

CONSERVATION PRACTICES ON WHEAT LANDS of the PACIFIC NORTHWEST--

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PACIFIC COAST REGION--SEVEN
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August, 1944

U.S. DEPT. of AGRICULTURE ----- SOIL CONSERVATION SERVICE

F O R E W O R D

Farmers and agricultural investigators for years have sought ways of keeping crop yields at high levels without destroying the soil upon which production depends. Both groups have found it to be a problem involving complex physical and operational difficulties, but have realized there can be no long continued or profitable agriculture if farming methods result in decreased soil fertility or actual physical loss of the land itself.

These facts are brought out effectively in this bulletin, the information for which was assembled by Mr. D. E. Stephens. He has taken the data of research findings from all sources, state and federal, and assembled them in an easily usable way. The information as it thus is presented should be immensely helpful to those who are concerned in the management of the world-renowned cereal producing lands of the Pacific Northwest.

Significant is the growing interest in the effects of soil erosion on continuance of a sound agriculture, as shown by the attention given to this important phase of the problem by many of the new experimental projects which have been organized by state and federal institutions. Consequently, we feel indeed indebted to our associates in the State Experiment Stations for their excellent experimental work and their fine response in meeting what now is recognized as being one of the foremost problems in American agriculture—that of maintaining the actual physical resource of the land itself.

In point is the attention that has been given to burning of straw, which for so long was an all too common practice in conjunction with grain farming. This practice violates a basic soil conservation principle—utilizing plant residues. In certain localities, burning sometimes has shown at least a temporary stimulation in crop yields. At the same time, soil analyses prove that approximately 35 percent of the soil's organic matter and about 50 percent of the soil nitrogen have been dissipated under constant wheat-fallow farming, including those areas in which burning has been practiced widely over a long period. The once high moisture holding capacity of the soil also has been destroyed, and the land has become harder to work and prepare for crops. First efforts in restoring organic matter and nitrogen by growing legumes as green manure crops in the rotation in many cases led to depressed grain yields afterward, it is true; but now, through these investigations, we are finding that there can be reconciliation between the use of plant stubble, rough tillage, and leguminous crops to help maintain and restore the crop producing capacity of these lands.

The men who are working on the farms where this and other intricate problems constantly are in the forefront are deeply indebted to the investigators who have brought forth such solutions.

J. H. Christ

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THE UNITED STATES DEPARTMENT OF AGRICULTURESoil Conservation ServiceEFFECT OF TILLAGE AND CROPPING PRACTICES ON RUNOFF, EROSION,
AND CROP YIELDS IN THE WHEAT GROWING AREAS OF
WASHINGTON, IDAHO, AND OREGON. /1

by

David E. Stephens
Principal Agronomist, Soil Conservation Service /2SUMMARY

In this publication results are given from independently and cooperatively conducted experiments at several locations in the Pacific Northwest that show the effect of different tillage and cropping methods on run-off, erosion and crop yields.

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- /1 For distribution to Soil Conservation Service Technicians and County Agricultural Agents,
- /2 Acknowledgements. Experimental data for this publication were furnished by Dr. G. M. Horner, Mr. Hugh McKay, and Mr. Joseph Belanger of the Soil Conservation Service; Prof. E. G. Schafer, and Dr. S. C. Vandecaveye of the Washington Agricultural Experiment Station; Mr. H. D. Jacquot, Superintendent of the Adams Branch Experiment Station at Lind, Washington; Dr. K. H. Kleges and Prof. G. O. Baker of the Idaho Agricultural Experiment Station; Mr. H. M. Oveson, Superintendent of the Sherman Branch Experiment Station at Moro, Oregon; and Mr. G. A. Mitchell, Superintendent of the Pendleton, Oregon, Branch Experiment Station. Grateful acknowledgement is made to Mr. H. E. Tower, Mr. H. M. Wanser, and Mr. W. A. Rockie of the Soil Conservation Service for critically reading the manuscript; also to other responsible technicians of the Soil Conservation Service and Bureau of Plant Industry of the U. S. Department of Agriculture; and of the Washington, Idaho and Oregon Experiment Stations, who read parts or all of the manuscript.

SOIL AND WATER LOSSES

Soil Conservation Experiment Station at Pullman, Washington. Soil losses and crop yields are shown in table 2 and figures 1 and 2 from Palouse silt loam soil with a 30% slope from (1) growing wheat alternating with fallow, (2) growing wheat in a rotation with sweetclover and with sweetclover and peas, (3) growing wheat continuously, (4) growing grass, and (5) from land not cropped and not cultivated but with weeds taken off with a hog.

The highest total soil loss for the 12-year period, 1932-1943, was 274.4 tons per acre on the bare, uncultivated plot. The total soil loss on plots devoted to wheat alternating with fallow ranged from 1.9 to 80.8 tons per acre for the 12-year period. The plots with highest soil losses had the lowest average yields. Plots with 10 inches of surface soil removed yielded less than half as much as plots with little soil loss (figure 3). In this instance the soil losses from the desurfaced plots were not heavy (table 2). There was no soil lost from the plot devoted to grass.

Total soil losses and yields for ten crop rotations for a 5-year period are shown in table 6. The highest total soil loss for a 5-year period, 23.9 tons per acre, was from the plots devoted to growing spring wheat after fallow, and the lowest soil loss, 3.7 tons per acre, from growing spring wheat after Hubam clover turned under. The soil loss from growing winter wheat and peas alternately was 9.3 tons per acre for the 5-year period.

Soil losses for different methods of straw utilization for wheat grown after fallow are shown in table 9. For the year 1942-43, the highest soil loss, 11.6 tons per acre, occurred on the plots plowed with a moldboard plow with the straw burned, and the least soil loss, 0.7 ton per acre, from subsurface tillage with one ton of straw on the surface.

The difference in runoff and erosion from new land, broken out of sod in 1934, and from land cropped to wheat for more than 50 years is shown in table 10. The total runoff for a 6-year period from the virgin land for the years when it was cropped to wheat alternating with fallow was only .06 inch as against 3.0 inches from the cultivated land. The soil loss for the same period from the virgin land was negligible, and was 8.9 tons per acre from the cultivated land. Wheat yields were higher from the virgin land.

The Teton, Idaho Branch Experiment Station. In table 14 are recorded the soil losses that occurred in the spring of 1943 from plots given various tillage and crop residue treatments during the fallow season of 1942. Soil losses as determined by the rill method were high for all plots where the straw was burned, varying from 33 tons to 68 tons per acre. Where the straw was utilized the highest soil loss from any of the initial tillage methods was 10 tons per acre. There was less erosion from subsurface tillage than from moldboard plowing or one way disking where the straw was burned.

The Sherman Branch Experiment Station at Moro, Oregon. Soil and water losses were measured at Moro, Oregon, for a 4-year period, 1940 to 1943, on Ritzville silt loam soil with an 8 to 10% slope devoted to growing winter wheat alternating with fallow. For three initial tillage methods, subsurface tillage, moldboard plowing, and one-way disking, the highest soil and water loss occurred from one-way disking as is shown in table 27 and figure 8.

CROP YIELDS

In trying to find cropping systems that will prove effective in preventing soil losses, consideration must be given to crop yields. Results are available from research centers in each of the States of Washington, Idaho, and Oregon giving yield data from (1) continuous cropping to wheat and growing wheat alternating with fallow with various fertilizer applications and different tillage and crop residue treatments, and (2) growing wheat in crop rotations, with and without legumes.

CONTINUOUS CROPPING TO WHEAT

Soil Conservation Experiment Station. Yield data are shown in table 7 for wheat grown every year, with and without commercial fertilizer applications and with straw burned and straw returned to the soil, at the Soil Conservation Experiment Station at Pullman, Washington. Returning the straw slightly decreased average yields for a 6-year period. The application of 160 lbs. of ammonium sulfate per acre increased the average yield 12 bushels per acre.

Washington Experiment Station. Results for a 22-year period, 1922-1943, are shown in table 12 for wheat grown every year with various fertilizer and residue applications, on the College Farm at Pullman, Washington. With the straw removed, the average yield was 19.7 bu. per acre; with 2700 lbs. of straw returned to the soil, the average yield was 19.0 bushels; with the straw returned and 286 lbs. per acre of ammonium sulfate applied the average yield was 31.1 bu. per acre.

Idaho Experiment Station. At the Idaho Station at Moscow, winter wheat every year for a 6-year period averaged 26.8 bu. per acre when initial tillage was done with a moldboard plow and the straw utilized; 30.5 when moldboard plowed with straw burned; and 23.5 when one-way disked and the straw utilized (table 19).

WHEAT ALTERNATING WITH FALLOW

Most of the work in recent years at the Stations investigating methods of raising wheat alternating with fallow has centered around the utilization of straw. For erosion control, straw on or near the surface has proved superior to plowing it under or burning it. In some of the higher rainfall areas, however, surface utilization of the straw has depressed yields. The reduced yields from heavy

straw appear to be caused largely by (1) reduced nitrification and (2) inability with present tillage and seeding implements to prepare a proper seed bed for winter wheat and to place all the seeds in moist soil.

Initial tillage methods. Yield comparisons from moldboard plowing, one-way disking, and subsurface tillage, are given in several tables under the headings showing results at the Pendleton and Sherman Branch Stations in Oregon and the Tetonia Branch Station in Idaho. Results from plowing under straw compared with removing or burning it also are shown from the Soil Conservation Experiment Station and the College Farm at Pullman, Washington, and the University Farm at Moscow, Idaho.

Subsurface tillage proved satisfactory at Tetonia, Idaho, higher yields being obtained from that method of initial tillage than from moldboard plowing or one-way disking (table 15). At Pendleton, Oregon, subsurface tillage resulted in significantly lower yields than were obtained from moldboard plowing or one-way disking (table 22). At Moro, Oregon, slightly lower average yields were obtained from subsurface tillage (tables 25 and 39).

Utilization of Straw. On most of the wheat lands of the Pacific Northwest, the straw is needed to protect the land from erosion. The use of straw residues produced different results at the different stations. At stations where the average precipitation was less than 12 inches, as represented by Lind, Washington, and Moro, Oregon, no yield depressions resulted from returning the straw and plowing with a moldboard plow. At Pendleton, Oregon, with higher precipitation than at Lind or Moro, higher average yields were obtained from land where the straw was burned than from land with the straw used and plowed with a moldboard plow or left as a mulch on the surface. It should be noted, however, that the experimental plots at Pendleton are located on fairly level land where the soil losses from erosion have been light.

The nitrogen level of the soil, which plays an important role in influencing crop yields, is especially important where heavy residues are either plowed under or used as a surface mulch. In areas where yield depressions occur from the utilization of heavy straw, they can be corrected by the application of nitrogenous fertilizers, either at plowing time or seeding time, as is indicated by the data in table 28. Depressed yields from the use of straw also are much less likely to occur when legumes have been grown in a rotation to help maintain a satisfactory soil nitrogen level.

At Moscow, Idaho, on land with a high fertility level, higher yields of wheat after fallow were obtained where all the straw (about 4 tons per acre) was utilized and initial tillage was done with a moldboard plow or one-way disk (table 19).

Fertilizers. The application of barnyard manure or of nitrogenous commercial fertilizers did not increase average wheat yields at Lind, Washington, or at Moro, Oregon. At Pendleton, Oregon, the application of barnyard manure, ammonium sulfate or calcium nitrate, and pea straw, significantly increased wheat yields (tables 28 and 35 and figure 9). At Pullman, Washington, on land with a higher nitrogen level than that at Pendleton, the application of nitrogenous fertilizers had very little effect on the yields of wheat grown after fallow. (table 11).

Nitrogen and Organic Matter Maintenance. At Pendleton, Oregon, the nitrogen level of the surface foot of soil was maintained when barnyard manure or pea straw were applied to the land, but where wheat straw was returned to the soil, with or without nitrogenous commercial fertilizers, or when the straw was burned, the total nitrogen content was slightly lower in 1941 than in 1931. (table 29 and figure 9). At Lind, Washington, where the nitrogen level of the soil is much lower than at Pendleton, Oregon, determinations made in 1922 and in 1940 indicated that the total nitrogen content of the soil was maintained in the surface six inches when 3200 lbs. of straw per acre were returned and when 3.5 tons of manure per acre were applied biennially. For other treatments, including the application of nitrogenous commercial fertilizers, the nitrogen level was lower in 1940 than in 1922. (figure 7A).

CROP ROTATIONS

Soil Conservation Experiment Station. Yield data for an 11-year period are shown in table 2 for a crop rotation of sweet clover and peas—sweet clover turned under—winter wheat—spring wheat, and for a similar rotation for a 6-year period without peas planted with the first year sweet clover, at the Soil Conservation Experiment Station at Pullman, Washington. The growing of peas with the first year sweet clover resulted in a decrease in the yield of second year sweet clover and also a decrease in the yield of the two wheat crops following the green manure (table 5). The decrease in wheat yields, however, was more than compensated for by the yield of peas with the first-year sweet clover. The yield of wheat after sweet clover turned under is compared with the yield of wheat after fallow in figure 1. The relation of winter wheat yields to the quantity of sweet clover turned under is shown in figure 5.

In table 6 are recorded average yields and soil losses for a 6-year period for ten crop rotations on the Soil Conservation Experiment Station. From the standpoint of total production, the growing of winter wheat and peas was the best rotation. A brief discussion of these ten rotations precedes table 6.

The Washington Experiment Station. In table 12 yield data are shown for a 24-year period for six crop rotations on the College Farm at Pullman, Washington. Because of the length of time these

rotations have been carried on, the following 24-year average yields should be of special interest:

<u>Rotation</u>	<u>Average annual production per acre, bushels*</u>
Spring wheat--peas	25.5
Winter wheat--peas	25.3
Winter wheat--spring wheat--peas	24.9
Spring wheat every year plus 6 tons manure every 3rd year	23.0
Winter wheat--fallow	21.6
Spring wheat every year	18.9

* Average yield of all crops divided by the number of years in the rotation.

In table 12 yield data also are given for five rotations that have been in progress for an 11-year period on the College Farm at Pullman. Three of these rotations include a green manure crop. In total production per acre neither of the rotations including green manure equalled the rotation of winter wheat and peas. Probably because of a higher nitrogen level of the land used for these rotations, winter wheat after turning under sweetclover did not show the upward trend in yield that occurred when winter wheat was grown after sweetclover turned under on the Soil Conservation Experiment Station. Compare the winter wheat yields after fallow and after sweetclover turned under as shown in figures 1 and 7.

The Idaho Experiment Station. Yield data are shown in table 20 for six rotations on the University Farm at Moscow, Idaho. One of these rotations included peas for green manure and another sweetclover for green manure. Neither of the rotations with green manure equalled the rotation of winter wheat and peas in total average production per acre. Winter wheat after fallow in these rotations averaged 60 bu. per acre, but winter wheat and peas grown alternately averaged 53.2 bu. of wheat and 22.4 bu. of peas per acre.

Interesting results are shown in table 21 from an experiment conducted on a south slope of a clay outcrop area on the University Farm at Moscow, Idaho. Where alfalfa and grass had been grown for four years and the land afterwards planted to spring wheat for two years, the average yields were more than twice those obtained from land in continuous spring wheat. The yield of spring wheat following Crested wheatgrass was about 22% more than the yield obtained from growing wheat continuously.

The Pendleton, Oregon, Branch Experiment Station. At the Branch Experiment Station at Pendleton, Oregon, the average yield of spring wheat after fallow with all straw plowed under for a 12-year period was 43.4 bu. per acre, and the average yield of winter wheat after

fallow for the same period was 43.6 bu. per acre. Winter wheat after manured fallow averaged 51.0 bu. per acre. Spring wheat and peas proved slightly better than winter wheat and peas in total production and both rotations were superior to growing wheat after fallow. From the standpoint of maintaining the nitrogen level of the soil, the wheat--pea rotations, with all residues utilized, were superior to growing winter wheat alternating with fallow. (table 29 and figure 10).

Annual and average yields are shown in tables 30 to 34, inclusive, for winter wheat grown after fallow preceded by alfalfa and by sweetclover, at Pendleton, Oregon. The yield of the first wheat crop grown after fallow on land that had grown alfalfa was less than from land on which no legume had been grown, because of high nitrates and insufficient moisture. Increases in yields were obtained for the second, third, fourth, and fifth wheat crops on the alfalfa land. That decreased yields would not be obtained for the first crop following alfalfa if moisture conditions were more favorable, is indicated from the data in table 33. With slightly higher precipitation at Pendleton, for the years 1939 to 1942, inclusive, higher yields were obtained for the first crop on land that had grown alfalfa than from land on which no alfalfa had been grown.

The Sherman Branch Experiment Station at Moro, Oregon. In table 41 results are shown for six 5-year periods for several crop rotations at the Sherman Branch Experiment Station, at Moro, Oregon. In average yield of pounds of grain per acre per year, spring wheat and peas proved to be the best rotation. Five other rotations also exceeded in total average production the yield obtained from winter wheat grown after fallow. In evaluating crop rotations other factors such as production costs would need to be considered as well as crop yields.

A discussion of yield trends of wheat grown after fallow for a 30-year period at Moro, Oregon, is given on pages 101 to 103, inclusive, and yield data are given in table 42.

INTRODUCTION

In this paper, results are summarized from experiments conducted by Soil Conservation Service Research; the Bureau of Plant Industry, Soils, and Agricultural Engineering; and the State Agricultural Experiment Stations in Washington, Idaho, and Oregon, which show the effect of certain tillage, cropping and fertilizer practices on crop yields and soil and water losses in the wheat growing areas of these three states.

Some of the experiments were conducted independently by the State Stations, and others by the State Stations in cooperation with the two above-named agencies of the U. S. Department of Agriculture. All the research conducted by the Soil Conservation Service was in cooperation with the State Stations. As some of the data herein reported have not been published, permission to use the data in publications should be obtained from the appropriate state or federal agency, and in any use credit should be given to the agency furnishing the data.

THE PALOUSE SOIL CONSERVATION EXPERIMENT STATION

AT PULLMAN, WASHINGTON

In 1931 there was established on the Soil Conservation Experiment Station at Pullman a series of plots known as the "South Control Plots" to study the effect under carefully controlled conditions of different soil management practices on runoff and soil losses and crop yield. Results are available from fifteen plots on Palouse silt loam soil with a 30% slope. Water and soil losses were measured in catchment basins, each plot being enclosed with a sheet metal border. From the 10-year summary report, (U.S.D.A. Technical Bulletin No. 860) table 1 was taken, which shows the effect of plant cover on runoff and soil losses on several of these plots for the 10-year period, 1933-1942. Table 1 also shows the annual and average precipitation for the 10-year period.

It will be noted from this table that the average soil losses during this period were not high, except for the bare, untilled plot. Observations indicate that they do not represent the actual soil losses that have occurred on the lighter soil types west and southwest of Pullman, where soil losses from erosion have been particularly heavy in recent years on fallow land not protected by straw residues. It will be noted from table 1 and figure 2 that severe erosion occurred on the Station plots in only two crop years, 1931-32 and 1933-34.

Table 1 —Effect of plant cover on erosion losses, South Control Plots

Plot No.	6	7	3,8	3,8	9-12	9-12	9-12	9-12	13
	Grass	S. wheat stubble fertilized	W. wheat stubble after fallow	W. wheat after fallow	W. wheat stubble after clover	S. wheat stubble after W. wheat	W. wheat after sw clover turned under	First year sweet- clover	Bare, untilled
Year*									
Water Loss in Surface Inches									
1932-33	1.309	0.693	4.478	2.134	5.247	1.610	3.272	4.276	7.200
1933-34	0.002	1.225	0.083	5.269	0.774	1.480	3.656	4.471	7.076
1934-35	0.025	0.015	0.033	0.203	0.007	0.003	0.094	0.009	2.294
1935-36	0.208	0.458	0.023	0.377	0.092	0.109	0.097	0.911	2.649
1936-37	0.178	0.021	0.198	0.685	0.132	0.147	0.509	0.344	3.465
1937-38	0.009	0.001	0.014	0.329	0.002	0.007	0.131	0.360	3.601
1938-39	0.149	0.046	0.210	0.645	0.060	0.074	0.268	0.077	4.295
1939-40	0.021	0.000	0.013	0.868	0.017	0.015	0.504	0.708	4.710
1940-41	0.001	0.222	0.026	0.183	0.169	0.000	0.074	0.018	3.377
1941-42	0.000	0.000	0.019	0.221	0.039	0.039	0.021	0.263	3.097
Average	0.190	0.268	0.510	1.091	0.654	0.348	0.863	1.144	4.176

* The data are based on 12-month periods beginning July 1 and ending June 30.

Precipitation:—1932-33, 21.54; 1933-34, 27.04; 1934-35, 18.57; 1935-36, 19.02; 1936-37, 20.12;
(Inches) 1937-38, 18.56; 1938-39, 15.38; 1939-40, 16.35; 1940-41, 26.59; 1941-42, 17.58. Ave. 19.76

Table 1 Continued --Effect of plant cover on erosion losses, South Control Plots

Plot No.	6	7	3,8	3,8	9-12	9-12	9-12	9-12	13	
		S. wheat stubble fertilized	W. wheat stubble after fallow	W. wheat after fallow	W. wheat after clover	W. wheat stubble after clover	S. wheat stubble after W. wheat	W. wheat after sw clover turned under	First year sweet- clover	Bare untilled
Year*	Grass									
Soil loss in Tons per Acre										
1932-33	0.76	0.45	0.49	1.10	1.04	0.72	3.13	2.43	20.00	
1933-34	0.00	3.96	0.08	29.58	1.60	9.24	23.19	21.87	38.69	
1934-35	0.00	0.02	0.01	0.10	0.00	0.00	0.04	0.00	9.27	
1935-36	0.01	2.17	0.00	1.41	0.00	0.11	0.00	8.16	9.15	
1936-37	0.00	0.00	0.01	0.08	0.00	0.01	0.95	0.11	25.52	
1937-38	0.00	0.00	0.00	0.12	0.00	0.00	0.01	1.06	22.72	
1938-39	0.00	0.00	0.00	0.80	0.00	0.00	0.01	0.00	11.98	
1939-40	0.00	0.00	0.00	6.91	0.00	0.00	3.57	4.87	45.37	
1940-41	0.00	0.15	0.11	0.40	0.15	0.00	0.25	0.00	13.21	
1941-42	0.00	0.00	0.00	5.69	0.00	0.02	0.26	0.31	24.95	
Average	0.08	0.68	0.07	4.62	0.28	1.01	3.14	3.88	22.08	

* The data are based on 12-month periods beginning July 1 and ending June 30.

Precipitation: --1932-33, 21.54; 1933-34, 27.04; 1934-35, 18.57; 1935-36, 16.02; 1936-37, 20.12;
(Inches) 1937-38, 18.56; 1938-39, 15.38; 1939-40, 16.35; 1940-41, 26.59; 1941-42, 17.58. Ave. 19.76

YIELDS AND SOIL LOSSES FROM SOUTH CONTROL PLOTS

Because data on runoff and soil losses in the Pacific Northwest are meager, it will be of interest to study the yield and erosion results from each of the plots of this series.

Table 2 shows the average yields and soil losses from each of the 15 plots in the South Control Series for the 12-year period, 1932 to 1943, inclusive. The total soil losses varied from a total of 274.4 tons per acre from the bare, uncultivated plot (No. 13) to less than 2 tons on plots 1 and 2. Plot 1 was a half-length plot, and lost 1.7 tons. Plot 2 was a double-length plot and lost 2 tons of soil per acre.

Seven of the South Control plots (Nos. 1, 2, 3, 5, 8, 14 and 15) were cropped to winter wheat alternating with fallow. Both the yields and soil losses from these plots were extremely variable. The highest average yield, 43.7 bu., was obtained from plot 3, with a total soil loss of 3.2 tons for the 12-year period. The lowest yield, excluding the desurfaced plots, was 29.8 bu., from plot 8, which had a total soil loss of 80.8 tons for the 12-year period. Plot 5 also had a high soil loss, 57.1 tons, and its average yield was 31.6 bushels per acre.

Plots 14 and 15 were desurfaced plots. Plot 14 had about 10 inches of topsoil removed and plot 15 had the surface soil removed and replaced with subsoil. Plot 14 had its highest soil loss, 10.9 tons per acre, in 1932. Soil losses on both these plots were not as high as was expected. The soil losses on plot 15 were especially low considering the fact that the surface soil had been replaced by a clay subsoil. Both plots 14 and 15 were cropped in the same years as plots 1, 2 and 3. The average yield from plots 14 and 15 was less than half that obtained from plots 1, 2 and 3.

Plot 4 was cropped to a rotation of sweetclover for green manure, followed by two wheat crops. Only one plot was used, hence the average yields are not comparable with the average yields from the other plots in the South Control series, except plot 9.

Plots 9, 10, 11 and 12 also were cropped to a rotation with sweetclover for green manure followed by two wheat crops, with peas grown with the first year clover.

Table 2 —Total soil losses, average annual soil losses, and average yields for the 12-year period 1932-43 from each cropping system on the South Control plots at the Soil Conservation Experiment Station, at Pullman, Washington.

Cropping method and plot number	Total soil Loss Tons per A	Av. annual soil loss Tons per A	Av. acre yield Bushels
Winter wheat — fallow			
Plots 1 and 2	1.9	0.16	39.8
Plot 3	3.2	0.27	43.7
Plot 5	57.1	4.76	31.6
Plot 8	80.8	6.74	29.8
Plot 14 (desurfaced)	36.5	3.04	17.8
Plot 15 (desurfaced)	9.9	0.83	22.3
Sweetclover—Sweetclover turned under— Winter wheat—Spring wheat			
Plot 4	3.0	0.25	
Winter wheat (3 years)			53.1
Spring wheat (3 years)			24.7
Sweetclover and peas—Sweetclover turned under—Winter wheat—Spring wheat			
Plots 9, 10, 11 and 12	28.5	2.38	
Winter wheat			48.5*
Spring wheat			17.3*
Peas			22.0*
Wheat continuously, fertilized, Plot 7	9.3	0.28	23.4**
Brome grass, Plot 6 (Av. 1934-1941)	0.0	0.0	1.1 tons
Bare uncultivated	274.4	22.83	

* 11-year average, 1933-1943

** 10-year average, 1932-1941

Effect of loss of topsoil on yields. Were the low yields obtained from plots 5 and 8 after fallow due to the high soil losses which occurred on these plots in 1932 and in 1934? A direct yield comparison of wheat grown after fallow for land with high and with low soil losses on these plots cannot be made because yields were not obtained in the same years. The plots with high soil loss were cropped in the even-numbered years, and those with low soil loss in the odd-numbered years. A comparison can be made, however, between the yields after fallow and after sweetclover turned under for the same years. This comparison is made in table 3 and in figure 1. Figure 2 shows the annual soil losses from the plots which grew wheat alternating with fallow and those devoted to the rotation with sweetclover as green manure.

In the odd-numbered years, the average yield of the wheat after sweetclover turned under exceeded the average yield of the wheat after fallow only 1.3 bu. per acre. In the even-numbered years, when the wheat after fallow was grown on plots with high soil losses, the wheat after sweetclover outyielded the wheat after fallow 21.2 bushels per acre. This comparison is shown in figure 3.

It will be noted from table 3 that the average yield of winter wheat after sweetclover turned under was higher in the even-numbered years than in the odd-numbered years, or the reverse of what was true for the wheat grown after fallow. This would indicate that the low yields after fallow in the even-numbered years were not due to adverse climatic conditions. The higher average yields after sweetclover turned under in the even-numbered years was no doubt because of the greater quantity of sweetclover turned under in those years. (See figure 5 for the relation of wheat yields to quantity of sweetclover turned under.) In the varietal trials on the College Farm at Pullman, the average yields of Hymar wheat, the variety used on the South Control plots, were nearly identical for the odd- and even-numbered years during the 10-year period, 1933-1942. Yield data for wheat grown after fallow on the College Farm are shown in figures 6 and 7.

Table 3 — Yields of winter wheat after fallow and after sweet-clover turned under in odd- and even-numbered years on the South Control plots of the Soil Conservation Service Experiment Station at Pullman, Washington.

Year	Wheat after fallow (Plots 1, 2 and 3)	Wheat after sw. clover turned under <u>/1</u>	Year	Wheat after fallow (Plots 5 and 8)	Wheat after sw. clover turned under <u>/1</u>
	bu.	bu.		bu.	bu.
1933	41.8	38.9 (1.7)	1934	27.3	41.5 (6.6)
1935	47.8	41.9 (4.7)	1936	35.2	46.7 (9.0)
1937	45.7	45.7 (1.5)	1938	35.4	54.6 (13.0)
1939	37.7	42.0 (5.9)	1940	23.3	52.7 (13.9)
1941	<u>45.8</u>	<u>58.2 (9.8)</u>	1942	<u>31.6</u>	<u>66.3 (23.6)</u>
Average	43.8	45.3		30.6	52.

Figures in parenthesis indicate green weight of sweetclover turned under in tons per acre.

/1 In a rotation of sweetclover with peas—sweetclover turned under—winter wheat—spring wheat on Plots 9, 10, 11 and 12.

