The effect of nitrogen fertilizer placement on quality and quantity of spring wheat on dryland

by Ahmad Y Alsayegh

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Soils at Montana State College
Montana State University

Abstract:
Experiments were conducted to determine the effect of nitrogen placement and time of application on quality and quantity of spring wheat produced on dryland in the vicinity of Bozeman, Montana. These experiments, which were carried out over a 2-year period, included the application of nitrogenous fertilizer at various stages of plant growth and by different methods.

The yield and protein content of grain are related to nitrogen uptake by the plant. This relationship is influenced by the amount of available soil moisture during the growing season.

It was found in 1957 that the yield increased significantly when nitrogen was applied with seed, on fallow, and at tillering stage.

These treatments, plus the treatment of nitrogen applied on surface, gave a higher protein content than the check.

Although grain yield differences were not statistically significant in 1958, they were appreciable on some treatments. The highest grain yield was produced by nitrogen applied at 6 inches deep, followed by nitrogen applied on surface; with seed; on fallow, early; and on fallow, late. The protein content increased statistically with nitrogen applied with seed, on surface, at 6 inches deep, and at early boot stage.

Because of the difference in rainfall distribution during the two growing seasons, there were differences in test weights and straws grain ratios. In 1957, late drought resulted in lower test weights and higher strawsgrain ratios than were obtained in the 1958 trial.

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ABSTRACT

Experiments were conducted to determine the effect of nitrogen placement and time of application on quality and quantity of spring wheat produced on dryland in the vicinity of Bozeman, Montana. These experiments, which were carried out over a 2-year period, included the application of nitrogenous fertilizer at various stages of plant growth and by different methods.

The yield and protein content of grain are related to nitrogen uptake by the plant. This relationship is influenced by the amount of available soil moisture during the growing season.

It was found in 1957 that the yield increased significantly when nitrogen was applied with seed, on fallow, and at tillering stage. These treatments, plus the treatment of nitrogen applied on surface, gave a higher protein content than the check.

Although grain yield differences were not statistically significant in 1958, they were appreciable on some treatments. The highest grain yield was produced by nitrogen applied at 6 inches deep, followed by nitrogen applied on surface; with seed; on fallow, early; and on fallow, late. The protein content increased statistically with nitrogen applied with seed, on surface, at 6 inches deep, and at early boot stage.

Because of the difference in rainfall distribution during the two growing seasons, there were differences in test weights and straw: grain ratios. In 1957, late drought resulted in lower test weights and higher straw:grain ratios than were obtained in the 1958 trial.

INTRODUCTION

It is frequently true that protein is limiting for human food throughout the world. The protein content in wheat depends upon the nitrogen content in the soil more than any other element (where all elements in soil are in balance). The nitrogen content of the soil influences both yield and protein content of wheat. There is no doubt that the protein is a limiting factor of wheat quality.

The objective of nitrogen fertilization of wheat in dryland areas is to obtain highest yield and best quality with lowest cost of production. Since nitrogen fertilizer is expensive and easily lost from the soil, many investigators have worked to find proper time, placement, and amount of it to apply with regard to climatic and soil factors. In irrigated areas, a tremendous amount of work has been done so far as fertilizer application is concerned. In dryland areas, the problem is entirely different because moisture is a limiting factor and precipitation varies from year to year. All the work which has been done on this subject has not given a satisfactory answer to this problem. It was frequently assumed that yield was controlled by available water. Only within about 10 years has fertility been seriously considered.

Nitrogen and phosphate are often deficient in Montana soils. Shaw and Klages (11) stated that the best results from fertilization of particular crops require the right kind and amount of plant nutrient supplied at the right time and place.

As mentioned before, most fertilizer studies concerning time and placement of applications have been conducted in humid and irrigated areas. In dryland areas, the use of fertilizer is relatively new, so it is important to find the best methods of using it to improve the quantity and quality of the crop. Since wheat is one of the principal crops in dryland areas in the state of Montana, it is important to find the right time and placement of fertilizer applications for this crop in order to improve its yield and quality. In order to do this, studies were undertaken to:

A. Determine the effect of nitrogen placement and time of application on growth, water use, and nitrogen uptake by wheat on dryland, and

B. Determine the effect of these factors on protein content and yield of wheat.

REVIEW OF LITERATURE

Desirable fertilizer practices are those that best provide for the plant. This involves not only the rate or the amount of fertilizer that must be used but also the depth of placement and time of application. Duley (4) found that fertilizer applied with seed gave higher yield than when applied either above or below the seed. Thompson (17) pointed out that the deeper placement of fertilizer helps to keep the plant going after the roots are feeding below the depth of the starter fertilizer. He considered soil climatic conditions in determining the depth of fertilizer placement. He said: "If the soil dries out quickly after a rain, the fertilizer should be applied deeper than the seed level. On the other hand, if the soil holds moisture well, the fertilizer should be applied at the seed level."

