14-year period since the experiment started. While yearly burning of stubble is inadvisable, yet there may be definite reasons for burning once in several seasons. The data given in Table 11 indicate up to the present that no detrimental effects have followed such a practice. Weed seed, seed of another cereal, insects such as the straw worm and joint worm, and other pests harbored by wheat lands may be wholly or partly controlled by burning.

Plowing

Of all tillage operations connected with crop growing on the dry-lands, plowing is most important and necessary. Plowing not only stirs the soil and breaks up the surface, but in addition covers all plant growth and organic residue, thus placing it in a favorable environment for disintegration. The three factors connected with plowing of importance are (1) time of plowing, (2) depth of plowing, and (3) type of plow.

Time of Plowing

Of the three factors enumerated in connection with plowing on the dry-lands, time-of-plowing is by far the most important. The success or failure of dry-farm cropping, as far as profitable returns are concerned, rests upon this one practice. A test to compare fall and spring plowing has been in operation at the Nephi Station since 1903. The results since 1910 are given in Table 12. While the yearly yields show variations, as indi-

Table 12. Annual and average yields of winter wheat when grown on fall-plowed land and spring-plowed land over the 20-year period from 1910 to 1929, inclusive.

TIME OF PLOWING	ANNUAL AND AVERAGE YIELDS IN BUSHELS PER ACRE											
	Total 1910–19	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Fall plowed—fallow given ordinary treatment	226.3	27.1	48.0	15.7	23.0	23.8	30.2	52.7	18.5	26.8	16.8	25.4
Spring plowed—fallow given ordinary treatment	236.8	27.5	38.4	12.8	24.5	21.7	30.4	42.0	17.0	28.8	20.0	24.9

cated, the average of 25.4 bushels for fall plowing as compared to 24.9 bushels for spring plowing is so nearly the same that no significance can be attached to the difference. These yields were secured from single tenth-acre plats.

Since the fall and spring plowing experiment has been under test over a 20-year period, averages have been taken at four 5-year intervals. These yields given in Table 13 show a progressive increase, especially for the two

Table 13. Average yields of wheat from fall and spring plowing divided in four 5-year periods from 1910 to 1929, inclusive.

TIME OF PLOWING	ANNUAL AND AVERAGE YIELDS IN BUSHELS PER ACRE				
	1910–14	1915–19	1920–24	1925–29	Avg.
Fall	22.4	22.8	27.5	29.0	25.4
Early Spring	23.3	24.0	25.0	27.6	24.9

latter periods. Favorable climatic conditions are probably responsible for part of the increase, but other factors, such as the introduction of Kanred wheat into the test in 1921 and the use of copper carbonate as a treatment for smut since 1923, can be credited with about 4 bushels of the added production.

It is likely that little difference in yield of winter wheat is connected with variation in time of fall plowing as judged from tests now under way at Nephi and from results at other stations. The highly significant reductions in yield are connected with delayed spring plowing. In 1916 a green-manure test was started with wheat and peas plowed under at various stages of growth at the Nephi Station. The volunteer on the wheat plats was supplemented with a thin sowing of seed. This test has not only been used to interpret green manure relationships but has also been employed to determine the effects of delayed plowing. The assumption that such a test can be used for this two-fold purpose is likely somewhat faulty since seldom, if ever, does stubble land have a uniform vegetative growth of wheat and weeds. Unquestionably, yields from later plowings, as given in Table 14, are somewhat lower than similar plowing times on ordinary fallow. From observation of returns on surrounding farms, however, a fairly close relationship has been found to exist between this test and time of plowing on ordinary stubble land.

The time that spring plowing can be started on the dry-farms in the Great Basin, generally, is more or less indefinite, because of the variability of the seasons. In some years plowing can be started as early as April 1, in other years not until May 1, and occasionally not until May 15. Because of this fact, the different growth stages, as given in Table 14, are probably a better guide than is a definite date. For fall plowing the land was turned about October 10. In spring the first plowing was done as soon as the plow would scour; the second, when the wheat growth was 6 inches high (between May 1 and 15); the third, when the wheat was 12 inches high (between May 15 and June 1); the fourth, when the wheat was just in head; and the fifth, when the wheat kernel was in the milk stage, a date which may be as early as June 15 and as late as July 1.

Table 14. Annual and average yields of winter wheat following plowing at the times indicated over the 14-year period from 1916 to 1929, inclusive.

TIME OF PLOWING	ANNUAL AND AVERAGE YIELDS IN BUSHELS PER ACRE														
	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Fall plowing about Oct. 10	20.0	23.6	17.4	21.9	25.5	38.9	14.1	21.6	17.6	29.7	44.0	15.2	20.9	18.3	23.5
Spring plowing early	17.1	28.8	16.3	22.1	26.2	34.7	12.5	23.8	22.6	32.0	37.0	16.8	29.1	22.3	24.4
When wheat was 6 in. high	16.1	21.9	15.6	16.5	22.2	32.9	10.4	19.6	16.8	25.3	41.6	12.5	21.1	11.7	20.3
When wheat was 12 in. high	15.6	22.6	15.7	17.6	19.0	30.4	9.7	19.0	12.1	23.5	30.0	12.2	14.4	8.1	17.8
When plants were in bloom	12.6	21.0	10.1	12.9	18.1	26.8	4.3	19.1	5.0	21.7	25.6	9.8	8.4	8.1	14.6
When kernels were in milk stage	9.9	21.7	9.7	5.5	18.1	27.7	5.3	14.7	3.0	22.3	24.2	7.5	5.1	9.0	13.0

The experiments were conducted on duplicate tenth-acre plats; each yield given in the table represents an average of the two pieces of land. An examination of the table indicates a close relationship in yield between fall and early spring plowing with the spring plowing having 0.9 bushel advantage, which is the reverse of yields given in Table 12. Again, it may be said that differences are so slight as to carry no importance. Further examination of yields in Table 14, however, shows a progressive decrease in yield with the lateness in plowing, until an average of 13 bushels is reached for plowing near July 1, when the volunteer and the seeded wheat was in the milk stage. At $1 a bushel such a loss is sufficient to pay for all effort connected with growing the crop at contract labor charges.

Thus, spring plowing needs to be started just as soon as the plow will scour. The length of time over which plowing can be done without measurably decreasing yields varies according to the time the operation can begin. If soil conditions are such that the land will break free from the moldboard on April 1, maximum returns can usually be expected for plowing done over about a 5-week period. If plowing is delayed until May 1, then the plowing period is limited to no more than three weeks; plowing not started until May 15, because of weather conditions, only allows a 2-

week period at most for highest yields. These statements have no exact data as a background; they came as a result of observation only, which leads to this general advice: **Leave for spring plowing no more land than can be turned within a period of three weeks, at most.** Plow the remainder in the fall, even though the expense for fall plowing is greater than spring plowing. The rotary-rod weeder can be employed to handle weed growth on summer fallow fall-plowed at a minimum of labor and expense.

Depth of Plowing

Depth of plowing has been a point of controversy ever since plowing began because the depth at which highest returns are secured varies with soil type under dry-land conditions; it is also probable that similar variations occur under irrigation and under humid conditions. Then, too, it is possible that various crops react differently to various depths of plowing even with the same soil type.

A depth-of-plowing experiment has been under test at Nephi since 1910, the results of which are given in Table 15. The various depths of plowing

Table 15. Annual and average yields of winter wheat as produced from various depths of plowing as listed over the 14-year period from 1916 to 1929, inclusive.

DEPTH OF PLOWING	ANNUAL AND AVERAGE YIELDS IN BUSHELS PER ACRE											
	Total* 1910–19	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Plowed 5 in. deep in fall..........	187.8	22.5	42.7	12.7	20.0	19.2	23.0	45.2	17.3	25.2	16.0	22.7
Plowed 8 in. deep in fall..........	195.0	27.1	48.0	15.7	23.0	23.8	30.2	52.7	18.5	26.8	16.8	25.2
Plowed 10 in. deep in fall.........	195.5	24.5	48.2	14.2	25.5	23.5	29.2	51.3	20.2	26.3	17.3	25.0
Subsoiled 15 in. deep in fall.......	195.3	24.5	43.4	17.2	21.5	20.8	31.0	49.2	15.7	26.8	12.2	24.1
Subsoiled 18 in. deep in fall.......	182.0	26.8	44.2	15.2	22.5	22.2	30.8	52.7	17.7	25.7	14.2	23.9
	1916–19											
Plowed 8 in. fall, 3 in. spring......	78.2	32.0	41.1	14.8	20.3	21.2	26.9	50.0	16.2	27.3	12.7	24.3
Plowed 3 in. fall, 8 in. spring......	72.5	28.0	38.7	13.3	17.8	18.8	24.3	48.7	16.3	24.2	15.5	22.7
Plowed 8 in. fall, 8 in. spring......	75.3	27.5	38.4	12.5	19.0	16.5	24.9	40.7	14.7	27.8	14.5	22.3

*1915 results not given

and subsoiling, ranging from 5 to 18 inches show differences favoring 8 inches as compared to shallower or greater depths. The early theory on deep plowing and subsoiling, recently revived in connection with the same principle as subsoiling, was (1) that deep tillage allowed for greater penetration of precipitation, (2) that deep tillage increased development of the rooting system, (3) that deep stirring of the soil favored oxidation and other chemical processes in making plant-food more available to the plants, and (4) that bacterial activity tended to increase—all of which, if true, unquestionably would be reflected in greater yield. In light of these data for the particular soil type on the Levan Ridge the theory evidently did not hold. The year of 1913 came nearer to being a failure for wheat on the Nephi Station than during any other year before or since. The yields of that particular season included in the totals in Table 15 were as follows: 5-inch plowing, 10 bushels; 10 inches, 7 bushels; 15-inch subsoiling, 6 bushels; and 18-inch subsoiling, 4 bushels. With the exception of 1922 this tendency is noted in every year of low yields since the beginning of the test. Clearly, if maximum returns are to be secured, deeper or much shallower tillage than 8 inches has no place on Utah dry-land where the texture of the soil is a clay loam. Data taken in nearby states on different soil types make it necessary to qualify this statement somewhat. The results at Moro, Oregon, secured on a silt loam soil, indicate that 5 to 6 inches is deep enough for such a soil type. For sandy loams, data at Lind, Washington, show that 4- to 5-inch plowing is sufficient.

In the second part of Table 15 data for another plowing test are given. Before a weeder efficient enough to handle weeds on fall-plowed fallow land was manufactured, often it was necessary to replow the land again in spring to control weed and volunteer growth. Plowing to a depth of 8 inches in fall followed by plowing to a depth of 3 inches the following spring has given the highest yields. Comparing the two parts of Table 15 and referring again to Table 12, it is evident that one plowing of normal depth either in fall or spring is sufficient.

All of the results on depth of plowing were secured from single tenth-acre plats.

Type of Plow

While the type of plow is possibly not so important from the standpoint of effect on yield as other factors connected with plowing, yet when the cost of plowing, the most expensive single tillage operation in wheat growing, is considered, it may be possible appreciably to reduce the cost of production of wheat at this point by employing some other means of turning or breaking the surface than by using the present types of plow.

One year's results from the use of the Wheatland plow and the chiseler, as compared to a moldboard plow, have been secured from duplicate tenth-acre plats at the Nephi Station. The results follow:

Moldboard plow	15.7	bushels
Chiseler	16.5	"
Wheatland plow	17.3	"

The yields which favor the Wheatland plow from only one year cover so short a period that no comment can be made on the differences.

Treatment of Summer Fallow

At one time care of summer fallow was considered to be highly important in successful dry-farming. It was thought that harrowing immediately after plowing followed by frequent harrowings during the summer was necessary for profitable yields. Careful treatment of the fallow, as far as

Table 16. Annual and average yields of winter wheat grown on tenth-acre plats plowed in fall and in spring, or both, treated in various ways over the 14-year period from 1916 to 1929, inclusive.

TREATMENT	ANNUAL AND AVERAGE YIELDS IN BUSHELS PER ACRE											
	Total 1916–19	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Ordinary Cultivation												
Fall plowed	82.6	27.1	48.0	15.7	23.0	23.8	30.2	52.7	18.5	26.8	16.8	26.1
Spring plowed	88.3	27.5	38.4	12.8	24.5	21.7	30.4	42.0	17.0	28.8	20.0	25.1
Weeds Hoed												
Fall plowed	83.9	23.8	45.7	12.5	23.3	22.0	29.0	40.0	17.8	24.5	16.7	24.2
Spring plowed	84.7	27.7	42.2	12.2	25.8	21.3	26.8	41.7	18.7	30.5	20.0	25.1
Cultivated Frequently												
Fall plowed	78.9	23.7	42.3	15.1	21.0	21.2	26.7	52.0	17.2	23.5	13.0	23.9
Fall and spring plowed	85.3	28.0	44.3	15.2	22.8	20.5	31.3	55.2	18.5	23.7	11.0	25.4
Spring plowed	77.5	28.5	35.9	15.3	20.8	22.7	27.5	48.5	16.7	28.7	17.7	24.3

weeds are concerned, is of major importance. Rigid weed control cannot be too strongly stressed. In light of present results, data from the Nephi Station, however, indicate that some of the early opinions were not consistent. Since 1916 at Nephi three methods of cultivating the fallow have been tried on fall and spring plowing. Table 16 shows these results.