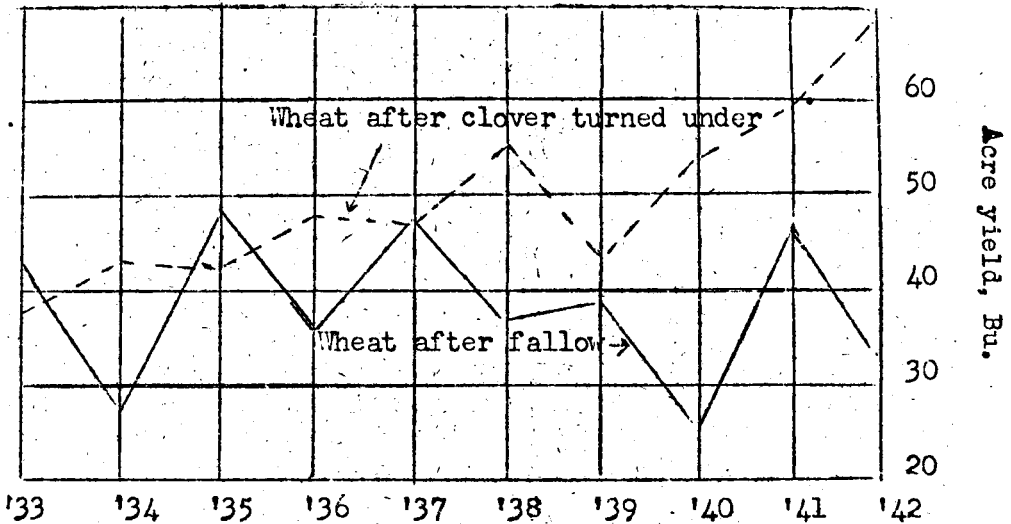
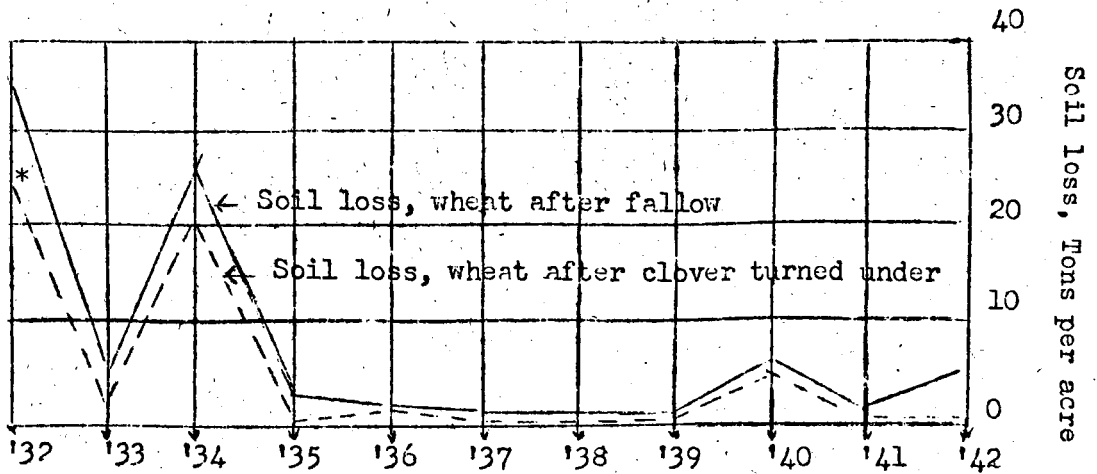


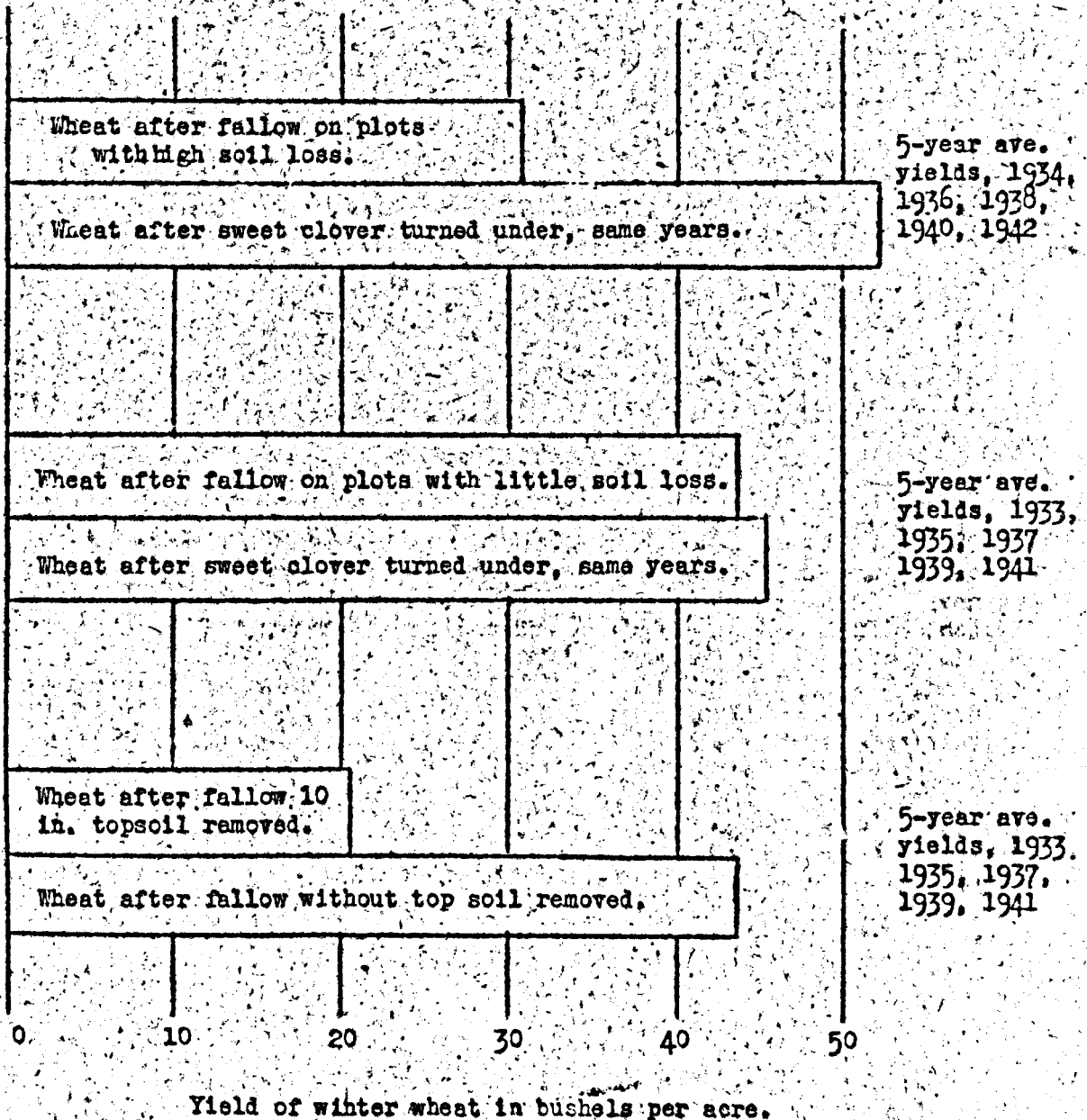
Figure 1 --Yields of winter wheat after sweetclover turned under in a rotation of peas with sweetclover--sweetclover turned under--winter wheat--spring wheat, and after fallow in a rotation of winter wheat--fallow, for the years 1933 to 1942, inclusive, at the Soil Conservation Experiment Station at Pullman, Washington.



* After fallow in 1932

Figure 2 --Soil losses on fallow land and on land with sweetclover plowed under in the years 1932 to 1942, inclusive, at the soil Conservation Experiment Station at Pullman, Washington.

Figure 3 --Yields of winter wheat from plots with high soil loss and from plots with little soil loss compared with yields of winter wheat after sweet clover turned under; also yields of winter wheat after fallow from desurfaced soil compared with yields after fallow from soil without high soil loss.



In an attempt to determine whether variations in the amount and distribution of precipitation were responsible for the wide differences in yields between the odd and even numbered years, table 4 was prepared, which records the yields of wheat after fallow and after sweetclover turned under on several of the South Control plots, together with precipitation data and total soil losses.

The precipitation by crop years indicates that the soil in the spring of the crop year after a season of fallow was probably filled with water to its moisture holding capacity in all years. The lowest precipitation for any two consecutive years was 34.43 inches in 1935 and 1936.

The precipitation for April, May, and June, the amount and distribution of which may have influenced wheat yields, averaged 4.13 inches for the 11-year period, ranging from a low of 1.22 inches in 1939 to a high of 10.23 inches in 1941. In the latter year there was much more moisture in the soil than the crop used, while the yields for 1939, both after fallow and after sweetclover, indicate that the wheat probably suffered for lack of moisture.

The precipitation for the months of November to March, inclusive, is given in table 4 because excessive precipitation during these months might cause leaching of nitrates and thus adversely effect yields. For this 5-month period the average precipitation was 13.17 inches, the lowest being 10.37 in 1941-1942 and the highest 16.51 inches 1931-32.

A study of the precipitation data does not reveal any good reason for the low yields obtained after fallow in the even-numbered years. The yield reductions, however, seem entirely too high to attribute to a loss of a little more than one-half inch of topsoil. The removal of about ten inches of topsoil from the desurfaced plots (see table 2) resulted in a 56% reduction in yield as compared with the yield of plot 3. The South Control plots are located on class three land, low in total nitrogen, and with only 6 to 8 inches of topsoil. A removal of small amounts of nitrogen with the eroded topsoil, therefore, might result in much greater yield reductions than would occur from a deeper soil with a higher nitrogen level.

Another factor which possibly might have been responsible for lower yields in some of the even-numbered years was excessive precipitation during the winter and early spring months of the crop year, which might have caused more leaching of nitrates in fallow land than in land with a crop of sweetclover turned under. No nitrate data are available, however, to prove that this occurred.

Figure 3 shows a comparison of yields obtained in the even- and odd-numbered years from wheat after fallow and after sweetclover turned under; also a comparison of yields from the two desurfaced plots and from plots with little soil loss cropped in the same years.

Figure 4 shows the runoff and soil loss, by 4-year periods, for land growing wheat alternating with fallow and for land seeded to winter wheat after turning under sweetclover for green manure. As compared with growing wheat after fallow, there was an indication that soil erosion became progressively less in the rotation with sweetclover upon completion of several cycles of the rotation.

Figure 5 shows the yields, by moving 4-year averages, of wheat after sweetclover turned under, the green weight of sweetclover turned under, and the yield of wheat after fallow. The yield trend for the wheat after turning sweetclover was decidedly upward and the yield was positively correlated with the quantity of green manure turned under. The yield trend was downward for the wheat grown after fallow.

Table 4 --Yield of winter wheat after fallow and after sweetclover turned under and precipitation data for the years 1932 to 1942, inclusive, at the Erosion Station at Pullman, Washington.

	Precipitation			Yield per acre				Yield after Sweetclover Turned under/ ¹ Plot	Yield after fallow compared with yield after clover		
	Crop year Ending July 31	April May & June	Nov. to March, inc.	After fallow					Plot	%	bu.
				Plot 3	Plot 8	Plots 1 & 2	Plot 5				
	in.	in.	in.	bu.	bu.	bu.	bu.	bu.			
1931-32	23.66	3.66	16.51		31.9		31.3	30.7	10	²	
1932	30.99	2.47	15.81	44.4		39.1		38.9	9	107	+ 2.9
1934	26.95	4.63	15.67		22.9		31.7	41.5	12	66	-14.2
1935	18.55	3.00	11.32	51.3		44.2		41.9	11	114	+ 5.9
1936	15.88	2.41	11.78		37.1		33.2	46.7	10	75	-11.5
1937	21.22	7.47	11.25	48.0		43.3		45.7	9	100	0.0
1938	19.08	2.98	15.86		34.9		35.8	54.6	12	65	-19.2
1939	16.64	1.72	11.08	39.5		35.8		42.0	11	90	-4.3
1940	18.52	2.64	13.63		19.5		27.0	52.7	10	44	-29.4
1941	28.03	10.73	10.84	46.3		45.2		58.2	9	78	-12.4
1942	19.82	4.77	10.34		32.7		30.4	66.3	12	48	-34.7
Average	20.85	4.13	13.17	45.9	29.8	41.5	31.6	48.9	³		
Total soil loss, tons per A				3.1	80.8	1.7	57.1				

¹ In a rotation of peas with sweetclover--sweetclover turned under--winter wheat--spring wheat.

² Plot 10 was fallowed in 1931.

³ Excluding 1932

South Control Plots
SCS Expt. Station, Pullman, Wash.



Wheat after sweetclover turned under for green manure.
Wheat after fallow

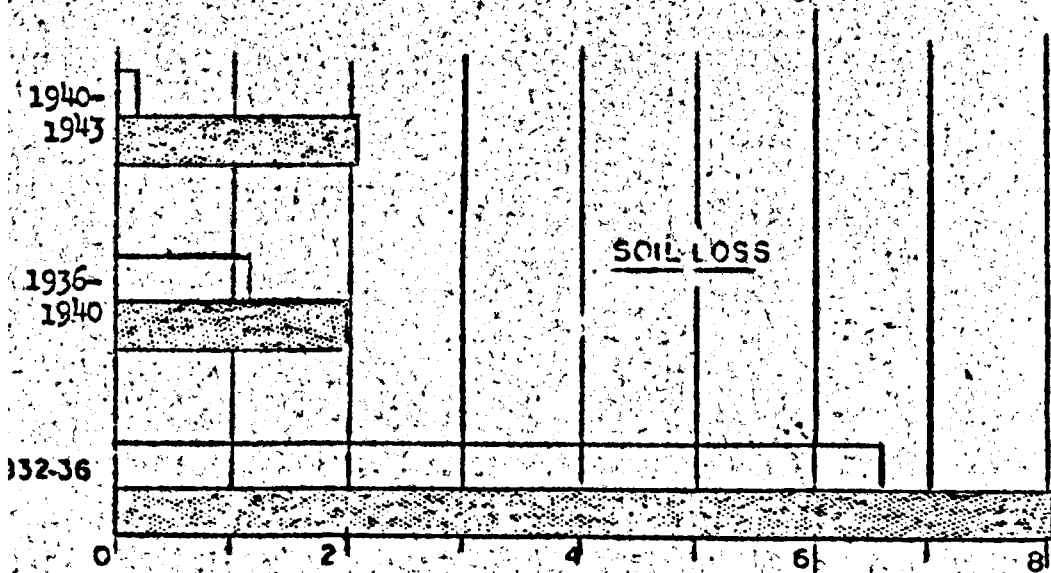
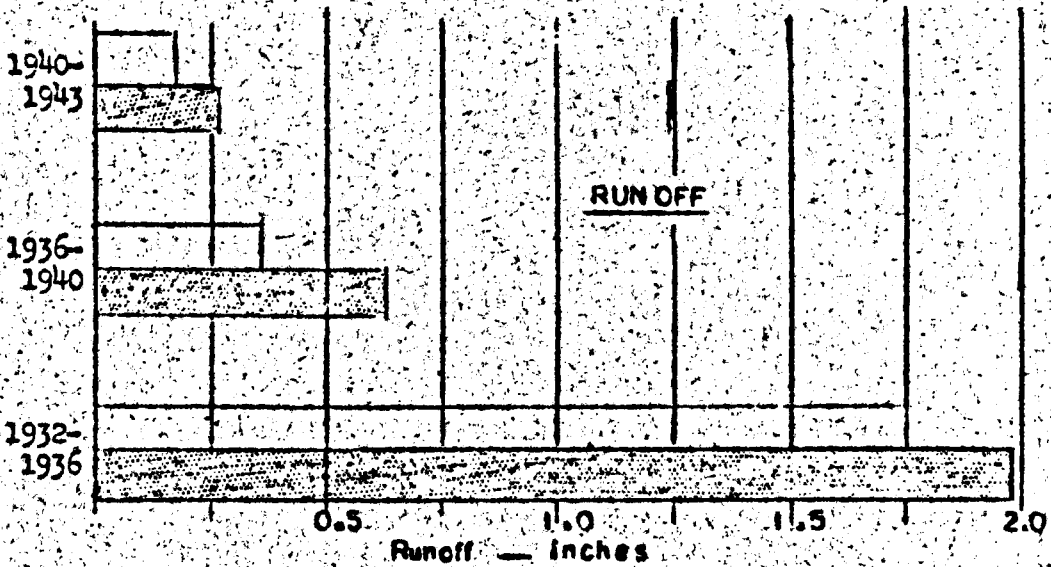


Figure 4 — Comparison of erosion losses from summer fallow land and sweetclover land seeded to winter wheat. Average annual (July-June) values. (From U.S.D.A. Tech. Bul. 560)

South Control Plots — SCS Expt. Station, Pullman, Washington

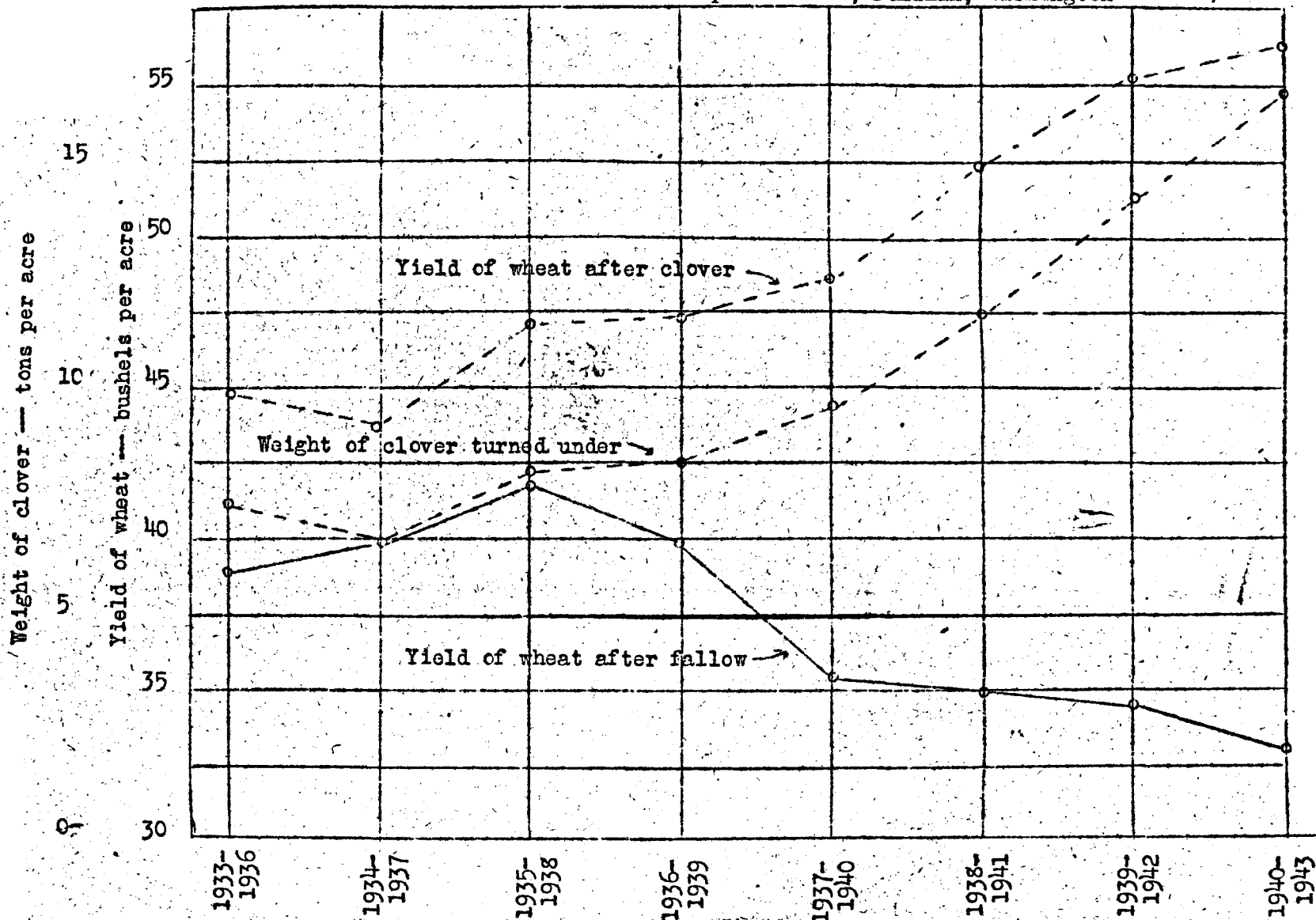


Figure 5 —Yield of winter wheat grown after summer fallow and after sweetclover for green manure. (From U.S.D.A. Tech. Bul. 860)

Growing peas with first year sweetclover. Plots 4 and plots 9 to 12, inclusive, were devoted to a rotation of sweetclover for green manure followed by two wheat crops. On plots 9-12, peas were grown with the first year sweetclover and on plot 4 sweetclover was grown alone. In the rotation without the peas, only one plot was used and the results, therefore, cannot be compared with the similar rotation on plots 9-12 except for six of the twelve years.

Plots 4 and 7 were cropped to wheat in the same years, 1933, 1934, 1937, 1938, 1941 and 1942. The wheat yields are shown in table 5, and also the tonnage of sweetclover turned under the year preceding the one when the winter wheat was grown.

It will be noted that higher yields of both winter and spring wheat were obtained from plot 4 in all years except 1937, when the winter wheat yields were practically identical. A much higher tonnage of sweetclover was produced on plot 4, indicating that the peas grown with the first year sweetclover on plots 9-12 reduced the yield of sweetclover the second year, with a resultant reduction in the average yield of winter and spring wheat. This reduction, of course, was more than compensated for by the yield of peas grown with the first year sweetclover, which averaged 22 bu. per acre. (See table 2)

Table 5, —Acre yields of winter and spring wheat and quantity of sweetclover turned under on plot 4, in a rotation of sweetclover—sweetclover for green manure—winter wheat—spring wheat, and from plot 9 in a similar rotation with peas grown with the first year sweetclover.

Year	Plot Number and Crop	Acre Yield Bushels	Sweetclover Turned under Tons
1933	Plot 4 Winter wheat	50.8	16.4
1933	Plot 9 Winter wheat	38.9	1.7
1934	Plot 4 Spring wheat	15.6	
1934	Plot 9 Spring wheat	12.0	
1937	Plot 4 Winter wheat	45.3	9.4
1937	Plot 9 Winter wheat	45.7	1.5
1938	Plot 4 Spring wheat	21.1	
1938	Plot 9 Spring wheat	15.0	
1941	Plot 4 Winter wheat	63.2	18.8
1941	Plot 9 Winter wheat	58.2	9.8
1942	Plot 4 Spring wheat	36.8	
1942	Plot 9 Spring wheat	22.9	

Average 3-year yield of winter wheat on plot 4 — 53.1 bushels

" " " " " " " " 9 — 47.6 bushels

Average 3-year yield of spring wheat on plot 4 — 24.7 bushels

" " " " " " " " 9 — 16.6 bushels

Increase in yield of winter wheat in rotation without peas — 5.5 bu.

" " " " spring " " " " " — 8.1 bu.

Average yield of peas with first year sweetclover — 21.0 bu. (6 yrs.)

CROP ROTATION PLOTS

West of the south control plots on the Soil Conservation Experiment Station, there was established in 1937 a series of ten crop rotation systems involving 29 randomized plots on a 30% slope. Yields and soil losses are shown in table 6. The yields indicate that the fertility level of the soil of these plots is not quite as high as that of the soil of the "south control plots."

Five and six years' yield data and five years' erosion data are available for eight of the rotations on the crop rotation plots. Two to five years' yield data also are available for two other rotations (Nos. 9 and 10), which include the growing of alfalfa and of sweetclover and grass. No run-off or soil loss measurements were made from the plots devoted to rotations 9 and 10 until 1943.

Because of the relatively short time these rotations have been in progress, the results should be considered indicative rather than conclusive. The average yields of both winter wheat and spring wheat after fallow seem entirely too low. The average yield of winter wheat after fallow in rotation 1 was lower than the average yield of winter wheat after peas in rotation 3. This was because of an extremely low yield (19.1 bu.) of winter wheat after fallow in 1940.

Of the eight rotations for which soil loss data are available, the wheat-fallow rotations had the greatest soil losses. Growing wheat alternating with fallow resulted in considerably greater soil losses than growing wheat and peas alternately. The two rotations with wheat and Hubbs sweetclover turned under for green manure had the least soil losses for the 5-year period. The yield of winter wheat after turning under the annual sweetclover averaged 8.5 bu. per acre more than the yield of winter wheat after fallow.

Rotation 3, winter wheat-peas, was the outstanding rotation for total production per acre. This rotation produced an average total annual yield per acre of 26.2 bu. (16.0 bu. of winter wheat and 10.2 bu. of peas), as compared with 21.9 bu. (11.2 bu. of wheat and 10.7 bu. of peas) from the spring wheat-pea rotation. Either winter wheat and peas or spring wheat and peas also proved to be good rotations on the College Farm at Pullman, Washington, at Moscow, Idaho, and at Pendleton and Moro in Oregon (see tables 12, 20, 29 and 41). The rotation of winter wheat and peas, a common one in the Palouse area, is not considered a very satisfactory one for long continued use because of difficulty in controlling weeds. Where the pea straw has been burned or where the soil has been too finely pulverized in seedbed preparation, considerable erosion also may occur on pea land seeded to winter wheat. Another objection to the winter wheat-pea rotation has been the difficulty in normal times of disposing of large quantities of peas at a satisfactory price.

The soil loss for the two rotations of winter wheat--peas and spring wheat--peas was practically identical for the 5-year period on the crop rotation plots. Ordinarily very little soil loss would be expected from a spring wheat--pea rotation, even on a fairly steep slope, if rough contour fall tillage is practiced and the residues utilized. Practically all the soil loss in the spring wheat--pea rotation occurred in the spring of 1940. In the fall of 1939 the spring wheat plot was plowed up and down the hill with a moldboard plow and left in that condition over winter. The soil loss the next spring amounted to 19.5 tons of soil per acre. For the other four years when contour tillage was used there was practically no soil lost from either of the plots used in this rotation. In areas where spring wheat yields about as much as winter wheat, the spring wheat--pea rotation would be preferable because of somewhat more effective erosion control. However, the spring wheat--pea rotation would be less effective than the winter wheat--pea rotation in controlling wild oats and similar weeds.

The five-year rotation (No. 9) with sweetclover and grass used for green manure in a rotation with wheat and peas, produced an average annual yield per acre of 19.8 bushels (14.3 bu. of wheat and 5.5 bu. of peas.) The wheat and pea yields were considerably higher in rotation 9 than in rotation 3 (winter wheat--peas), but the return per acre per year was considerably less for rotation 9, because two-fifths of the land was devoted to growing the green manure crop. In rotation 9, with only two crops of wheat and one of peas in a 5-year period, an increase of more than 50% in the wheat and pea yields over those obtained in rotation 3 would be needed in order to have rotation 9 equal rotation 3 in total production per acre. The yield of winter wheat after sweetclover and grass in rotation 9 was 37% greater than the yield of winter wheat after peas, and the yield of peas in rotation 9 was 34% higher than the yield of peas in rotation 3. That the yield of wheat in rotation 9 may increase as the rotation progresses, is indicated by the upward yield trend of the winter wheat after sweetclover turned under in the rotation on the south control plots (see table 3 and figure 1.) The substitution of winter wheat for spring wheat in rotation 9 would increase the average wheat yields. It would also increase the erosion hazard.

If peas could be grown with the first year sweetclover and grass and an average yield of 27 bushels per acre of peas obtained, the 5-year rotation would about equal the winter wheat--pea rotation in total production. The growing of peas with first-year sweetclover is now practiced by many farmers in the Palouse area, but it has not yet been demonstrated that peas can be seeded with sweetclover and grass and successful stands of grass and sweetclover obtained on the hilltops and upper slopes, the areas where legumes and grasses are most needed. In a few locations in the Palouse, especially in the Latah--Rock Creek Soil Conservation District in the vicinity of Fairfield, Washington,

farmers in recent favorable years have been successful in obtaining good stands of sweetclover and grass when seeded with peas. However, on hilltop seedings, or on land with a low nitrogen level, thin, weedy stands of grass and sweetclover usually resulted when these crops were grown with peas the first year.

Grass with sweetclover or alfalfa is considered highly desirable for retarding runoff and erosion because of more complete ground cover and because of the quantity of fibrous roots remaining in the soil after the legume-grass land is plowed and devoted to the growing of other crops. The inclusion of grass also would likely result in a better balance between nitrates and moisture for the crops following the grass-legume mixture and a possibility of prolonging the beneficial residual effect of the legume.

The five-year soil-building rotation with sweetclover and grass might exceed the wheat-pea rotation in net return if the sweetclover and grass could be utilized profitably as hay or pasture and the wheat and pea yields maintained at about the same level as when the legume-grass mixture was used for green manure.

That grass-legume mixtures can be utilized profitably for pasture in the Palouse is indicated by recently published results of pasture trials by the Washington Agricultural Experiment Station (see Wash. Agr. Exp. Sta. Bul. No. 444). In two favorable years for forage production, 1942 and 1943, 220 lbs. of beef per acre per year were produced from pasturing alfalfa-grass mixtures. In a one-year trial with a sweetclover-grass mixture, equally favorable results were obtained.

If we assume that these short-time average yields would be about the normal if these cropping systems were continued for a longer period, rotation 10 with four years of alfalfa and grass also would be a good rotation for the Palouse area. This rotation would permit a live-stock enterprise on the farm. Better weed control and less soil erosion would be expected from this rotation than from growing only wheat and peas.

The figures in table 6 under the heading "Average annual yield per acre for rotation", were obtained by dividing the yield of each crop by the number of years in the rotation. The figures, therefore, show the average annual production per acre for each rotation. To properly evaluate these rotations, however, other factors such as prices, production costs, suitability of farms in the area for keeping livestock the year round, etc., would need to be considered as well as crop yields or gross returns.

Table 6 —Average yields and soil losses from crop rotation plots at the Soil Conservation Experiment Station at Pullman, Washington, for the years 1938 to 1943, inclusive.

No.	Rotation	6-year average yield bu.	Av. annual yield per acre for rotation. bu.	Total Soil Loss 5-yrs. T/A tons
1.	Winter wheat—fallow	30.7	15.4	17.8
2.	Spring wheat—fallow	23.4*	11.7	23.9
3.	Winter wheat—peas: Winter wheat after peas Peas after winter wheat	32.0 20.4	16.0 10.2	9.3
4.	Spring wheat—peas Spring wheat after peas Peas after spring wheat	22.4* 21.4	11.2 10.7	10.0
5.	Winter wheat—peas and spring wheat for green manure	31.6	15.8	11.2
6.	Spring wheat—peas and spring wheat for green manure	26.1*	13.0	5.6
7.	Winter wheat—Hubam clover for green manure	39.2	19.6	4.3
8.	Spring wheat—Hubam clover for green manure	26.0	13.0	3.7
9.	Sweetclover and grass—sweet-clover and grass turned under—winter wheat—peas—spring wheat: Winter wheat after clover and grass t.u. Peas after winter wheat Spring wheat after peas	43.9 <u>1</u> 27.4 <u>2</u> 27.7 <u>3</u>	14.3 wheat 5.5 peas	
10.	Four years alfalfa and grass—spring wheat—winter wheat—peas—spring wheat: Spring wheat after alfalfa and grass Winter wheat after spring wheat Peas after spring wheat Spring wheat after peas Alfalfa and grass	25.2 <u>1</u> 35.6 <u>1</u> 25.0 <u>2</u> 30.3 <u>3</u> 2.3 T	11.4 bu. wheat 3.1 bu. peas 1.2 t. alfalfa & grass	

1 5 yr. average yield
2 4 yr. average yield
3 2 yr. average yield

* 5-year average yields, 1942 missing

RESULTS FROM OTHER EXPERIMENTS

Utilization of straw on land cropped continuously to wheat. In table 7 yields of winter and spring wheat are given from an experiment to determine the effect on yield of wheat of burning vs. utilizing the straw and of the application of nitrogenous commercial fertilizer. The land was cropped every year. Spring wheat was grown in 1941 and winter wheat the other five years. Soil and water losses were not measured. With continuous cropping, erosion was light.

The beneficial effect of the fertilizer on yield is clearly indicated. Utilizing the straw slightly depressed yields, the average reduction being 1.5 bushels per acre for all trials.