Smith (12) concluded in 1947 that nitrogen and P_2O_5 gave highly significant increases in the yield of wheat when either one or both of these materials were placed with the seed. He could not find clear indication of the fertilizer application effect on protein content. Russell (10) demonstrated the effect of nitrogenous fertilizer on the protein content of hay crops. He said: "This effect depends upon the responsiveness of the crop, as well as the time of fertilizer application relative to development of the crop." He added that, if the fertilizers are applied sufficiently near harvest time for the crop to absorb much of the added nitrogen, 1 to 3 weeks before harvest, the protein content of the hay will be increased. During World War II, the Germans experimented on this method of converting nitrogenous fertilizers into protein by applying them to cereal and potato crops at flowering time. They found that nitrates were more efficient than ammonia and that dressing of 40 pounds of nitrogen per acre gave a substantial increase in the protein content of the crop.

Olson and Dreier (8) found that time and method of fertilizer application influenced the stand and the growth of small grains in Nebraska.

Hunter et al. (5) found that protein content of pastry wheat was not raised to objectionably high values until more nitrogen was applied than was required to produce maximum yield with nitrogen fertilization at seeding time. So long as increased nitrogen applications increased the yields significantly, the yields increased more rapidly than the protein. With further increases in nitrogen, protein increased more rapidly than yields. These results were from 3 years of experiments conducted on 133 farms in dryland areas in Oregon.

Nitrogen recovered from different soil depths as it is affected by moisture and soil water movement has been considered by Stewart and Eck (16) in their studies. They found that applied nitrate nitrogen moved into the soil at all moisture levels from the moisture equivalent to the 15-atmosphere percentage. There was a downward movement of surface-applied nitrate nitrogen at all moisture levels. The amount and depth of nitrogen movement was definitely affected by the moisture content in the soil.

Davidson and LeClerc (2) found that changes in protein content of the straw of wheat followed the same pattern as changes in protein content of the grain; i.e., there was an increased protein content as a result of nitrate applied at heading time. They also noted that there was an increase in the yield of both straw and grain when nitrates were applied at tillering time.

MATERIALS AND METHODS

Experimental Design

The experiments were carried out under dryland conditions. Thatcher spring wheat was used in this study. A completely randomized design was employed in 1957. This type of design is that in which treatments are allotted to the experimental plots entirely by chance (figure 1). In 1958, randomized block was used. This is a design in which the treatments are assigned at random to the experimental plots in each replication (figure 2). The plots were 6 feet wide and 30 feet long, with 12-inch spacing between rows.

Fertilizer Rate

Thirty pounds of nitrogen per acre was applied. Ammonium nitrate was used for all treatments except the check and the one where nitrogen was supplied as ureaformaldehyde. All plots received a uniform application of 30 pounds of P_2O_5 per acre.

The 1957 experiment was seeded on April 27, and the 1958 experiment on April 30. Treatments are presented in tables I and II.

Experimental Site

The two experiments were conducted in the Springhill area of the Gallatin Valley on soils known to give nitrogen response. One of these experiments was located in the southwest quarter of Section 27, the other was located in the northwest quarter of Section 26, Township 1 North, Range 5 East.

The climate (3) of this valley is continental in character and is subject to a wide range of seasonal and daily temperatures. The lowest