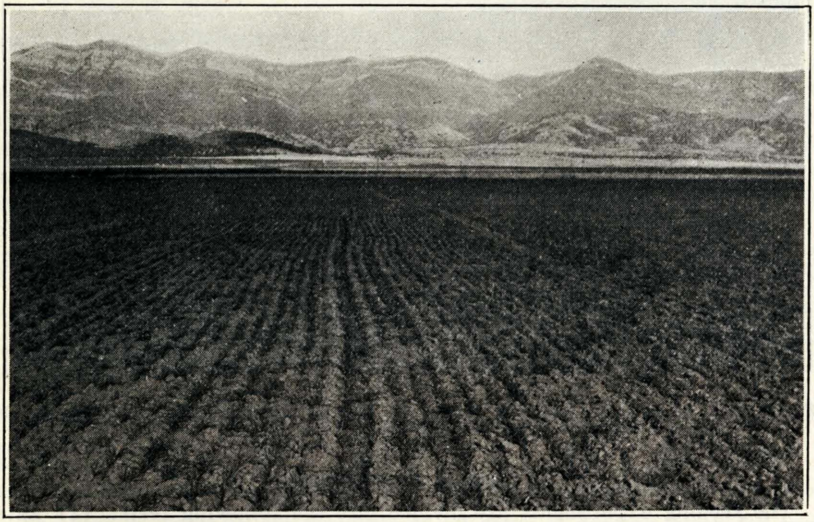

Figure 3—Successful dry-farming in the Great Basin depends on a clean summer-fallow.

Under ordinary cultivation fall-plowed land was harrowed in the spring as soon as possible, followed by one or two weedings, as necessary, followed in turn by a leveling and another harrowing. Spring-plowed land was harrowed twice and leveled, with one weeding required only in occasional years.

In the second method as outlined no cultivation was given the fallow other than that necessary to keep weeds down which was done by pulling and hoeing with the least possible stirring of the soil. Winter wheat was sown on the rough, uneven land. In addition to weedings and one leveling the plats cultivated frequently were harrowed every two weeks during the fallow period. In all, this land was given about eight cultivation treatments. The results were secured from single tenth-acre plats.

The average yields of this test show no advantage from frequent tillage as compared to ordinary cultivation. In fact, for the single fall and spring plowing the comparisons indicate a reduction in yield for frequent tillage.

Comparing ordinary fallow with that left uncultivated the average yields for spring plowing are identical—25.1 bushels. The same comparison for fall plowing shows a difference of approximately 2 bushels in favor of normal tillage. On the fall-plowed land volunteer and weed growth possibly take sufficient moisture from the soil to cause part of the reduction. Then, too, the physical condition of fall-plowed untilled land is slightly more unfavorable for a seedbed than is the same treatment of spring plowing.

These tests clearly show that cultivation of fallow beyond a certain limit is a waste of time. **Weed control is the essential factor.**

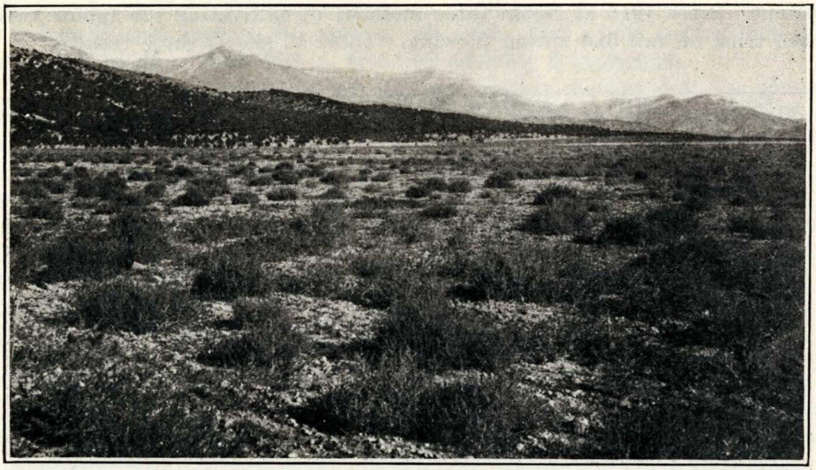

Figure 4—A weedy fallow not only reduces the yield of wheat which is to follow but also makes it expensive to prepare a seedbed.

Seeding Experiments

The seeding experiments are divided into the following tests: (1) Rate-and-date-of-seeding experiments with winter wheat, (2) spacing test on seeding winter wheat in rows of various widths cultivated and uncultivated, (3) use of the common drill as compared to the furrow type, and (4) seed treatment for smut as affecting yields and efficiency of smut control.

Rate-and-Date-of-Seeding Experiments

Rate-and-date-of-seeding on the dry-land has become fairly well standardized. The acre-rate of seeding on clay loams is regularly 5 to 6 pecks, with less on the lighter soils. While there is some little variation in date of seeding, most of the sowing is finished by October 1 or soon thereafter.

The rate-and-date-of-seeding test at the Nephi Station consists of seeding on twentieth-acre plats from 2 to 8 pecks, inclusive, on August 1 and 15, on September 1 and 15, on October 1 and 15, and on November 1.

Table 17. Average yields from all rates of seeding for winter wheat from 2 to 8 pecks, inclusive, given for each date of sowing averaged for the full period of the test from 1921 to 1929, inclusive.

Aug. 1	Aug. 15	Sept. 1	Sept. 15	Oct. 1	Oct. 15	Nov. 1
20.2	20.1	19.9	22.2	23.1	22.2	22.9

In Table 17 all rates are averaged and given for each date of sowing. As the data indicate, there is little difference between sowings made on August 1, on August 15, and on September 1; likewise, there is little difference between seedings made from September 15 to November 1, inclusive. However, between September 1 and 15, there is a break of 2.4 bushels favoring the later sowing. Up to about September 10 the Great Basin is sometimes visited by heavy torrential showers. These storms frequently result in a crusting of the surface soil, which often prevents grain from emerging to good stands. A part of the lower yields coming from early seeding can be charged to this factor. After September 10 the storms come more as gentle rains causing little detrimental effect to the physical condition of the soil. It has also been observed that at times there is sufficient moisture remaining in the seeding area at the end of the summer period to start germination. A long dry period following often causes the young plants to die, thus accounting for a part of the reduction from early seeding. If there is sufficient moisture to allow for a uniform germination, August seeding will normally give higher yields than later seeding. This also holds true for early September seeding. On the other hand, if the soil is too dry in the seeding zone for germination it is advisable to delay drilling until the last of September or the first part of October.

Table 18. Average yields from all dates of seeding of winter wheat for every 15 days from August 1 to November 1, inclusive, given for each rate for the full period of the test from 1921 to 1929, inclusive.

	RATE OF SEEDING (PECKS)						
	2	3	4	5	6	7	8
Actual yield.....	18.2	20.2	21.9	22.2	22.6	22.7	22.8
Net yield........	17.7	19.4	20.9	20.9	20.1	20.9	20.8

The data in Table 18 are averages of all dates of seeding given for each rate with actual yield and net yield. Considering the actual yields, a gradual increase is shown with increased rates up to 5 pecks. From this point on to 8 pecks the differences are so small as to be negligible. The results in the net yield columns indicate that the **highest returns are secured at about 4 to 6 pecks.**

Table 19. Annual and average yields of winter wheat seeded at rates varying from 2 to 8 pecks, inclusive, for the optimum date, October 1, covering the period of 1917 to 1929, inclusive.

RATE OF SEEDING	ANNUAL AND AVERAGE YIELDS IN BUSHELS PER ACRE													
	1917	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Actual Avg.	Net Avg.
2 pecks	17.4	16.3	10.3	34.7	2.7	20.7	16.7	28.7	26.7	8.7	22.3	18.0	18.5	18.0
3 pecks	19.6	18.1	15.8	33.0	4.3	20.0	16.7	32.3	30.0	13.3	26.0	16.3	20.4	19.7
4 pecks	21.6	19.4	19.0	36.3	6.0	21.8	18.0	30.0	34.7	10.7	30.0	19.0	22.2	21.2
5 pecks	22.3	21.5	19.2	35.3	8.3	22.3	20.7	35.0	33.7	13.7	26.7	24.0	23.5	22.2
6 pecks	24.8	21.0	20.3	35.7	5.1	23.3	19.3	29.3	35.0	13.3	31.0	23.3	23.6	22.1
7 pecks	26.3	23.5	19.0	40.0	12.0	23.3	18.7	30.0	32.3	17.3	26.7	20.7	24.2	22.4
8 pecks	28.3	22.5	19.2	39.7	11.3	22.3	21.0	32.0	34.3	14.3	29.3	19.3	24.4	22.4

The data in Table 19 give in detail the results of seeding winter wheat at rates from 2 to 8 pecks, inclusive, on October 1, the date which has given the highest yields. The actual average yields show a difference between 2-peck and 3-peck seedings of approximately 2 bushels and the same between 3 and 4 pecks. From 4 pecks on to 8 the increase is smaller. Considering the net average an increase is indicated up to and including 5 pecks. From 5 pecks on to 8 the variation is slight. With the use of copper carbonate these results would indicate that where formerly sowing of 6 pecks of winter wheat was recommended the amount can now be decreased with safety to 5 for clay loam soils. For the sandy soils experience points to sowings as low as 2 pecks where moisture conditions are favorable. Favorable moisture conditions on clay loam soils would also allow for further reductions in the rate with 4 pecks as a minimum.

Spacing Test

The spacing test was conducted to determine the effect of sowing winter wheat in rows spaced at various distances apart, together with cultivation and no cultivation of the growing wheat. The results of this test are shown in Table 20. It will be noted that the uncultivated wheat rows were spaced 7, 14, 21, and 28 inches apart, with the same arrangement for the plats receiving cultivation. The test is seeded on twentieth-acre plats replicated twice covering the 7-year period from 1923 to 1929, inclusive.

Table 20. Annual and average yields of Kanred winter wheat when sown in rows of various widths with the first set of plats left uncultivated in spring of cropped year with the other set cultivated when the wheat was about 4 inches high over the 7-year period from 1923 to 1929, inclusive.

	ANNUAL AND AVERAGE YIELDS PER ACRE (BUSHELS)							
	1923	1924	1925	1926	1927	1928	1929	Avg.
Spacings Uncultivated								
7 inches	27.5	23.1	40.1	37.0	18.9	32.8	21.1	28.6
14 inches	24.6	22.2	34.2	38.7	17.5	30.2	21.0	26.9
21 inches	21.8	23.8	31.1	36.8	20.2	30.0	20.3	26.3
28 inches		22.1	31.7	31.1	16.0	30.6	24.5	26.0
Average	24.6	22.8	34.3	35.9	18.1	30.9	21.7	26.9
Spacings Cultivated								
7 inches	22.1	21.7	35.9	38.7	19.5	37.5	18.3	27.7
14 inches	20.8	19.0	29.8	35.3	17.2	33.5	17.3	24.7
21 inches	19.7	22.2	27.4	34.3	18.0	32.5	21.8	25.1
28 inches		21.9	24.3	34.1	16.5	28.3	20.6	24.3
Average	20.9	21.2	29.3	35.6	17.8	32.9	19.5	25.4

The yields of winter wheat, as given in Table 20, with rows spaced 14, 21, and 28 inches apart for both the cultivated and the uncultivated, show only slight variation. The normal drill widths in each case produced yields somewhat higher. Comparing the cultivated wheat with that left uncultivated the differences of all row widths were in favor of no cultivation, with the final average of 26.9 bushels for uncultivated grain and 25.4 bushels for cultivation.

Type of Drill

The furrow drill which is now being used so extensively on the Great Plains has been tested at the Nephi Station since 1923. The results of this test with the yields from the common drill used as a comparison are given in Table 21. The experiment has been conducted on twentieth-acre plats replicated from three to six times each season. The drouthy season of 1924 was the only year in which the furrow drill showed a significant advantage over the common type. The average yields as produced by the ordinary

Table 21. Annual and average yields of Kanred wheat when sown with ordinary grain drill and the furrow drill in the 7-year period from 1923 to 1929, inclusive.

DRILL USED	ANNUAL AND AVERAGE YIELDS PER ACRE (BUSHELS)							
	1923	1924	1925	1926	1927	1928	1929	Avg.
Ordinary drill......	31.4± .33	24.0± .85	37.0±1.66	32.4± .45	18.3± .69	29.3±1.23	21.2± .62	27.7± .83
Furrow drill.......	28.4±1.00	27.6± .99	36.2± .51	31.6± .52	17.8± .42	27.1±1.48	20.2± .47	26.9± .77

type drill are slightly higher than the yields following the furrow drill; the figure is so small, however, that no importance can be attached to the difference. The data do indicate that the furrow drill has no place on the dry-lands of the Great Basin where winter killing and soil blowing are not encountered as definite problems in wheat growing.

Seed Treatment for Smut

Covered smut or bunt has always been a problem in wheat growing of major importance, and in spite of the fact that treatment is now more widespread among farmers than ever before smut is on the increase in the Great Basin. The 1929 records from Ogden showed that 45 per cent of all carloads of wheat passing through this city graded "smutty." Very likely this situation will continue until the problem is solved by breeding resistant strains of wheat which are adapted to this region. At present, however, careful treatment of selected seed needs to be given each season.