Utilization of straw on land cropped to wheat alternating with fallow. In table 8 yields are shown for winter wheat grown after fallow in 1941 to 1943, inclusive, in an experiment to determine the effect on yield of burning the straw, turning the straw under with a moldboard plow and spreading straw on the surface after plowing with a moldboard plow. In 1942 subsurface tillage was used instead of spreading the straw on the surface after plowing. There were duplicate plots for each treatment.

In 1941 there was not much of a spread in yield from the different treatments except for the plots with straw burned. Severe lodging occurred on one of these plots, and as a result the yield was low. In 1942 the plots with two tons of straw plowed under yielded highest. The differences in yields from the other treatments were well within the range of experimental error.

The superiority of subsurface tillage in reducing soil losses is clearly indicated from the results shown in table 9. With the straw burned, the subsurface tilled plots lost less soil than did the moldboard plowed plots with the straw utilized. The highest soil loss occurred on the moldboard plowed plots with the straw burned. These results should be compared with those obtained in Southern Idaho as shown in table 14.

Table 7 — Effect of stubble utilization and nitrogen fertilizer on yields from land cropped every year to winter wheat on the Soil Conservation Experiment Station at Pullman, Washington.

Treatment	1937	1938	1939	1940	1941 /2	1942	Average
	bu.	bu.	bu.	bu.	bu.	bu.	bu.
Straw returned	11.7	12.0	17.3	12.7	8.3	23.5	14.3
Straw burned	11.5	15.1	20.8	17.7	7.0	21.2	15.6
Straw returned + 80# fertilizer /1	16.4	25.8	27.1	14.6	9.0	33.1	21.0
Straw burned + 80# fertilizer	19.5	30.4	28.4	18.2	9.7	33.7	23.3
Straw returned + 160# fertilizer	21.4	34.1	31.6	24.5	10.0	38.2	26.6
Straw burned + 160# fertilizer	19.5	34.8	37.4	23.3	12.2	36.7	27.3
Averages on all plots							
Straw returned	16.5	24.0	25.3	17.3	9.1	31.6	20.6
Straw burned	16.8	26.8	28.9	19.7	9.6	30.5	22.1
No fertilizer	11.6	13.6	19.1	15.2	7.7	22.4	15.0
80# fertilizer /1	18.0	28.1	27.8	16.4	9.4	33.4	22.2
160# fertilizer	20.5	34.5	34.5	28.9	11.1	37.5	27.0

/1 Ammonium sulfate per acre applied in the fall.

/2 Spring wheat planted in 1941.

Table 8 —Annual and average acre yields of Hymar winter wheat grown after fallow in 1941, 1942, and 1943 with straw burned, one and two tons of straw plowed under and one and two tons of straw spread on land after plowing with a moldboard plow in 1941 and 1942, and subsurface tilled in 1943.

Residue Treatment	1941	1942	1943	Average
Burned	36.1	33.2	35.4	34.9
One ton under	44.6	33.2	33.9	37.2
Two tons under	41.2	35.8	29.2	35.4
One ton on surface	43.7	31.5	33.9 Δ	36.4
Two tons on surface	42.6	32.3	31.7 Δ	35.5
Burned subsurface tilled			33.1	

Δ Subsurface tilled

Table 9 —Soil losses on stubble utilization plots, season of 1942-1943, at the Soil Conservation Experiment Station, Pullman, Washington.

Treatment		Soil Loss
Straw Returned Tons/Acre	Type of Tillage	Tons/Acre
0	Subsurface (straw burned)	6.02
1	Subsurface (stubble mulch)	0.74
2	Subsurface (stubble mulch)	1.30
0	Moldboard plow (straw burned)	1.64
1	Moldboard plow	9.18
2	Moldboard plow	8.41

Productivity and erodibility of virgin and cultivated land. Runoff, soil losses and yields from old cultivated land and from adjacent land broken out of sod in 1934, cropped to wheat alternating with summer fallow, are shown in table 10. The results show that the newer land absorbed water more readily and was more resistant to erosion than the land that had been cropped for a long time. This indicates that in the earlier years of cropping in the Palouse area, when the soil was higher in organic matter, soil erosion was probably much less prevalent than now. The limited yield data also indicate a substantial decline in the productivity of the land that had been cropped largely to grain for more than 50 years. The plot that was planted to grass in 1936, plowed in the spring of 1942, and planted to spring wheat in 1943, yielded at the rate of 41.5 bu. per acre, three bu. per acre less than the yield from "virgin" land, but 6.3 bu. per acre more than from the land that had been cropped to grain for a long period.

Because of squirrel damage in some years and an infestation of cheat in other years, comparable yield data were obtained in only five years, 1938 and 1940 to 1943, inclusive. The average yield from the old land for those years was 24.5 bushels and from the new land, 39.8 bushels.

Table 10 — Soil and water losses from virgin land (cultivated since 1934) and land cultivated for 50-60 years at Pullman, Washington.

College Farm Plots

Year	Winter wheat		Wheat stubble		Grass	
	Runoff Depth in.	Soil loss Tons/A	Runoff Depth in.	Soil loss Tons/A	Runoff Depth in.	Soil loss Tons/A
<u>Virgin land</u>						
1936-37	0.006	0.000	0.005	0.001	0.010	0.00
1937-38	0.004	0.000	0.003	0.001	0.000	0.00
1938-39	0.000	0.000	0.000	0.000	0.000	0.00
1939-40	0.000	0.000	0.000	0.000	0.000	0.00
1941-42	0.005	0.014	0.000	0.000	0.000	0.00
1942-43	<u>0.048</u>	<u>0.011</u>	<u>0.028</u>	<u>0.049</u>	<u>0.000</u>	<u>0.00</u>
Total	0.063	0.025	0.036	0.051	0.010	0.00
<u>Cultivated land</u>						
1936-37	0.574	4.337	0.006	0.004	0.080	0.01
1937-38	0.000	0.000	0.000	0.000	0.000	0.00
1938-39	1.163	0.203	0.000	0.000	0.000	0.00
1939-40	0.700	2.789	0.000	0.000	0.000	0.00
1940-41	0.000	0.000	0.023	0.087	0.000	0.00
1941-42	0.154	0.707	0.000	0.000	0.000	0.00
1942-43	<u>0.375</u>	<u>0.883</u>	<u>0.020</u>	<u>0.022</u>	0.123 *	0.00 *
Total	2.966	8.919	0.049	0.113		

* This plot, which was planted to grass in 1936, was plowed in the spring of 1942, fallowed and planted to wheat in the spring of 1943. It yielded at the rate of 41.5 bu. per acre.

Yield, bushels per acre *

	Virgin land	Cultivated land
1938	31.29	26.3
1939	—	— (squirrel damage)
1940	54.9	25.0
1941	20.7	12.7
1942	46.0	23.3
1943	<u>44.6</u>	<u>35.2</u>
Average	39.8	24.5

* Spring wheat in 1943; winter wheat in all other years.

NEW EXPERIMENTS

Results from other experiments, including terracing and hydrologic studies, are given in the ten-year progress report by Glenn H. Horner, A. G. McCall and F. G. Bell. (See U.S.D.A. Technical bulletin No. 860.)

There have been recently inaugurated on the Erosion Station a series of new rotations to determine the effect on soil and water losses and on crop yield of (1) different methods of handling sweetclover in a rotation with wheat (2) methods of residue utilization in a wheat-pea rotation and (3) grass, alfalfa, and grass-alfalfa mixtures in long-time rotations with wheat and peas.

THE WASHINGTON AGRICULTURAL EXPERIMENT STATIONCROP RESIDUE AND FERTILIZER TRIALS

The effect of certain farming practices on soil nitrogen and organic matter maintenance and on erosion was pointed out by Sievers and Holtz of the Washington Station more than 20 years ago (See Washington Station Bulletin No. 166). Crop rotation, tillage and fertilizer experiments have been continued on that Station from which yield data are available for a long period of years.

In table 11 yields are reported from an experiment to determine the effect on yield, soil nitrogen and organic matter maintenance, of various fertilizer and residue applications on winter wheat grown every year and also on winter wheat grown after fallow. Yield data are given in table 11 for two eleven-year periods for the continuous winter wheat plots and for two ten-year periods for the wheat alternating with fallow.

Figure 6 shows the annual yields obtained from the plots receiving no fertilizers, with straw removed and with 2700 lbs. of straw plus the binder stubble returned to the soil for the years 1923 to 1943, inclusive. Yields are shown for the plots cropped to wheat alternating with fallow and also those cropped to wheat every year. The precipitation by crop years ending August 31 also is shown in figure 6.

It will be noted that extreme variations in yield occurred during the 21-year period both for the wheat after fallow and for wheat grown continuously. There were four years, 1923, 1928, 1935 and 1943, when the wheat on the two plots after fallow averaged close to 60 bushels per acre. There were two years, 1927 and 1936, when extremely low yields were obtained from these two plots. Injury from hail reduced the yields in 1927. The low yields in 1936 were due to severe winter killing. In that year the yield was low on all plots in the experiment except those to which commercial fertilizer had been applied. The three plots receiving sodium nitrate applications yielded slightly in excess of 40 bu. per acre in 1936, while the yields from the plots with no fertilizer applied and those to which alfalfa, alfalfa and straw, and manure were applied ranged from 14.4 to 22.5 bu. per acre. On the continuously cropped plots in 1936, winter injury was so severe that all plots were reseeded late in the spring. (May 5). Due to failure to get stands, spring wheat also was used in these trials in a few other years, as is indicated in the footnote of table 11.

On the continuously cropped plots with fertilizer applications, high yields were obtained in only 5 of the 21 years. The highest yields, 34.8 and 41.0 bushels were obtained from these two plots in 1943.

The data in figure 6 show that there was no significant correlation between yield and crop-year precipitation for wheat after fallow or for wheat grown continuously. Apparently there were other factors such as distribution of the precipitation, winter killing, prevalence of weeds, and lodging, that influenced yields in certain seasons enough to interfere with the relation that would be normally expected between crop yield and crop year precipitation.

Following are some points brought out by the data in table 11:

1. For winter wheat every year:

- a. Nitrogenous fertilizers significantly increased yields. The 22-year average yield from the five plots with commercial fertilizer or manure applications was 10.3 bushels per acre more than the average yield from the two plots without fertilizer applications.
- b. Where fertilizers were not applied, the yield trend was downward, or 2.3 bu. per acre less for the second 11-year period than for the first 11-year period.
- c. Averaging yields for the 7 fertilizer treatments the yield trend was slightly upward, 28.4 bu. for the first 11-year period and 29.3 bu. per acre for the second 11-year period.
- d. Utilizing the straw as compared with removing it, without fertilizer applications, decreased yields only slightly, .7 of a bushel or 3.6% for a 22-year average.
- e. With 370 lbs. per acre of sodium nitrate applied the average yields were practically identical from plots with straw removed and with 2700 lbs. of straw added.

2. For wheat alternating with fallow:

- a. Nitrogenous fertilizers had little effect on yield. The highest yield (20-year average) was 45.8 bu. per acre (straw + 286 lbs. ammonium sulfate) and the lowest yield was 43.6 bu. per acre (2700 lbs. straw and no fertilizer).
- b. For the first 10-year period, the lowest yield was obtained from the application of 6 tons per acre of barnyard manure for each crop. For the second 10-year period, the manured plots had the highest average yield.

- c. Based on 10-year average yields, the yield trend was slightly downward for all treatments, except where barnyard manure was applied and where the straw was removed and 370 lbs. per acre of sodium nitrate applied. In the latter case, the second 10-year period averaged 0.5 of a bushel more than for the first 10-year period. Where barnyard manure was applied the average yield for the second 10-year period was 4.7 bu. more than for the first 10-year period.
- d. Utilizing the straw, without fertilizer applications, resulted in a decrease in average yield of 1.7 bu. per acre or 3.8% for the 20 years.
- e. With 370 lbs. per acre of sodium nitrate applied, the average yield of the plots with straw removed was 1.1 bu. per acre more than the average yield of the plots to which 2700 lbs. of straw were added.

Table 11 --Acre yields in bushels by 11 and 10-year periods of winter wheat grown after various crop residue and fertilizer treatments on the college farm at Pullman, Washington, in the years 1922 to 1943, inclusive. (Binder stubble was left on the land for all treatments. The land was plowed with a moldboard plow and the fallow cultivated with ordinary tillage implements.)

Plot No.	Treatment	1922-1932	1933-1943	22-yr. av. yield
		bu.	bu.	bu.
<u>Winter wheat every year</u>				
100	2700 lbs. straw and 370 lbs. per A NaNO_3^*	27.5	31.0	29.2
101	2700 lbs. alfalfa	27.3	27.2	27.3
102	1350 lbs. straw and 1350 lbs. alfalfa	23.2	23.4	23.3
103	2700 lbs. straw	19.7	18.3	19.0
104	Check, straw removed	21.2	18.2	19.7
105	2700 lbs. straw and 370 lbs. NaNO_3^{**}	31.8	29.7	30.7
106	Straw removed and 370 lbs. NaNO_3	29.8	29.0	29.4 $\frac{1}{2}$
107	2700 lbs. straw and 286 lbs. $(\text{NH}_4)_2\text{SO}_4$	30.4	31.8	$\frac{1}{1}$ 31.1 $\frac{1}{2}$
108	6 tons per A. manure	26.9	29.7	$\frac{1}{1}$ 28.2
<u>Winter wheat alternating with fallow</u>				
		1923-1932	1933-1943	20-yr. av. yield
		BU.	bu.	bu.
200				
300	2700 lbs. straw and 370 lbs. per A NaNO_3^*	44.2	42.9	43.5
201				
301	2700 lbs. alfalfa	46.4	43.6	45.0
202				
302	1350 lbs. straw and 1350 lbs. alfalfa	44.8	43.4	44.1
203				
303	2700 lbs. straw	44.1	43.1	43.6
204				
304	Check, straw removed	45.9	44.7	45.3
205				
305	2700 lbs. straw and 370 lbs. NaNO_3^{***}	45.6	45.5	45.6
206				
306	Straw removed, 370 lbs. NaNO_3	44.4	44.9	44.7
207				
307	2700 lbs. straw and 286 lbs. $(\text{NH}_4)_2\text{SO}_4^{***}$	47.2	44.4	45.8
208				
308	6 tons per acre, manure	42.0	46.7	44.4

* Fertilizer applied in spring

** Fertilizer applied in fall

*** Fertilizer applied at time of plowing for summer fallow

$\frac{1}{1}$ 10-year average yield, 1939 missing

$\frac{1}{2}$ 21-year average yield, 1939 missing

$\frac{1}{3}$ Omitting 1936 yields because of differential winter-killing

Spring wheat was grown on continuously cropped plots in 1922, 1933, 1937, 1938 and 1943.

Spring wheat was grown on fallow plots in 1926, 1933, 1938 and 1943.

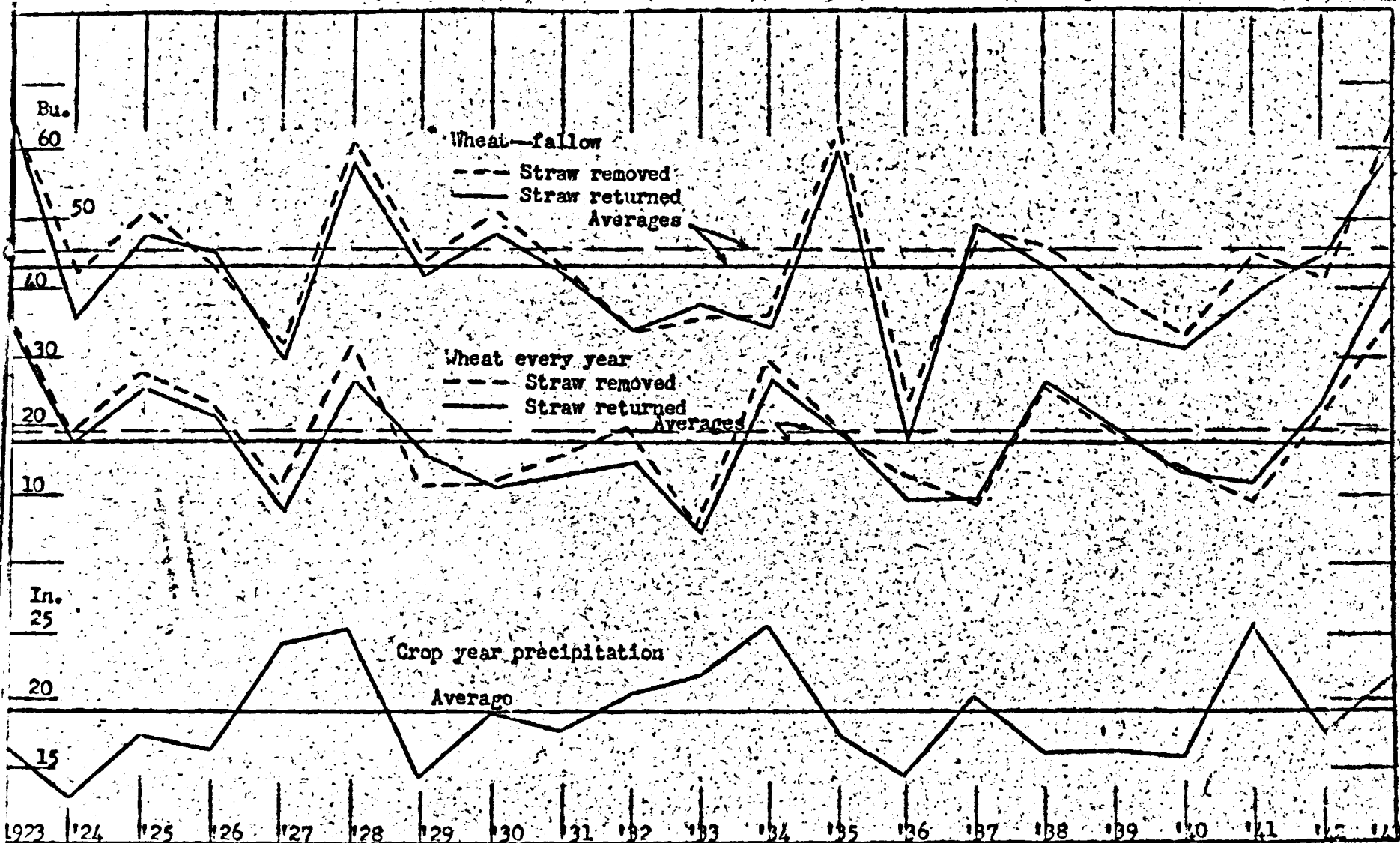


Figure 6—Acre yields in bushels of winter wheat grown after fallow, and grown every year with straw removed and straw returned for the years 1923 to 1943, inclusive; also crop year precipitation for the same period at Pullman, Washington.

A complete discussion of the results from this experiment, with analytical data on soil carbon and nitrogen, was published by Drs. Holtz and Vandecaveye in 1938 in the February issue of Soil Science, with the following summary:

The results of laboratory studies on CO₂ evolution and nitrate-nitrogen accumulation indicated a possible relationship between available nitrogen and the formation of humus in the soil.

Applications of various organic residues under field conditions or of nitrogen fertilizers alone or as a supplement to the organic residues did not result in appreciable increases in yield under alternate cropping and summer-fallow but, on an average, caused substantial increases in yields of wheat under annual cropping, the increases being roughly proportional to the amounts of nitrogen applied to the soil. Yields under annual cropping gradually declined, regardless of soil treatments.

The addition of substantial quantities of nitrogen to the soil in various forms resulted in an increased average nitrogen content of the grain. Not all the nitrogen disappearing from the plowed layer could be accounted for by the amounts assimilated by crops. Probably some of it was lost by leaching to lower depths, and it appears that this loss was considerably greater under alternate cropping and summerfallow than under annual cropping.

The carbon-nitrogen ratio of the soil humus in the various plots appeared to be slightly greater after 13 years of soil treatment than before such treatment but remained remarkably uniform in all plots regardless of the system of cropping practiced or of the nature and amount of crop residues and nitrogen fertilizers applied to the soil.

Annual applications of organic residues, except the application of straw alone, were effective in increasing the humus content of the soil under annual cropping with wheat. The gain in humus was roughly proportional to the amount of nitrogen supplied to the soil by means of organic residues or as a supplement to these residues.

A marked loss of soil humus occurred under alternate cropping and summer-fallow in spite of additions of organic residues. The loss of humus by microbial activity was so great during the summer-fallow year that it could not be overcome fully by applications of organic residues in amounts consistent with field practice.

Convincing evidence was produced to show that the decomposition of organic residues in Palouse silt loam under its natural climatic environment results in the formation of humus with a carbon-nitrogen ratio of approximately 12. Any carbon added in excess of this ratio by means of organic residues was rapidly dissipated by CO₂ evolution.

The practice of returning straw to this soil, although having a beneficial physical effect on the soil and causing a decline in the rate of loss of soil humus under the prevailing cropping practices, cannot be expected to result in the production of substantial quantities of new humus unless the straw is supplemented with some form of available nitrogen in sufficient amounts to make the total supply approximately equivalent to that in alfalfa hay.

CROP ROTATION TRIALS

A series of crop rotations has been in progress on the College Farm at Pullman since 1920 (see bulletin No. 344 of the Washington Agricultural Experiment Station). The results from some of these rotations are shown in table 12 by 5-year periods, beginning with 1920 and ending in 1943. Average yields for an 11-year period (1932-1942) are also shown in table 12 for another series of rotations designed primarily to study the effect of the different cropping systems on soil nitrogen and organic matter maintenance.

For the rotations in progress for the 24-year period, the two wheat-pea rotations returned the highest total annual crop yield per acre. There was no significant difference in the average yields obtained from the rotation of winter wheat-peas and spring wheat-peas. The total annual production from the 3-year rotation of winter wheat-spring wheat-peas also was almost as much as was obtained from the 2-year rotations of wheat and peas. For growing spring wheat every year, the application of 6 tons of manure every third year increased the average yields 4.1 bu. per acre for the 24-year period.

For the other group of rotations, the 11-year average yield also was highest for the rotation of winter wheat-peas. The yield of winter wheat after turning under a green manure crop of Hubam clover was not quite so high as for growing winter wheat after fallow.

In the 3-year rotation of peas with sweetclover-sweetclover turned under-winter wheat, the yield of wheat after sweetclover turned under was slightly less than from growing wheat after fallow. The average annual grain yield per acre also was considerably less in this 3-year rotation than in the rotation of winter wheat and peas.

The annual yields of wheat after sweetclover turned under in the rotation are compared with the yields of winter wheat after fallow in figure 7.

The yield of winter wheat in this 3-year rotation did not show the decidedly upward trend that occurred in the winter wheat yield after sweetclover in the 4-year rotation on the Soil Conservation Experiment Station, as shown in figure 1. The probable reason for this discrepancy in results is that the soil fertility level of the land is higher on the College Farm, high enough apparently, that ample nitrates were available for the winter wheat after a season of fallow. On the Soil Conservation Experiment Station, too, severe erosion occurred in 1932 and 1934. No data are available for soil losses on the College Farm plots, but any severe losses doubtless would have been recorded. The yields of wheat after fallow on the College Farm plots do not indicate the high soil losses that occurred on the Erosion Station in 1931-1932 and 1933-1934. The yield in 1934 was exceptionally low, as also was the yield on the Soil Conservation Experiment Station plots. The same plots on the College Farm that gave a low yield after fallow in 1934, were exceptionally high in yield in 1936, which was not true on the Soil Conservation Experiment Station plots. (See figure 1).

Table 12 —Average yields by 5-year periods from five crop rotations from 1920 to 1943, and 11-year average yields from five other rotations on the College Farm at Pullman, Washington. (See Washington Station Bulletin No. 344)

Rotation	1920- 1924	1925- 1929	1930- 1934	1935- 1939	1940- 1943*	24-year average	Average annual yield per acre**
	bu.	bu.	bu.	bu.	bu.	bu.	bu.
Winter wheat—fallow:							
Winter wheat after fallow	45.2	40.6	42.2	45.9	41.3	43.2	21.6
Winter wheat—peas:							
Winter wheat after peas	35.4	28.6	30.9	29.0	35.4	31.7	15.9
Peas after winter wheat	22.2	17.7	15.5	15.3	24.6	18.8	9.4
Spring wheat—peas:							
Spring wheat after peas	33.0	32.8	27.1	31.5	30.9	31.1	15.6
Peas after spring wheat	25.6	18.8	15.8	15.3	24.4	19.8	9.9
Winter wheat—spring wheat— Peas:							
Winter wheat after peas	33.7	30.0	32.3	31.6	39.2	33.3	11.1
Sp. wheat after w. wheat	20.6	20.9	22.0	22.9	19.4	21.2	7.1
Peas after spring wheat	23.4	19.0	16.5	16.9	26.1	20.1	6.7
Spring wheat every year:							
Without manure	21.1	19.9	16.2	19.0	18.1	18.9	18.9
With manure (6 tons every third year)	22.8	20.8	20.2	26.4	25.5	23.0	23.0

* 4-year period

** Average yield of each crop divided by the number of years in the rotation.

Table 12 Continued--Average yields by 5-year periods from five crop rotations from 1920 to 1943, and 11-year average yields from five other rotations on the College Farm at Pullman, Washington. (See Washington Station Bulletin No. 344)

	11-year ave. yield (1932-1942)	Average annual** yield per acre
	bu.	bu.
Winter wheat--fallow	44.7	22.4
Winter wheat--peas:		
Winter wheat after peas	37.6	18.8
Peas after winter wheat	17.1	8.6
Winter wheat--Hubam clover turned under	42.7	21.4
Winter wheat--Hubam clover turned under--peas:		
Wheat after peas	43.0	14.3
Peas after sweetclover under	16.4	5.5
Sweetclover and peas--Sweetclover turned under--winter wheat:		
Winter wheat after sweetclover turned under	39.4	13.1
Peas with sweetclover	14.3	4.8

** Average yield of each crop divided by the number of years in the rotation.

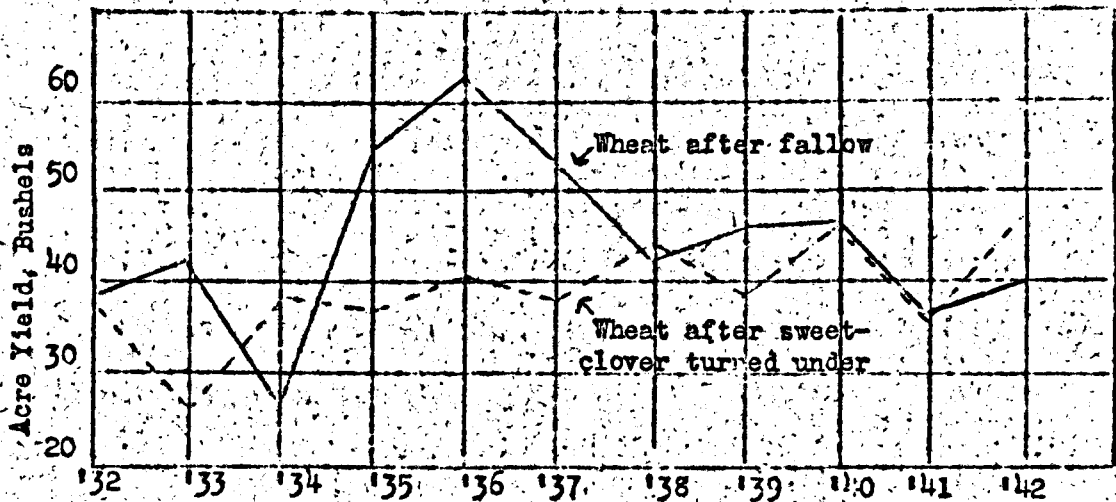


Figure 7 --Yields of winter wheat after sweetclover turned under in a rotation of peas with sweetclover--sweetclover turned under--winter wheat, and yields of winter wheat alternating with fallow for the years 1932 to 1942, inclusive, on the College Farm at Pullman, Washington. (Compare with figure 1).

New Rotations: The following crop rotations were started in the spring of 1940 on the College Farm. Each rotation is triplicated and each phase of the rotation is represented every year for each replicate.

1. Alfalfa and grass 4 years--winter wheat--spring wheat
2. Sweetclover and grass for hay 2 years--winter wheat--spring wheat--fallow--winter wheat
3. Sweetclover and peas--sweetclover hay--winter wheat--peas--spring wheat
4. Sweetclover and grass for hay 2 years--winter wheat--spring wheat
5. Winter wheat--fallow
6. Winter wheat--fallow (stubble mulch)
7. Winter wheat--fallow (straw burned)
8. Winter wheat--peas
9. Winter wheat--peas turned under

THE ADAMS BRANCH EXPERIMENT STATION

at

LIND, WASHINGTON

The Adams Branch Station at Lind, Washington, is located on Ritzville soil in an area where the average annual precipitation is only about 9 inches. The research work on the Station at Lind has been largely on cereal production, including breeding and adaptation studies and tillage methods for growing wheat alternating with fallow. In recent years, considerable work has been done in testing grasses and legumes and in determining best methods of getting these established.

The greatest erosion hazard in the Big Bend area, as represented by the Lind Station, is from wind, and practically all soil management practices are directed toward the control of soil blowing. Using straw residues as a surface mulch and avoiding excessive soil pulverization are essential features in the handling of summer fallowed soil. Soil and water losses are occasionally high from melting snow on frozen ground during the winter or early spring months. During the season of 1940-1941, Mr. Jacquet, Superintendent of the Adams Branch Station, estimated that some fields seeded to winter wheat after fallow lost as much as 40 tons of soil per acre.

Since 1931 run-off measurements have been made on a small representative watershed of 377 acres. The greatest amount of water lost, .94 inch, was in 1932. The average annual loss for a twelve-year period was .31 inch.

In table 13, average yields for the 18-year period, 1923-1940, and the annual and average yields for 1941, 1942, and 1943 are given for Baart spring wheat grown after fallow with various residue and fertilizer applications. For the 18-year period with an average precipitation of only 8.63 inches, there were no significant differences in the average yields obtained from the various treatments. The application of as much as 3200 lbs. of straw per acre apparently had no effect on yield, nor did the application of 100 lbs. of ammonium sulfate per acre. For the 3-year period, 1941-1943, with above normal precipitation, there was some indication of increased yields from the fertilized plots, especially those receiving applications of manure, but no indication of any depression in yields from straw residues. For the 21-year period, 1923-1944, the variations in average yields were small, the average yields ranging from 16.7 to 17.8 bu. per acre.

Under the direction of Dr. S. C. Vandecaveye, total nitrogen and carbon determinations were made from the soil of these plots in 1922 and 1940. The total nitrogen in the surface six inches of soil on these two dates, as reported by Mr. Vance T. Smith in a thesis submitted to the Washington State College faculty in 1941, is shown in figure 7A. In spite of the extremely low nitrogen level of the

surface six inches of the soil of these plots, there was a further decline during the 18-year interval for all treatments except where 3200 lbs. of straw per acre were plowed under or where 3.5 tons of manure per acre were applied biennially.