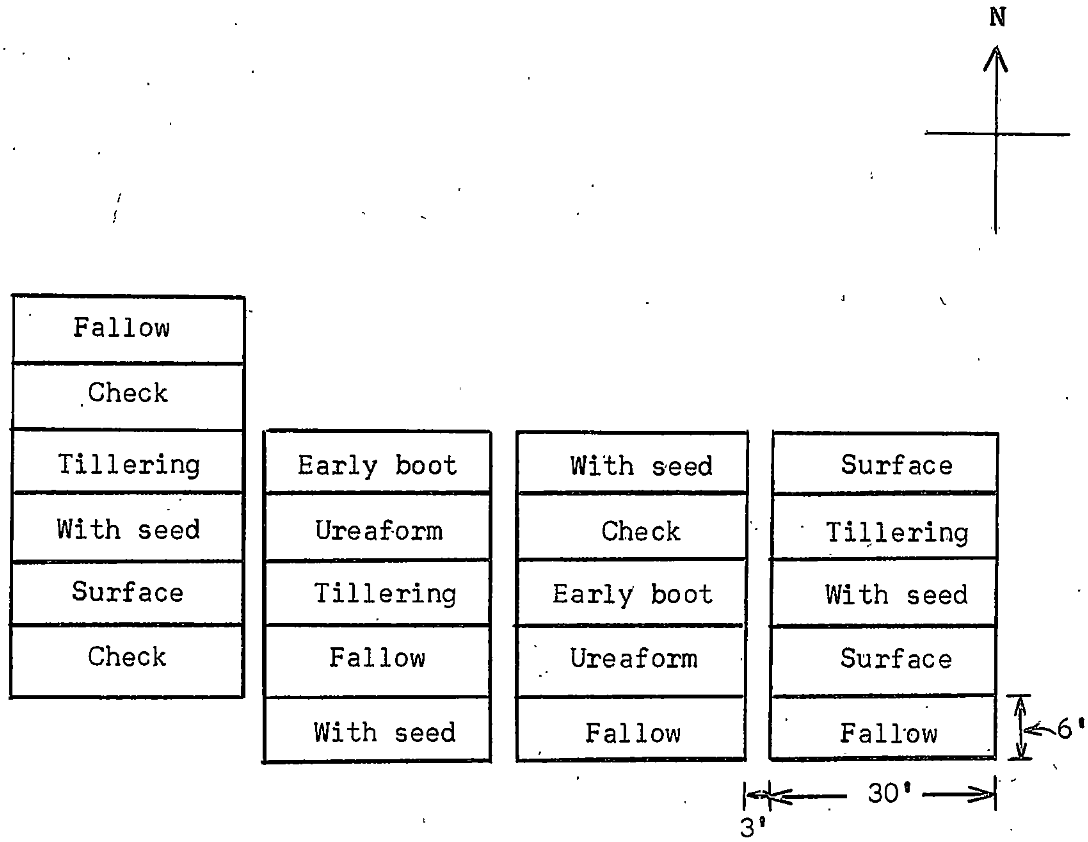

Figure 1. Field plot diagram of 1957 trial—completely randomized design.