The seed-treatment experiment conducted at the Nephi Station for the past six years is divided into two parts: The first has to do with the efficiency of various disinfectants in controlling smut on smutted grain; the second is the measurement of the effect of smut treatment on the yield of winter wheat.

Table 22. Annual and average percentages of smutted plants of the Kanred variety after various treatments over the 6-year period from 1924 to 1929, inclusive.

TREATMENT	AVERAGE AND ANNUAL PERCENTAGES OF SMUT AFTER TREATMENT OF GRAIN WITH VARIOUS DISINFECTANTS						
	1924	1925	1926	1927	1928	1929	Avg.
Unsmutted seed treated with copper carbonate 20%......	Trace	.2± .02	Trace	0	0	0	
Unsmutted and untreated seed..	4.0± .16	4.7± .64	1.6± .31	2.0± .27	0.6± .22	Trace	2.15± .27
Smutted seed, no treatment....	61.0±4.00	92.0±1.91	83.6± .66	73.1±1.46	59.0±1.98	66.2±1.22	72.50±1.87
Smutted seed treated with copper carbonate, 20%.....	....	8.8± .82	8.8± .60	4.0± .78	0.6± .10	8.6±1.40	6.16± .74
Smutted seed treated with copper carbonate, 50%.....	1.5± .07	....	2.9± .34	1.8± .43	Trace	2.6± 1.3	1.76± .19
Smutted seed treated with copper sulphate, blue vitriol.	1.0± .05	3.7± .66	5.9±1.11	1.2± .29	0.2± .10	1.0± .03	2.17± .37
Smutted seed treated with formalin	Trace	.7± .09	2.6± .57	4.0± .54	0.4± .24	0	1.28± .24
Smutted seed treated with Semesan	....	....	....	....	....	5.4± .63	....
Smutted seed treated with Dupont Dust No. 37........	....	....	31.2±2.95	11.8±1.29	7.0± .50	22.0±1.65	18.0 ±1.6

The data accumulated on the efficiency of various disinfectants in control of smut over the period from 1924 to 1929, inclusive, are given in Table 22. The figures given are averages collected by repeating each test in two drill widths and taking five counts of 50 plants from each drill width each season. An examination of these data will show that seed treated with copper carbonate of 18 per cent copper equivalent will control smut on ordinary unsmutted wheat. However, the data show that where treatment was not given during each season sufficient smut escapes from the previous year's treatment to give at least a trace each season to as high as 4 per cent smutted plants. This indicates that no year should pass without treating seed wheat in spite of the fact that no smut was visible in the crop from which the seed was taken. Comparing the efficiency of the various treatments when used on artificially smutted wheat, formalin, allowing an average of 1.28 per cent smut, was most efficient, followed by copper carbonate of 50 per cent pure copper which allowed 1.76 per cent smut. The copper carbonate of 20 per cent copper showed 6.16 per cent smut. It is thus evident that if wheat is smutty and it is necessary to use it for seed, formalin or copper carbonate of 50 per cent copper are the best measures of control. If the seed is fairly free from smut, under ordinary conditions, copper carbonate of 20 per cent copper is sufficient to control the smut.

Table 23. Annual and average yields of Kanred wheat when treated with various disinfectants for smut in the 6-year period from 1924 to 1929, inclusive.

SEED TREATMENT	ANNUAL AND AVERAGE YIELDS PER ACRE (BUSHELS)						
	1924	1925	1926	1927	1928	1929	Avg.
No treatment	22.4± .52	42.1±1.61	37.0± .17	17.3± .77	29.9±1.38	21.2± .62	28.3± .85
Copper carbonate (dust)	23.7± .36	40.2±1.26	36.3± .10	17.5± .71	29.3±1.82	19.3± .55	27.7± .80
Copper sulphate, blue vitriol	19.6± .97	40.6± .75	33.2±1.50	17.3±1.21	27.5± .34	19.2±2.27	26.2±1.01
Formalin	20.2± .79	39.4±1.42	34.2± .90	17.5± .72	26.2± .55	19.4±4.95	26.1±1.55

The second part of the test is the determination of the effect of the various smut treatments, as listed in Table 23 on yield of winter wheat. Average results over the 6-year period show that wheat treated with copper carbonate yielded 1.5 bushels higher than blue vitriol and 1.6 bushels more than wheat treated with formalin. The probable errors also show more variation for the wet treatment than no treatment or treatment with copper carbonate. Unquestionably, formalin is the most efficient of all disinfectants used in these tests for killing smut spores, yet it is used with most risk. The data in Table 23 show no disastrous effect from this treatment, even though half of the sowings were made in soil too dry for germination until weeks after seeding. The low yields of 1918 at the Nephi Station, however, were due to formalin injury even though the treatment was properly given. Many farmers have suffered similar effects. Because of this uncertainty **the use of formalin is not advised unless the seed can be sown in moist soil where germination will be rapid and uniform.**

CROPPING EXPERIMENTS

After three-quarters of a century of experience in which experimental work has had a directing hand during the latter part of the period, wheat growers on the dry-land of the Great Basin have come to the almost universal practice of alternate crop and fallow. In a few areas where rainfall is sufficient, however, intertilled crops such as beans, peas, corn, and potatoes are grown in place of the fallow, and in certain sections two crops of wheat are produced with one fallow period. However, these are exceptions to the general practice of wheat and fallow in the Great Basin.

Table 24. Annual and average acre-yields in bushels of winter wheat when grown in various cropping systems over the 26-year period from 1904 to 1929, inclusive.

METHOD OF CROPPING	ANNUAL AND AVERAGE YIELDS IN BUSHELS PER ACRE																	
	Total 1904–14	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Total	Avg. per Crop
Continuous Fall plowed ..	136.2	12.8	8.3	16.5	11.4	2.0	13.7	16.1	7.2	14.0	7.0	20.4	5.2	5.0	5.2	5.3	286.3	11.1
Alternate Spring plowed	131.5	....	15.3	....	20.4	....	20.0	....	13.3	....	20.0	....	40.2	....	29.3	....	290.0	22.3
2 Crops in 3 years Fall plowed ..	138.5	13.6	....	23.3	9.0	....	16.8	17.9	....	24.1	3.8	....	37.3	3.7	....	15.5	303.5	17.8
1 Crop in 3 years Spring plowed	65.3	....	18.6	....	....	21.6	....	....	16.5	....	....	41.4	....	....	34.5	....	197.9	21.9

Since 1903 a cropping test of winter wheat has been a part of the experimental procedure at the Nephi Station; the first results appeared in 1904. These data, as given in Table 24, were produced on single fifth-acre plats. Continuous cropping has produced a total of 286.3 bushels, with an average crop yield of 11.1 bushels to an acre. Alternate cropping, fallow, and crop with spring plowing for fallow has produced a total of 290 bushels over the period of the test, with an average crop yield of 22.3 bushels. It will be observed that the totals of these two systems were so nearly the same as to be within the error of measuring the yields. Divided by years rather than by crops the alternate practice gave an average acre-yield of 11.15 bushels—almost identical with continuous cropping. Continuous cropping is not advised, however, since the expense incident to growing the wheat would be almost double that of the alternate practice.

The cropping practice giving the highest total production was two crops in three years with one fallow period, the total of which over a 26-year period is 303.5 bushels, with an average crop yield of 17.8 bushels. With a higher rainfall, better distributed during the growing period, this system might be economic.

The last test indicated in Table 24 is one crop in three years with two intervening fallows. The total production and crop yield of this practice were below the figures for alternate cropping, thus precluding any possibility of this method being considered in dry-land practice.

In Table 25 the yields from the continuous cropping test are divided into 5-year periods, beginning with 1904 and ending with 1928. As the data show, there is no significant trend indicated over the 25-year period of cropping.

Table 25. Average acre-yields of winter wheat produced from continuous cropping divided into 5-year averages for the period from 1904 to 1928, inclusive.

METHOD OF CROPPING	AVERAGE YIELDS IN BUSHELS PER ACRE					
	1904–08	1909–13	1914–18	1919–23	1924–28	Avg.
Continuous........................	14.7	7.7	14.6	10.6	8.3	11.1

As the data indicate in Table 24, no provision was made for the various cropping arrangements to give yields each year except under the continuous system. To make the test more inclusive and get the effect of each season on the different cropping practices the experiment was re-planned in 1915, the results of which appear in Table 26. The highest average yield produced over the 15-year period was 22.8 bushels from one crop and two fallow periods. The test on alternate cropping is divided into spring plowing for fallow, disking instead of plowing in fall just before seeding, and alternate cropping with no tillage. There is a marked decrease in yield for fall disking immediately before seeding and no tillage as compared to the ordinary practice of an early spring-plowed clean summer fallow.

Table 26. Annual and average acre-yields of winter wheat produced from various cropping systems over the 15-year period from 1915 to 1929, inclusive.

METHOD OF CROPPING	ANNUAL AND AVERAGE YIELDS IN BUSHELS PER ACRE															
	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
1 Crop in 3 years (spring plowed)	10.1	17.8	25.0	17.4	18.7	16.7	40.5	15.2	23.3	17.8	37.9	31.6	18.8	32.1	19.7	22.8
Alternate (spring plowed)	8.0	13.8	24.9	17.9	15.0	19.9	31.4	17.4	21.2	18.1	25.3	35.0	12.2	28.8	16.7	20.4
Alternate, disked in fall......	13.0	4.3	8.7	6.1	2.1	13.8	11.9	6.8	14.2	9.8	16.2	11.3	5.2	8.7	3.8	9.1
Alternate, no tillage..........	9.8	1.3	7.8	3.0	1.7	8.7	13.4	3.3	11.5	4.0	16.4	5.5	5.2	13.3	4.5	7.3
2 Crops in 3 years, spring plowed, 1st crop	14.0	17.3	23.3	15.7	16.3	16.8	30.3	12.0	24.1	18.2	29.6	37.3	15.3	30.0	15.5	21.0
2 Crops in 3 years, fall plowed, 2d crop	....	8.4	19.5	9.0	3.3	19.3	17.9	7.0	17.8	3.8	21.6	3.8	3.7	7.0	5.2	10.5
2 Crops in 3 years, spring plowed, 1st crop	10.5	18.3	22.2	16.0	7.5	21.0	23.1	12.2	21.7	18.2	30.2	33.0	16.0	28.3	17.2	19.7
2 Crops in 3 years, disked for 2d crop	....	11.4	16.7	7.2	1.3	18.7	22.6	6.3	14.5	3.2	19.7	3.0	4.8	6.3	3.3	9.8
Continuous fall plowed........	13.7	9.3	17.6	10.3	2.3	13.6	18.7	6.2	14.8	5.8	19.5	4.7	5.7	5.5	6.4	10.2
Continuous disked	10.6	3.6	11.0	5.5	2.1	10.6	13.1	3.6	14.0	2.9	16.3	3.7	5.6	5.0	2.6	7.3
Continuous tillage	8.1	3.4	6.9	3.0	2.5	9.3	16.7	2.0	11.3	5.5	12.0	3.6	4.0	3.4	3.2	6.3

The test of two crops in three years, as given in Table 26, is divided into two parts. In the first test the land is plowed for the second crop, in the second disking precedes the second crop; otherwise the soil preparation is the same. The acre-yield for the first test is about 1 bushel higher than for the second; the relationships between the first and second crop in each case, however, are about the same, indicating that disking, in light of the reduced cost, is preferable to plowing where moisture conditions are such as to favor this cropping practice.

Continuous cropping fall-plowed land, as given in the last part of Table 26, shows a yield of 10.2 bushels, exactly half the average acre-yield of ordinary alternate cropping. Comparing the different methods of soil preparation for fall sowing of winter wheat in continuous cropping, the yields indicate a decided advantage for plowing as against disking only and no tillage. Again, it may be stated that **under climatic conditions similar to those at Nephi alternate cropping of winter wheat and fallow is safest**, but in regions with additional moisture distributed more favorably to the growing plants two crops with one fallow may have significant advantages in production.

CEREAL VARIETIES

An extensive study of crops and crop varieties has been made at the Nephi Dry-farm Substation for the 27 years that the farm has been in operation. In spite of the fact that winter wheats have been the dominant crop on the dry-lands, many other crops such as peas, beans, corn, potatoes, beets, flax, grasses, rape, barley, oats, and spring wheats, have been grown to determine yield possibilities under arid conditions. Since most of the minor crops have been discarded from the varietal trials after being reported in previous publications, this discussion is limited to (1) varieties of winter and spring wheats, (2) winter barley varieties, and (3) spring oats.

Winter Wheats

Of the sixteen winter wheat varieties listed in Table 27, Sevier 34 and Sevier 59 have given yields significantly higher than any other variety; next in order come Kanred and Turkey 26. Both of the Sevier wheats are pureline selections made from the variety Sevier at Logan. Turkey 26 and Turkey 926 are pureline selections made from the variety Turkey at Nephi. Because Sevier lacks somewhat in winter resistance and because of its not being as adaptable to milling as Kanred and Turkey these wheats have not been generally distributed. In the latter part of Table 27 four varieties are listed which have been included in the test since 1927, with Sevier 34 for comparison. It will be noted that two years out of three Turkey 926 gave yields higher than Sevier 34, with an average of only 0.6 bushel under this variety. Both Turkey 26 and 926 have strong straw, standing up much better than other varieties under conditions which tend to favor lodging. At present, however, no variety, the seed of which can be secured in large

Table 27. Annual and average yields of winter wheat varieties covering the period from 1924 to 1929, inclusive.