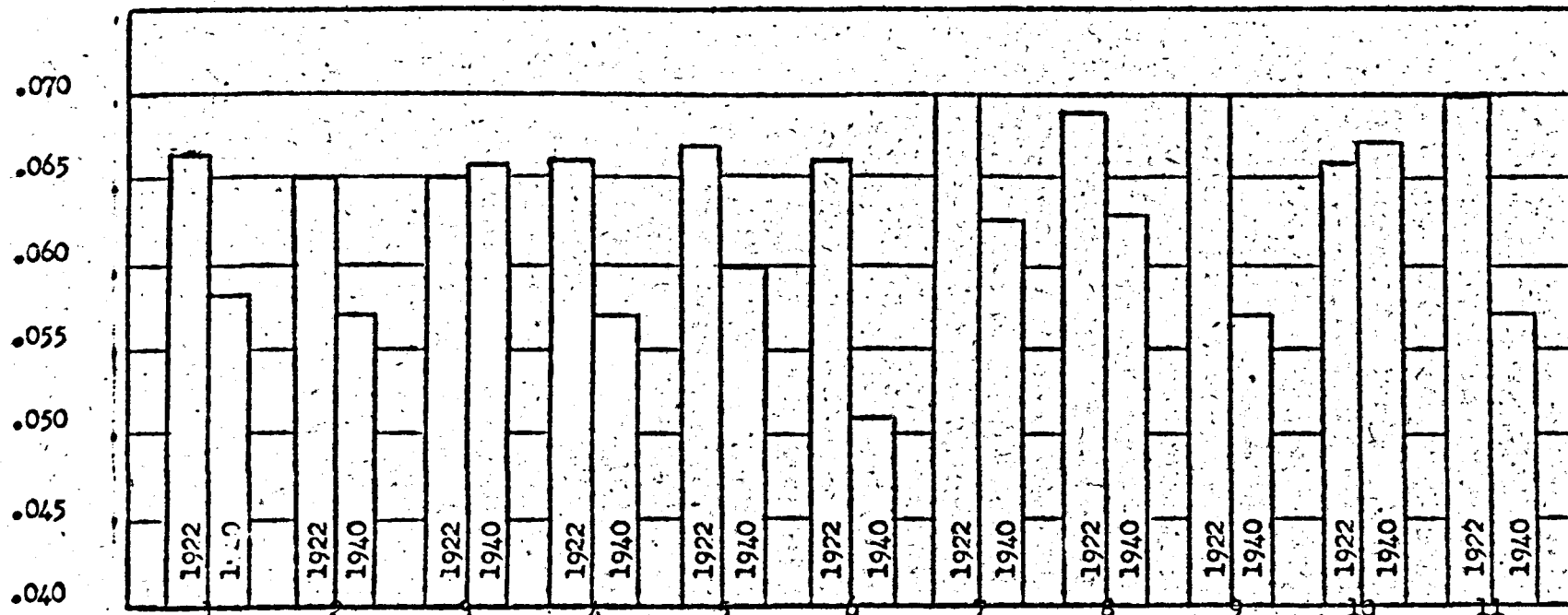
In this experiment the moldboard plow was used for initial tillage. The fallow was kept free from weeds with a revolving rod weeder. Prior to seeding in the spring the land was harrowed with a spring tooth harrow and then seeded with either a hoe or single disk drill.

Table 13 --Acre yields in bushels, of Turkey winter wheat* and Baart spring wheat grown after fallow in an organic matter maintenance experiment at Lind, Washington.

Residue applied in pounds per acre**	Acre yield, bushels					
	1923- 1940	1941	1942	1943	Av. 1941-43	Av. 1923-43
1. Check (none)	14.9	27.6	40.0	25.5	31.0	17.2
2. 1600 lbs. straw**	15.1	29.4	40.0	26.6	32.8	17.6
3. 3200 lbs. straw	14.8	30.5	40.9	26.1	32.5	17.3
4. 800 lbs. straw	14.5	27.4	39.1	22.5	29.7	16.7
5. No straw and 50 lbs. of ammonium sulfate	14.4	27.6	40.0	24.3	30.6	16.7
6. Check (none)	15.2	24.0	39.1	21.2	28.1	17.0
7. 800 lbs. straw and 50 lbs. ammonium sulfate	15.4	27.8	41.3	28.6	32.6	17.8
8. 1600 lbs. straw and 100 lbs. ammonium sulfate	15.2	28.5	39.1	27.9	31.8	17.6
9. No straw and 100 lbs. ammonium sulfate	14.8	26.3	40.0	28.2	31.5	17.2
10. Manure, 3.5 tons	15.2	25.8	42.7	30.6	30.0	17.8
11. Check (none)	14.6	22.2	37.7	28.8	29.6	16.7
Average of all checks	14.9	24.6	38.9	25.2	29.6	17.0
Crop year precipitation, inche	8.68	18.00	12.29	11.65	13.89	9.43

* Turkey winter wheat was grown in 1923, 1924, 1926, 1927, 1928, 1931, 1934, and 1935 and Baart spring wheat in all other years.

** Residue applied does not include binder stubble.



1. Check. No residues applies; binder stubble plowed under
2. 1600 lbs. straw per acre plowed under
3. 3200 " " " " " "
4. 800 lbs. straw per acre plowed under
5. 50 lbs. per acre ammonium sulfate
6. Check
7. 50 lbs. per acre ammonium sulfate and 800 lbs. per acre of straw plowed under
8. 100 lbs. per acre ammonium sulfate and 1600 lbs. of straw per acre plowed under
9. 100 lbs. per acre ammonium sulfate, no straw.
10. 3.5 tons per acre of manure plowed under
11. Check

Figure 7A —Total nitrogen in 1922 and in 1940 in the surface six inches of soil of several plots given various fertilizer and crop residue treatments. Duplicate plots were used for each treatment, one in crop and one in fallow. The total nitrogen, in percent, is the average for two plots.

THE IDAHO AGRICULTURAL EXPERIMENT STATION

Crop production studies in Idaho are carried on at the University Farm at Moscow and at branch stations at Sandpoint, Tetonía, and Aberdeen. A brief description of climatic conditions at these locations is given in Idaho Station Bulletin No. 227, "Crop Rotation Studies" by Baker and Klages.

STUDIES ON CROPPING METHODS FOR EROSION CONTROL

IN THE DRY FARM AREAS OF SOUTHEASTERN IDAHO

In 1939 a cooperative project between the Idaho Agricultural Experiment Station and the Soil Conservation Service was started on the Branch Station at Tetonía to determine the effect of various tillage methods on soil erosion and yields of wheat when grown after fallow on the dry-farmed lands in south-eastern Idaho, with Mr. Hugh C. McKay as project leader. The following is a condensation of Mr. McKay's latest progress report. A more complete report of results from these studies is contained in Idaho Experiment Station Bulletin No. 255 by Hugh C. McKay.

The Tetonía Branch Experiment Station is located in the dry farm region of south-eastern Idaho in Teton County. It is 7 miles north-west of Tetonía, Idaho, or 30 miles east of Rexburg, Idaho, on highway No. 33. It is located at the northeastern end of the Rexburg bench area at an elevation of 6,000 feet. The soil corresponds to the Ritzville series. The average annual precipitation is 13.1 inches.

Purpose and Plan of Experiments: The purpose of the cooperative work on the Tetonía Branch Experiment Station is to study the effect of several types of initial tillage implements and methods of fallow cultivation on placement of crop residues, roughness, and cloddiness of surface soil; and to study the accompanying effect of these on resistance to erosion, moisture conservation, nitrates, and yield. The initial tillage implements used are the moldboard plow, one-way disk, listerbottom plow, moldboardless plow, and the revolving rod weeder with shovel attachments. To carry the program through the entire cropping cycle, studies were started in 1941 to include method of cultivating the fallow and methods of seeding on soil given initial tillage with all the above types of implements. In the studies of methods of handling fallow land are included the practices of stubble burning, rod weeding immediately after initial tillage, rod weeding only when necessary for weed control, and disking in the fall and spring before plowing. In the seeding trials, two types of drills are used, the single disk and the deep furrow disk drill.

It is evident that the success or failure of an agricultural system

or practice must depend upon the average results that flow from it over a considerable period of years. Although temporary success may be achieved under abnormal conditions in spite of the violation of accepted farming practices, the favorable results from stubble mulch tillage for four successive years indicate that it has a very definite place in the dry farm agriculture of southern Idaho.

Soil Losses. The value of crop residues for erosion control and their effect on the soil is highly dependent upon the amount to be utilized and their placement during the initial tillage operations. In these studies, three placements of straw residues are used: The residue is turned completely under with the moldboard plow, mixed with the surface soil with the one-way disk, and left on the surface with subsurface tillage implements. In order to differentiate between the effects of types of initial tillage and the effect of straw residues, all tillage methods were replicated on soil where all the residues were burned.

The soil losses in tons per acre for one season are shown in table 14 for land given various tillage treatments, with straw burned and straw utilized. Soil losses were determined in the spring of 1943 on land that was fallowed in 1942 and seeded to winter wheat in the fall of that year.

Table 14 -- Soil losses in tons per acre from various initial tillage and residue treatments at the Tetonia Branch Experiment Station, Tetonia, Idaho, 1943. Soil loss determinations were made by the rill method on land with 4500 pounds of stubble and straw residue and 15 to 20% slope. Seeding was done on the contour.

Method of tillage	With straw burned	With straw utilized			Ave. straw used
		Weeded when necessary	weeded im- mediately	disked before plowing	
Moldboard plowing	46	7	10	9	8.6
One-way disking	40	5	9	9	7.7
Listerbottom plowing	33	trace	4	2	2.0
Moldboardless plowing	33	trace	3	3	2.0
Disk before plowing with moldboardless plow	48	3	5	4	4.0
Rad weeder with shovels*	68	4	5	2	3.6
Average	44.8	3.2	6.0	4.8	

* Only one replication for this implement; duplicate one-sixth acre plots, randomized, for all other treatments.

out

With/exception, the average soil losses from the plots with straw burned were many times greater than the corresponding losses from the plots with straw utilized, especially where the straw was used in the form of a mulch on the surface. The excess of losses ranged from about 6 to 33 times as much.

In comparing losses from the plots with straw burned, the average soil loss from the plots given initial tillage with the moldboardless and listerbottom plows was less than from those on which other types of implements were used. This was largely due to the fact that the moldboardless and lister-bottom plows left the surface in a much cloddier condition. A higher soil loss was expected from the plots plowed with the moldboard plow with straw utilized, but due to the length of the stubble some of it remained on or near the surface after initial tillage, thus affording some protection.

It is indicated in table 14 that any excess working of the soil before or during the fallow season has a tendency to increase erosion. The least erosion occurred when the fallow was weeded only when necessary to control weeds. Since all of the plots were seeded on the contour, it is plainly evident from these data, that when seeding on the contour is the only erosion control measure employed, it is not sufficient to protect against soil loss.

Winter wheat yields. The yields of winter wheat in bushels per acre for the various tillage methods for the years 1940 to 1943, inclusive, are given in table 15. All plots were harvested with a combine.

As shown by the yield data, surface utilization of straw was definitely superior to mixing it with the surface soil or turning it completely under in growing wheat after fallow. For the plots with straw utilized the average yield for those given initial tillage with the lister-bottom plow was 34.6 bushels per acre as against 31.4 for the one-way disk, and 31.6 for the moldboard. These differences were large enough to be statistically significant.

Table 15 —Acre yields, in bushels, of winter wheat grown after fallow in tillage and crop-residue trials at Tetonía, Idaho for the years 1940 to 1943, inclusive, in duplicated and randomized 1/6-acre plots.

	1940	1941	1942	1943	Average
Moldboard plow, straw utilized	25.8	29.2	36.5	34.8	31.6
" " , straw burned	28.3	31.5	35.7	37.8	33.3
One-way, straw utilized	23.9	30.1	40.5	31.2	31.4
" " straw burned	26.7	31.4	36.7	32.1	31.7
Listerbottom, straw utilized	28.4	33.0	41.5	35.4	34.6
" " , straw burned	31.8	37.5	37.0	37.4	35.9
All tillage methods:					
Straw utilized	26.0	30.8	39.5	33.8	32.7
Straw burned	28.9	33.5	36.5	35.8	33.7
Moldboard (straw utilized and straw burned)					32.5
One-way (" " " " ")					31.6
Listerbottom (" " " " ")					35.3

The average yield obtained from the plots with straw burned was 1.1 bushels greater than from those with straw utilized, a difference not great enough to be significant. It is felt that these figures will soon reverse themselves as the erosion increases. In years with light straw such as 1941 the yields obtained from the plots with straw utilized were higher than they were from the plots with straw burned.

In the summerfallow studies, rod weeding only when necessary to control weeds gave the highest yields except for the plots with straw burned. Weeding immediately after plowing gave a lower yield each year, although the difference was not great enough to be significant.

The average yields from all initial tillage methods for the practice of disking before plowing did not show an increase in yield, but it did help materially in the ease of later operations. The practice of disking before plowing with the moldboardless plow gave a higher yield in 1943.

The data for the last four years definitely indicate that erosion can be controlled by the stubble mulch type of tillage, and the yields maintained at a point equal to or greater than from burning the straw and using the one-way disk for initial tillage. For the 4-year period there was an average difference in yield of 2.8 bushels in favor of the plots tilled with the listerbottom plow with straw utilized over those one-way disked with straw burned.

Moisture data. Due to the lack of summer rainfall at Tetonía, very little moisture conservation is expected during the fallow season. An increase in soil moisture from spring to fall is experienced only in abnormally wet years. Table 16 shows the inches of water gained

or lost during the summerfallow season for the last 5 years.

Table 16 —Average inches of water gained or lost during the fallow season in 6 feet of soil for the various initial tillage methods at the Tetonia Branch Experiment Station, 1939-1943.

Initial Tillage	1939	1940	1941	1942	1943	Ave.
Moldboard, straw burned	-0.51	0.69	0.21	-1.66	-2.41	-0.74
" , straw utilized	-0.73	0.98	0.89	-1.79	-1.96	-0.52
one-way disk, straw burned	-3.37	0.63	2.77	-2.16	-1.42	-0.81
" " , straw utilized	-0.22	0.41	2.82	-2.27	-2.69	-0.39
Listerbottom, straw burned	-3.32	0.34	1.35	-2.19	-1.87	-1.14
" , straw utilized	-2.57	0.49	0.93	-2.94	-1.61	-1.14
Average, all methods	-1.79	0.59	1.41	-2.17	-1.99	-0.79
Precipitation between dates of sampling, inches	3.82	6.61	6.39	2.02	2.99	4.37
Total water lost, inches	-5.61	-6.02	-4.98	-4.19	-4.98	-5.16

The highest average soil moisture loss during the fallow season occurred under the listerbottom type of initial tillage. The similarity in moisture loss, regardless of whether the straw was utilized or not, indicates that leaving the straw on the surface did not result in getting much more water into the soil during the fallow season. The greatest value of straw on the surface in this area is to prevent runoff in the spring. There was a slightly greater average moisture loss for the plots where the straw was burned than for the plots where the straw was utilized, but the difference was not significant. Averaging all methods for the five years, a little more than 5 inches of water were lost annually during the fallow season.

Nitrate Data. In this area the formation of nitrates during the fallow season depends largely upon the amount of moisture and straw present in the surface soil during the fallow season. Table 17 shows parts per million of nitrates as nitrogen at time of seeding in soil given initial tillage with various tillage implements, with straw burned and straw utilized.

Table 17 --Total nitrate nitrogen in parts per million in two feet of soil at time of seeding winter wheat for various initial tillage methods at the Tetonla Branch Experiment Station, 1939-1943.

Initial tillage	1939	1940*	1941*	1942	1943	Ave.
Moldboard, straw burned	12.9	24.3	67.0	53.6	32.7	38.1
straw utilized	9.5	34.3	71.8	33.1	28.6	35.5
One-way disk, straw burned	16.2	18.9	64.0	37.8	39.4	35.3
straw utilized	9.5	26.3	72.8	25.2	31.6	33.1
Listerbottom, straw burned	8.8	19.0	54.6	24.6	30.9	27.6
straw utilized	8.1	22.3	68.6	19.0	15.9	26.8
Average, all years, straw burned						33.7
straw utilized						31.8

*Light stubble in 1940 and 1941, less than one ton per acre; heavy stubble, 2 to 2½ tons in other years.

Surface Residues Resulting from Various Tillage Operations. The erosion control value of crop residues depends upon how much of the residue is left on the surface and how much of it remains on the surface during the summer fallow and after seeding operations. The pounds of straw on the surface before plowing, the amount left after three initial tillage operations, and the amount left after the summerfallow season of 1939 are shown in table 18.

Table 18 --Pounds of straw per acre on the surface before and after three different initial tillage operations and the pounds lost from the surface, Tetonla, Idaho, 1939.

Type of plowing	Before plow- ing lbs./A	After plow- ing lbs./A	Pounds turned under	Percent turned under	lbs. on surface time of seeding	Pounds lost from surface	Percent lost from surface	Percent left for erosion control
Moldboard	4977	00	4977	100.0*				0.0
One-way disk	4947	2955	1989	40.2	2454	50.1	17.0	42.8
Listerbottom	5052	4775	277	5.5	4075	69.9	14.6	79.9

*With heavy straw, some residue may remain on the surface after plowing with a moldboard plow, the amount depending upon the depth of plowing and whether the land was disked prior to plowing.

Of the implements used in this study the listerbottom plow left the maximum amount of straw on the surface for erosion control. Only 5.5 percent of the straw was turned under while 40.2 percent was turned under with the one-way disk, and 100 percent with the moldboard plow. During the fallow season, 17 percent of the straw was lost from the surface of the land that was one-way disked, and 14.6 percent from the land that was listerbottom plowed.

CONCLUSIONS AND RECOMMENDATIONS

From the results of the experiments and experiences for the 4-year period, the following conclusions can be drawn:

1. Burning straw residues is the greatest single factor contributing to erosion of crop land in the southeastern Idaho dry farm area.
2. Working summerfallow more than is necessary to control weeds has a tendency to increase erosion.
3. For wheat yields and erosion control, surface utilization of straw is superior to mixing it with the surface soil or turning it completely under.
4. With heavy straw, burning gave a small increase in yield, but with light straw, no advantage was gained by burning. The burning of straw in all cases contributed to the erosion problem.
5. After initial tillage, the method of cultivating the fallow giving best results was rod weeding only when necessary.
6. Subsurface tillage implements leave from 90 to 95 percent of the straw and stubble on the surface.
7. The low organic matter and nitrogen content of the surface soil of southern Idaho wheat lands strongly indicate the necessity of not only utilizing all crop residues, but also of adopting crop rotations to help maintain soil fertility.
8. The success of stubble mulch tillage depends upon the timeliness and quality of operations. All initial tillage and fallow operations should be completed before the weeds and volunteer wheat have made much growth. No subsurface tillage should be undertaken during rainy weather.
9. Straw spreaders should be used on all combines.

A few preliminary recommendations can be made from results and experiences to date in regards to handling wheat straw residues as a stubble mulch.

Previous wheat yield Bushels	Approximate straw yields Pounds per acre	Practice recom- mended at present
10-20	up to 2500	Any subsurface tillage implement such as a duckfoot or modified moldboard plow. No extra disking of stubble needed. Use any drill for seeding.
20-35	2500-4000	Spring or fall disking of stubble, spring preferred. Spring till with subsurface implement. Seed with deep furrow drill if straw is heavy.
Over 35	Over 4000	Best method known at present is to fall plow with modified moldboard. If stubble is extremely heavy and the ground plowed in the spring, both fall and spring preparatory disking should be done. Weed with rod weeder and seed with deep furrow drill. In areas adapted to spring seeding, spring wheat should be used. Some mechanical method of breaking up the stubble into small pieces before plowing would help greatly in all later operations.

RESULTS AT MOSCOW, IDAHO.

Yield data are given in Idaho Experiment Station bulletin No. 227 for a group of crop rotations for a 23-year period and for another group for a 15-year period, together with a discussion of yield trends. Since the publication of these results, the following rotations have been started on the University Farm at Moscow:

Rotations started in Field No. 7 in 1938: (all straw returned)

1. Winter wheat--peas
2. Winter wheat (straw plowed under)--fallow
3. Winter wheat (wheatland plow)--fallow
4. Winter wheat (straw burned)--fallow
5. Peas with sweetclover--sweetclover plowed under--winter wheat--winter wheat
6. Peas for green manure--winter wheat--winter wheat
7. Red clover--Red clover for seed--winter wheat--winter wheat
8. Crested wheatgrass--do.--do.--do.--flax--winter wheat

Rotations started in Field No. 1 in 1941: (all straw returned)

10. Alfalfa-grass 4 years--spring wheat--winter wheat--peas--winter wheat
13. Winter wheat--peas
14. Peas with sweetclover--sweetclover plowed under--spring wheat--winter wheat--peas--winter wheat
15. Sweetclover and grass--sweetclover and grass plowed under--spring wheat--winter wheat--peas--winter wheat
16. Peas with alfalfa--alfalfa--alfalfa--alfalfa--spring wheat--winter wheat--peas--winter wheat

The following management practices studies were started in 1938 in Field No. 7 with continuous wheat, with all straw returned to the plots unless otherwise indicated. Treatments Nos. 1 to 9, inclusive, are triplicated.

1. Winter wheat, moldboard plowing.
2. Winter wheat, wheatland plow.
3. Winter wheat, modified moldboard plow (started fall of 1941)
4. Winter wheat, straw burned, moldboard plow.
5. Winter wheat, twice the straw returned and burned, moldboard plow.
6. Winter wheat, 150 lbs. Am. sulfate applied to straw before plowing with moldboard plow.
7. Winter wheat, 10 tons manure every third year, moldboard plow.
8. Spring wheat, fall plow with moldboard plow, leave rough.
9. Spring wheat, stubble to stand over winter, spring plow with moldboard plow.

10. Winter wheat, twice the straw returned and plowed with the moldboard plow (single plot).
11. Continuous winter wheat fertilized, single plots, Fertilizer applied annually in the fall before plowing with the moldboard plow:
 - Check, no fertilizer
 - Ammonium sulfate, 100 lbs.
 - Ammonium sulfate, 200 lbs.
 - Treble superphosphate, 40 lbs.
 - N P (N supplied by 100 lbs. Ammonium sulfate)
 - N K (K supplied by K_2SO_4 , 50 lbs.)
 - P K
 - N P K
13. On south slope, clay outcrop area:
 1. Continuous spring wheat
 2. Alfalfa
 3. Alfalfa, and grass (Brome and Crested wheat)
 4. Crested wheatgrass
 5. Continuous spring wheat
 6. Alfalfa
 7. Alfalfa and grass
 8. Crested wheatgrass
 9. Continuous spring wheat

Plots 6, 7, and 8 were plowed in the fall of 1941 and will be planted to continuous spring wheat. Plots 2, 3 and 4 will be plowed in the fall of 1945 and planted to continuous spring wheat.

Table 19 shows the results for a five-year period from growing winter wheat after fallow at Moscow with three initial tillage methods: the moldboard plow and the one-way with the straw utilized, and the moldboard plow with the straw burned.

The average yields from moldboard plowing and one-way disking were almost identical and slightly higher than from moldboard plowing with the straw burned. Straw yields, too, were heavy, averaging about 3.5 tons per acre, exclusive of the binder stubble. The total straw, therefore, was well above 4 tons per acre. Lodging was very bad on summerfallow plots which probably accounts for lower yields on the plots where the straw was burned.

Contrary to results at Pendleton, Oregon heavy straw applications caused no reduction in yield. Apparently the land used for this experiment has a high enough nitrogen level that, even with the use of heavy straw residues, enough nitrates are available to meet the needs of the wheat crop when grown after a season of fallow.

When wheat was grown continuously on the same land, burning the straw resulted in higher yields, as is shown in table 19. And the 6-year average yield from the land plowed with a moldboard plow was 3.3 bu. more than the average yield obtained from the land on which the one-way disk was used for initial tillage.

Table 19 —Acre yields in bushels of winter wheat grown after fallow plowed with a moldboard plow and one-way disk with straw utilized and straw burned at Moscow, Idaho, for the five-year period, 1939-1943.

	Moldboard Plow- ing Straw Utilized	One-way disking; straw Utilized	Moldboard Plow- ing Straw Burned
	bu.	bu.	bu.
1939	55.0	53.8	52.5
1940	59.0	64.0	64.8
1941	49.5	43.3	41.0
1942	69.0	72.5	60.3
1943	67.5	71.3	63.3
Average	60.0	61.0	56.4

Average straw yields, exclusive of binder stubble:

Moldboard plowing, straw utilized	3.57 tons per acre
Moldboard plowing, straw burned	3.80 " " "
One-way disking, straw utilized	3.54 " " "

Winter wheat every year (6-year average yields, 1938-1943):

	Bu. per acre
Straw utilized, moldboard plow	26.8
straw utilized, one-way disk	23.5
Straw burned, moldboard plow	30.0

Average straw yields, exclusive of binder stubble:

Straw utilized, moldboard plow	1.09 tons per acre
Straw utilized, one-way disk	.95 " " "
Straw burned, moldboard plow	1.09 " " "

In table 20 are recorded the yields from several of the newer rotations at Moscow, Idaho. For the short period of time the four rotations were in progress, the results show that the two-year rotation of winter wheat and peas gave highest returns. The highest yield of wheat was obtained after fallow, but the highest total crop production per acre was produced from the rotation of

winter wheat and peas. The high yields obtained indicate that the present fertility level of the land used for these rotations is high enough that the practice of fallowing or of turning under green manure crops is not necessary.

Table 20 --Average yields per acre from several rotations in Field 7 at the Moscow, Idaho, Experiment Station.

Rotation No.	Acres yield	Av. yield per acre per year for all crops*
1. Winter wheat--peas	bu.	bu.
Winter wheat	53.2 /a	
Peas	22.4 /b	37.8
2. Winter wheat--fallow		
Winter wheat	60.0 /a	30.0
(Moldboard plow with straw utilized)		
5. Peas with sweetclover--sweetclover under--winter wheat--winter wheat		
Peas with sweetclover	24.6 /b	
Sweetclover turned under		
T/A air dried	3.0 /a	
Winter wheat after clover turned under	56.5 /a	
Winter wheat after w. wheat	44.7 /c	31.5
6. Peas for green manure--winter wheat--winter wheat		
Winter wheat after peas turned under	51.8 /b	
Winter wheat after w. wheat	37.2 /c	
Peas plowed under T/A air dried	2.2 /a	29.7

/a 5-year average yield

/b 6-year average yield

/c 4-year average yield

* Total yield of all crops divided by the number of years in the rotation.

The results in 1942 and 1943, shown in table 21, from the experiment conducted on a clay hilltop are interesting, and important if they are indicative of future results. Good yields of alfalfa and grass were obtained. After the plots with alfalfa and the alfalfa-grass mixture were cropped to wheat, the yields were more than twice those obtained from the plots that had continuously grown wheat. The wheat yield after grass alone was much lower than the yields after

alfalfa or after the alfalfa-grass mixture. At some other stations wheat yields after fallow on land that had been in grass for a period of years were little or no higher than the yields on land where no grass had been grown. Where grass is grown without an accompanying legume and cut for hay or seed, the soil fertility level apparently is not changed enough to appreciably influence wheat yields. Where an erosion hazard exists, the residual effect of the grass sod would aid in preventing soil and water losses. And it would be expected that any saving of topsoil or of water would be reflected in yields of subsequent crops.

Table 21.—Crop yields in 1942 and 1943 on a south slope (clay outcrop area) and yields of spring wheat when grown continuously and when grown after alfalfa and after grass at Moscow, Idaho. (Started spring 1938).

Plot No.		Yield per Acre		
		1942	1943	Average
1,5,9	Continuous spring wheat, bu.	14.0	19.4	16.7
2	Alfalfa, tons	3.2	3.6	3.4
3	Alfalfa, Brome and Crested wheat-grass, tons	2.8	3.7	3.3
4	Crested wheatgrass, lbs. seed	35.0	44.0	39.5
6	Spring wheat after 4 years of alfalfa, bu.	31.5	51.3	41.4
7	Spring wheat after 4 years alfalfa & grass, bu.	32.7	45.5	39.1
8	Spring wheat after 4 years of crested wheatgrass, bu.	18.7	22.2	20.5

Plots 1, 5, and 9 are in continuous wheat. Since 1938 plot 6 was in alfalfa, plot 7 in alfalfa and grass, and plot 8 in Crested wheatgrass. Each of these plots was plowed in the fall of 1941 and planted to spring wheat in 1942 and 1943.

THE OREGON AGRICULTURAL EXPERIMENT STATION

Tillage, crop rotations and fertilizer investigations in the wheat growing areas of eastern Oregon are carried on by the Branch Stations at Moro, Pendleton and Union. The work at Moro and at Pendleton is conducted cooperatively by the State Agricultural Experiment Station and two Bureaus of the U. S. Department of Agriculture, the Bureau of Plant Industry, Soils and Agricultural Engineering, and the Soil Conservation Service.

METHODS OF EROSION CONTROL FOR SUMMER-FALLOWED LAND

Under the leadership of Mr. Joseph Belanger of the Soil Conservation Service, a cooperative project was initiated in 1939 to study the effect on erosion, yield, soil moisture and nitrates, of various tillage methods on land in eastern Oregon devoted to growing wheat alternating with fallow. Work on the project is under way on the Branch Stations at Pendleton and at Moro. The tabular data which follow were taken from Mr. Belanger's progress reports.

Results at Pendleton. A summary of the results of an experiment to determine the effect on yield of depth of tillage, straw position and light nitrate fertilizer applications at Pendleton is given in table 22. For each treatment, triplicated and randomized plots were used.

tillage
For the three initial methods, the results were not consistent for the four years the experiment was under way at Pendleton. The average yields from the subsurface tilled and one-way disked plots were identical in 1940, and averaged 5.1 bu. per acre less than from the moldboard plowed plots.

In 1941 the average yields from the three initial tillage methods were very close together, but in 1942 the subsurface tilled plots were low in yield. In 1942 the average yields from the moldboard plowed and one-way disked plots were identical. In 1943 the plots plowed with a moldboard plow exceeded the yield of the plots one-way disked 6.6 bu. per acre, and exceeded the yield of the subsurface tilled plots 12.8 bu per acre.

The deeper initial tillage increased average yields two bushels per acre when done with the moldboard plow or one-way disk, but failed to increase yields when the land was subsurface tilled.

Light applications (50 lbs.) of ammonium sulfate slightly increased yields from land plowed with the moldboard plow and from one-way disked land, but did not increase the average yield from land subsurface tilled. In another experiment conducted in 1941 and 1942 (see table 24), applications of 50, 100 and 150 lbs. of ammonium sulfate to stubble mulch fallow resulted in substantial yield increases both years. Why contradictory results were obtained from the two experiments is not yet known. Additional trials will be needed to determine whether the response from nitrogenous commercial fertilizers will vary for the three types of initial tillage.

Table 22 --Yields of winter wheat grown after fallow at the Pendleton, Oregon, Field Station, with various tillage and fertilizer treatments, for the year 1940 to 1943, inclusive.

Straw Position	Year	5 inches deep		8 inches deep		Average
		Check No ferti- lizer	50 lbs Am. Sulfate before plowing	Check No ferti- lizer	50 lbs Am. Sulfate before plowing	
		bu.	bu.	bu.	bu.	bu.
Straw covered (moldboard plow)	1940	27.1	33.0	30.2	37.9	32.2
	1941	32.1	36.0	37.9	39.4	35.6
	1942	35.2	39.1	34.3	39.7	37.1
	1943	45.6	50.2	46.8	47.3	47.7
Average		35.0	39.6	37.5	41.1	
Straw on top (Subsurface Tillage)	1940	27.8	28.0	24.7	27.5	27.0
	1941	34.8	36.5	36.2	36.8	36.1
	1942	34.2	33.1	31.5	31.6	32.6
	1943	36.6	31.8	34.7	36.5	34.9
Average		33.4	32.4	31.8	33.1	
Straw mixed (one-way disk)	1940	26.0	25.8	26.2	30.3	27.1
	1941	34.9	39.2	37.2	40.0	37.1
	1942	35.2	37.8	36.6	39.0	37.2
	1943	38.2	41.1	40.5	44.5	41.1
Average		33.6	36.0	35.1	38.5	
		<u>5-inch tillage</u>		<u>8-inch tillage</u>	<u>5 & 8 inch</u>	
Moldboard plowing, 4-year average		37.3		39.3	38.3	
Subsurface tillage, 4-year average		32.9		32.5	32.7	
One-way disking, 4-year average		34.8		36.8	35.8	

These studies also have shown that the accumulation of nitrates in the soil during the fallow season has been influenced by the position of the straw. The greatest build-up has occurred where the surface was black (straw covered), next where the straw was mixed, and least where the straw was on the surface. The difference ordinarily has not been great at seeding time. In the spring, following fall seeding, there is another period when surface straw has caused less nitrates to be available for the crop, as is indicated by the data in table 23, which show the quantity of nitrates in parts per million on four dates in the spring of 1942 in the surface 3 inches of fallow land not fall seeded:

Table 23 —Nitrates in parts per million in surface three inches of soil on various dates in the spring of 1942, at Pendleton, Oregon.

Date of Sampling	No Straw	10% Density	18% Density	35% Density
March 25	12	10	7	6
April 10	18	14	10	8
April 25	33	28	15	13
June 1	47	21	17	11

(Variation of 5 PPM significant to 5%)

10% density, about 1 ton per acre

18% density, about 2 tons per acre

35% density, about 3 tons per acre

Where the nitrate depression caused by stubble mulch has resulted in a yield reduction, the possibility of overcoming this reduction by the addition of available nitrogen is indicated by the data in table 24.

Table 24 —Effect on yield at Pendleton, Oregon, of varying quantities of ammonium sulfate applied to stubble mulch fallow at time of initial tillage.

Pounds per acre $(\text{NH}_4)_2\text{SO}_4$	0	50	100	150
Bushels wheat per acre 1941	34.0	38.1	43.2	48.1
Bushels wheat per acre 1942	32.3	36.6	39.5	43.6
Mean	33.1	37.4	41.4	45.8

Results at Moro. Table 25 gives the yield data for winter wheat grown after fallow at Moro on a series of plots with initial tillage so as to have the straw covered (moldboard plowed), the straw on top (subsurface tilled), and straw mixed (one-way disked). Each initial tillage method was done at two depths and with light fertilizer applications for each of the four years 1940-1943. No significant yield differences were obtained from plowing 5 inches and 8 inches deep, and the yields recorded in table 25 are averages from two depths of initial tillage each year. The yields were exceptionally low in 1940 and higher than normal for each of the other three years. For the first 3 years the average yields were nearly identical from the three initial tillage methods. In 1943 the subsurface tilled plots averaged about 5 bu. per acre less than from the moldboard and one-way disked plots.

Table 25 —Yields of winter wheat after fallow plowed with a moldboard plow, one-way disked, and subsurface tilled, with and without fertilizer applications, at Moro, Oregon, for the years 1940 to 1943, inclusive.

Treatment and year		Moldboard plowed	One-way disked	Subsurface tilled
No fertilizer	1940	8.8	9.8	9.8
	1941	41.6	39.4	41.6
	1942	38.8	38.4	39.3
	1943	<u>33.2</u>	<u>31.2</u>	<u>27.4</u>
	Average	30.6	29.7	29.5
Ammonium sulfate, 50 lbs. per acre at time of seeding	1940	8.4	11.0	9.7
	1941	44.6	42.1	44.8
	1942	38.6	38.0	40.6
	1943	<u>36.2</u>	<u>37.2</u>	<u>29.4</u>
	Average	32.0	32.1	31.1
Ammonium sulfate, 50 lbs. per acre at time of plowing	1940	10.2	9.9	10.2
	1941	42.9	41.4	43.7
	1942	38.3	36.8	40.3
	1943	<u>33.0</u>	<u>34.6</u>	<u>30.4</u>
	Average	31.1	30.7	31.2
Average for all treatments		31.2	30.8	30.6

Differences in moisture content of the soil at Moro under different straw positions are most pronounced in the first foot, as is indicated by the data in table 26.

Table 26 --Percent moisture in the soil, at 3-inch intervals, at seeding time in the fall of 1942 at Moro, Oregon.

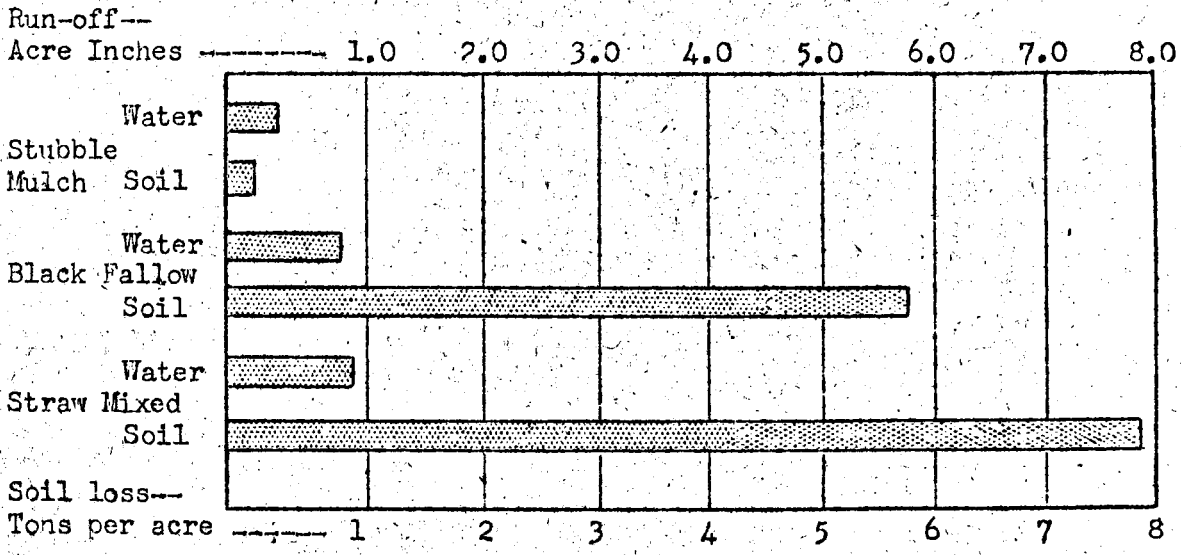
	<u>Straw on Surface</u>	<u>Straw mixed</u>	<u>Straw covered</u>
First 3 inches	7.1	3.8	2.5
Second 3 inches	12.5	9.1	7.4
Third 3 inches	13.9	10.6	11.1
Fourth 3 inches	14.1	11.1	11.2

Runoff and soil loss data for the plots at Moro are given in table 27 and are shown graphically in figure 8. Soil erosion on the stubble mulch tillage was practically negligible. In 1942 the one-way disked plots lost one inch of water as runoff and 12 tons of soil per acre. The differences in soil loss between the one-way disked (straw mixed) plots and the moldboard plowed (straw covered) plots may have been caused by an extra disking of the fallow after initial tillage on the one-way disked plots in order to get the straw thoroughly mixed with the surface soil. The highest soil and water losses occurred in 1943, when both the moldboard plowed and one-way disked plots lost a little more than 1.5 inches of water and about 19.5 tons of soil per acre.

Table 27 --Water and soil loss from land planted to winter wheat after a season of fallow for the years 1940 to 1943, inclusive, at Moro, Oregon. (6 plots, 2 of each tillage treatment, each year. Plots 87' x 10', Slope, 8% to 10%)

Type of Tillage (Straw Position)	Water loss expressed as acre inches. Soil loss expressed as ton per acre									
	1940		1941		1942		1943		Mean	
	Water	Soil	Water	Soil	Water	Soil	Water	Soil	Water	Soil
Stubble Mulch (Sub-tillage)	.0	.0	.18	Trace	.53	.25	.65	.28	.34	.13
Black Fallow (Moldboard)	.22	Trace	.33	Trace	.84	3.00	1.72	19.68	.78	5.67
Straw Mixed (Disk)	.58	Trace	.54	Trace	1.03	12.00	1.68	19.22	.96	7.80

Figure 8 --Water and Soil losses, 4 year Average, as Shown in Table 27.



The following is taken from a summary in Mr. Belanger's latest progress report:

In the Columbia Basin counties of Oregon the two main factors influencing crop yields are available nitrogen and moisture. Repeated fertilizer trials on the Experiment Stations at Moro and Pendleton have shown nitrogen to be the only plant food element to which wheat will respond. The response to added nitrogen may be an increase or a decrease in yield, depending on whether a deficiency or a sufficiency of available nitrogen was already present. Whether a given amount of available nitrogen is deficient, sufficient, or excessive depends not on the absolute quantity of nitrogen available but on whether an inadequate or an adequate supply of moisture also is available. The effect of either of these two factors, then, is one of relationship to the other, rather than a result of the absolute quantity of either. This relationship is absolutely basic and must be taken into account in any experiments to determine the influence on wheat yields of tillage, fertilizers, or crop residue disposal.

As compared to the traditional black summerfallow, results thus far indicate that:

Stubble mulch decreases the supply of nitrates available to the crop.

Stubble mulch increases the supply of moisture available to the crop.

The decrease in nitrates under stubble mulch occurs largely in the spring of the crop year, following fall seeding, and probably is due to reduced soil temperature and excessive straw in the top 3 inches of soil.

The increase in available moisture under stubble mulch is due to a reduction in evaporation losses (which may, as in the case of nitrates, be due to lower surface temperatures) as well as to reduced loss through direct run-off.

In areas of less than about 12 inches annual precipitation the normal nitrate development in soil of early plowed, clean cultivated fallow usually is adequate or slightly in excess of the amount needed to have a correct balance between nitrates and available moisture. Added nitrates cause "burning" or drought injury. Reduced moisture also causes burning. The safe way to vary the two main factors controlling yield in this area is to increase moisture and to decrease nitrates. In this area, therefore, the stubble mulch which is needed for erosion control acts as insurance when moisture is less than normal, but it may reduce the peak yields in years of abnormally high precipitation. By and large, in areas of less than 12 inches annual precipitation, surface stubble should maintain or increase yields.

In areas of more than 12 inches annual precipitation reduced nitrates reduce the grain yield and increased moisture may have little effect unless added nitrogen is supplied to the crop. Therefore, by and large, in areas of more than 12 inches annual precipitation, surface stubble will decrease yields on average soils that are low in total nitrogen.

THE PENDLETON BRANCH EXPERIMENT STATION

The Pendleton Branch Station was established in 1929. It is located on a comparatively level tract of land near Adams and about ten miles northeast of the city of Pendleton. The soil is typical Walla Walla silt loam. The Station land had been cropped to wheat and fallow for about 40 years before the establishment of the Station.

The average precipitation for the crop years ending August 31, was 14.68 inches for the years 1929 to 1942, inclusive. The lowest, 10.45, was in 1929 and the highest, 20.78 inches, was in 1942.

The principal lines of investigation in progress are crop rotation, tillage and fertilizer experiments, and cereal and forage crop improvement studies. All research work on the Station is conducted under cooperative agreements between the Oregon Agricultural Experiment Station and the Bureau of Plant Industry, Soils and Agricultural Engineering, and the Soil Conservation Service. Mr. George A. Mitchell has been in charge of the work since the establishment of the Station.

CROP RESIDUE EXPERIMENTS

Since the establishment of the Station at Pendleton, studies have been in progress to determine the effect of various tillage and cropping practices on the yield of wheat after fallow.

In table 28 are given the annual and average yields of winter wheat grown after fallow for the 12-year period, 1931-1942, inclusive, for several methods of crop residue disposal, including the application of barnyard manure and nitrogenous commercial fertilizers. The crop year precipitation, ending August 31, for each of the years 1931 to 1942 is also shown.

The land used in this experiment was plowed 7 to 8 inches deep early in the spring with a moldboard plow and all plots given uniform cultivation during the fallow season. The cultivation necessary to control weeds and volunteer growth usually was two harrowings with a spring tooth harrow and two weedings with a revolving rod weeder. The plots were rod weeded and spike tooth harrowed immediately prior to seeding and seeded with a single disk drill.

For the first three years yields from most of the different treatments were quite close together. Since 1934, the fertilized plots in most years yielded highest. There was quite a decided upward trend in yield from the manured plots, as shown in figure 9. In 1942, with a yield of 62 bushels per acre, lodging occurred for the first time on the manured plots. Slight lodging also occurred on the plots to which pea straw was applied, but no lodging occurred on any of the other plots. Based on a four-year average, the yield trend was downward for all treatments except

for the application of manure and the addition of pea straw, as is shown in figure 9. The yield from the plots to which one ton of pea straw was plowed under with the wheat straw exceeded the yield of the plots receiving 150 lbs. of nitrogenous commercial fertilizer in each four-year period. The value of pea straw as a fertilizer apparently is not appreciated by farmers, many of whom in the Palouse area burn the pea straw after harvest on land where it is needed to help maintain the nitrogen level of the soil. The pea straw, especially if left on or near the surface, also will aid in controlling erosion.

From yield data in table 28 and figure 9, the evidence is convincing that the application of nitrogenous fertilizers was beneficial. The greatest increase in yield was obtained from the application of 10 tons per acre of barnyard manure for every crop. The greater yield increase from the manure was no doubt because the quantity applied contained about three times as much nitrogen as was contained in the amount applied in the commercial fertilizer. The application of 150 lbs. per acre of ammonium sulfate or calcium nitrate more than counteracted the yield depression caused by utilizing the straw. For the first 4-year period, the average yields from the plots with commercial fertilizer applications and those with the straw burned were practically identical. For the second and third 4-year periods, however, the average yields from the plots with commercial fertilizer applications were higher than from those with the straw burned.

In figure 9, the average yields by 4-year periods are shown for winter wheat grown after fallow with five different treatments in the crop residue experiments, and also the crop year precipitation for the same 4-year periods. Yields also are shown for two 4-year periods for winter wheat grown after fallow, with all straw utilized, on land that had grown alfalfa for hay in 1930, 1931 and 1932. The wheat yields shown in the graph are for the second, third, fourth and fifth crops on the alfalfa land. As is shown later, there was a substantial reduction in yield for the first crop grown after fallow on the alfalfa land.

The average yields obtained from the second, third, fourth and fifth wheat crops after fallow on alfalfa land, with all straw plowed under, were significantly higher than the yields obtained from fallow land which had grown no legume with straw plowed under, straw burned, or straw plowed under plus 150 lbs. per acre of calcium nitrate.

Table 28 — Annual and average acre yields in bushels of fall sown wheat after fallow plowed with a moldboard plow in the crop residue experiments at Pendleton, Oregon, for the years 1931 to 1942, inclusive, (4 one-tenth acre plots were used for each treatment, two in crop and two in fallow. Plots were harvested with a small combine.)

Treatment	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	Average
10 T per acre manure added to total straw	44.4	51.3	50.5	38.4	49.5	50.5	52.8	48.3	45.7	53.1	43.8	62.0	49.2
1 T pea straw added to total straw	45.7	49.4	53.2	36.6	46.6	41.6	49.8	38.7	40.9	41.2	48.5	54.9	45.6
Fall disked, all straw plowed under + nitrate fertilizer*	35.5	51.6	50.8	38.4	48.8	42.8	45.1	41.5	43.3	38.8	34.3	51.8	43.6
Spring disked, all straw plowed under + nitrate fertilizer	38.2	49.5	51.2	37.1	44.7	41.8	48.0	39.1	41.4	37.5	34.5	51.8	42.9
Straw burned in spring	45.0	48.7	51.4	33.5	44.0	40.2	47.2	33.7	39.9	37.7	31.0	46.2	41.5
Straw burned in fall	39.9	49.7	49.3	33.4	43.2	38.6	42.3	32.7	39.4	34.6	30.9	43.4	39.8
All straw plowed under not disked	42.2	49.0	48.8	34.0	41.0	35.3	43.4	34.1	35.6	31.9	27.5	46.2	39.1
All straw plowed under Spring disked	36.7	50.3	50.2	30.3	39.4	33.9	41.4	38.8	36.8	30.3	27.5	43.1	38.2
All straw plowed under Fall disked	37.6	49.7	49.9	28.5	39.3	31.9	41.0	30.6	35.7	31.4	26.8	42.2	37.1
Average	40.6	49.9	50.6	34.5	44.1	39.6	45.7	37.5	39.9	37.3	33.9	49.1	
Crop year precipitation, inches	13.7	15.5	14.3	12.9	13.3	13.0	14.9	15.7	12.4	16.1	19.9	20.8	15.2

*Fertilizer - 150 lbs. per acre of ammonium sulfate or calcium nitrate.

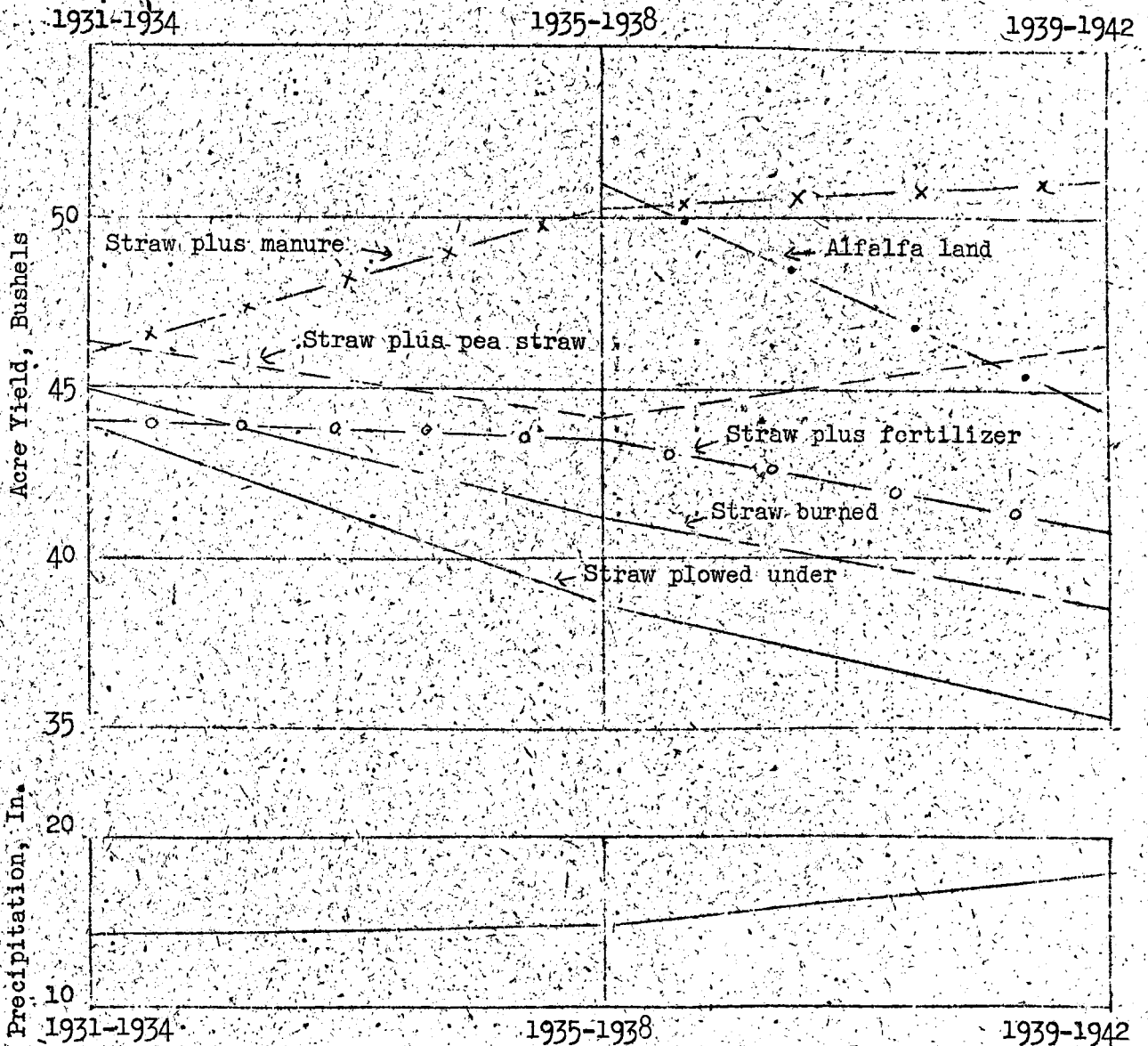


Figure 9 ---Acre yields in bushels, by 4-year periods, of winter wheat grown after fallow with various residue and fertilizer applications, and yields of winter wheat after fallow on alfalfa land; also crop-year precipitation by 4-year periods at the Pendleton Branch Experiment Station, Pendleton, Oregon.

EFFECT OF CROPPING SYSTEMS ON SOIL ORGANIC

MATTER AND TOTAL NITROGEN

Under the supervision of Prof. J. S. Jones of the Oregon Experiment Station, total nitrogen and organic matter determinations were made in 1931 and in 1941 of the soil of the plots used in the crop residue and crop rotation experiments at the Pendleton Branch Experiment Station. Only very slight changes in the total nitrogen occurred during this interval in the surface foot of soil of most of the plots. The soil of the plots devoted to winter wheat and fallow, except those receiving applications of barnyard manure and of pea straw, showed a slight decrease in total soil nitrogen in the surface foot. These losses ranged from .001% to .008% in the soil of 12 one-tenth acre plots in the crop residue trials with straw utilized. Where 10 tons per acre of manure were applied biennially, there was a slight increase in total soil nitrogen. Where one ton of pea straw per acre was applied, and plowed under with the wheat straw, the total nitrogen of the soil was approximately the same in 1941 as in 1931. In the rotation experiments also there was a slight decrease in total nitrogen of the surface foot of soil of the plots devoted to winter wheat and fallow, and an increase in nitrogen of the soil of the plots devoted to rotations of wheat and peas and of winter wheat-mahured fallow. In the wheat-pea rotations both the wheat straw and pea straw were utilized.

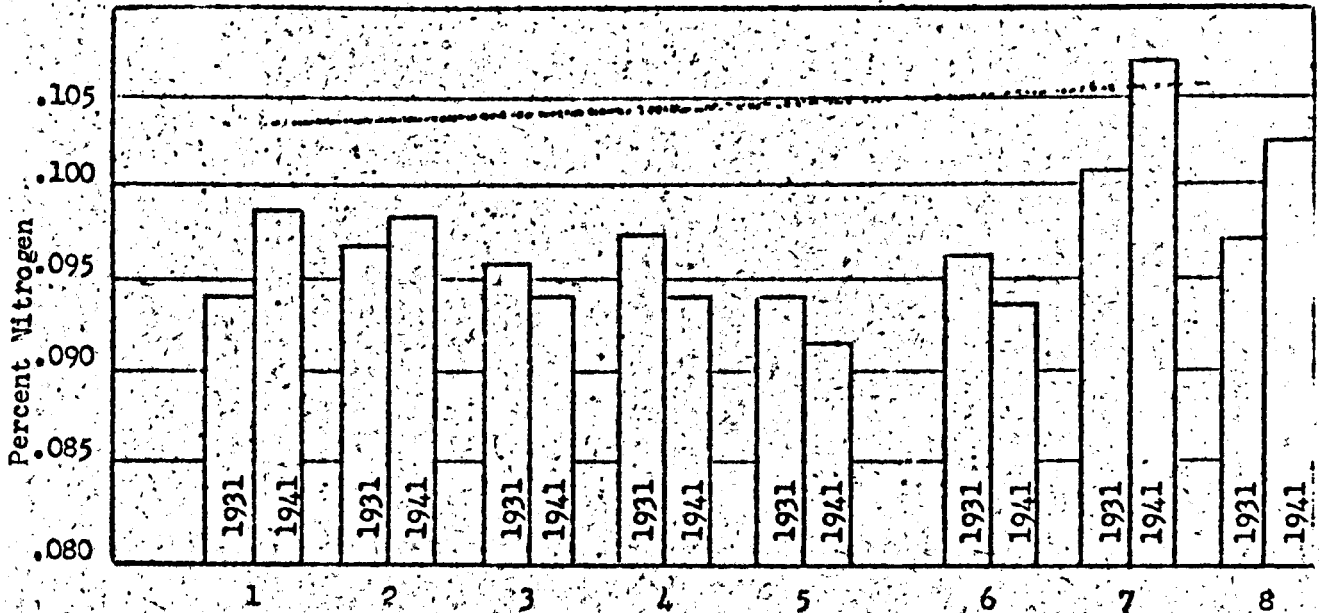
If the soil had been sampled only to a 6- or 7-inch depth, greater differences no doubt would have been obtained, as the greatest changes in total nitrogen would be expected to occur in the plowed layer. The differences in total nitrogen in the surface foot of soil, though small, were consistent enough in the many plots sampled to indicate a definite trend.

The total nitrogen in the surface foot of soil in 1931 and 1941 of the plots of the crop residue experiments and of several of the rotation plots, is shown graphically in figure 10, and yield data are shown in table 29.

Total nitrogen determinations of the second foot of soil of these plots also were made in 1931 and in 1941, as well as organic matter determinations for the first and second feet. The data for the nitrogen determinations for the second foot were not as consistent for different plots given identical treatments as were those from the first foot, indicating either more soil variability or a greater sampling error, or both, for the second foot of soil. The nitrogen changes in the second foot of soil also did not always show the same trend as did those in the first foot.

All plots in the crop residue trials showed losses in organic matter for the first and second feet of soil, with higher losses in most cases for the second foot. The magnitude of these losses for most treatments was in excess of the experimental error of .2% allowed in soil organic matter determinations. (See U.S.D.A. circular 139 of the Division of Soil Chemistry and Physics.) The smallest losses in organic matter occurred in the soil of the plots to which manure and pea straw were applied.

The results from other soil organic matter and nitrogen determinations at Pendleton, as well as those from similar studies from the rotation plots at the Sherman Branch Station at Moro, should be published in the near future. More information is needed to determine more accurately the effect of different cropping practices on soil nitrogen and organic matter, and how variations in these important soil constituents affect erosion, tilth, infiltration, nitrification, and crop yields.



Crop Residue Trials (winter wheat--fallow):

1. Straw plus manure (4 plots)
2. Straw plus pea straw (4 plots)
3. Straw plus fertilizer (8 plots)
4. Straw plowed under (12 plots)
5. Straw burned (4 plots)

Crop Rotations:

6. Winter wheat--fallow (4 plots)
7. Winter wheat--fallow plus manure (8 plots)
8. Wheat--peas (8 plots)

Figure 10 --Percent nitrogen in 1931 and in 1941 in the surface foot of soil in the crop residue plots and in the soil of plots used in three rotations at the Pendleton Branch Experiment Station at Pendleton, Oregon. Each comparison is an average of from 4 to 12 one-tenth acre plots, with eight composited soil samples from each plot. All crop residues were utilized except where indicated.

Table 29 —Average 12-year yields and gains or losses in total nitrogen in the surface foot of soil of plots in the crop residue experiments and several rotations at the Pendleton Branch Experiment Station.

	12-year ave. acre yields bu.	Gain + or loss - in nitrogen lbs. per acre surface foot 1931-1941 /1
<u>Crop Residue Experiments</u>		
(Wheat after fallow)		
Straw plowed under	38.2	-105
Straw burned	40.7	-140
Straw plus 150 lbs. per acre commercial fertilizer plowed under	43.3	-70
Straw plus one ton pea straw plowed under	45.6	+35
Straw plus 10 tons manure plowed under	49.2	+175
<u>Rotation Experiments</u>		
Winter wheat after fallow	43.6	-105
Spring wheat after fallow	43.4	+35
Winter wheat after manured fallow	51.0	+175
Winter wheat after fallow with top dressing of manure in spring	49.6	+245
Winter wheat after peas	29.9	+140
Peas after winter wheat	20.6	+140
Spring wheat after peas	32.1	+210
Peas after spring wheat	20.3	+210

/1 Based on 3.5 million lbs. as weight of an acre foot of soil.

LEGUMES IN ROTATION WITH CEREALS

Alfalfa and sweetclover, two crops which, when grown in mixtures with grasses, are highly recommended for their value in controlling erosion and maintaining soil fertility, have been grown in a few rotations on the Pendleton Station

In the spring of 1930 fourteen one-tenth acre plots were seeded to alfalfa. In the spring of 1932 six of these plots (Nos. 1308, 1309, 1310, 1318, 1319 and 1320) were plowed and left fallow during the summer. Two plots, Nos. 1308 and 1318 were seeded to winter wheat in the fall of 1932, two plots were seeded to spring wheat and two to spring barley in the spring of 1933. Winter wheat, spring wheat, and barley alternating with fallow have been continued on these same plots since 1933.

The other plots were plowed in the spring of 1933, fallowed during the summer and also seeded to winter wheat, spring wheat, and barley. Yield data, therefore, are available for each of these crops grown after fallow on land which had grown alfalfa for two years and for three years respectively.

A comparison of the yields of winter wheat on the alfalfa land and on land similarly cropped in the crop residue and rotation experiments is given in table 30. The 1941 yield in the crop residue experiment is not included in the comparison because of a difference in date of seeding for that year.

Similar comparisons are made for spring wheat and for spring barley in tables 31 and 32.