VARIETY	ANNUAL AND AVERAGE YIELDS IN BUSHELS PER ACRE						
	1924	1925	1926	1927	1928	1929	Avg.
Sevier 34	22.0	30.1	43.1	16.1	34.6	14.0	26.8
Sevier 59	21.0	34.3	45.9	13.9	31.1	13.9	26.7
Kanred	19.4	30.9	32.5	15.2	31.0	13.5	23.8
Turkey 26	17.5	27.7	39.4	15.8	28.7	12.9	23.7
Kofod 125	....	30.8	34.0	13.3	26.5	11.7	23.2
Turkey	18.5	27.1	33.9	15.1	30.0	12.7	22.9
Kofod	19.7	29.5	35.6	11.4	27.3	11.2	22.4
Alton x Kanred 237	....	....	35.4	11.9	28.7	12.9	22.2
Black Hull	18.3	26.6	33.5	13.5	26.5	12.0	21.7
Alton	18.0	27.7	27.0	10.0	29.8	15.8	21.4
Kharkof	16.0	27.0	31.3	10.7	27.7	14.8	21.1
Goldcoin	14.8	17.8	25.8	5.4	24.0	....	17.5
Sevier 34	....	....	....	16.1	34.6	14.0	21.5
Turkey 926	....	....	....	16.2	31.2	15.3	20.9
Kharmont	....	....	....	13.0	30.8	13.7	19.2
Utac	....	....	....	11.7	27.0	14.4	17.7

quantities, is superior to Kanred. Winter wheat varieties were grown on twentieth-acre plats replicated three times.

Spring Wheats

Spring wheats have practically disappeared from the dry-lands of the Great Basin. In fact, the only place spring varieties have in dry-farm practice in this territory is to supplement winter wheats in case of winter injury. While a varietal test of spring wheat has been a project of the Nephi Station since 1904, the yields given in Table 28 date only from 1922 to 1929, inclusive.

Early Baart, with a yield of 12.6 bushels, stands first, with Kota second. It will be noted that the highest yielding spring wheat has produced a yield only half that of the winter varieties. For this reason there seems little wisdom in the sowing of spring varieties except under the conditions stated. Spring wheat varieties were grown on duplicate twentieth-acre plats.

Table 28. Annual and average yields of spring wheat varieties covering the 8-year period from 1922 to 1929, inclusive.

VARIETY	ANNUAL AND AVERAGE YIELDS IN BUSHELS PER ACRE								
	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Early Baart	7.3	14.4	6.1	31.0	4.7	11.0	11.5	14.5	12.6
Kota	9.2	14.0	6.8	21.2	4.9	10.3	11.1	10.5	11.0
Chul	6.9	11.7	6.5	20.5	7.0	8.8	10.6	13.0	10.6
Kubanka	7.8	11.3	5.5	23.5	5.5	9.3	6.5	14.0	10.4
Regenerated Defiance	4.9	11.1	2.5	25.5	6.1	7.0	8.3	10.6	9.5
Marquis	7.3	13.5	1.8	23.5	3.8	7.0	8.6	9.9	9.4
Hard Federation	4.6	11.6	4.3	22.5	1.8	4.0	7.6	9.3	8.2

Winter Barley

Winter barley, practically unknown on the dry-lands of the Great Basin, has been under study in a varietal test over the period from 1914 to 1927, inclusive. Bulgarian, with an average acre-yield of 29.8 bushels, stands first in the list, closely followed by Turkestan (Table 29). This test was conducted on twentieth-acre plats replicated three times.

If winter wheat on the dry-farms has a competitor it is winter barley. The yield of 23.8 bushels for Kanred, as given in Table 27, when converted into pounds equals 1418, as compared to 1430 pounds for the 29.8 bushels of Bulgarian barley. However, none of the barleys are strictly winter-hardy, all of them showing winter-killing in severe seasons.

Table 29. Annual and average yields of winter barley varieties grown over the 14-year period from 1914 to 1927, inclusive.

VARIETY	ANNUAL AND AVERAGE YIELDS IN BUSHELS PER ACRE														
	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	Avg.
Bulgarian	59.0	49.6	13.7	24.3	36.5	18.6	19.4	48.4	15.1	18.6	19.3	35.7	45.3	14.2	29.8
Turkestan	61.7	50.2	7.9	25.1	30.4	14.3	12.5	61.3	13.2	17.2	17.6	33.4	42.6	14.0	28.6
Tennessee	50.9	43.5	8.1	21.7	26.0	13.6	16.7	41.1	10.0	11.5	13.2	31.5	39.6	13.2	27.2
Utah Winter	39.8	53.5	12.2	16.7	20.1	13.6	16.7	36.2	11.9	16.4	18.1	32.9	41.0	13.5	24.4

Spring Oats

A varietal test of spring oats, the annual and average yields of which are given in Table 30, extends over the 10-year period from 1917 to 1926, inclusive. The test was conducted on duplicate twentieth-acre plats. While spring oats are regularly grown on some of the dry-lands of the state, principally in San Juan County, the yields are far from being high enough to justify growing oats under conditions similar to those at Nephi.

Table 30. Annual and average acre-yields of spring oat varieties over the 10-year period from 1917 to 1926, inclusive.

VARIETY	ANNUAL AND AVERAGE YIELDS IN BUSHELS PER ACRE										
	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	Avg.
Aurora	....	....	....	24.0	25.6	6.7	18.1	4.6	25.0	3.8	15.4
Black American	14.7	27.7	5.0	17.8	26.4	7.3	18.2	5.1	25.4	4.9	15.2
Swedish Select	8.6	23.1	4.4	18.9	28.5	8.1	16.8	4.2	27.6	4.2	14.4
Sixty-Day	19.4	18.6	5.6	14.4	27.5	4.1	15.1	3.1	26.2	4.5	13.8
Big Four	8.7	24.4	4.1	12.2	19.1	6.5	20.3	4.8	24.0	4.1	12.8

FERTILITY EXPERIMENTS

Most of the dry-lands in the Great Basin are comparatively still virgin in relation to fertility. While a few dry-farms have been cropped for over 50 years, 30 to 40 years ago most of the land now in wheat was in sage-brush. Under the alternate cropping system this means that approximately 15 to 20 crops have been taken from each tilled acre. The average acre-yield in Juab Valley is near 22 bushels, making a total of about 330 bushels harvested from each acre for the 30 years of cropping. In Cache Valley, where precipitation is higher, average acre-yields are about 30 bushels. However, these lands have been cropped for a period of approximately 40 years. For 20 crops at an estimated acre-yield of 30 bushels, approximately 600 bushels have been harvested from each acre. With the phosphorus content of the dry-lands about 0.36 per cent and with a potassium content near 1.37 per cent the small amount of these elements taken out by the wheat, especially where the straw is left on the ground and plowed under, is no greater than the error of taking the soil samples and making the determinations. With nitrogen the situation is somewhat different. Characteristically, arid lands are low in nitrogen, that element used most by the wheat plant as compared to the amount present in the soil. The amount of nitrogen varies from 0.1 to 0.2 per cent in the cropped dry-lands of Utah. With soil moisture maintained at a comparatively high content during the fallow season and with organic matter in the form of straw plowed into the soil each alternate year, environmental conditions for nitrogen-fixing organisms are probably better than in virgin land. Analysis of cropped lands, however, shows a slight decrease of this important element as compared to virgin lands immediately adjacent. With a cropping system of alternate wheat and fallow, and with the straw returned to the land and plowed under, the fertility of the dry-lands should maintain maximum yields over a long period of time since there is only one source of loss, removal in the crop. This holds for most of the important elements, with the exception of nitrogen which is normally low.

In replanning some of the experimental work in 1915, a fertility test was added to determine the reaction on yield of dry-farm land to fertilizer. This project is divided into three parts: (1) Application of barnyard manure in various quantities and at various times, (2) plowing under green manure crops such as peas and wheat at different intervals of growth, and (3) disposal of the stubble in various ways. Data on the third phase of the project have already been given under treatment of land before plowing.

Application of Barnyard Manure

On the basis of the application of the manure this test is divided into three parts: (1) Various amounts of manure applied each alternate year or each stubble year, (2) different quantities of manure applied every four years, and (3) manure applied in certain definite amounts in 1915, with no later applications.

Table 31. Annual and average yields of winter wheat produced from no manure, 1 ton per acre, 2.5 tons per acre, 5 tons per acre, and 10 tons of manure per acre each alternate year over the 15-year period from 1915 to 1929, inclusive.

AMOUNT OF MANURE	ANNUAL AND AVERAGE YIELDS PER ACRE IN BUSHELS															
	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
No manure	10.4	17.1	28.8	16.3	22.1	26.2	35.0	12.5	23.8	22.6	32.0	37.0	16.8	29.1	21.3	23.4
1 ton each alternate year	10.6	14.9	27.5	15.9	21.3	22.1	37.2	12.5	26.0	20.3	32.7	36.8	18.1	26.0	21.6	22.9
2.5 tons each alternate year	9.8	15.2	27.0	14.9	22.3	23.3	36.2	11.5	25.3	21.5	38.2	37.9	19.8	29.5	23.1	23.7
5 tons each alternate year	11.7	15.1	30.0	16.1	25.0	25.5	41.5	13.1	30.3	22.1	38.9	39.3	22.2	33.2	25.8	26.0
10 tons each alternate year	13.4	17.8	30.3	18.5	26.1	28.4	45.6	14.1	35.0	23.6	49.7	39.6	23.3	35.1	26.0	28.3

The dates for the alternate applications are given in Table 31. As indicated, the amounts of manure applied are: 1 ton, 2.5 tons, 5 tons, and 10 tons each alternate year, with no manure serving as a check. This test has been conducted in duplicate on twentieth-acre plats. When compared to the plats receiving no manure the 1- and 2.5-ton applications showed no effect when measured in yield of wheat. Both the 5- and 10-ton amounts, however, gave significant increases. Since the beginning of the test, the years 1919, 1924, 1927, and 1929 have been unfavorable for wheat yields; but in each case the manured plats receiving 5 and 10 tons to an acre have shown increased production.

To determine the accumulative effect of manure during the 15 years over which the results in Table 31 were collected, each of the three 5-year

Table 32. Average yields of winter wheat giving the total and three 5-year periods from 1915 to 1929, inclusive, produced from various amounts of barnyard manure applied each alternate year.

AMOUNT OF MANURE	AVERAGE YIELDS IN BUSHELS PER ACRE							
	1915–19		1920–24		1925–29		Avg.	
	Avg. Yield	Relative Yield Check 100	Avg. Yield	Relative Yield Check 100	Avg. Yield	Relative Yield Check 100	Avg. Yield	Relative Yield Check 100
No manure	18.9	100	24.0	100	27.4	100	23.4	100
1 ton each alternate year	18.0	95	23.6	98	27.0	98	22.9	98
2.5 tons each alternate year	17.8	94	23.5	98	29.7	109	23.7	101
5 tons each alternate year	19.6	103	26.5	110	31.9	116	26.0	111
10 tons each alternate year	21.0	111	29.3	122	34.7	126	28.3	121

periods was averaged and included in Table 32. In addition, the relative standing of each average is compared with those plats receiving no manure. Again, the data show that the soil did not respond to the small amounts, as indicated by yields but more clearly shown in the relative standing. Considering the figures for the larger amounts of manure, it is apparent that for the first five years 5 tons of manure showed little increase, most of the increased yield coming in the second and third periods. With 10 tons the increased yield of wheat was quite regular, with the greatest increases coming in the first and second periods. The second period is 11 per cent greater than the first with the third 26 per cent higher than the check but only 4 per cent above the second 5-year period. It is also noticeable that the second and third periods are much higher in yield than the first for all tests including "no-manure" check.

With the check the last period was 45 per cent higher than the first; with 10 tons of manure the increase amounted to 65 per cent. Introduction of Kanred wheat into the test in 1921 and the use of copper carbonate since 1923 instead of formalin accounts for part of the increase, together with the grouping of more favorable seasons for wheat growing. A comparison of yields from land receiving no manure and that from land given a 10-ton application each alternate year is graphically shown in Figure 5.

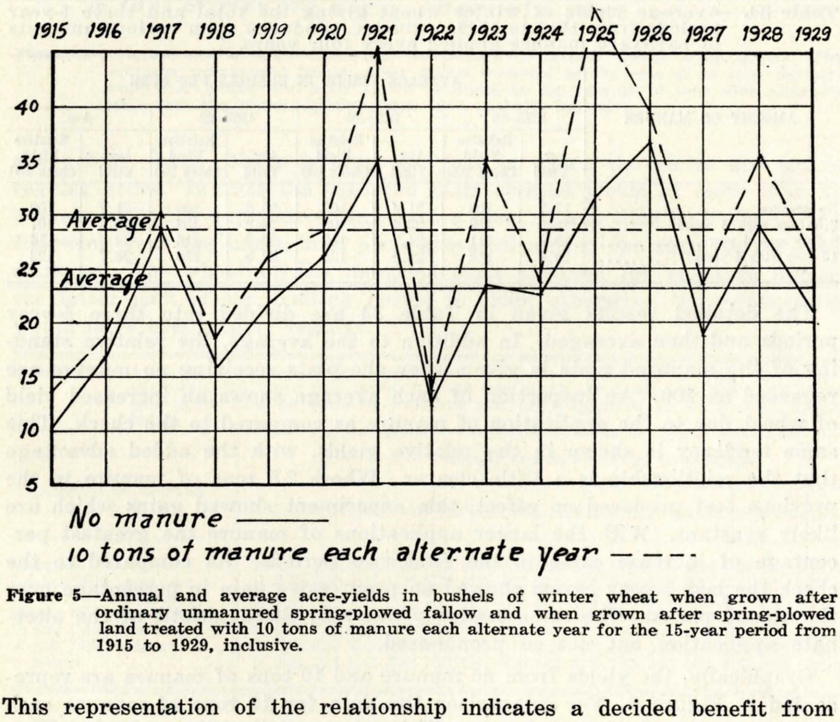

Figure 5—Annual and average acre-yields in bushels of winter wheat when grown after ordinary unmanured spring-plowed fallow and when grown after spring-plowed land treated with 10 tons of manure each alternate year for the 15-year period from 1915 to 1929, inclusive.

This representation of the relationship indicates a decided benefit from manure in seasons such as 1921, 1923, and 1925, and also shows that the differences in yield between manured and unmanured plats tend to increase with time.

Table 33. Annual and average yields of winter wheat produced from no manure, 2.5 tons of manure per acre, 5 tons of manure per acre, and 10 tons of manure per acre applied every four years over the 15-year period from 1915 to 1929, inclusive.

AMOUNT OF MANURE	ANNUAL AND AVERAGE YIELDS PER ACRE IN BUSHELS															
	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
No manure	11.2	13.9	27.0	14.1	22.5	22.9	31.9	10.5	22.6	19.2	29.1	37.0	15.2	28.1	20.8	21.7
2.5 tons manure each 4 years	10.9	15.1	26.8	16.5	22.5	22.4	37.8	12.5	24.0	20.2	36.1	36.6	17.0	29.6	21.8	23.3
5 tons manure each 4 years	11.8	18.2	29.1	16.3	23.3	25.5	36.9	13.6	27.0	20.4	38.9	36.8	18.0	33.5	24.6	24.9
10 tons manure each 4 years	13.5	18.1	30.5	15.1	25.0	25.2	45.0	13.2	28.8	22.3	43.2	39.0	20.6	33.0	28.7	26.7

The detailed data for the second part of the barnyard manure test in which 2.5 tons, 5 tons, and 10 tons have been applied to the plats every four years as compared to land untreated are given in Table 33. An examination of the average acre-yields of winter wheat as affected by manure (Table 33) show a progressive increase in yield with the manure applied. Ten tons of manure applied every four years has increased the avearge yield 23 per cent above no manure. It is also noticeable that the seasons of low yield, part of which were droughty, show similar effects of the manure.

Table 34. Average yields of winter wheat giving the total and three 5-year periods from 1915 to 1929, inclusive, produced from various amounts of barnyard manure applied every four years.

AMOUNT OF MANURE	AVERAGE YIELDS IN BUSHELS PER ACRE							
	1915–19		1920–24		1925–29		Avg.	
	Avg. Yield	Relative Yield Check 100	Avg. Yield	Relative Yield Check 100	Avg. Yield	Relative Yield Check 100	Avg. Yield	Relative Yield Check 100
No manure	17.7	100	21.4	100	26.0	100	21.7	100
2.5 tons each 4 years	18.3	103	23.4	109	28.2	108	23.3	107
5 tons each 4 years	19.7	111	24.7	115	30.3	116	24.9	114
10 tons each 4 years	20.4	115	26.9	125	32.9	126	26.7	123

The detailed results given in Table 34 are divided into three 5-year periods and then averaged. In addition to the average, the relative standing of the manured plats is given when the plats receiving no manure are regarded as 100. An inspection of each average shows an increased yield of wheat due to the application of manure as compared to the check. This same tendency is shown in the relative yields, with the added advantage that the relationship is a little clearer. Where 2.5 tons of manure in the previous test produced no effect, this experiment showed gains which are likely constant. With the larger applications of manure the greatest percentage of increase came in the first two periods. As compared to the check the last 5-year period showed no progressive gain in percentage over the second period. The same tendency was also characteristic of the alternate application but not so pronounced.

Graphically, the yields from no manure and 10 tons of manure are represented in Figure 6. For comparison the data for 10 tons of manure each alternate year are also given. It will be observed that the yields as illustrated by lines take positions farther apart with time, with 10 tons of manure each alternate year only slightly above 10 tons of manure applied

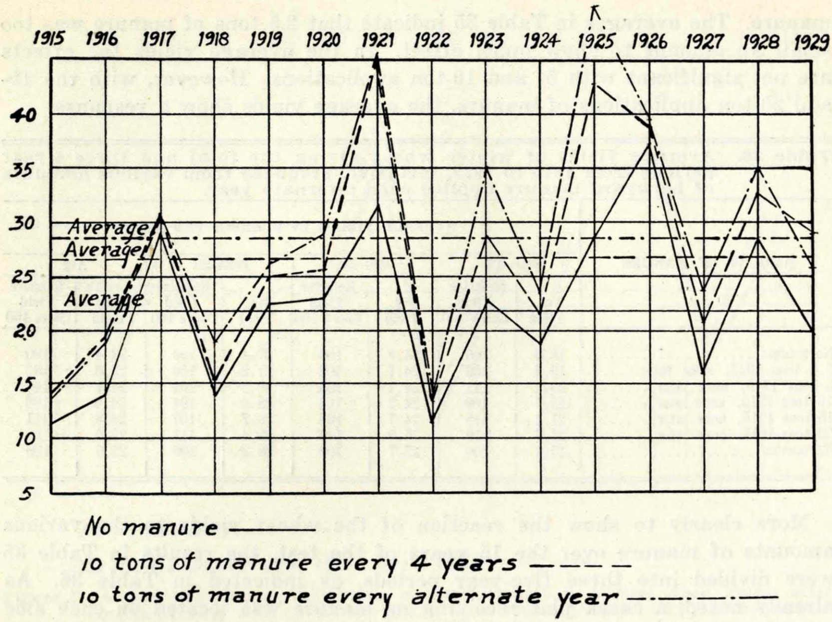

Figure 6—Annual and average acre-yields in bushels of winter wheat when grown after ordinary unmanured fallow, after fallow manured at the rate of 10 tons per acre every four years, and after fallow manured at the rate of 10 tons each alternate year over the 15-year period from 1915 to 1929, inclusive.

every four years. There is only one year in which the yields are not in regular order. In 1925 the manured plats showed yields of more than 40 bushels while the unmanured land gave a yield of less than 30 bushels. The following year the unmanured plats averaged almost the same as the land manured. The wheat on the manured plats suffered for moisture during the latter part of the fruiting period in 1926; otherwise, the relationship would have been nearly regular.

Table 35. Annual and average yields of winter wheat produced from no manure, 2.5 tons per acre, 5 tons per acre, 10 tons per acre, 15 tons per acre, and 20 tons of manure per acre applied in 1915 with none later.

AMOUNT OF MANURE	ANNUAL AND AVERAGE YIELDS PER ACRE IN BUSHELS															
	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
No manure	10.4	17.1	28.8	16.3	22.1	26.2	35.0	12.5	23.8	22.6	32.0	37.0	16.8	29.1	22.3	23.4
2.5 tons 1915, none later.....	11.9	15.5	30.1	17.1	22.3	26.6	35.3	12.3	25.3	20.9	32.6	37.0	17.5	26.2	22.7	23.6
5 tons 1915, none later.......	12.7	17.1	32.4	15.7	23.8	24.0	36.1	13.3	27.0	20.1	37.5	37.3	18.0	27.1	21.3	24.1
10 tons 1915, none later......	13.1	17.2	28.8	16.5	23.0	25.1	34.7	12.2	27.3	21.9	32.8	37.8	19.3	27.5	22.5	24.0
15 tons 1915, none later......	13.6	21.9	31.0	16.3	22.5	25.3	38.1	12.3	26.8	21.3	34.0	38.6	19.3	30.8	21.0	24.8
20 tons 1915, none later......	13.7	20.0	29.8	16.0	24.0	24.4	40.7	13.6	26.1	20.4	35.2	39.9	18.8	30.5	22.7	25.0
No manure	11.2	14.1	28.0	13.8	18.7	22.7	37.0	10.9	22.3	20.7	32.2	37.0	17.3	25.0	20.2	22.0

The third test which has to do with a study of the residual effect of barnyard manure on wheat yields is given in detail in Table 35. It will be noted that the test is adjoined on each side by a check plat receiving no manure. The averages in Table 35 indicate that 2.5 tons of manure was too small an amount to show much effect. In the average yields the effects are not significant with 5- and 10-ton applications. However, with the 15- and 20-ton applications of manure, the average yields show a response.

Table 36. Average yields of winter wheat giving the total and three 5-year periods from 1915 to 1929, inclusive, produced from various amounts of barnyard manure applied each alternate year.

AMOUNT OF MANURE	AVERAGE YIELDS IN BUSHELS PER ACRE							
	1915–19		1920–24		1925–29		Avg.	
	Avg. Yield	Relative Yield Check 100	Avg. Yield	Relative Yield Check 100	Avg. Yield	Relative Yield Check 100	Avg. Yield	Relative Yield Check 100
No manure	18.9	100	24.0	100	27.4	100	23.4	100
2.5 tons 1915, none later	19.4	103	24.1	102	27.2	100	23.6	102
5 tons 1915, none later	20.3	111	24.1	103	28.2	104	24.1	105
10 tons 1915, none later	19.7	109	24.2	104	28.0	104	24.0	106
15 tons 1915, none later	21.1	118	24.7	106	28.7	107	24.8	111
20 tons 1915, none later	20.7	119	25.0	109	29.4	111	25.0	112
No manure	17.1	100	22.7	100	26.3	100	22.0	100

More clearly to show the reaction of the wheat yields to the various amounts of manure over the 15 years of the test, the results in Table 35 were divided into three five-year periods, as indicated in Table 36. As already noted, a check plat receiving no manure was located on each side of the manured plats. It will also be observed that the check plats differ somewhat in yield. In order to give each manured plat the proper relative value, a correction was made of the check plat yields. Because of there being five manured plats it was decided to divide each check plat yields into fifths. Then, to make the proper correction with the yield of wheat produced on the plat receiving 2.5 tons of manure in the first 5-year period, four-fifths of 18.9 bushels, the yield of the first check, was added to one-fifth of 17.1 bushels, the second check, this serving as the basis for determining the relative yield of 19.4 bushels, which is 103. For the plat receiving 5 tons of manure in 1915 and with none later, two-fifths of 18.9 bushels, the yield of the closest check, was added to three-fifths of the 17.1 bushels, this serving as the relative value for calculating the figure of 20.3 bushels. For the center yield of 19.7 bushels produced from 10 tons of manure, half of each check was added together to determine the relative yield. All figures in Table 36, other than actual yields, were calculated as outlined above.

As the relative yields in Table 36 indicate, all application of manure made in 1915 with none later showed an effect in the first 5-year period with increasing value for the larger amounts of manure. In the next 5-year period the percentage gains in wheat yield were more than cut in two, with the exception of the 2.5-ton application, thus showing a gradual decrease in the residual value of the manure. In the third and last period the 2.5-ton application lost its effect, but the higher applications show no decrease over the previous 5-year period, thus indicating that the large amounts of manure produced an effect through ten years and on into the period between ten and fifteen years. Referring to the detailed data in Table 35, it is apparent that the yields of 1928, for at least the 15- and 20-ton applications, showed an effect from manure, and it is probable that the 1929 yields also gave increased yields for these higher amounts.

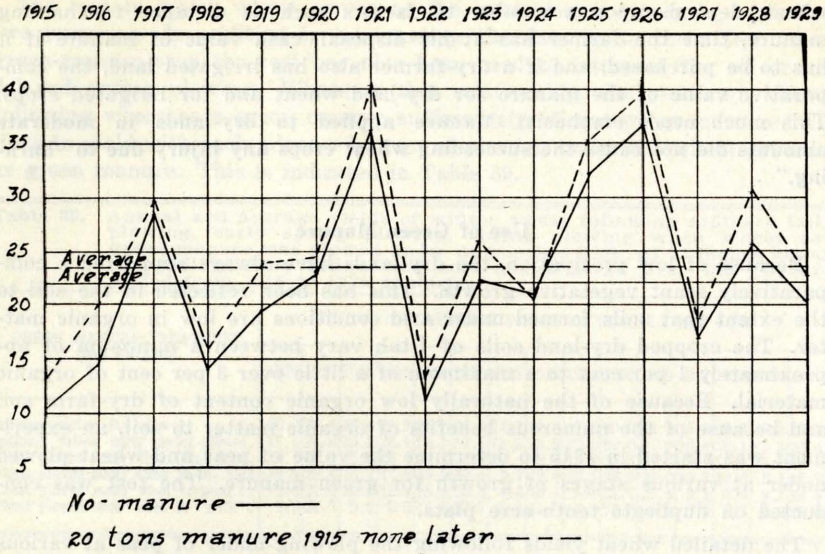

Figure 7—Annual and average acre-yields of winter wheat in bushels when grown after spring-plowing with no manure and with 20 tons applied in 1915 with none later for the 15-year period from 1915 to 1929, inclusive.