It will be noted from these tables that rather large reductions in yield occurred for the winter wheat, spring wheat, and barley the first year these crops were grown after fallow on the alfalfa land. For the second, third, and fourth crops, however, substantial increases in yields were obtained in nearly all cases on the alfalfa land, especially on the plots that had been in alfalfa for three years.

Table 33 shows the yields of wheat in two rotations, one with and one without a legume at the Pendleton Station. Rotation 142 is a 6-year rotation and includes three years of alfalfa, fallow the fourth year, winter wheat the fifth year, and corn the sixth year. The alfalfa yields in this rotation averaged 1/2 ton per acre the year the alfalfa was seeded, and 1.5 tons per acre the second and third years. The winter wheat in this rotation, each crop of which was after fallow preceded by three years of alfalfa, yielded considerably less than did the winter wheat in Rotation 186, with no legume, except for the last three years when the precipitation was higher than normal. This added moisture in 1940, 1941 and 1942 increased the yields on the alfalfa land, but failed to

appreciably increase the yields of wheat in the other rotation with no legume. This emphasizes the importance of the relationship or balance between moisture and nitrates in influencing yields on dry lands. An abundance of nitrates without adequate moisture will often result in "burning" or drought injury. On the other hand, an abundance of moisture without an adequate supply of nitrates will result in low yields of low protein wheat.

In table 34 yield data are given for a 3-year rotation of winter wheat—sweetclover—sweetclover for hay. For comparison, yields also are given for another 3-year rotation (No. 568), winter wheat—winter wheat—fallow. The yields of winter wheat after fallow in the latter rotation were considerably higher every year than those obtained after sweetclover:

In 1939 the sweetclover rotation was discontinued and the land thereafter cropped to a rotation identical with No. 568, winter wheat—winter wheat—fallow. Yield comparisons for four years, therefore, can be made between two identical rotations, one on land that had previously grown sweetclover for hay and one on land that had never grown a legume. The data in table 34 show that the wheat after fallow on the sweetclover land for a four-year period averaged 6.4 bushels more per acre, and that the wheat after wheat on the sweetclover land for a 3-year period averaged 10.8 bushels more per acre than did the wheat in the same rotation without the legume.

All plots for which wheat yields are listed in tables 30 to 34, inclusive, were harvested with a small combine and all straw was plowed under with a moldboard plow.

Table 30 —Acre yield, in bushels, of winter wheat grown after fallow on land previously cropped to alfalfa and on land on which no legume had been grown at Pendleton, Oregon.

Year	After alfalfa 2 or 3 years and fallow	(1)	(2)	Average of (1) and (2)	Increase (+) or Decrease (-) for alfalfa land	
1933	33.5 <u>/a</u>	48.8	47.2	48.0	-14.5	(1st crop after 2 yrs. alfalfa and fallow)
1934	29.2 <u>/b</u>	34.0	36.4	35.2	- 6.0	(1st crop after 3 yrs. alfalfa and fallow)
1935	49.5	41.0	49.5	45.3	+ 4.2	(2nd crop on 2 yr. alfalfa land)
1936	45.0	35.3	41.5	38.4	+ 6.6	(2nd crop on 3 yr. alfalfa land)
1937	53.1	43.4	43.8	43.6	+ 9.5	(3rd crop on 2 yr. alfalfa land)
1938	55.9	34.1	43.1	38.6	+17.3	(3rd crop on 3 yr. alfalfa land)
1939	41.8	35.6	39.3	37.5	+ 4.3	(4th crop on 2 yr. alfalfa land)
1940	39.0	31.9	33.8	32.9	+ 6.1	(4th crop on 3 yr. alfalfa land)
1941	44.4	27.5 <u>/c</u>	48.0	48.0	- 3.6	(5th crop on 2 yr. alfalfa land)
1942	<u>53.8</u>	<u>46.2</u>	<u>52.7</u>	<u>49.5</u>	+ 4.3	(5th crop on 3 yr. alfalfa land)
Average	44.5	38.9	43.5	41.7		

(1) Yield in Crop Residue Experiments, straw utilized, no disking.

(2) Yield in Rotation 267, winter wheat—fallow

/a First crop after two years of alfalfa and fallow.

/b First crop after three years of alfalfa and fallow.

/c Omitted from average. See text.

Table 31 --Acre yields, in bushels, of spring wheat grown after fallow on land previously cropped to alfalfa and on land on which no legumes had been grown at Pendleton, Oregon.

Year	After alfalfa 2 or 3 years and fallow	After fallow with no legume (Rotation 181)	Increase (+) or Decrease (-) for alfalfa land	Remarks
1933	38.3 /1	51.6	-13.3	1st crop after two years of alfalfa and fallow
1934	30.5 /2	40.8	-10.3	1st crop after 3 years of alfalfa and fallow
1935	45.5	45.8	- 0.3	2nd crop on 2 yr. alfalfa land
1936	48.3	46.2	+ 2.1	2nd crop on 3 yr. alfalfa land
1937	49.5	45.8	+ 3.7	3rd crop on 2 yr. alfalfa land
1938	54.6	47.9	+ 6.7	3rd crop on 3 yr. alfalfa land
1939	40.9	40.3	+ 0.6	4th crop on 2 yr. alfalfa land
1940	41.0	35.2	+ 5.8	4th crop on 3 yr. alfalfa land
1941	40.0	44.8	- 4.8	5th crop on 2 yr. alfalfa land
1942	50.4	47.2	+ 3.2	5th crop on 3 yr. alfalfa land
Ave.	43.9	44.6		

/1 1st crop after two years alfalfa

/2 1st crop after three years alfalfa

Table 32 — Acre yield of Trebi Spring Barley after fallow in varietal trials and after fallow preceded by two or three years of alfalfa.

Year	Barley after fallow on alfalfa land bu.	Barley after fallow, with no legume bu.	Increase (+) or decrease (-) for alfalfa land bu.
1933	50.6 /1	74.5	-23.9
1934	25.5 /2	49.2	-23.7
1935	46.6	44.3	+ 2.3
1936	67.3	63.0	+ 4.3
1937	70.2	67.8	+ 2.4
1938	72.7	55.1	+17.6
1939	60.3	59.6	+ 0.7
1940	56.3	38.2	+18.1
1941	82.5	68.8	+13.7

/1 1st crop after two years alfalfa

/2 1st crop after three years alfalfa

Table 33 —Acre yields of winter wheat after fallow in rotation 142, winter wheat—corn—alfalfa 3 years—fallow; and in rotation 186, winter wheat—corn—spring wheat—fallow, with crop year precipitation, for the years 1931 to 1942, inclusive.

Year	Wheat after fallow preceded by 3 years of alfalfa (Rotation 142)	Wheat after fallow in (Rotation 186)	Crop year Precipitation
	bu.	bu.	in.
1933	36.2	53.3	14.29
1934	32.4	35.3	12.86
1935	43.3	44.3	13.32
1936	37.0	42.4	13.04
1937	25.6	50.8	14.90
1938	33.8	46.7	15.74
1939	45.8	41.1	12.43
1940	48.8	39.9	16.08
1941	69.6	49.7	19.87
1942	64.6	55.5	20.78

Table 34 —Acre yields from two rotations at the Pendleton Branch Experiment Station for the years 1931 to 1942, inclusive.

Year	Rotation 189			Rotation 568	
	Winter wheat—sweetclover for hay			Winter wheat—winter wheat—fallow	
	Wheat after sweetclover cut for hay	1st year sweet- clover	2nd year sweet- clover	wheat after fallow	Wheat after wheat
	bu.	lbs.	lbs.	bu.	bu.
1931	13.5	600	3750	36.4	10.5
1932	30.7	—	730	47.1	14.6
1933	36.8	300	6650	46.8	16.8
1934	26.7	—	2850	31.1	12.9
1935	34.2	—	2455	47.4	16.8
1936	34.7	1055	875	45.4	10.4
1937	27.0	1400	1600	47.0	11.0
1938	38.8	—	3275	47.8	13.7
1939	34.2	—			11.5
<hr/>					
Rotation changed to winter wheat—winter wheat—fallow					
	Wheat after fallow	Wheat after wheat			
1939	50.2	—		45.5	—
1940	50.1	25.5		42.2	13.7
1941	58.0	21.5		50.5	15.4
1942	<u>67.7</u>	<u>23.0</u>		<u>62.1</u>	<u>8.5</u>
Average	56.5	23.3		50.1	12.5

FERTILIZER TRIALS

The adoption by farmers of the practice of using straw as a mulch for erosion control has been greatly retarded in some sections because of yield reductions resulting from the utilization of the straw as compared with burning it before plowing. These reduced yields usually are more pronounced on the higher producing lands that have been continuously cropped to wheat for so long that soil nitrogen has become the most important factor limiting crop yields. In soil low in nitrogen, too much straw, either mixed with the soil or on the surface, may retard nitrification processes, enough to reduce yields. To help overcome this, the nitrogen supply of the soil can be built up by (1) the application of barnyard manure (2) the growing of legumes or grass-legume mixtures at periodic intervals (3) the plowing under of leguminous green manure crops; or (4) additional nitrates can be supplied in the form of nitrogenous commercial fertilizers.

The response from certain fertilizers on land cropped to wheat alternating with fallow, with all the straw utilized, at the Pendleton Branch Experiment Station is shown in table 35. Duplicate plots, systematically repeated, were in crop every year, with every third plot left untreated as a check. The close agreement between the yields of the several check plots indicates a high degree of uniformity in the productivity of the soil of the area used in this trial.

As is shown in table 35, no increase in yield was obtained for the first 4-year period from the fertilized plots. Significant increases in yield were obtained from the plots receiving applications of manure or nitrogenous commercial fertilizers in the second and third 4-year periods.

Table 35 --Yield of winter wheat, by 4-year periods, in the fertilizer experiments at the Pendleton Branch Experiment Station for the years 1931 to 1942, inclusive.

Fertilizer Treatment	Acre yield, Bushels			
	1931- 1934	1935- 1938	1939- 1942	12-year average
Check, No fertilizer	39.9	37.8	36.4	38.0
150 lbs. Calcium Nitrate at seeding time	40.4	47.3	42.2	43.3
150 lbs. Calcium Nitrate in the spring	37.9	45.8	42.4	42.0
Check, No fertilizer	36.9	39.3	37.0	37.7
150 lbs. Am. Sulfate at seeding time	35.8	46.0	41.8	41.2
150 lbs. Am. Sulfate in the spring	37.7	45.7	44.8	42.7
Check, No fertilizer	40.2	38.7	36.7	38.5
200 lbs. Superphosphate at seeding time	39.8	39.8	36.2	38.6
10 tons strawy manure as top dressing	40.1	49.1	44.2	44.5
Check, No fertilizer	39.1	37.4	36.2	37.6
150 lbs. 6-10-4 at seeding time	39.1	41.0	38.4	39.5
150 lbs. 6-10-4 in the spring	37.7	41.9	38.0	39.2
Check, No fertilizer	39.6	36.5	35.1	37.1
Average	38.8	42.0	39.2	
Average precipitation by crop years, in.				
	14.1	14.2	17.3	
	<u>1st 4-yr. period</u>	<u>2nd 4-yr. period</u>	<u>3rd 4-yr. period</u>	<u>Ave.</u>
Average of check plots	39.1	37.9	36.3	37.8
Average of plots with only nitrate fertilizer and manure applications	<u>38.4</u>	<u>46.8</u>	<u>43.1</u>	<u>42.8</u>
Deviation from check plots	- 0.7	+ 8.9	+ 6.8	+5.0

TILLAGE EXPERIMENTS

In the date and depth of plowing experiments with the moldboard plow for growing wheat after fallow at the Pendleton Branch Station, the highest average yields for an 11-year period were obtained from land plowed early in the spring. For the deep and shallow (9 and 5 inches) plowing, the average yield for the 11-year period for the early (March 10) plowed land was 1.5 bushels more than for land plowed on April 15, 2.3 bushels more than for land plowed for fallow in the fall, and 4.8 bushels more than for land plowed late in the spring (May 15.) The land plowed 9 inches deep quite consistently outyielded the land plowed 5 inches deep for each of the four plowing dates, the average difference in favor of the deeper plowing being about 3.5 bushels per acre. In order to determine whether this decreased yield was due to the fact that much more straw was left on or near the surface from the shallow tillage, an experiment was started in 1938 to compare the two depths of plowing on land with all straw burned and all straw plowed under on four dates of plowing. The results from this experiment are shown in table 36.

The data in table 36 show that the straw was at least partly responsible for the reduced yields obtained from the shallow tillage. The greatest spread in yield between the plots plowed 9 and 5 inches deep occurred in 1938. The plots plowed 9 inches deep outyielded those plowed 5 inches deep 2.9 bushels per acre for the 6-year period where the straw was burned; where the straw was plowed under the average difference in yield was 3.1 bushels per acre in favor of the deeper plowing.

In table 37 the average yields for a 12-year period are shown for fallow given initial tillage in the early spring with a moldboard plow, one-way disk and double disk. Four one-tenth plots were used for each treatment, two in crop and two in fallow. The wheat was harvested with a small combine and all the straw was left on the land. During the fallow season, a revolving rod weeder was used to eradicate weeds. In most seasons little difficulty was encountered in handling the straw on the shallow plowed and disked plots where most of the straw was on or near the surface. The seeding was done with a single disk drill. The plots are located on comparatively level land and very little erosion occurred in any year.

As is shown in table 37, highest average yields were obtained from the plots plowed 9 inches deep with a moldboard plow and the lowest from the plots continuously one-way disked. For the plots alternately plowed and disked, either with the one-way or double disk, slightly higher yields were obtained from the plots plowed with the moldboard plow.

In 1936 another experiment was started to compare different methods of plowing, disking, and chiseling for initial tillage of land for fallow. The results are given in table 38. The 8-year average yield was highest for the land plowed early in the spring with a moldboard plow. The lowest average yield was obtained from the land double disked every year and next to the lowest yield from the land that was chiseled in the fall 10 to 12 inches deep and spring double disked. The land that was spring plowed with the moldboard plow outyielded the land that was fall and spring one-way disked 3.2 bushels per acre.

Table 36 —Acre yields of winter wheat from land plowed on various dates with a moldboard plow at two depths, and with all straw plowed under and all straw burned before plowing at Pendleton, Oregon, for the six-year period, 1938-1943.

Time of Plowing for fallow	Year	Straw burned		Straw Plowed under		Average
		Deep 9 in.	Shallow 5 in.	Deep 9 in.	Shallow 5 in.	
Fall (October 15)	1938	43.2	40.0	49.5	40.5	
	1939	41.5	40.8	38.0	40.7	
	1940	38.3	38.3	32.2	28.5	
	1941	36.3	33.5	32.8	27.5	
	1942	38.0	42.0	38.2	39.0	
	1943	<u>59.7</u>	<u>57.0</u>	<u>53.7</u>	<u>58.8</u>	
Average		42.8	41.9	40.7	39.0	41.1
Early Spring (March 15)	1938	53.5	38.8	45.3	39.6	
	1939	37.7	43.5	36.4	35.5	
	1940	41.5	37.3	35.0	30.4	
	1941	35.8	39.5	28.7	29.2	
	1942	41.3	39.2	40.1	37.6	
	1943	<u>59.0</u>	<u>55.2</u>	<u>57.8</u>	<u>55.1</u>	
Average		44.8	42.3	40.6	37.9	41.4
Medium early spring (April 15)	1938	51.0	42.7	48.3	40.9	
	1939	43.3	38.8	40.6	33.2	
	1940	37.8	34.5	34.1	26.8	
	1941	30.7	27.7	29.8	21.3	
	1942	37.3	37.0	37.3	32.4	
	1943	<u>52.8</u>	<u>49.0</u>	<u>51.9</u>	<u>47.9</u>	
Average		42.2	38.3	40.3	33.8	38.7
Late Spring (May 15)	1938	40.5	33.5	39.0	32.2	
	1939	33.5	35.7	35.0	33.8	
	1940	34.3	28.2	20.3	21.2	
	1941	31.5	33.3	23.2	25.7	
	1942	39.0	35.5	36.3	32.8	
	1943	<u>51.0</u>	<u>56.7</u>	<u>53.3</u>	<u>51.5</u>	
Average		38.1	37.2	34.5	32.9	35.7
Average for all dates of plowing		42.0	39.9	39.0	35.9	

Six-year average, all dates:

	Deep	Shallow
Straw burned	42.0 bu.	39.7 bu.
Straw plowed under	<u>39.9 bu.</u>	<u>35.9 bu.</u>
Difference	2.1 bu.	3.8 bu.

Table 37 — Average yields of winter wheat after fallow with several methods of initial tillage at the Branch Experiment Station at Pendleton, Oregon, for the 12-year period 1931-1942.

Treatment	Average 12-year yield Bushels
Moldboard plowing, 9 inches deep	40.9
Moldboard plowing, 5 inches deep	37.4
One-way disking, 6-7 inches deep	36.0
One-way disking and plowing alternating:	
One-way disking, 6 to 7 in. deep	37.0
Moldboard plowing, 7 in. deep	38.3
Double disking and plowing alternating:	
Double disking, 5 to 6 in. deep	37.3
Moldboard plowing, 7 inches deep	38.0

Table 38 — Annual and average acre yields of winter wheat after fallow prepared with the moldboard plow, one-way disk, chisel and double disk at Pendleton, Oregon, for the years 1936 to 1943, inclusive.

Time and method of initial tillage	Yield in bushels per acre								
	1936	1937	1938	1939	1940	1941	1942	1943	Average
Early spring moldboard plowed	32.0	40.6	40.6	29.0	30.0	32.3	47.1	50.5	37.8
One-way disked, fall and spring	38.4	32.5	40.8	24.8	27.0	31.9	44.0	37.0	34.6
Fall moldboard plowed	34.6	35.1	42.5	23.4	33.6	34.0	51.9	40.0	36.9
Fall chiseled, spring double disked	32.6	29.9	42.4	23.7	28.8	32.3	46.7	36.3	34.1
Fall and spring double disked	30.5	31.8	39.8	23.8	26.4	33.9	42.9	34.5	32.9

THE SHERMAN BRANCH EXPERIMENT STATIONMORO, OREGON

Production studies with various crops have been in progress at the Branch Station at Moro since 1912. Detailed information about soil and climatic conditions at the station and the results obtained from all experiments except those recently initiated are available in U.S.D.A. and Oregon Experiment Station Bulletins.

Following is a brief summary of the results from the tillage, crop residue and rotation experiments taken from Supt. M. M. Oveson's 1943 annual report.

TILLAGE EXPERIMENTS

(Binder stubble only left on the land)

Disking before plowing. Fall disking has had no beneficial influence on wheat yields at Moro on the average, and early spring disking has proved profitable only when the land was plowed later in the spring than May 1.

Disking vs. plowing for fallow. On shallow land, (3 to 4 feet to basalt) alternately disked and plowed for fallow, the average yields of both winter and spring wheat were practically identical from the plowed and from the disked fallow. In a field trial with winter wheat on deeper soil, higher yields were obtained from land plowed for fallow than from land continuously disked for fallow.

Time of plowing. The 30-year average yield of winter wheat from land plowed early in the spring (April 1) and given clean cultivation was 26.7 bushels per acre; from land plowed medium early (May 1) 24.9 bushels, and from land plowed late in the spring (June 1) 19.3 bushels per acre.

Depth of plowing. Land plowed 5 inches deep for fallow averaged 21.0 bushels per acre of winter and spring wheat for a 30-year period and 21.5 per acre on land plowed 10 inches deep.

Cultivation of summer fallow. The 17-year (1927-1943) average wheat yields obtained from three methods of cultivating summer fallow after plowing with a moldboard plow were as follows:

Minimum cultivation (weeds taken off before maturity with a hoe or with a rod weeder)	22.3 bu. per acre
Clean cultivation (harrowing immediately after plowing and rod-weeding often as necessary to control weeds)	24.2 bu. per acre
Delayed cultivation (harrowing 30 days after plowing and rod-weeding often as necessary to control weeds)	23.7 bu. per acre

CROP RESIDUE EXPERIMENTS

The plowing under of wheat straw has not decreased the yield of wheat at Moro. Plots on which the total wheat straw was returned averaged 26.4 bushels per acre, while adjacent plots on which the straw was burned averaged 24.6 bushels for a 19-year period.

In this same experiment, the average yield from plots with 10 tons per acre of coarse barnyard manure plowed under for each crop averaged only 24.0 bushels of wheat per acre. A top dressing of pea straw before plowing has not increased wheat yields over land with the total wheat straw plowed under. For a nine-year period, the land receiving one ton of pea straw before plowing for fallow averaged 24.3 bushels per acre of spring wheat while land with the wheat straw returned averaged 24.4 bushels.

An experiment was started in 1937 to determine the effect of surface straw on yields of winter wheat when grown after fallow. Two tons per acre of straw were applied on eight plots. For initial tillage in the spring of 1937 four of these plots were double disked twice, and four were plowed with the moldboard plow with jointer attachments. For the fallow seasons of 1938 and 1939, the "stubble mulch" plots were disked once and then plowed with a lister bottom plow. In 1940, 1941 and 1942 the stubble mulch plots were given initial tillage with a lister bottom plow. In all years, the "black fallow" plots were plowed with a moldboard plow with jointer attachments. A revolving rod-weeder was used to eradicate weeds during the fallow season on all plots. The plots are located on comparatively level land and there was no appreciable soil loss from any of the plots in any year.

All plots were seeded with a double disk drill for the first three years. In 1941 and in 1942 they were seeded with a deep-furrow drill. Hard Federation 31 spring wheat was seeded in 1943 with a single-disk drill.

The yield data for this experiment are given in table 39. The results show that in each of the six years lower yields were obtained from the stubble mulch plots, the greatest differences being in 1938 and 1943. In three out of the six years the yield differences were great enough to be statistically significant. In 1938 the plots that had received two double diskings for initial tillage were quite heavily infested with weeds. In the other five years weeds were not a factor in influencing yields.

Table 39 — Annual and average yields of Oro winter wheat in bushels per acre grown on two different types of summer fallow at Moro, Oregon during the years 1938 to 1943, inclusive. Yields for each type of fallow are averages from four one-tenth acre plots.

Method of Fallow	1938	1939	1940*	1941	1942	1943*	Total	Ave.
Stubble mulch fallow	23.3	26.9	14.4	32.0	29.9	23.7	150.2	25.0
Black fallow	27.6	28.9	15.0	33.8	31.7	33.2	170.2	28.4

Stubble mulch fallow was prepared with a double-disk harrow for 1938, with a double disk harrow followed with a lister-bottom plow for 1939, and with a lister-bottom plow only for 1940 to 1943, inclusive. Black fallow was prepared with a moldboard plow with jointer attachments all six years.

* 1940 crop was average of two fall seeded plots of Oro winter wheat and two spring seeded plots of Baart wheat. Hard Federation 31 spring wheat was grown in 1943.

In an attempt to determine the reason for yield differences, soil moisture and nitrate determinations were made each year on two of the stubble mulch and two of the black fallow plots. The data for the early spring samplings are given in table 40. It will be noted from this table that the soil moisture, for both the first foot and for six feet, was practically identical for both types of tillage, but that the nitrates were slightly higher, on the average, in the soil of the black fallow plots. The yields in table 40 are for the plots that were sampled for moisture and nitrates.

Table 40 —Soil moisture and average nitrates per foot in stubble mulch fallow and black fallow in the early spring of each of the crop years from 1938 to 1943, inclusive, at Moro, Oregon.

Year	Moisture %				Nitrates, ppm				Acre Yield	
	Stubble mulch		Black fallow		Stubble mulch		Black fallow		Stubble mulch	Black Fallow
	1st foot	1-6 feet	1st foot	1-6 feet	1st foot	1-6 feet	1st foot	1-6 feet	bu.	bu.
	%	%	%	%	ppm	ppm	ppm	ppm		
1938	14.0	14.9	15.3	14.8	2.5	10.3	3.7	17.0	23.1	27.6
1939	14.9	13.3	13.4	12.7	4.8	6.5	19.5	11.7	27.7	29.2
1940	15.1	12.4	14.4	12.6	7.3	11.6	12.0	12.6	13.8	14.6
1941	15.2	15.3	15.5	16.2	4.9	12.3	5.3	9.9	32.6	34.3
1942	11.4	13.7	10.6	13.2	14.4	16.9	14.6	18.7	29.9	32.1
1943	14.6	15.6	14.1	14.9	10.1	11.9	12.6	17.5	23.7	31.6
Ave.	14.2	14.2	13.9	14.1	7.3	11.6	11.3	14.6	25.2	28.2

CROP ROTATIONS

The substitution of a profitable crop rotation for the present practice of growing wheat alternating with fallow would result in marked decreases in soil losses from water erosion. A series of crop rotations have been carried on at Moro since 1912, one of the objectives being to determine what crops, if any, might be grown as a substitute for fallow. Peas and corn were the crops selected for growing in rotations with the small grains.

In table 41 are given the yield data by 10-year periods from a few of the most promising rotations at Moro in comparison with the yields obtained from growing wheat alternating with fallow. The yields in the tables are for Turkey winter wheat, Baart spring wheat, Club Mariout or Meloy Spring barleys, Minn. 13 corn, and O'Rourke field peas. O'Rourke is a white round pea, with a yellow cotyledon, similar to White Canada and First and Best. The peas were grown in double rows 35 inches apart and given one or two cultivations during the growing season.

The seed bed preparation for grain following peas or corn was double disking and harrowing. For peas and corn following grain, the land was plowed with a moldboard plow and harrowed before and after planting.

Based on average annual total production per acre, most of the rotations listed in table 41, were superior to raising winter wheat alternating with fallow. This would not necessarily mean that the rotation with the highest average annual production would be the most profitable one. Prices and production costs would have to be considered in determining relative profits.

The rotation of wheat and peas, which proved to be a good one on both the Erosion Station and the College Farm at Pullman, Washington, on the University Farm at Moscow, Idaho, and on the Pendleton Branch Station in Oregon, also was the best rotation from the standpoint of total production on the Branch Station at Moro, Oregon.

Table 41.—Acre yields, in bushels, by 10-year periods from several crop rotations at the Sherman Branch Experiment Station at Moro, Oregon, in the years 1913 to 1942, inclusive.

Rotation	1913-1923-		1933-	30-yr.	Av. annual grain yield per acre for rotation
	1922	1932	1942	Ave.	
	Bu.	Bu.	Bu.	Bu.	lbs.
Winter wheat—fallow:					
Winter wheat after fallow	28.4	23.8	23.7	25.3	759
Spring wheat—fallow:					
Spring wheat after fallow	22.9	23.4	22.6	23.0	690
Spring barley—fallow:					
Spring barley after fallow	41.1	38.5	37.1	38.9	934
Spring wheat—spring barley—Corn:					
Spring wheat after corn	16.6	18.8	18.8	18.1	
Barley after wheat	21.3	20.3	17.1	19.6	883
Corn after barley	15.5	10.0	7.9	11.1	
Spring wheat—peas:					
Spring wheat after peas	22.3	23.7	21.9	22.6	
Peas after spring wheat	9.7	10.5	9.6	9.9	975
Spring wheat—peas—spring wheat—fallow:					
Wheat after fallow	21.7	24.3	22.4	22.8	
Wheat after peas	18.8	21.5	18.9	19.7	786
Peas after wheat	10.8	10.2	8.8	9.9	
Spring wheat—Spring wheat—peas turned under—Spring barley:					
Wheat after barley	13.0	15.4	13.6	14.0	
Wheat after wheat	12.1	13.9	13.1	13.0	790
Barley after peas turned under	29.7	33.7	33.0	32.1	
Peas continuously:					
Peas after peas	12.7	13.5	11.2	12.5	750

GRASSES AND LEGUMES

Although not included in any of the regular rotations at Moro, grasses and legumes have been grown in plot and field trials for many years. No great difficulty has been experienced in getting stands. In years with about normal precipitation, harvestable yields of grass and alfalfa were obtained only when they were grown in cultivated rows or thin stands. Crested wheatgrass and alfalfa have proved valuable pasture and erosion control crops, but their forage yields have not been dependable enough to rely upon their use for hay.

When alfalfa land is plowed, left fallow one season and planted to wheat, reduced yields for the first crop are usually obtained at Moro because of "burning" or drought injury. In dry years, reduced grain yields may be obtained the second year that the land is cropped to wheat after early plowed, clean cultivated fallow, because of too large a nitrate supply in proportion to available moisture.

When crested wheatgrass land is plowed, left fallow one year, and planted to wheat, excessive vegetative growth does not occur, as is usually the case after alfalfa. Yields of wheat, when grown after fallow on land previously devoted to crested wheatgrass, have been no higher at Moro than yields on land on which no grass has been grown.

POT EXPERIMENTS

To supplement the plot and field trials, winter wheat and spring wheat have been grown at Moro for many years in large galvanized iron containers. Water was supplied to the growing crop as needed by surface applications. One series of pots was fallowed and one cropped. During the fallow year no water, except precipitation, was added to the soil.

In figure 11 is shown the grain yield of winter wheat when grown after fallow with (1) manure applied at the beginning of the fallow year at the rate of 10 tons per acre (2) all straw returned to the soil and (3) straw returned and burned. Yields are shown for five 4-year periods from 1923 to 1942, inclusive.

For the first 4-year period, the lowest yield was obtained from the soil to which manure had been applied. In all subsequent periods the manured soil yielded highest.

For the first eight years the crop grown in the soil to which the straw was returned equalled the yield of the crop grown in

manured soil, but for the third, fourth and fifth 4-year periods the crop yield from the soil with straw returned was much less than that from the manured soil. After the second 4-year period, practically identical yields were obtained from the soil with straw burned and from the soil with the straw returned.

The trend in yield was upward from the soil to which manure was applied, and downward from the soil with straw burned or straw added. Similar results were obtained with spring wheat. (See Oregon Experiment Station Technical Bulletin 1).

In order to get some idea of the difference in productivity between virgin soil and soil that had grown wheat alternating with fallow for a long period of years, a series of pots was filled with surface virgin soil and another series with surface soil from an adjacent field that had been cropped to wheat and fallow for at least 40 years. One series of pots with the virgin soil was alternately cropped to wheat and fallow, one series cropped every year with straw returned, and another series cropped every year with straw removed. The series of pots with soil from the cropped field was devoted to growing wheat alternating with fallow. All pots received water as needed.

The average winter wheat yields from these pot trials for a 5-year period are shown graphically in figure 12. The superiority of the virgin soil in producing wheat when ample water was supplied to the growing crop was clearly demonstrated. The virgin soil, with continuous cropping, was almost as productive as the cropped soil that was fallowed every other year.

The yield data in figures 11 and 12 are given as grams per pot and not as bushels per acre. The pots used for the trial with virgin and cropped soil (fig. 12) were smaller than those used for the crop residue trial shown in figure 11; hence the yield data from the two trials are not comparable. If yields were computed as bushels per acre on the basis of the surface area of the soil in the pots, they would be slightly greater than the yields given as grams in the crop residue trial (figure 11) and considerably greater than those shown as grams in the trial with virgin and cropped soil (figure 12).