The relation of wheat yield between 20 tons of manure applied in 1915 with none later and no manure, with corrected yields, is given in Figure 7. It is apparent from the graph that the effect of the manure has been reflected in the yields of wheat throughout the entire 15-year period of the test. Only once in the whole period do the lines cross, and this was in 1924.

In addition to the effect of manure on yield it also influences the protein content of the grain. The data in Table 37 show that where no manure was added to the soil the average protein content of the wheat was 11.83 per cent; it was 12.59 per cent for wheat grown on land treated with 5 tons of manure each alternate year and 13.41 per cent for wheat produced on land which received 10 tons of manure each alternate year. As indicated, the protein content for the individual years held rather closely to the relationship of the averages.

Table 37. Percentage of crude protein in winter wheat produced on land treated with various amounts of manure each alternate year for the 4-year period from 1926 to 1929, inclusive.

AMOUNT OF MANURE	AMOUNT OF CRUDE PROTEIN IN PERCENTAGE					
	1926	1927	1928	1929	Avg.	Relative Percentage Protein
No manure	11.49	11.98	10.73	13.12	11.83	100
5 tons manure each alternate year	11.85	12.85	11.65	14.00	12.59	106
10 tons manure each alternate year	12.42	13.43	13.05	14.76	13.41	113

Briefly, it may be stated from the foregoing data that manure applied to dry-land in moderate amounts—10 tons each alternate year or each four years—affect the yield benefically to the extent of over 20 per cent. Whether or not this is profitable to a wheat grower in light of prices for wheat, depends upon a number of factors such as distance for hauling manure, time the farmer has at his disposal, cash value of manure if it has to be purchased, and if a dry-farmer also has irrigated land, the comparative value of the manure for dry-land wheat and for irrigated crops. This much needs emphasis: **Manure applied to dry-lands in moderate amounts did not cause the succeeding wheat crops any injury due to "burning."**

Use of Green Manure

Because of low precipitation, the dry-lands have always supported a comparatively scant vegetative growth. This has been reflected in the soil to the extent that soils formed under arid conditions are low in organic matter. The cropped dry-land soils of Utah vary between a minimum of approximately 1 per cent to a maximum of a little over 3 per cent of organic material. Because of the naturally low organic content of dry-farm soil and because of the numerous benefits of organic matter to soil, an experiment was started in 1915 to determine the value of peas and wheat plowed under at various stages of growth for green manure. The test was conducted on duplicate tenth-acre plats.

The detailed wheat yields following the plowing-under of peas at various stages of growth covering the 14-year period from 1916 to 1929, inclusive, are given in Table 38. It will be observed that in the seasons of generally

Table 38. Annual and average yields of winter wheat following ordinary fall plowing, spring plowing when peas as green manure were plowed under at 6 inches high, 12 inches high, at bloom stage, and at pod stage over the 14-year period from 1916 to 1929, inclusive.

GREEN MANURE TREATMENT FOR FALLOW	ANNUAL AND AVERAGE YIELDS IN BUSHELS PER ACRE														
	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Ordinary fallow—fall plowed........	8.5	24.6	18.7	23.1	24.4	38.2	16.1	20.2	17.5	33.7	46.2	17.3	21.5	19.8	23.5
Peas plowed when 6 inches high.....	16.4	26.0	16.6	19.9	24.2	38.5	12.6	20.3	17.2	32.6	40.6	16.4	23.2	18.5	23.1
Peas plowed when 12 inches high...	17.2	26.6	14.9	15.3	24.9	41.7	13.3	22.7	16.6	34.3	38.9	19.6	22.8	18.2	23.3
Peas plowed when in bloom.........	17.0	25.0	13.4	14.7	25.0	38.5	12.1	24.5	14.6	34.3	32.9	17.9	22.2	16.3	22.0
Peas plowed when in pod..........	17.0	22.3	15.4	12.3	26.3	34.7	13.6	23.8	15.2	32.2	29.9	18.9	21.6	16.2	21.4

low yields (such as 1918, 1919, 1922, 1924, and 1929, with an exception of 1917), the wheat yield was depressed as compared to the check by a late plowing-under of the peas. This, however, was partly compensated for by the years of high yields, as is indirectly shown in the averages. Wheat yields after peas plowed under at 6 and 12 inches high are almost identical with ordinary fall-plowed fallow. The yields of wheat following peas plowed under as green manure at the more advanced stages show a slight reduction. Since the wheat yields following peas as green manure show no increase in yield it may be considered that no effect is produced, yet, unquestionably, the peas have reacted favorably to the wheat growth in spite of the fact that there is no measurable difference. If some crop other than a legume extracted the same amount of moisture from the soil as do peas, the yield of wheat would probably show significant reductions in yield as compared to ordinary fallow. The addition of the peas to the soil has added sufficient nitrogen that the soil tends to be higher in nitrates and, therefore, more productive to growth.

The test in which wheat serves as the green-manure crop is used for two purposes. In addition to interpreting the data as to the effect of a green-manure crop the test has also been used to interpret the effect of delayed spring plowing. Whatever this relationship, the yields of wheat following wheat as a green manure suffered significant progressive reductions in yield with each advanced stage of plowing under the wheat growth as green manure. This is indicated in Table 39.

Table 39. Annual and average yields of winter wheat following ordinary fall plowing, early spring plowing, spring plowing when wheat as green manure was plowed under at 6 inches high, at 12 inches high, at heading time, and at the soft dough stage over the 14-year period from 1916 to 1929, inclusive.

GREEN MANURE TREATMENT FOR FALLOW	ANNUAL AND AVERAGE YIELDS IN BUSHELS PER ACRE														
	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Ordinary fallow fall-plowed	20.0	23.6	17.4	21.9	25.5	38.9	14.1	21.6	17.6	29.7	44.0	15.2	20.9	18.3	23.5
Ordinary fallow early spring-plowed	17.1	28.8	16.3	22.1	26.2	34.7	12.5	23.8	22.6	32.0	37.0	16.8	29.1	22.3	24.4
Wheat plowed under when 6 in. high	16.1	21.9	15.6	16.5	22.2	32.9	10.4	19.6	16.8	25.3	41.6	12.5	21.1	11.7	20.3
Wheat plowed under when 12 in. high	15.6	22.6	15.7	17.6	19.0	30.4	9.7	19.0	12.1	23.5	30.0	12.2	14.4	8.1	17.8
Wheat plowed under when in head	12.6	21.0	10.1	12.9	18.1	26.8	4.3	19.1	5.0	21.7	25.6	9.8	8.4	8.1	14.6
Wheat plowed under when in "milk"	9.9	21.7	9.7	5.5	18.1	27.7	5.3	14.7	3.0	22.3	24.2	7.5	5.1	9.0	13.0

Aside from measuring the yields for the green-manure experiments, protein analyses were made of the wheat produced on the several plats. These data are given in Table 40. It is observed that wheat following peas showed

Table 40. Annual and average percentage of protein in winter wheat grown after wheat and after peas plowed under at various stages of growth.

TREATMENT	PERCENTAGE PROTEIN			AVERAGE	
	1927	1928	1929	Average Percentage Protein	Relative Percentage Protein
Peas plowed under for green manure, 6 inches high	.....	12.02	14.60	13.31	106
Peas plowed under for green manure, 12 inches high	.....	11.97	15.16	13.56	108
Peas plowed under for green manure, bloom stage	.....	13.74	15.40	14.57	116
Peas plowed under for green manure, sod stage	.....	14.30	15.16	14.73	117
Fall-plowed ordinary treatment	.....	11.02	14.14	12.58	100
Wheat plowed under for green manure, 6 inches high	11.83	12.21	12.56	12.13	98
Wheat plowed under for green manure, 12 inches high	12.01	10.82	12.37	11.73	94
Wheat plowed under for green manure, bloom stage	12.66	11.32	13.16	12.41	100
Wheat plowed under for green manure, soft dough stage	12.46	10.58	13.40	12.13	98
Fall-plowed ordinary treatment	12.38	11.22	13.60	12.40	100

significant increased amounts of protein, with the greatest increases occurring when peas were plowed at the bloom and pod stages. This relationship is especially indicated by the relative percentage of protein. With wheat serving as the green-manure crop a slight tendency for reduction in protein is noted for the delayed plowings.

Briefly, the relation of wheat yields to green manuring practice on the dry-lands shows that any deviation from the ordinary practice of crop and fallow with fall or early spring plowing for fallow is not justified. While no appreciable reductions in yield of winter wheat followed peas used as green manure, yet when the extra labor of seeding the peas and the cost of the seed is considered, such a practice is not justified. The reductions in yield of wheat following wheat as green manure were so pronounced as to unqualifiedly condemn that practice.

Rotations

In the early development of dry-farming in Utah, the system of cropping was not standardized as is the case today. The continuous growing of wheat was a rather common practice in some areas and continued until about 20 to 30 years ago. At present, alternate crop and fallow is generally followed, with a few areas having the possibility of replacing the fallow with a cultivated crop such as peas, potatoes, corn, or beans. Under this alternate system, only half of the land is cropped each year, the other half being in fallow. Naturally, this is a rather expensive practice as taxes must be paid each year on the cropped as well as the uncropped land, and interest on the total investment must be charged to the crop which is produced on only half the area. Dating back to 1908 experiments were planned on this particular problem, and in 1915 several additions were made to the project, all with the hope that a crop would be found to replace the fallow and to alternate profitably with wheat. In all, there are now 26 different cropping arrangements in operation at the Nephi Station in which winter wheat is the major crop, supplemented with oats and winter barley as cereals and with the addition of peas, corn, and potatoes as intertilled crops.

The data given in the following tables were secured from single tenth-acre plats. The tillage preceding the sowing of the various crops consisted of disking and harrowing all plats growing intertilled crops, and of fall plowing of grain-stubble to prepare for the spring seeding of corn, potatoes, and peas.

In planning the cropping systems the several rotations were classified according to the time taken to complete a cropping arrangement. On this basis the experiment was divided into (1) two-course rotations, (2) three-course rotations, (3) four-course rotations, (4) five-course rotations, (5) six-course rotations, and (6) eight-course rotations.

Two-Course Rotations

The results of the oldest rotation, established at the Nephi Station in 1908 and consisting of wheat alternating with peas, with potatoes, or with corn as compared to wheat alternating with fallow, are given in Table 41.

Table 41. Annual and average yields of Kanred wheat in rotation with corn, potatoes, peas, and fallow with yearly yields given for the 10-year period 1920 to 1929, with average covering the 22-year period from 1908 to 1929, inclusive.

CROPS IN ROTATION	ANNUAL AND AVERAGE YIELD IN POUNDS AND BUSHELS											
	Total 1908–19	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Corn	11,940	560	1407	1230	1500	400	2230	920	550	380	3200	1107
Wheat	247.0	20.8	31.8	14.0	26.2	17.3	33.4	16.8	23.0	20.2	15.3	21.2
Potatoes	341.2	11.0	31.6	38.5	30.7	4.1	23.7	4.7	54.5	2.5	31.5	26.1
Wheat	240.6	22.3	33.9	14.3	24.5	16.3	31.1	26.7	18.3	25.0	15.7	21.3
Peas—Seed	23.2	5.2	5.3	4.7	4.8	1.8	4.3	2.2	6.1	2.2	4.7	3.6
Peas—Fodder	5585	1050	1300	720	905	450	2150	1000	1050	890	2000	780
Wheat	255.4	22.7	31.0	14.3	24.3	17.3	33.2	21.0	18.3	26.7	15.3	21.8
Wheat and Fallow	256.4	20.8	34.9	16.5	25.7	21.5	32.7	38.2	19.3	33.3	15.2	23.4

The average yields of wheat after the intertilled crops were surprisingly uniform with yields slightly above 21 bushels. Wheat after fallow, however, has given an average about 2 bushels above the yields after the rowed crops. As compared to yields on irrigated lands or in humid areas, the average acre-yields of 1107 pounds of field dry corn fodder, 26.1 bushels of potatoes, and 3.6 bushels of peas are too low to be profitable. The 2-bushel decrease in yield of wheat after the intertilled crops would not be important, provided the production of the row crops was sufficient to justify the practice. The highest yield of corn since 1920, as given in the detailed results of the table, was 2230 pounds and the lowest 400 pounds. In certain seasons of high seasonal rainfall previous to 1920, dry fodder acre-yields have reached 4500 pounds and acre-yields of potatoes have been secured above 100 bushels.

In 1915 several additions were made to the rotation experiments. The results of one of the two-course rotations given in Tables 42 and 43 con-

Table 42. Annual and average yields of peas, corn, and potatoes after fallow; and yields of peas, corn, and potatoes after wheat for the 15-year period from 1915 to 1929, inclusive.

CROPS IN ROTATION	ANNUAL AND AVERAGE YIELDS IN BUSHELS AND POUNDS PER ACRE															
	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Peas after fallow—Fodder.....	560	580	1080	1170	0	870	1360	820	1060	330	2150	950	670	990	1840	962
—Seed.......	3.2	3.0	4.7	6.4	0	5.3	5.3	2.5	5.2	0.7	7.0	1.9	3.7	3.5	4.3	3.8
Corn after fallow—Fodder.....	1670	590	1640	730	0	720	1260	460	1200	230	1910	710	260	360	1750	899
Potatoes after fallow.........	24.5	32.1	31.7	33.3	0	10.0	16.8	32.0	10.7	9.0	16.8	7.3	22.5	6.7	40.0	19.5
Peas after wheat—Fodder.....	420	560	740	1480	0	1150	1260	1100	1165	390	1970	850	870	680	2250	992
—Seed.......	4.2	3.2	4.3	7.1	0	5.8	5.3	4.0	6.2	1.2	4.3	1.5	4.8	1.8	6.7	4.0
Corn after wheat............	1910	800	2180	950	0	780	1300	1400	1370	385	2760	2550	880	370	3700	1422
Potatoes after wheat.........	26.7	23.3	25.0	18.3	0	11.3	23.7	38.3	46.3	2.4	23.5	10.4	45.0	3.2	43.3	22.7

Table 43. Annual and average yields of wheat after peas, corn, and potatoes for the 15-year period from 1915 to 1929, inclusive.

ROTATION	ANNUAL AND AVERAGE YIELDS IN BUSHELS PER ACRE															
	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Wheat after peas............	32.7	16.7	21.3	18.7	5.5	20.0	25.8	12.8	23.5	16.7	29.2	23.5	17.3	23.7	14.3	20.1
Wheat after corn.............	30.5	14.8	23.7	16.3	8.7	18.5	27.1	12.2	25.5	15.8	31.4	15.2	18.3	29.0	15.2	20.2
Wheat after potatoes	24.7	17.7	22.7	14.5	6.1	17.3	26.5	14.7	22.3	13.8	32.1	31.5	17.7	22.0	16.3	20.0

sist of peas, corn, or potatoes alternating with fallow; and peas, corn and potatoes alternating with wheat for comparison. An examination of the data in Table 42 shows interesting relationships. The yield of peas after wheat and after fallow was practically the same. With corn, however, the yield was significantly higher after wheat than after fallow. The same relationship is observed in regard to potatoes. In observing the yearly record of corn it is noticeable that the yield after fallow shows a tendency to decrease while the reverse was true with corn after wheat. The same tendency is noted with potatoes, although it is not so pronounced. In observing these crops in the field there is as much difference in the appearance of the corn and potatoes, as is indicated by the yields. The probable reason for such a reaction is an organic relationship which apparently overbalances the extra moisture carried by the fallow plats.

Three-Course Rotations

In all there are twelve three-course rotations with wheat, oats, barley, corn, potatoes, and peas in various cropping arrangements. With the first three of these rotations, given in Table 44, wheat was seeded after the fallow period and the row crop, such as corn, peas, and potatoes followed the wheat. The wheat land was spring plowed for the fallow. The average wheat yields show little variation, with wheat in rotation with peas slightly lower than wheat in the cropping system with corn and potatoes. The wheat yields, as shown in Table 44, were higher than the yields of wheat after fallow, as shown in Table 41. While not a logical comparison this is the only one that can be used as a check. Making the same comparison for the intertilled crops it is noticeable that the differences are slight.

Table 44. Annual and average yields of peas, corn, and potatoes following Kanred wheat with wheat following fallow over the 14-year period from 1916 to 1929, inclusive.

CROPS IN ROTATION	ANNUAL AND AVERAGE YIELDS IN BUSHELS AND POUNDS PER ACRE														
	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Wheat	11.8	23.3	20.0	22.5	18.8	30.4	18.8	26.2	21.2	44.9	35.0	22.8	33.5	24.7	25.3
Fallow															
Corn	1630	1330	855	0	430	1090	1190	970	360	3530	930	670	360	2650	1071
Wheat	13.8	25.3	18.7	22.0	20.5	32.9	16.7	23.7	17.7	41.8	30.8	22.3	32.7	23.2	24.4
Fallow															
Peas—Seed	3.3	4.3	4.2	0	6.1	4.2	5.8	4.8	0.8	5.7	2.0	4.3	1.6	4.7	3.8
Peas—Fodder	660	920	840	0	805	850	820	730	420	2160	870	800	680	2080	902
Wheat	12.5	22.6	17.5	20.7	19.2	35.4	16.8	25.0	21.7	43.2	37.3	25.3	32.2	22.3	25.2
Fallow															
Potatoes	28.7	25.7	27.7	0	7.0	28.7	48.7	35.7	3.7	29.3	4.7	40.7	2.8	31.5	22.5

Table 45. Annual and average yields of peas, corn, and potatoes rotated in a continuous system of cropping with Kanred wheat following the rowed crops and Bulgarian winter barley after wheat over a 14-year period from 1916 to 1929, inclusive.

CROPS IN ROTATION	ANNUAL AND AVERAGE YIELDS IN BUSHELS AND POUNDS PER ACRE														
	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Wheat	10.3	22.3	18.3	8.8	22.7	35.8	16.0	25.8	18.0	33.4	16.2	20.8	25.7	10.0	19.6
Corn	1130	2000	1320	0	410	1435	580	1930	710	3980	1280	1720	380	3600	1462
Barley	4.9	16.0	14.6	8.0	19.2	24.5	10.6	15.4	3.7	30.0	6.5	8.1	10.8	4.3	11.9
Wheat	12.4	22.0	17.9	7.1	20.7	32.8	13.0	22.7	17.5	32.1	26.0	21.3	22.0	15.3	20.2
Peas—Seed	2.2	4.2	4.1	0	6.2	5.2	5.0	5.8	0.8	6.2	2.2	5.0	0.9	6.0	3.8
Peas—Fodder	600	1140	800	0	790	1040	710	1050	420	2100	970	860	590	2350	958
Barley	7.5	13.3	10.8	2.1	18.3	21.3	11.2	16.4	4.0	33.5	6.5	9.6	6.7	6.5	11.9
Wheat	8.3	23.8	15.2	12.1	20.5	31.2	15.2	21.7	15.5	32.5	30.0	20.7	19.5	20.0	20.4
Potatoes	28.0	30.0	27.2	0	7.8	26.2	52.5	45.8	3.7	36.2	5.0	53.0	5.2	26.5	24.8
Barley	3.6	18.5	5.3	3.7	18.3	22.0	10.0	16.3	4.2	30.9	7.4	5.0	8.9	8.5	11.6

The crop sequence, as shown in Table 45, is the same as that shown in Table 44, with the exception that the system is continuous with barley introduced to replace the fallow. For sowing of wheat the corn, potato, and pea land was disked after harvest. In preparing the wheat land for barley the plats were plowed.

It will be observed from Table 45 that the average yields of both cereals, wheat and barley, in each rotation vary within the narrow range of a bushel, which is rather close uniformity, with 20.4 bushels as high for wheat and 19.6 bushels low and with 11.9 bushels high for barley and 11.6 bushels low. The average yield of corn was 1462 pounds, while in the previous rotations with fallow in place of barley the average corn yield was 1071 pounds. The same tendency is noted with potatoes, with peas remaining the same. In observing the annual yields it will be noted that the cereals produced the lowest yields in 1919, with failures for the inter-tilled crops. In 1925 wheat, barley, peas, and corn produced higher yields than in any year before or after. The season of 1927, a poor cereal year, was best for potatoes.

Table 46. Annual and average yields of peas, corn, and potatoes rotated in a continuous system of cropping with Kanred wheat and Swedish Select oats over a 14-year period from 1916 to 1929, inclusive.

CROPS IN ROTATION	ANNUAL AND AVERAGE YIELDS IN POUNDS AND BUSHELS														
	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Wheat	11.0	23.3	10.6	6.0	22.9	31.0	15.3	24.8	16.0	36.7	17.8	20.0	26.0	13.3	19.6
Corn	1750	1550	1290	0	580	1625	1530	1650	640	4235	1300	1000	550	2100	1414
Oats	8.9	16.0	30.3	1.8	17.2	15.0	8.0	13.1	1.2	27.5	1.6	10.6	9.3	5.0	11.8
Wheat	9.7	20.5	13.2	6.3	21.7	28.2	15.0	22.8	15.2	32.2	24.7	19.2	21.5	13.8	18.8
Peas—Seed	2.3	3.8	6.5	0	2.7	5.4	6.3	6.3	0.7	5.0	2.2	5.3	1.7	5.5	3.8
Peas—Fodder	710	920	1080	0	650	1350	1170	880	230	2000	990	910	790	2060	981
Oats	9.9	15.2	16.9	2.2	16.2	11.9	9.0	10.3	1.5	21.4	2.5	10.6	9.7	4.7	9.3
Wheat	9.7	24.3	15.0	7.8	23.3	27.8	15.5	22.0	15.8	35.4	32.2	20.5	20.0	15.8	20.3
Potatoes	28.0	28.3	29.2	0	8.0	26.0	48.3	48.3	3.4	30.8	6.8	59.2	7.2	23.2	24.8
Oats	8.6	18.3	14.0	2.8	17.5	15.0	10.0	12.8	1.2	11.6	3.1	6.4	9.4	5.0	9.7

Rotations given in Table 46 are the same in cropping arrangement as rotations given in Tables 44 and 45, with the exception that spring oats is used to replace barley. The average wheat yields are not quite as uniform as in the rotations given in Table 44. Wheat after peas, with an average of 18.8 bushels was low, with wheat after corn second and wheat after potatoes first. Oats likewise gave the lowest yield with peas in the rotation and the highest yield with corn. It will be observed in checking detailed data from 1916 that corn has varied in acre-yield from a maximum of 4235 pounds of fodder in 1925 to a complete failure in 1919. Peas varied from 6.5 bushels in 1918 to a complete failure in 1919. Wheat yields have ranged between 6 bushels in 1919 to 36.7 bushels in 1925. Potatoes failed in 1919, but in 1927 produced the highest yield of the 14 years—59.2 bushels. In 1919 oats were low (2.2 bushels) and highest in 1918 with a yield of 30.3 bushels.

Rotations given in Table 47 are similar to previous three-course rotations except that winter wheat was grown for two successive years in alternation wtih corn, peas, and potatoes. Again, in this case the first wheat crop after peas was low. The highest average for wheat (20.9 bushels to an acre) came after potatoes, which follows in consistent order

Table 47. Annual and average yields of peas, corn, and potatoes rotated in a continuous system of cropping with two years of Kanred wheat over a 14-year period from 1916 to 1929, inclusive.

CROPS IN ROTATION	ANNUAL AND AVERAGE YIELDS IN POUNDS AND BUSHELS														
	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Corn	1180	1560	1180	0	720	1150	1650	1670	320	3770	1260	1030	360	1000	1200
Wheat—2d crop after corn	9.7	14.2	10.8	2.7	19.2	23.3	5.7	15.7	4.3	22.1	4.3	6.2	6.3	2.3	10.5
Wheat—1st crop after corn	11.0	23.4	17.0	8.1	20.8	34.9	14.7	22.5	16.5	33.0	14.5	17.2	25.7	9.3	19.2
Peas—Seed	1.7	4.2	6.2	0	5.8	4.7	5.0	5.2	0.7	7.0	1.5	5.5	1.5	6.5	4.0
Peas—Fodder	550	800	1090	0	1050	1240	1200	870	220	2230	780	1020	710	2200	996
Wheat—2d crop after peas	10.8	14.2	8.9	2.7	18.7	20.5	6.7	14.7	2.5	23.3	4.3	7.3	3.8	3.7	10.1
Wheat—1st crop after peas	14.5	22.0	17.6	5.7	18.8	31.1	14.5	21.0	15.3	33.2	24.7	16.2	18.0	9.7	17.9
Potatoes	27.0	25.0	30.8	0	12.0	31.0	48.5	38.8	3.0	31.7	6.3	50.1	4.7	23.3	23.7
Wheat—2d crop after peas	12.6	16.0	8.6	2.3	21.7	16.5	8.0	11.0	2.2	28.4	4.8	7.0	6.8	2.3	9.8
Wheat—1st crop after peas	16.0	26.7	17.9	9.5	23.1	36.4	16.7	19.2	12.5	34.8	30.3	19.5	17.8	12.8	20.9

the other three-course rotations. The data also indicate that the second crop of wheat is about half the yield of the first crop. The average yields of corn, peas, and potatoes were little different to yields of these crops in previous cropping systems.

In observing the detailed yields it will be noted that due to drought, peas, corn, and potatoes all failed in 1919 and in 1925 corn yielded 3770 pounds of dry fodder and 7 bushels of peas to an acre, both of which were high for the entire period of the test. The yield for potatoes in 1927 (50.1 bushels an acre) was high. The highest yields of wheat for both first and second crop after an intertilled crop came in 1925 in rotation with potatoes; the lowest yields followed peas in 1919.

Four-Course Rotations

The four-course rotations, three in number, began in 1916 (Table 48). In the cropping arrangement there is only one difference: In the first

Table 48. Annual and average yields of corn in rotation with Kanred wheat. In the first test fallow is included, in the second, pea fallow, and in the third rotation rye fallow is included with wheat and corn. This rotation covers a 14-year period from 1916 to 1929, inclusive.