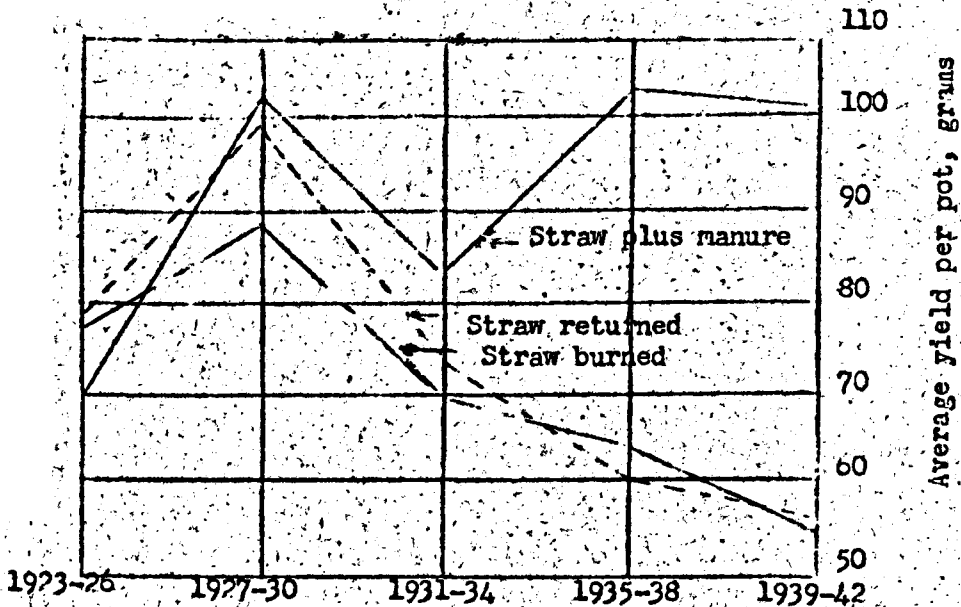
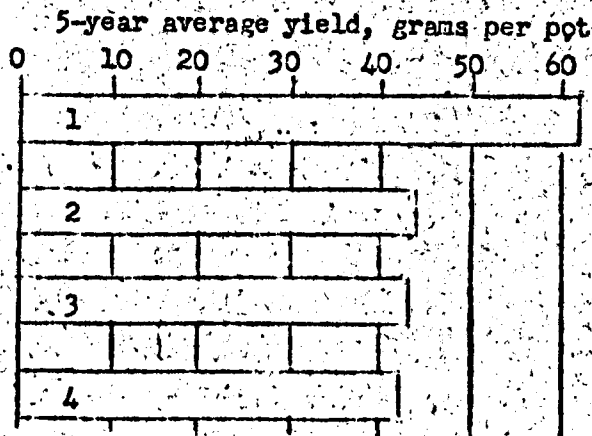


Figure 11 —Average yields by 4-year periods of winter wheat grown after fallow in large pots with manure added to the soil for every crop at the rate of ten tons per acre; with straw returned to the soil, and with straw burned, for the 20-year period 1923 to 1942, at Moro, Oregon.



1. Virgin soil fallowed
2. Cropped soil fallowed
3. Virgin soil, cropped every year - Straw removed
4. Virgin soil, cropped every year - Straw returned

Figure 12 —Five-year average yields of winter wheat grown in large pots filled with (1) virgin soil fallowed every other year, (2) soil from an adjacent field that had been cropped to wheat for more than 40 years and fallowed every other year, (3) virgin soil cropped every year with straw removed and (4) virgin soil cropped every year with straw returned.

YIELD TRENDS

Yield data from experiments at Moro provide some interesting information about the trend in wheat yields for a 30-year period. In the time of plowing experiments Turkey winter wheat was grown in the years 1913 to 1942, except for the years 1933 and 1940 when Baart spring wheat was grown. Tillage methods were identical for the whole period. Similar data are available from the rotation experiments where both winter and spring wheat have been grown after fallow and after various crops since 1913. In all cases, the straw, except the binder stubble, was removed from the land. The land had been cropped to wheat alternating with fallow for about 25 years prior to the establishment of the station.

Table 42 shows the precipitation at Moro by crop years ending July 31, the seasonal precipitation (March to July inclusive), the average yield of Turkey wheat from 6 check plots plowed for fallow early in the spring and given clean cultivation, and the bushels of wheat produced for each inch of crop year precipitation for each of the years 1913 to 1942, inclusive. The data also are averaged by 10-year periods.

The precipitation data by crop years in table 42 show that there was an unusual drought period from 1929 to 1935, inclusive. During these seven years the precipitation was considerably below normal in all years except one. The precipitation pattern during these seven years differs from that of any similar period in the 30 years, in that there were three consecutive years with below normal precipitation, then one year with slightly above normal precipitation, followed by another three consecutive years with below normal precipitation. Except for this period, there were no two consecutive years with precipitation very much below normal. When wheat is grown after fallow, below normal precipitation for one year may not greatly affect yields, but when two or more consecutive years occur with very much below normal precipitation, yields are likely to be appreciably reduced, especially in areas where the normal precipitation is 12 inches or less.

It will be noted from table 42 that the wheat yields from 1929 to 1935 ranged from a low of 7.6 to a high of 22.5 bu. per acre. Except for this seven-year period, yields of less than 20 bushels were obtained in only two other years, 1936 and 1940.

The efficiency of the precipitation in producing wheat also was less in the drought years, as is shown in the column under "bushels of wheat for each inch of precipitation," in table 42. The greatest efficiency in the use of water would be expected when an adequate supply was available in the soil to meet the needs of the plants during their entire growth period. There is rarely a season

at Moro when there is enough available water in the soil at all times during the growing season to supply a winter wheat crop with the quantity needed for optimum yields. Drought injury, in varying degrees, generally occurs during the latter part of the growing season, being most severe in seasons when there is a moisture deficiency in the fourth, fifth and sixth feet of soil in the early spring of the crop year. Soil moisture deficiency in the early spring is rarely made up by extra rainfall in May and June because the total normal rainfall for those two months is only 1.38 inches.

Based on average yields for each of three 10-year periods, the yield trend was downward. The precipitation trend also was downward; hence, the lower wheat yields obtained in the second and third decades cannot be attributed entirely to a change in soil productivity.

There was a difference of 5.0 bu. between the average yields obtained in the first and third decades, with a difference of nearly an inch of precipitation in favor of the first decade. Based on the average efficiency of the precipitation in producing wheat, an inch would account for 2.2 bu. With the same efficiency in producing wheat as in the first decade, the expected yield for the second decade, with an average precipitation of 10.66 inches, would be 25.1 bushels. The actual yield for the second decade was 22.9. Similarly, the expected yield for the latest decade, with 10.98 inches precipitation, would be 25.9 bushels. The actual yield for the latest decade was 23.1 bushels.

Based on crop year precipitation data alone, it appears that there has been a decline in the productivity of the soil of these plots. In the two latest decades, the efficiency of the precipitation was less, but this may have been because there were more drought years in the later decades. Averaging the data by 7-year periods beginning with 1915, the results would be as follows:

	1915- <u>1921</u>	1922- <u>1928</u>	1929- <u>1935</u>	1936- <u>1942</u>
Crop year precipitation	12.48	11.34	9.07	11.55
Precipitation for May and June	1.45	1.00	1.18	1.59
Yield per acre, bu.	30.00	29.00	14.10	25.5
Yield per inch of crop year precipitation	2.40	2.56	1.55	2.21

The above data show that the precipitation was not used as efficiently in the last 7-year period as it was in the two 7-year periods, 1915-1921 and 1922-1928.

To be more certain as to whether there has been any significant decline in the productivity of this land, an analysis would need to be made of factors other than precipitation that influence wheat yields, such as winter and growing season temperatures and time of emergence of the winter wheat. So far as precipitation is concerned, the latest 7-year period was more favorable than the second 7-year period, but the average yield was 3.5 bushels per acre less for the latest period.

It is certain that the soil contains less organic matter and nitrogen than it did 30 years ago. But the present nitrogen level of the soil at Moro appears to be high enough so that, under normal conditions, enough nitrates accumulate during a season with early-plowed, well-prepared fallow to provide about as high a yield as can be expected with a moisture supply of only 11 inches annually. With slightly higher soil moisture, a little higher nitrogen level, with accompanying higher nitrification during the fallow period, would be needed to get optimum yields. A higher nitrogen level, too, might make it possible to adopt a rougher, cloddier type of fallow and the use of straw for erosion control without reduction in yields.

It must be kept in mind that an annual precipitation of 11 inches does not imply that all of this water gets into the soil. Evaporation and runoff take a heavy toll. Long time soil moisture records at Moro show that, on the average, the total water in the soil in the early spring (April 1) of the crop year after a season of fallow is only about 12.5 inches in a six-foot section. About 5.0 inches of this amount is not available to the wheat plants, that being the quantity of water left in the soil immediately after the wheat is harvested. The accumulated water in the soil from the time the crop was taken off the land in July to the early spring of the next crop year (20 months) was only 7.5 inches. The average precipitation for this 20-month period was 20.1 inches. Sixty-two and one-half percent of the precipitation, therefore, was lost through evaporation and runoff. This emphasizes the importance of tillage methods for the drier areas that will capture and retain in the soil more of this lost precipitation.

At the Pendleton Branch Station there was a significant downward trend in the yield of winter wheat from the non-fertilized plots of the crop residue and fertilizer experiments in the 12-year period, 1931-1942, as was shown in tables 28 and 35 and figure 9. The nitrogen level of the soil at the Pendleton Station is higher than that of the soil at Moro. The precipitation, too, is enough higher at Pendleton to increase average wheat yields after fallow without fertilizer applications more than 50% over those at Moro. Substantial increases in yield were obtained at Pendleton from an application of nitrogenous fertilizers to the land. At Moro, fertilizer applications have not increased wheat yields after fallow because of the limited moisture supply.

The efficiency of the precipitation in producing wheat at Pendleton was higher than at Moro because at Pendleton, with more favorable moisture conditions, drought injury was absent or at least less frequent. Averaging results for a 12-year period, the non-fertilized plots at Pendleton produced 2.57 bushels of wheat for each inch of crop year precipitation, and the fertilized plots 3.0 bu. per inch.

Table 42 — Precipitation and yields of Turkey winter wheat at Moro, Oregon for the years 1913 to 1942, inclusive.

Year	Precipitation ¹		May & June	Acre yield of Turkey wheat	Bu. of wheat for each inch of crop year precipitation
	Annual in.	Seasonal in.			
1913	11.08	5.06	3.66	23.9	2.16
1914	12.53	3.67	1.42	26.7	2.13
1915	13.31	4.91	2.42	26.8	2.01
1916	16.62	7.07	3.35	37.2	2.24
1917	8.62	2.84	0.85	24.8	2.88
1918	12.43	1.75	0.88	22.6	1.82
1919	10.72	2.11	0.25	37.2	3.47
1920	11.35	3.28	0.81	26.8	2.36
1921	12.34	2.92	1.46	34.9	2.83
1922	10.32	2.03	0.36	20.4	1.98
Ave.	11.92	3.56	1.56	28.1	2.39
1923	12.84	4.39	1.07	30.7	2.39
1924	7.72	0.92	0.32	23.3	3.02
1925	12.16	3.56	2.34	25.5	2.10
1926	9.52	1.96	0.79	24.6	2.58
1927	14.22	2.60	1.52	37.9	2.67
1928	12.62	3.21	0.61	40.6	3.22
1929	8.07	1.88	0.92	7.6	0.94
1930	7.78	1.32	0.41	12.2	1.57
1931	9.48	4.45	1.75	13.3	1.40
1932	12.23	4.60	2.08	13.2	1.08
Ave.	10.66	2.89	1.18	22.9	2.10
1933	9.58	3.23	1.86	22.5 ²	2.35
1934	9.95	2.12	0.17	18.8	1.89
1935	9.40	2.19	1.06	11.3	1.20
1936	11.00	3.16	1.91	19.5	1.77
1937	11.05	6.35	2.66	25.2	2.28
1938	12.51	4.27	1.20	30.9	2.47
1939	7.67	1.95	0.73	24.5	3.19
1940	12.14	3.93	0.44	17.0 ³	1.43
1941	13.01	3.41	1.79	32.2	2.48
1942	13.46	3.77	2.40	29.4	2.18
Ave.	10.98	3.44	1.42	23.1	2.12
30-yr.					
Ave.	11.20	3.30	1.38	24.7	2.2

¹ Annual precipitation is for crop year ending July 31. Seasonal Precipitation is for the months of March to July, inclusive.

² Baart Spring wheat

³ Average yield of Turkey wheat from 20 plots in the depth of plowing experiment, substituted for the yield of Baart spring wheat which was grown in the time of plowing experiment in 1940.

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Pullman, Washington, April 30, 1946

To: Soil Conservation Service Technicians and County Agents
From: D.E. Stephens
Subject: Recent results from Pacific Northwest Experiment Stations

The following tables and graphs bring up to date some of the data in the mimeographed publication, "Conservation Practices on Wheat Lands of the Pacific Northwest," sent to you in 1944. The tables and graphs are numbered to conform with the numbers of the tables and graphs in that publication.

Several new tables are included giving tentative results from experiments that have been in progress for only a few years.

The heavy soil losses from Pacific Northwest wheat lands during the past winter suggest the need for added emphasis on erosion control practices and the adoption of rotations which include grasses and legumes. This thesis is supported by data in the tables, especially those from the Soil Conservation Experiment Station at Pullman, Washington.

A brief explanation of some of the tables may be helpful to those of you who do not have copies of the publication referred to above. No more copies of this publication are available.

WASHINGTON

Table 6. Note that the soil losses are given for the entire rotation. For winter wheat-fallow, the soil loss during the erosion period late in December, 1945, for the fallow plot seeded to winter wheat was 35 tons per acre, or 17.5 tons per acre for the rotation. There was no soil lost from any plots with undisturbed grain stubble on the land. The same also was true of land in grass, alfalfa, or alfalfa-grass mixtures.

Table 6A. The results given in this table are from a rotation started in 1941 to learn something about the effect of different methods of utilizing sweetclover and wheat straw in a 5-year rotation. Only one cycle of the rotation has been completed and as yet no significant differences in yields have been obtained. It is of interest to note that the 3-year average yield of peas where the wheat straw was returned was slightly higher than the yield where the wheat straw was burned. Burning stubble in the fall, a too common farm practice in the Palouse area, apparently does not increase pea yields, but it does contribute to erosion hazards from both wind and water.

Table 6B shows the results obtained for only two years from different tillage and crop residue disposal methods in a winter wheat - pea rotation. The average yields of wheat and peas show no significant differences. Yield differences no doubt will show up later. For erosion control, subsurface tilled pea land was much superior to one-way disking or moldboard plowing as a seed bed preparation for winter wheat.

Table 8 shows soil losses, runoff, and yields from a series of plots devoted to growing wheat after fallow. Note the effect of straw placement on erosion in 1942-43 and in December, 1945. Subsurface tillage^{even} with straw burned was more effective in controlling erosion than turning under two tons per acre of straw with a moldboard plow. And for moldboard plowing, the addition of straw only slightly reduced erosion. Further results will be needed before drawing conclusions from the yield data.

Table 12A shows the results from a group of rotations, with plots randomized and triplicated, on the College Farm at Pullman. Here again too few years are represented to justify drawing conclusions. The outstanding result was the failure to get satisfactory yields following "trashy fallow."

Table 13A indicates that farmers in the Big Bend area of Washington have quite a wide choice of initial tillage methods for growing wheat after fallow. That some kind of tillage is necessary is shown from the low yields obtained from the "non-tilled" plots. The average yields obtained from all other methods were fairly close together.

The graph on page 48A shows that there was a reversal in average wheat yields at Lind in the earlier and later years from the plots with straw and no straw added. If this reversal in yield was not associated with the increased precipitation in the later years, it may be significant. Further results under more normal moisture conditions will no doubt clear up this point. The soil at Lind has a very low nitrogen level, but the addition to the soil of as much as 3200 lbs. of straw per acre, or about twice the quantity of straw produced at this location in years of normal precipitation, did not depress wheat yields (Table 13). The nitrogen content of this soil also was maintained during an 18-year period where 3200 lbs. of straw were added.

IDAHO

Subsurface tillage continued to give satisfactory results at Tetonia, Idaho (Table 15). The 6-year average yield from this method of initial tillage was just a little higher than that obtained from either moldboard plowing or one-way disking. Idaho Experiment Station bulletin No. 256 by Hugh C. McKay and W. A. Moss gives detailed information about stubble mulch farming in southern Idaho.

The possibilities of increasing production from Palouse hill-top lands by the growing of legumes are indicated from the results obtained by the Idaho Experiment Station at Moscow (Table 21). Spring wheat grown continuously for four years, preceded by four years of alfalfa, averaged 30 bushels per acre in yield, or more than twice the average yield obtained from spring wheat grown on land where no legume had been previously grown.

OREGON

Six-year average yields from plot trials at Pendleton and at Moro, Oregon (Table 22), show a yield reduction from subsurface tillage at both locations, especially at Pendleton. The reasons for the difference in results from subsurface tillage in southern Idaho and in the Columbia River Basin of Oregon are not fully explained from either the soil moisture or the nitrate data collected at both locations.

Two graphs (on pages 77B and 77C) show the influence on crop yield of varying amounts of precipitation on fertilized and unfertilized land at the Pendleton, Oregon, Branch Experiment Station when wheat was grown after fallow and when wheat and peas were grown in a rotation. An increase in the average precipitation above 14 inches failed to increase average yields of wheat grown after fallow on land not fertilized. In a winter wheat--pea rotation an increase in precipitation slightly increased the yield of wheat and markedly increased the yield of peas.

In table 38 yields of winter wheat are shown from five methods of initial tillage for growing winter wheat after fallow at the Pendleton, Oregon, Branch Experiment Station. Note the difference in average yields obtained in the even and odd-numbered years. Difference in weed infestation on the land used is offered as a probable reason for the difference in the results.

If you should wish to use any of the data in these tables in any type of publication, permission should first be obtained from the Experiment Station furnishing the data.

I shall be glad to try to answer any questions you may wish to ask about any of the data in the tables.

D. E. Stephens,
Principal Agronomist, Research

Table 3. Yields of winter wheat after fallow and after sweet clover turned under in odd and even-numbered years on the South Control plots of the Soil Conservation Service Experiment Station at Pullman, Washington.

Year	Wheat after fallow Plots 1, 2 & 3*	Wheat after sweetclover turned under /1	Year	Wheat after fallow Plots 5 & 8*	Wheat after sweetclover turned under /1
1933	41.8	38.9 (1.7)	1934	27.3	41.5 (6.6)
1935	47.8	41.9 (4.7)	1936	35.2	46.7 (9.0)
1937	45.7	45.7 (1.5)	1938	35.4	54.6 (13.0)
1939	37.7	42.0 (5.9)	1940	23.3	52.7 (13.9)
1941	45.8	58.2 (9.8)	1942	31.6	66.3 (23.6)
1943	32.0	45.4 (15.0)	1944	17.8	36.7 (15.6)
1945	33.1	40.3 (10.7)			
Average	40.6	44.6		28.4	49.8

Figures in parentheses indicate green weight of sweetclover turned under, in tons per acre.

/1 In a rotation of sweetclover with peas - sweetclover turned under - winter wheat - spring wheat on Plots 9, 10, 11, and 12.

*Total soil losses from 1932 to 1944, inclusive, averaged 69 tons per acre from plots 5 and 8 and only 2.2 tons per acre from plots 1, 2 and 3.

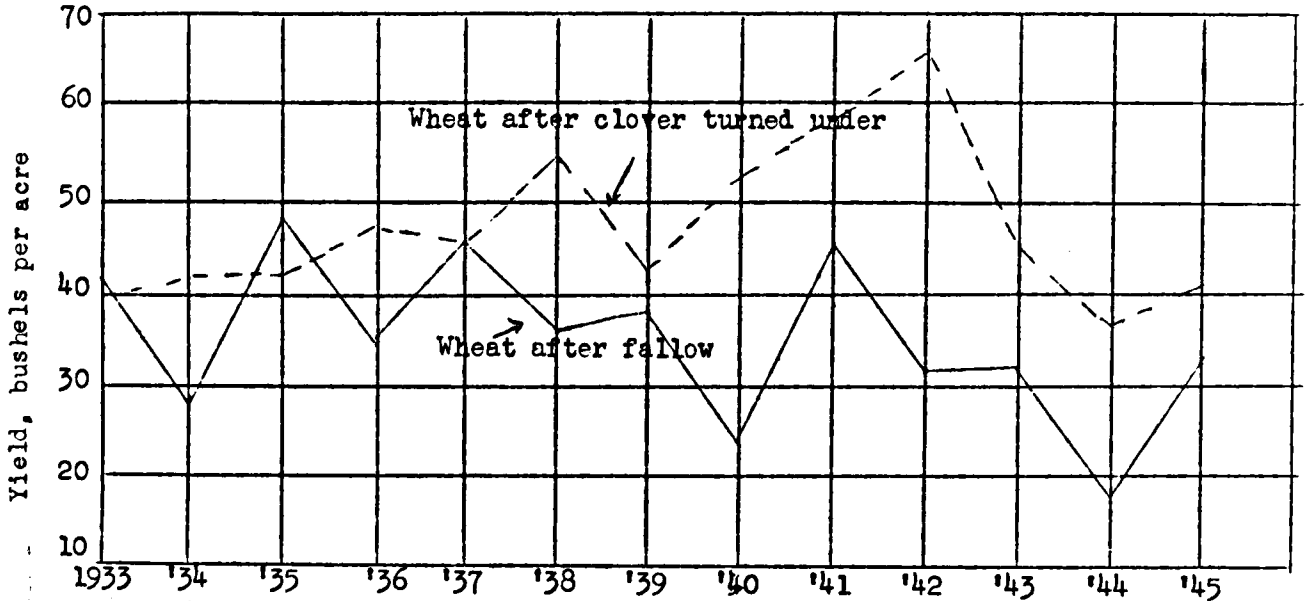


Figure 1--Yields of winter wheat after sweetclover turned under in a rotation of peas with sweetclover--sweetclover turned under--winter wheat--spring wheat, and after fallow in a rotation of winter wheat--fallow, for the years 1933 to 1945, inclusive, at the Soil Conservation experiment station at Pullman, Washington

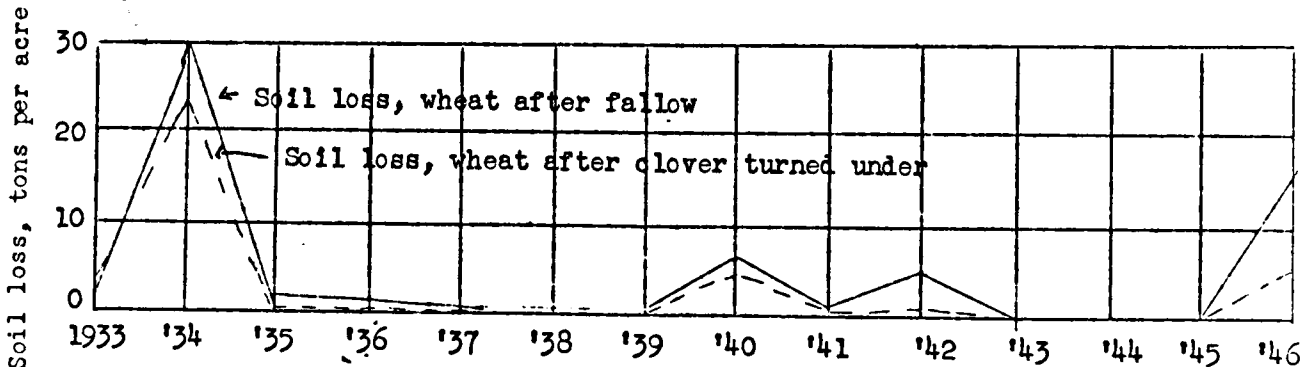


Figure 2--Soil losses, in tons per acre, from land sown to winter wheat after fallow and sown to winter wheat after turning under sweetclover for green manure in the years 1933 to 1946, inclusive, at the Soil Conservation Experiment Station at Pullman, Washington. Data are for years ending June 30, except for 1946, which include soil losses up to Jan. 1, 1946.

Table 6. Average yields and soil losses from crop rotation plots at the Soil Conservation Experiment Station at Pullman, Washington, for the year 1938 to 1945 inclusive.

No.	Rotation	8-year Av. Yield, Bu. (1938-1945)	Soil loss for rotation	
			Total 1938-45* Tons per A	During Dec., 1945 Tons per A.
1.	Winter wheat - fallow	29.6	17.8	17.5
2.	Spring wheat - fallow	24.0	23.9	15.9
3.	Winter wheat - peas:		9.3	10.9
	Winter wheat	29.4		
	Peas	23.1		
4.	Spring wheat - peas:		10.0	1.8
	Spring wheat	22.4		
	Peas	21.3		
5.	Winter wheat - peas for green manure	31.3	11.2	5.8
6.	Spring wheat - peas for green manure	26.1	5.6	0.0
7.	Winter wheat - Hubam clover for green manure	34.7	4.3	7.2
8.	Spring wheat - Hubam clover for green manure	23.2	3.2	00.0
9.	Sweet clover and grass - sweet clover and grass turned under - winter wheat - peas - spring wheat.			3.6
	Winter wheat after clover and grass	41.4		
	Peas after winter wheat	24.4		
	Spring wheat after peas	28.4		
10.	Four years alfalfa and grass - spring wheat - winter wheat - peas - spring wheat (1941-1945):			
	Spring wheat after four years alfalfa and grass	28.9		
	Winter wheat after spring wheat	35.3		
	Peas after spring wheat	27.9		
	Spring wheat after peas	27.4		
	Alfalfa and grass	2.17		

*Years ending June 30.

Table 6A. Acre yields of winter wheat and peas in a 5-year rotation of sweetclover - sweetclover - winter wheat - peas - winter wheat, at the SCS Experiment Station at Pullman, Washington.

Year	Crop	With no Grass	With Grass	Clover turned under	Clover cut for hay	Wheat straw returned	Wheat Straw burned
		bu.	bu.	bu.	bu.	bu.	bu.
1943	Winter wheat after sweet- clover	41.6	41.4*	40.4	42.6	40.7	42.3
1944	Winter wheat after sweet- clover	56.1	53.8	55.6	54.3	54.8	55.2
1945	Winter wheat after sweet- clover	<u>33.3</u>	<u>33.9</u>	<u>33.5</u>	<u>33.7</u>	<u>33.2</u>	<u>34.0</u>
	Average	43.7	43.0	43.2	43.5	42.9	43.8
1944	Peas after winter wheat	20.7	20.6*	20.8	20.5	21.0	20.3
1945	Peas after winter wheat	<u>24.7</u>	<u>24.1</u>	<u>23.7</u>	<u>25.0</u>	<u>25.9</u>	<u>22.8</u>
	Average	22.7	22.9	22.3	22.8	23.5	21.9
1945	Winter wheat after peas	39.8	40.2*	40.5	39.5	39.5	40.5

*No grass was seeded with the sweetclover in 1941.

Table 6B. Yields of winter wheat and peas in a winter wheat - pea rotation, with various tillage and crop residue disposal methods at the Soil Conservation Experiment Station at Pullman, Washington, for the years 1944 and 1945.

Winter wheat after peas:

(All residue disposal methods on moldboard plowed, one-way disked, and subsurface tilled pea land.)

	<u>1944</u> bu.	<u>1945</u> bu.	<u>Average</u> bu.
1. All residues utilized	45.9	35.0	40.5
2. Pea straw returned, wheat straw burned	45.6	34.4	40.0
3. Wheat straw returned, peas straw burned	46.0	35.5	40.8
4. Wheat and pea straw burned	44.1	35.0	39.1
-0-			
a. Moldboard plowed	46.2	32.9	39.1
b. One-way disked	45.8	35.4	40.8
c. Subsurface tilled*	44.3	36.6	40.5

-0-

Peas after winter wheat:

(All plots fall plowed with moldboard plow.)

1. All residues utilized	14.4	18.1	16.3
2. Pea straw returned, wheat straw burned	15.0	15.9	15.5
3. Wheat straw returned, pea straw burned	15.0	19.4	17.2
4. Wheat and pea straw burned	14.4	17.5	16.0

*During an erosion period late in December, 1945, there was practically no soil lost from the subsurface tilled plots. Moderate soil loss occurred on the one-way disked plots, and heavy soil loss from the moldboard plowed plots.

Effect of type tillage and amount of straw returned to the soil on erosion losses and on crop yields of winter wheat grown after fall low on the stubble utilization plots, Soil Conservation Experiment Station, Pullman, Washington.

Year	Subsurface Tillage			Moldboard Plow		
	Burned	1 ton straw	2 tons straw	Burned	1 ton straw	2 tons straw
	<u>Soil losses -- tons per acre</u>					
1942-43	6.02	0.74	1.30	11.64	9.15	8.41
1943-44	0.01	0.00	0.00	0.02	0.01	0.01
1944-45	0.01	0.01	0.00	3.03	0.00	0.00
1945-46*	<u>27.99</u>	<u>8.70</u>	<u>1.03</u>	<u>41.96</u>	<u>39.09</u>	<u>37.90</u>
Average	8.51	2.36	0.58	14.6	12.06	11.58
	<u>Runoff -- inches</u>					
1942-43	1.891	1.296	1.358	2.505	2.171	2.012
1943-44	0.004	0.002	0.008	0.011	0.004	0.002
1944-45	0.022	0.043	0.00	0.159	0.007	0.000
1945-46*	<u>1.494</u>	<u>0.529</u>	<u>0.253</u>	<u>1.874</u>	<u>1.713</u>	<u>1.714</u>
Average	0.853	0.468	0.405	1.137	0.974	0.932
	<u>Winter wheat yield -- bushels per acre</u>					
1943	33.1	33.9	31.7	35.4	33.9	29.2
1944	43.3	42.0	36.7	45.8	42.9	42.0
1945	<u>32.0</u>	<u>29.8</u>	<u>29.4</u>	<u>32.5</u>	<u>32.7</u>	<u>35.7</u>
Average	36.1	35.2	32.6	37.9	36.5	35.6

* Includes data to December 31, 1945.

Table 12A--Yield Data from Crop Rotation Experiments on the College Farm at Pullman, Washington, 1941-1945.