CROPS IN ROTATION	ANNUAL AND AVERAGE YIELDS IN BUSHELS AND POUNDS PER ACRE														
	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Corn	1880	1530	1150	0	520	1295	1160	910	650	3640	1360	1730	500	4520	1489
Wheat	13.8	23.5	18.5	17.5	22.4	32.7	15.8	28.2	16.8	35.6	34.3	20.7	31.2	15.8	23.3
Fallow															
Wheat	9.1	25.5	15.2	6.5	14.0	36.6	16.0	24.7	16.0	36.4	12.9	17.3	23.2	8.2	18.6
Corn	1250	1280	1450	0	480	1365	1550	1110	330	3390	1280	1450	360	4050	1382
Wheat	5.2	20.3	16.5	9.0	18.2	28.3	11.8	24.3	12.5	35.0	20.7	12.2	17.8	12.0	17.5
Pea Fallow															
Wheat	6.7	21.5	15.3	9.3	17.8	28.5	13.5	21.3	17.5	35.8	15.3	15.2	22.2	11.2	17.8
Corn	1170	1240	1500	0	510	1365	1060	960	690	3150	1180	1230	520	4130	1329
Wheat	9.3	21.0	15.9	15.0	14.6	29.3	14.0	19.7	10.5	29.3	31.7	13.2	23.2	19.3	19.0
Rye Fallow															
Wheat	12.7	22.7	16.3	10.0	17.8	22.5	14.3	24.7	18.3	33.3	12.0	20.0	27.7	10.7	18.8

rotation, a fallow period is a part of the rotation; in the second, peas plowed-under for green manure serve as fallow; and in the third, rye is plowed-under for green manure. Inspection of the average yields in all three rotations shows that the yield of wheat following corn and following peas and rye plowed-under as green manure varied within rather narrow limits, with wheat after pea-fallow lowest and with wheat after rye-fallow highest. Wheat after ordinary fall-plowed alternate fallow was significantly higher than any other cropping arrangement. Data for the individual years of this test indicate that 1919, a year of low rainfall, gave the lowest wheat yields and failures for corn. Both corn yields and wheat yields were highest in 1925.

Six-Course Rotations

At the Nephi Station the six-course rotations have been under test over a 15-year period—from 1915 to 1929, inclusive. The first of these rotations (Table 49) consists of three cereals—oats, barley, and wheat in a

Table 49. Annual and average yields of winter wheat, corn, oats, peas, winter barley, and fallow in a seven-course rotation over a 15-year period from 1915 to 1929, inclusive.

CROPS IN ROTATION	ANNUAL AND AVERAGE YIELDS IN POUNDS AND BUSHELS PER ACRE															
	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Wheat	19.5	17.3	24.3	18.8	4.5	6.8	29.1	12.0	20.3	20.0	30.8	33.7	20.7	25.5	17.7	20.1
Corn	890	930	750	940	0	610	1055	680	1300	160	2365	2600	800	520	2100	1046
Oats	....	12.2	16.9	20.7	2.5	15.9	12.2	10.9	13.4	4.4	25.0	4.4	5.0	6.5	4.4	11.1
Peas—Seed	4.5	2.3	4.3	7.5	0	5.3	5.0	7.8	2.5	1.9	5.7	1.0	2.2	2.6	4.0	3.7
Peas—Fodder	750	390	840	1150	0	1040	870	1170	510	675	2360	720	310	1180	1270	882
Winter barley	27.1	14.2	23.1	12.7	6.6	8.7	33.9	10.8	13.1	16.7	42.1	20.9	10.4	17.3	5.2	17.5
Fallow																

cropping sequence with corn, peas, and fallow. The average yields of wheat, oats, and barley were characteristic of the yields of these crops in the other rotations. Corn was somewhat lower than the average yield in other rotations, with peas approximately normal.

Table 50. Annual and average yields of oats, corn, wheat, and three years of alfalfa in a six-course rotation over a 15-year period from 1915 to 1929, inclusive.

CROPS IN ROTATION	ANNUAL AND AVERAGE YIELDS IN POUNDS AND BUSHELS PER ACRE															
	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Oats	20.0	17.5	12.7	21.7	1.8	10.0	13.0	9.1	10.3	3.6	20.0	3.1	5.3	5.0	3.1	10.4
Corn	1690	730	930	520	0	520	1370	1620	880	0	2320	450	780	155	2150	933
Wheat	9.0	17.0	12.3	6.3	2.0	12.3	10.3	8.8	16.0	0	22.0	2.0	5.3	2.8	3.3	8.6
Alfalfa 3d year	....	1940	2200	3600	1780	1770	2340	2700	2510	880	3450	2100	1940	1000	650	1984
Alfalfa 2d year	....	2050	2830	2650	1860	1620	2105	2010	1600	920	3375	1900	1060	600	720	1807
Alfalfa 1st year	....	140	....	....	....	....	340	....	....	....	....	....	....	....	....	....

Data from the second six-course rotation, consisting of spring oats, corn, winter wheat, and three years of alfalfa, are given in Table 50. The average yields of wheat following alfalfa and corn following wheat were significantly lower than the average of these crops in other rotations.

Oats were only somewhat lower. The appearance of wheat and corn during the growth period was characteristic of the effect of alfalfa. Early in the season the growth was vigorous and highly vegetative; later as the dry weather started the plants usually showed severe drying. Considering the yields of these crops in other rotations it seems evident that wheat immediately after the alfalfa suffered most, followed by corn and oats last. The production of alfalfa in the third year of its growth was approximately one ton to the acre, with the second year of alfalfa slightly over 1800 pounds. One of the difficulties encountered in growing alfalfa on the drylands is that of getting a normal stand. A number of the low yields recorded for the individual years were due to this cause; the rotation is too short to allow a thickening of stands and have it reflected in the weights.

Eight-Course Rotation

But one eight-course rotation is under test at the Nephi Station. This consists of winter barley, potatoes, winter wheat, corn, and four years of alfalfa, as indicated in Table 51. The yield of alfalfa in this rotation is

Table 51. Annual and average yields of winter barley, potatoes, winter wheat, corn, and four years of alfalfa in an eight-course rotation over a 14-year period from 1916 to 1929, inclusive.

CROPS IN ROTATION	ANNUAL AND AVERAGE YIELDS IN POUNDS AND BUSHELS PER ACRE														
	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Avg.
Barley	6.8	26.0	12.7	3.3	16.6	25.4	8.7	16.9	12.3	47.9	27.0	12.7	11.7	8.8	16.9
Potatoes	29.7	19.7	20.7	0	8.8	28.2	42.0	29.3	1.3	37.7	5.2	46.5	0.8	36.8	21.9
Wheat	11.2	23.7	13.7	5.7	8.7	20.5	11.8	24.7	8.7	36.9	2.8	13.7	9.8	3.0	13.9
Corn	880	1810	715	0	610	1265	1280	1060	0	1330	220	170	90	800	731
Alfalfa 4th year	....	2430	2480	1660	1880	1805	3370	2360	580	3960	2160	2150	1080	1000	2070
Alfalfa 3d year	....	2860	2560	1800	1760	2260	3200	2790	680	3400	2050	2330	1550	1040	2175
Alfalfa 2d year	....	2320	2140	1520	1890	2300	1600	2480	910	3150	1810	940	1600	530	1783
Alfalfa 1st year	....	....	....	....	....	560	....	....	....	....	....	....	....	....	....

slightly higher than in the six-course rotation given in Table 50. Location may have something to do with this difference, but the greater length of time the crops remain on the same land allowing for thickening of thin stands is probably responsible for part of the increase. Corn following alfalfa gave an average acre-yield of 731 pounds. As is indicated in Table 51, wheat gave an average yield of 13.9 as compared to 8.6 bushels in the previous rotation where alfalfa sod was plowed under for wheat.

The advisability of growing alfalfa on the dry-land depends upon yields and use to which the crop can be put. If a dry-farm is located at a considerable distance from irrigated lands and if horses are used for the different operations connected with growing a crop of wheat, yields of 1 or more tons of alfalfa would justify having a sufficient acreage to take care of the feed requirements of the draft animals. With an acre-average of 2 tons or more of alfalfa, growing of feed for livestock would likely be profitable.

One of the main difficulties of growing alfalfa on the dry-farms is in getting a good stand of plants. By seeding early in the spring in a firm seedbed good stands can usually be secured, provided the seeding is done on clean unplowed stubble land or on fall-plowed land well worked down before winter.

SUMMARY

Dry-farming began in Boxelder County in 1863 and has now extended to all parts of the state where precipitation and topography permit favorable development. Turkey or Kanred winter wheat is grown on about 95 per cent of the dry-farms. Alternate cropping with fall or early spring plowing is the general practice. From 1924 to 1928 the winter wheat acreage, most of which is dry-farm land, increased 22 per cent. During the same period the spring wheat acreage increased 40 per cent.

Weather Data. Weather records taken at the Station show an average annual rainfall of 13.05 inches, with measurements taken over the 32-year period 1898 to 1929, inclusive. From 1908 to 1929, inclusive, and during the months of April to October, inclusive, there was an average total evaporation of 47.352 inches. For the same period, the average wind velocity from April to October 31, inclusive, was 3.5 miles an hour. The average frost-free period from 1908 to 1929, inclusive, was 112 days.

Treatment of Land Before Plowing. In treatment of land before either fall or spring plowing, disking in the fall has been found to decrease yields. While burning of stubble has given slightly higher yields than similar treatments with stubble plowed under, the practice is not advised, except under special conditions demanding such treatment.

Plowing. Between fall and early spring plowing there is practically no difference, but between early spring plowing and plowing done as late as July 1 there is a drop from 24 to 13 bushels an acre. On a clay loam soil, plowing should be done to a depth of 7 or 8 inches. On silt loams the depth may be reduced to 6 inches and on sandy loams to 5 inches. The data indicate that subsoiling has no place in the tillage operations on the dry-lands of those parts of the Great Basin similar to Juab Valley.

Treatment of Summer Fallow. On spring-plowed land left rough and uncultivated, the yield is equal to spring-plowed fallow harrowed during the fallow period. The same treatment for all plowing showed the advantage to be with normal tillage of the fallow. Frequent tillage of fall or spring plowing reduced yields as compared to normal tillage.

Seeding Experiments. Highest yields were produced from sowing after September 15. If the soil is moist enough to force a rapid and uniform germination at an earlier date, early seeding is advisable. Where the soil is dry, however, later seeding is preferable. For October 1 seeding, the date giving the highest yield, the net yields showed a gradual increase up to and including 5 or 6 pecks. For silt and sandy loams lighter seeding may be advisable. The spacing test shows that the normal drill width of 7 inches produced higher yields than did wider spacing. Cultivation with variously spaced drill rows reduced yields when compared to tests left uncultivated. A comparison between the furrow and common drill, measured in wheat yields, favored the common drill.

Of the several smut treatments used, formalin and copper carbonate, with 50 per cent copper equivalent, were most efficient in reducing smut on smutted wheat. When wheat was practically free from smut, copper carbonate with 18 or 20 per cent copper was found to be sufficient to keep smut under control. With untreated wheat, even though treated for several seasons previous with copper carbonate of 20 per cent copper, there is always a small percentage of smut. Copper carbonate was found to give higher acre-yields (approximately 1.5 bushels) than either formalin or copper sulphate.

Cropping Experiments. The practice of alternating wheat and fallow (the general practice on the dry-lands of Utah) was found to be safer under all conditions tried than was any other system.

Cereal Varieties. Winter wheat has been, and probably always will remain, the dominant crop on the dry-lands of Utah. At present Kanred wheat is the variety best adapted to general seeding. Selections from Turkey and various hybrids in the next few years will replace in all probability a part of the acreage of this variety. Winter Bulgarian barley has produced acre-yields in pounds equal to Kanred wheat; however, it sometimes winterkills heavily.

Spring wheat has no place on the dry-lands of the Great Basin except as it may be necessary to re-seed winter wheat because of winter-killing. Of the spring wheats, Baart has given highest yields at Nephi. Spring oats, except in a few moister sections of Utah, has no place on the dry-farm.

Fertility Experiments. Application of fertilizer in the form of barnyard manure, applied to the land each alternate year or every four years, has increased wheat yields for 10-ton amounts to the extent of over 20 per cent. Twenty tons of manure applied to plats in 1915 with no later applications still showed a small residual effect in the 1929 yields. Peas plowed-under at various growth stages for green manure did not increase wheat yields. Wheat plowed-under at similar stages of growth to peas significantly reduced yields.

Rotations. Wheat grown after the row crops gave an acre-yield of approximately 21 bushels as compared with 23.4 bushels after fallow. Average corn yields varied from approximately 1000 pounds up to over 1400 pounds; potato acre-yields ranged between 20 and 25 bushels; and average acre-yields of peas varied from 3.7 bushels to 4 bushels. These yields are too small to warrant the growing of intertilled crops. In certain sections of the state where the total and seasonal rainfall are higher than at Nephi, the fallow season may be used to an advantage by growing one or more of the row crops which would best fit into a farm plan. Though the yields of the intertilled crops at the Nephi Station were not profitable, valuable crop relationships were revealed.

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