	5-Yr.av. yield 1941-1945
1. ALFALFA & GRASS 4 YRS.--WINTER WHEAT--SPRING WHEAT:	
Alfalfa and grass, av. for 3 cutting yrs. tons	3.1
Winter wheat, bushels	33.6
Spring wheat, bushels	24.2
2. SWEETCLOVER & GRASS--CLOVER & GRASS TURNED UNDER--W. WHEAT--SP. WHEAT--FALLOW--W. WHEAT:	
Sweetclover and grass, tons	4.1*
Winter wheat after sweetclover, bu.	41.0
Spring wheat after w. wheat, bu.	21.8
Winter wheat after fallow	44.0
3. PEAS & SWEETCLOVER--CLOVER TURNED UNDER-- W. WHEAT--PEAS--SPRING WHEAT:	
Peas with sweetclover, bu.	26.9
Sweetclover, tons	3.1*
W. Wheat after clover, bu.	43.5
Peas after w. wheat, bu.	30.2
Sp. wheat after peas, bu.	35.3
4. SWEETCLOVER & GRASS--CLOVER & GRASS TURNED UNDER-- WINTER WHEAT--SPRING WHEAT:	
Sweetclover and grass, tons.	4.4*
Winter wheat, bu.	40.9
Spring wheat, bu.	22.9
5. WINTER WHEAT--FALLOW (binder stubble turned under)	44.8
6. WINTER WHEAT--TRASHY FALLOW	28.8**
7. WINTER WHEAT--FALLOW (stubble burned)	43.5
8. WINTER WHEAT--PEAS	
Winter wheat, bu.	38.8
Peas, bu.	27.9
9. WINTER WHEAT--PEAS FOR GREEN MANURE Winter wheat, bu.	46.9

*Air-dry weight of sweetclover turned under for green manure

**Low yield believed to be due to lack of suitable implements to handle trashy fallow and prepare proper seedbed.

Table 13. Acre yields, in bushels, of Baart spring wheat and turkey winter wheat* in an organic matter maintenance experiment at Lind, Washington.

Residue Applied	Acre Yield, Bushels						23 Yr. Av. 1923-45
	1923- 1940	1941	1942	1943	1944	1945	
Check (None)	14.9	27.6	40.0	25.5	26.7	15.6	17.5
1600 lbs. straw**	15.1	29.4	40.4	26.6	29.5	15.7	18.0
3200 lbs. straw	14.8	30.5	40.9	26.1	28.9	15.0	17.7
800 lbs. straw	14.5	27.4	39.1	22.5	26.4	15.5	17.0
No straw and 50 lbs. Am. Sulfate	14.4	27.6	40.0	24.3	26.6	14.2	17.0
Check (None)	15.2	24.0	39.1	21.2	26.4	14.5	17.3
800 lbs. straw and 50 lbs. Am. Sulfate	15.4	27.8	41.3	28.6	30.2	13.8	18.2
1600 lbs. straw and 100 lbs. Am. Sulfate	15.2	28.5	39.1	27.9	24.4	13.1	17.7
No straw and 100 lbs. Am. Sulfate	14.8	26.3	40.0	28.2	22.8	11.1	17.2
Manure, 3.5 Tons	15.2	25.8	42.7	30.6	31.3	10.1	18.0
Check (None)	14.6	22.2	37.7	28.8	26.0	12.9	17.0
Average of all checks	14.9	24.6	38.9	25.2	26.4	14.2	17.3
Crop Year Precipitation, in.	8.68	18.00	12.29	11.65	8.60	10.05	9.43

*Turkey winter wheat grown in 1923, 1924, 1926, 1927, 1928, 1931, 1934, and 1935 and Baart spring wheat in all other years.

**Straw applied does not include binder stubble.

Table 13A--Average acre yields in bushels of Baart spring wheat grown after fallow with various initial tillage methods, with and without applications of straw, at the Adams Branch Experiment Station at Lind, Washington, for the seven-year period 1939-1945.

Time of initial tillage and implement used. . .	7 Year average Yield 1939-1945
1. Early spring, one-way disk (check)	20.9
2. Early fall, one-way disk + straw*	22.4
3. Subsurface tillage after harvest, early spring one-way disk + straw*	23.3
4. Late fall (wet), one-way disk	21.0
5. Late fall (wet), one-way disk + straw*	21.2
6. Early spring, one-way disk + straw*	22.0
7. Early spring, one-way disk (check)	22.1
8. Early spring, one-way disk and moldboard plow alternating + straw*	21.0
9. Early spring, moldboard plow	22.5
10. Early spring, moldboard plow + straw*	21.7
11. Late spring, one-way disk	19.1
12. Late spring, one-way disk + straw*	19.9
13. Early spring, one-way disk (check)	20.9
14. Early spring, one-way disk + straw*	20.7
15. Early spring, duckfoot cultivator + straw*	19.9
16. Fall chisel, alternate fallow years, spring double disk + straw*	20.3
17. Non-tilled/1 + straw	16.0
18. Non-tilled /1	16.1
19. Early spring, one-way disk (check)	19.5

*1200 lbs. of straw per acre applied after harvest to binder stubble; all other plots, binder stubble only.

/1Weeds on non-tilled plots taken off with a hoe; other plots rod-weeded during the fallow season often as necessary to control weeds. All plots were harrowed with spring tooth harrow before seeding.

Yields of Baart spring wheat, by 10-year moving averages, after fallow with 3200 lbs. of straw returned to the land after every crop and with no straw returned at Lind, Washington, for the years 1923 to 1945, inclusive.

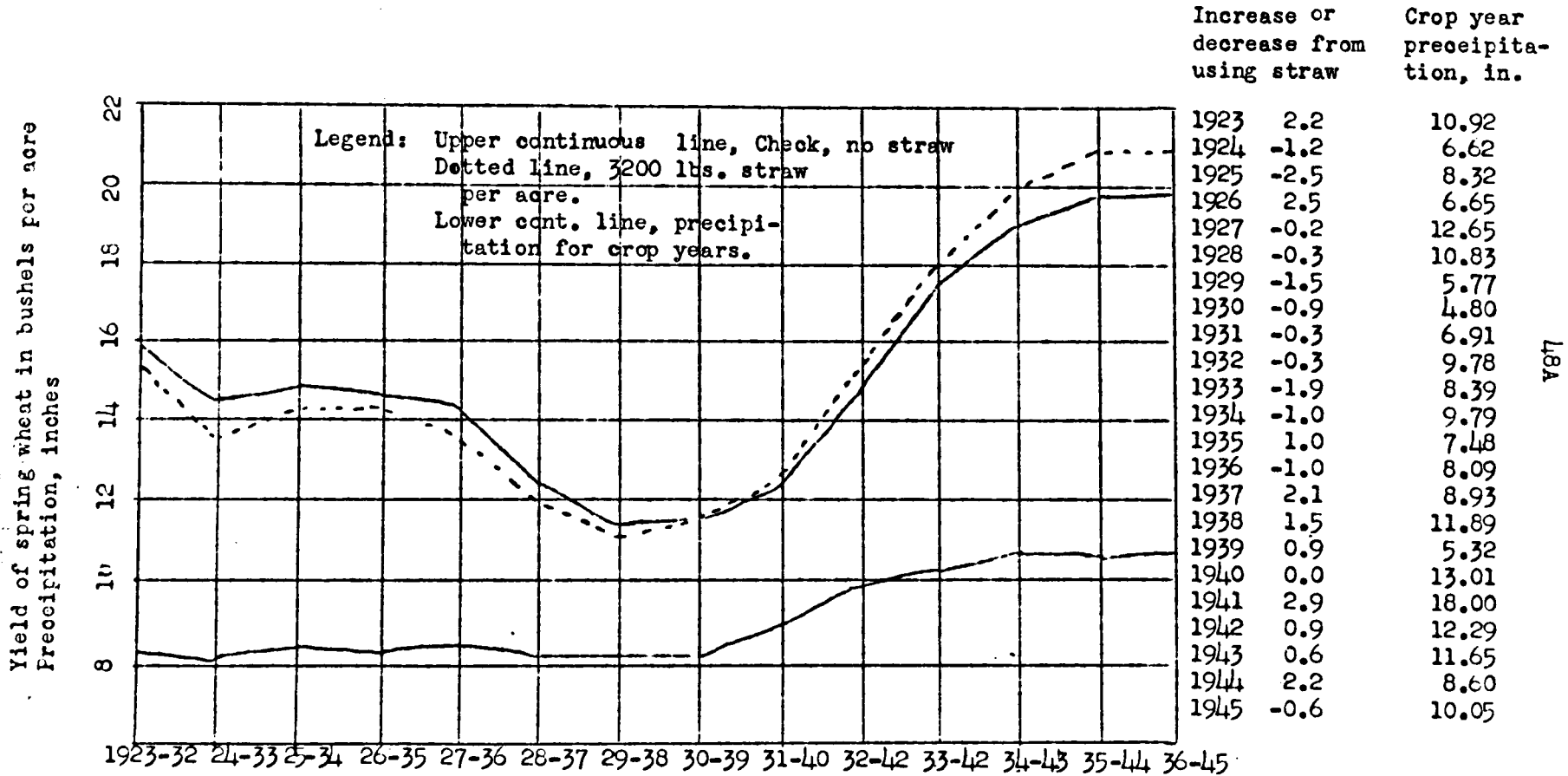


Table 15. Six-year (1940-1945) average yields in bushels of winter and spring wheat* grown after fallow with various initial tillage methods, and with all straw utilized and all straw burned at Tetonia, Idaho.

Moldboard plow:

Straw utilized	32.4	
Straw burned	<u>34.5</u>	33.5

One-way disk:

Straw utilized	33.1	
Straw burned	<u>33.6</u>	33.4

Subsurface tillage:

Straw utilized	35.1	
Straw burned	<u>36.1</u>	35.6

Straw utilized, all tillage methods 33.6

Straw burned, all tillage methods 34.7

*Turkey winter wheat in 1940-1942, inc., and Idaho spring wheat in 1943-1945, inc.

In 1945, eleven stubble-mulch field trials, of from 20 to 50 acres each in size, were conducted at widely separated locations in southeastern Idaho. In all trials, except one where the yields were equal, the yield was greater from stubble mulch tillage. The average yield from the stubble mulch fallow was 33.6 bushel per acre, and from adjoining check fields of ordinary black fallow the average yield was 28.3 bushel per acre.

Table 19--Acre yields of winter wheat grown after fallow plowed with a moldboard plow and one-way disk with straw utilized and straw burned at Moscow, Idaho, for the 7-year period, 1939-45.

Year	Moldboard plowing straw utilized bu.	One-way disking straw utilized bu.	Moldboard plowing straw burned bu.
1939	55.0	53.8	52.5
1940	59.0	64.0	64.8
1941	49.5	43.3	41.0
1942	69.0	72.5	60.3
1943	67.5	71.3	63.3
1944	57.5	46.0	50.0
1945	<u>46.2</u>	<u>49.8</u>	<u>46.5</u>
Average	57.7	57.2	54.1

Average straw yields, exclusive of binder stubble:

Moldboard plowing, straw utilized	3.38 tons per acre
Moldboard plowing, straw burned	3.54 " " "
One-way disking, straw utilized	3.50 " " "

Winter wheat, every year (8-year average yields, 1938-1945):

Straw utilized, moldboard plow	24.0 bu. per acre
Straw utilized, one-way disk	21.2 " " "
Straw burned, moldboard plow	27.4 " " "

Average straw yields, exclusive of binder stubble:

Straw utilized, moldboard plow	1.01 tons per acre
Straw utilized, one-way disk	.90 " " "
Straw burned, moldboard plow	1.08 " " "

Table 20--Average yields from several rotations on Field 7 at the Moscow, Idaho, Experiment Station.

<u>Rotation</u>	<u>Acre yield, bu.</u>
1. Winter wheat - peas:	
Winter wheat	49.5 <u>a/</u>
Peas	19.6 <u>b/</u>
2. Winter wheat - fallow	57.7 <u>a/</u>
5. Peas with sweetclover - sweet clover under - winter wheat - winter wheat:	
Peas with sweetclover	21.3 <u>b/</u>
Sweetclover turned under T/A air dried	2.96 <u>a/</u>
Winter wheat after clover t.u.	54.1 <u>a/</u>
Winter wheat after winter wheat	38.6 <u>c/</u>
6. Peas for green manure - winter wheat - winter wheat:	
Winter wheat after peas t.u.	52.5 <u>a/</u>
Winter wheat after winter wheat	34.1 <u>c/</u>

a/ 7-year average yield.

b/ 8-year average yield.

c/ 6-year average yield.

Table 21--Crop yields from 1922 to 1945, inclusive, on a south slope (clay outcrop area), with yield comparisons of spring wheat grown every year with and without being preceded by alfalfa, alfalfa and grass, and grass alone, at Moscow, Idaho.

<u>Plot No.</u>	<u>1942</u>	<u>1943</u>	<u>1944</u>	<u>1945</u>	<u>Av.</u>
1, 5, 9 Continuous spring wheat, bu.	14.0	19.4	9.5	14.1	14.3
2 Alfalfa, tons	3.2	3.6	2.1	1.8	2.7
3 Alfalfa, brome and crested wheat, tons.	2.8	3.7	3.3	1.8	2.9
4 Crested wheatgrass, lbs. seed	35.0	44.0	0.0	00.0	--
6 Spring wheat after 4 years of alfalfa, bu.	31.5	51.3	19.8	17.8	30.1
7 Spring wheat after 4 years of alfalfa and grass, bu.	32.7	45.5	21.0	15.8	28.8
8 Spring wheat after 4 years of crested wheatgrass.	18.7	22.2	15.2	19.4	18.9

Plots 1, 5, and 9 are in continuous wheat. From 1938 to 1941, inclusive, plot 6 was in alfalfa, plot 7 in alfalfa and grass, and plot 8 in crested wheatgrass. Each of these plots was plowed in the fall of 1941 and planted to spring wheat in 1942, 1943, 1944, and 1945.

Table 22--Acre yields, in bushels, of winter wheat from moldboard plowed, one-way disked, and subsurface tilled fallow at Pendleton and at Moro, Oregon, for the years 1940 to 1945, inclusive. (Belanger's plot trials).

Pendleton

	MOLDBOARD FLOWED		ONE-WAY DISKED		SUBSURFACE TILLED	
	<u>5 in.</u>	<u>8 in.</u>	<u>5 in.</u>	<u>8 in.</u>	<u>5 in.</u>	<u>8 in.</u>
1940	30.1	34.4	25.9	28.3	27.9	26.1
1941	34.1	38.7	37.1	38.6	35.7	36.5
1942	37.2	37.0	36.5	37.8	33.7	31.6
1943	47.9	47.1	39.7	42.5	34.2	35.6
1944	40.8	38.8	35.4	33.6	32.9	31.8
1945	<u>19.2</u>	<u>21.3</u>	<u>22.5</u>	<u>24.5</u>	<u>22.1</u>	<u>20.3</u>
Average	34.9	36.2	32.9	34.2	31.1	30.3
Average of 5 and 8 in. depths	35.6		33.6		30.7	

Moro

	MOLDBOARD FLOWED		ONE-WAY DISKED		SUBSURFACE TILLED	
	1940	9.1		10.2		9.9
1941	43.0		41.0		43.4	
1942	38.6		37.7		40.1	
1943	34.1		34.3		29.1	
1944	32.6		30.3		22.7	
1945	<u>24.2</u>		<u>21.5</u>		<u>20.8</u>	
Average	30.3		29.2		27.7	

Table 28. Average acre yields, in bushels, by 5-year periods, of fall sown wheat after fallow plowed with a moldboard plow with various fertilizer applications and straw disposal methods at the Pendleton Branch Experiment Station near Pendleton, Oregon, for the years 1931 to 1945, inclusive.

TREATMENT	1st 5-Yr. Period 1931-35	2nd 5-Yr. Period 1936-40	3rd 5-Yr. Period 1941-45	15 Yr. Average
10 T. per acre manure added to total straw	46.8	50.1	50.1	49.0
1 T. pea straw added to total straw	46.3	42.5	49.8	46.2
Fall disked, all straw plowed under + nitrate fertilizer*	45.0	42.3	44.9	44.1
Spring disked, all straw plowed under + nitrate fertilizer*	44.1	41.6	45.3	43.7
Straw burned in spring	44.5	39.7	43.6	42.6
Straw burned in fall	43.1	37.5	41.1	40.6
All straw plowed under, not disked	43.0	36.1	40.6	39.9
All straw plowed under, spring disked	41.4	36.2	39.5	39.0
All straw plowed under, fall disked	41.0	34.1	39.2	38.1
Average	43.9	40.0	43.8	42.6
Average crop year precipitation, inches	13.9	14.4	17.6	15.3

*150 lbs. per acre of ammonium sulfate or calcium nitrate.

Table 29. Fifteen-year average yields and gains or losses in total nitrogen in the surface foot of soil of plots in the crop residue experiments and several rotations at the Pendleton, Oregon, Branch Experiment Station.

	15-year av. acre yield	Gain (+) or loss (-) ni- trogen lbs. per acre sur- face foot 1931-1941 ¹
<u>Crop Residue Experiments</u>		
<u>(Wheat after fallow)</u>		
Straw plowed under (8 plots)	Bu. 39.0	-105 (16)**
Straw burned (4 plots)	41.6	-140 (8)
Straw plus 150 lbs. per acre commercial fertilizer* plowed under (4 plots)	43.9	- 70 (8)
Straw plus one ton pea straw plowed under (2 plots)	46.2	+ 35 (4)
Straw plus 10 tons manure plowed under (2 plots)	49.0	+175 (4)
<u>Rotation Experiments</u>		
Winter wheat after fallow	42.2	-105 (4)
Spring wheat after fallow	42.7	+ 35 (4)
Winter wheat after manured fallow	50.9	+175 (4)
Winter wheat after fallow with top dressing of manure in spring	49.9	+245 (4)
Winter wheat after peas	28.9	+140 (2)
Peas after winter wheat	20.9	+140 (2)
Spring wheat after peas	31.1	+210 (2)
Peas after spring wheat	20.9	+210 (2)

¹ Based on 3.5 million lbs. as weight of an acre foot of soil.

* Ammonium sulfate or calcium nitrate.

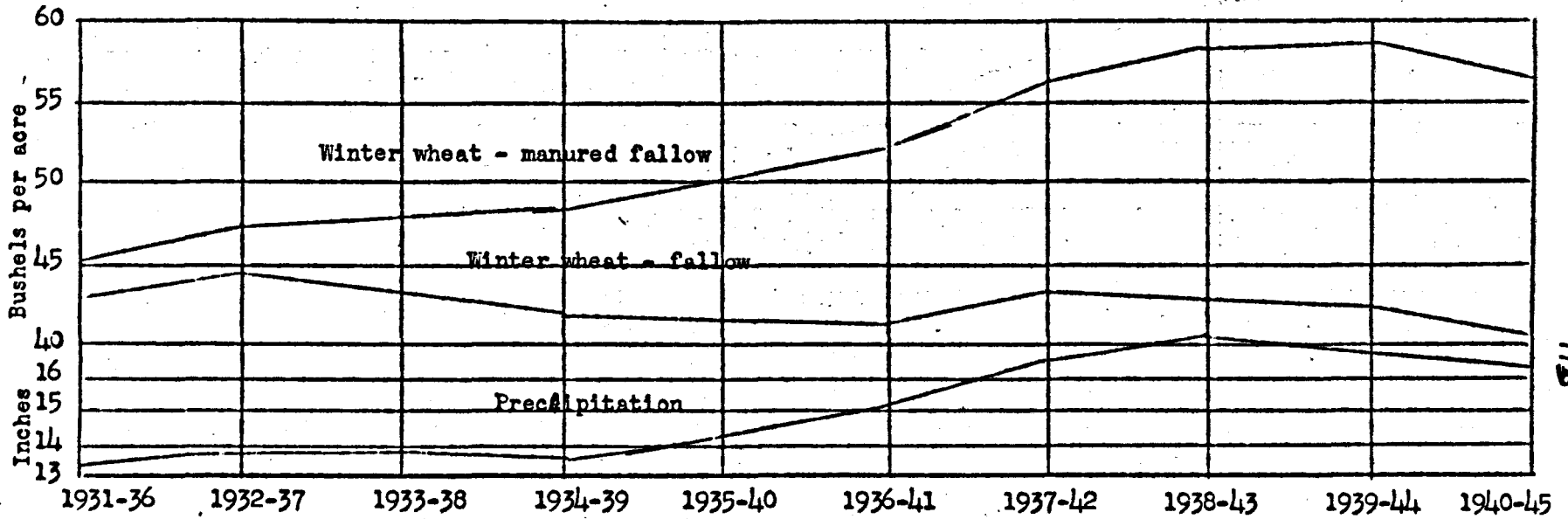
** Number of one-tenth acre plots.

Table 29A--Average yield comparisons from growing wheat after fallow and from several rotations with peas at the Pendleton, Oregon, Branch Experiment Station.

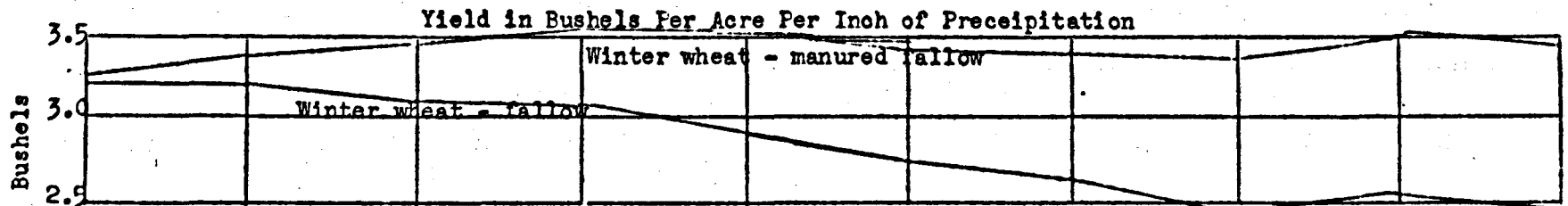
ROTATION	7-Yr. av. yield 1939-1945 bu.
175. WINTER WHEAT - PEAS TURNED UNDER - WINTER WHEAT - FALLOW:	
Winter wheat after fallow	48.0
Winter wheat after peas turned under	44.8
176. SPRING WHEAT - PEAS TURNED UNDER - SPRING WHEAT - FALLOW:	
Spring wheat after fallow	44.3
Spring wheat after peas turned under	43.9
177. WINTER WHEAT - PEAS:	
Winter wheat after peas	30.3
Peas after winter wheat	25.7
178. SPRING WHEAT - PEAS:	
Spring wheat after peas	31.1
Peas after spring wheat	25.7
181. SPRING WHEAT - FALLOW	41.1
267. WINTER WHEAT - FALLOW	40.6
192. SPRING WHEAT - FALLOW - PEAS:	
Spring wheat after peas	28.3*
Peas after fallow	39.0*
193. SPRING WHEAT - PEAS - FALLOW	
Spring wheat after fallow	45.6*
Peas after spring wheat	21.0*

*3-Year Average yield, 1943-1945

Yields of winter wheat after manured fallow (10 tons per acre) and after fallow with no fertilizer, by 6-year moving averages; also precipitation and bushels of wheat produced for each inch of precipitation, by 6-year moving averages, at the Pendleton, Oregon, Branch Experiment Station for the years 1931 to 1945, inclusive



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With fertility requirements satisfied (manured plots), the ratio of wheat yield to precipitation was about 3.5, i.e., the wheat yield was 3.5 times the average crop year precipitation. Because the increase in precipitation failed to increase average yields on the land not fertilized, the ratio of yield to precipitation dropped from a little more than 3 in the earlier years, when the average precipitation was about 14 inches, to about 2.5 in the later years, when the average precipitation was about 16.5 inches.

Yields of winter wheat and peas, by 6-year moving averages, in crop rotation experiments, and cro-
 year precipitation by 6-year moving averages, at the Pendleton, Oregon, Branch Experiment Station
 for the years 1931 to 1945, inclusive.

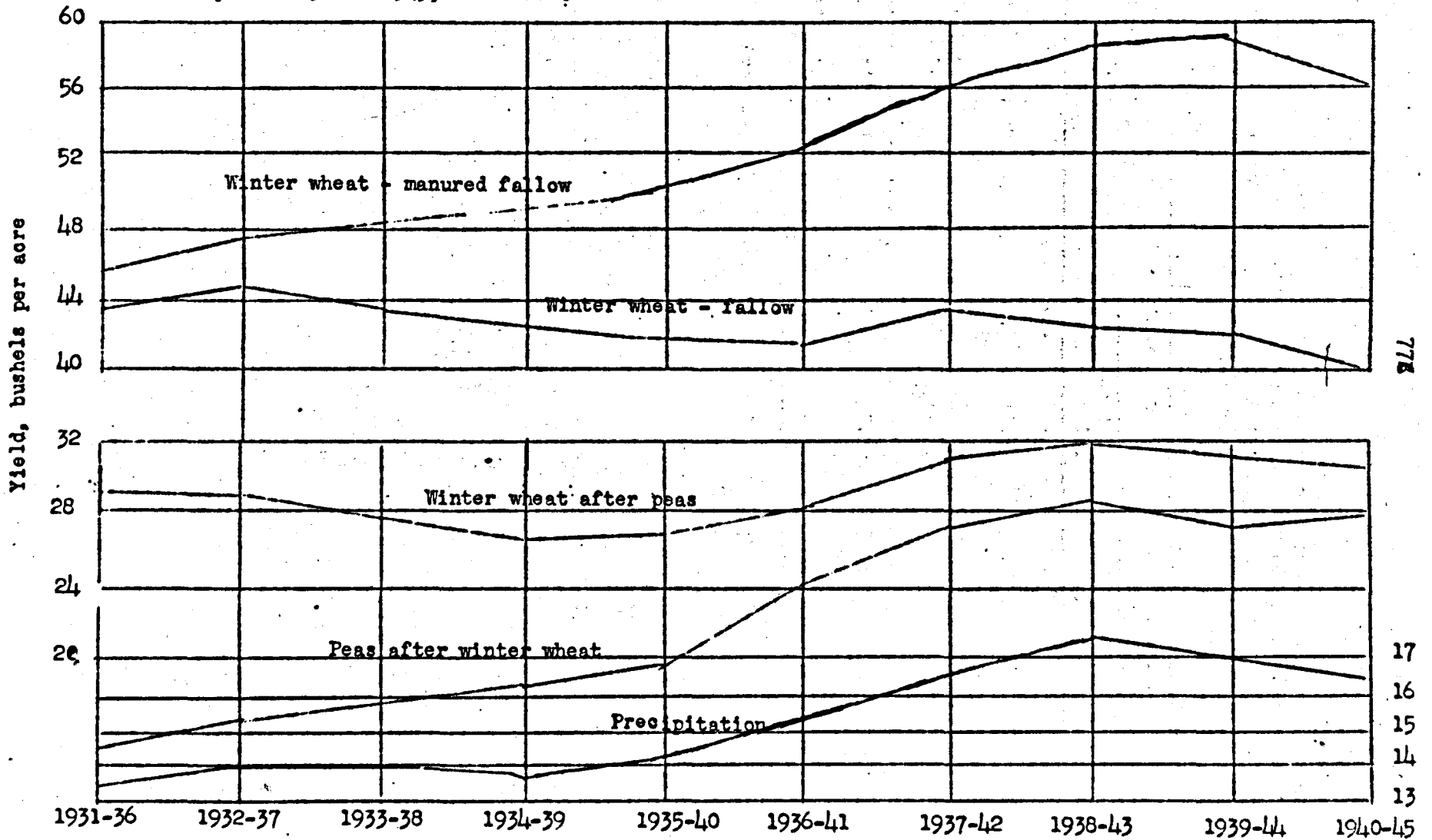


Table 36. Average yields of winter wheat from land plowed on various dates with a moldboard plow at two depths, with all straw plowed under and all straw burned, at the Pendleton, Oregon, Branch Experiment Station, for the 8-year period, 1938-1945.

Time of Plowing for Fallow	Straw Burned		Straw Plowed under		Average
	Deep 9 in.	Shallow 5 in.	Deep 9 in.	Shallow 5 in.	
	bu.	bu.	bu.	bu.	bu.
Fall (Oct. 15)	41.7	41.3	38.8	38.2	40.0
Early spring (March 15)	43.2	41.3	39.2	36.9	40.2
Medium early spring (April 15)	40.9	37.7	39.6	33.6	38.0
Late spring (May 15)	<u>38.2</u>	<u>38.1</u>	<u>33.9</u>	<u>33.5</u>	<u>35.9</u>
Average	41.0	39.6	37.9	35.6	

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	Deep	Shallow	Average
Straw burned	41.0	39.6	40.3
Straw plowed under	<u>37.9</u>	<u>35.6</u>	<u>36.8</u>
Difference	3.1	4.0	3.5

Table 38. Winter wheat yields, in bushels per acre, from five methods of initial tillage for fallow at the Pendleton, Oregon, Branch Experiment Station for five even-numbered and five odd-numbered years. The superiority of moldboard plowing in the odd-numbered years probably was due to heavier weed infestation on the land used in those years with better weed control from moldboard plowing.

	<u>1936</u>	<u>1938</u>	<u>1940</u>	<u>1942</u>	<u>1944</u>	<u>Average</u>
Early spring moldboard plowed	32.0	40.6	30.0	47.1	34.7	36.9
One-way disked, fall and spring	38.4	40.8	27.0	44.0	34.5	36.9
Fall moldboard plowed	34.6	42.5	33.6	51.9	40.1	40.5
Fall chiseled, spring double disked	30.5	39.8	26.4	42.9	37.8	35.5
	<u>1937</u>	<u>1939</u>	<u>1941</u>	<u>1943</u>	<u>1945</u>	
Early spring moldboard plowed	40.6	29.0	32.3	50.5	27.7	36.0
One-way disked, fall and spring	32.5	24.8	31.9	37.0	16.9	28.6
Fall moldboard plowed	35.1	23.4	34.0	40.0	29.5	32.4
Fall chiseled, spring doubled disked	29.9	23.7	32.3	36.3	15.1	27.5
Fall and spring double disked	31.8	23.8	33.9	34.5	17.0	28.2

10-Year Average Yields:

Early spring moldboard plowed	36.5
One-way disked, fall and spring	32.8
Fall moldboard plowed	36.5
Fall chiseled, spring doubled disked	32.8
Fall and spring double disked	31.9

Table 39. Annual and average yields of winter wheat in bushels per acre from two types of summer fallow with all straw utilized at Moro, Oregon for the years 1938 to 1945 inclusive. Yields are averages from 4 one-tenth acre plots each year.

<u>Year</u>	<u>Stubble Mulch Fallow</u>	<u>Black Fallow</u>
1938	23.3	27.6
1939	26.9	28.9
1940	14.4	15.0
1941	32.0	33.8
1942	29.9	31.7
1943	23.7*	33.2*
1944	30.1	28.7
1945	16.5	17.7
Average	24.6	27.1

*Spring wheat in 1943.