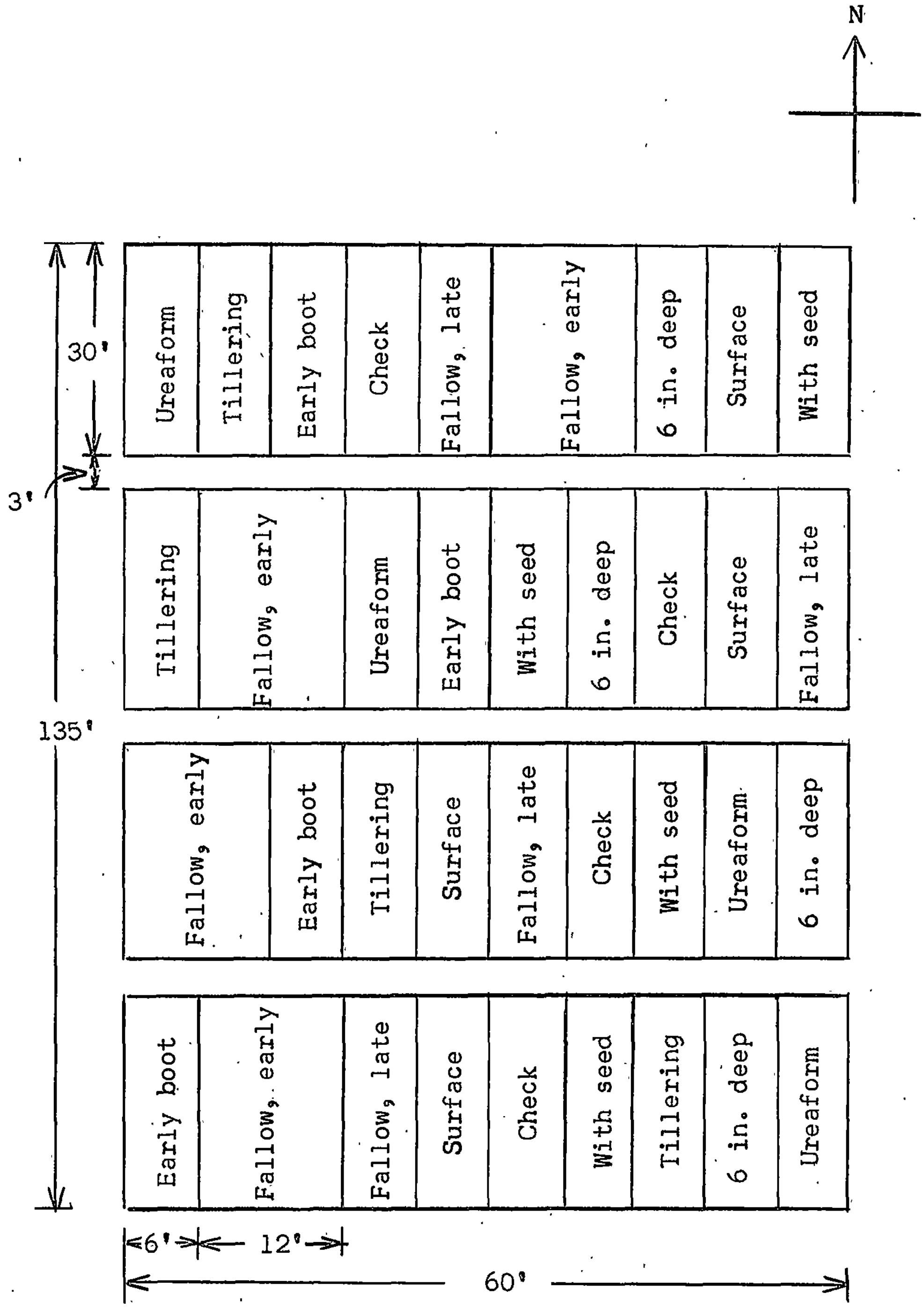

Figure 2. Field plot diagram of 1958 trial--randomized block design.

Table I. Treatments used on field experiment, 1957.

Designation		Treatment
1	Check	No fertilizer was added.
2	Fallow	Fertilizer was added in September, 1956.
3	Tillering	Fertilizer was added on surface, June 12, 1957.
4	Early boot	Fertilizer was added on July 12, 1957.
5	Surface	Fertilizer was added on the surface immediately after seeding.
6	With seed	Fertilizer was added with the seed.
7	Ureaform	Ureaformaldehyde was added with the seed.

Table II. Treatments used on field experiment, 1958.

	Designation	Treatment
1	Check	No fertilizer was added.
2	Fallow, early	Fertilizer was added in September, 1956.
3	Fallow, late	Fertilizer was added in October, 1957.
4	6 inches deep	Fertilizer was added immediately before seeding time.
5	With seed	Fertilizer was added with the seed.
6	Surface	Fertilizer was added immediately after seeding.
7	Ureaform	Ureaformaldehyde was added with the seed.
8	Tillering	Fertilizer was added on the surface, May 28, 1958.
9	Early boot	Fertilizer was added on July 8, 1958.

period of cold weather is -20 to -30° F. The highest period of hot weather is 100 to 110° F. The mean annual temperature is 42° F. The last killing frost in the spring generally occurs about the latter part of May, and the first killing frost in the fall about the middle of September. The average frost-free season is about 102 to 114 days.

The average annual precipitation is about 10 to 18 inches. May and June are the wettest months of the year.

The elevation varies in this valley from 4,000 to 6,000 feet above sea level. The area in which the experiments were located is 4,500 feet high.

The principal crops produced in the Gallatin Valley are wheat, oats, barley, alfalfa, and grass. Wheat is the most important cash crop in the valley.

Soil Description (3)

Classification

The soil is classified as Amsterdam silt loam, which is one of the most important soil types in this area. It is a Chestnut-Brown intergrade. The profile description is as follows:

Depth in inches	
0-6	Fine granulated brown silt loam
6-12	Coarse granular and prismatic light brown silt loam
12-24	Gray very fine sandy loam which is very calcareous
24-48	Light gray very fine sandy loam

Soil analyses

Two samples were taken from the locations of the trials at a depth of 0-6 inches for the purpose of mechanical and chemical analysis.

Mechanical analysis data are given in table III. These data indicate that both soils are classified as silt loams.

Chemical analysis data are given in table IV. The pH determinations indicate that both soils are slightly below neutral. The soils can be classified as nonsaline soils. Not much difference exists in total exchange capacity of the two soils. They are low in phosphorus according to the standard now in use at Montana State College. They are also low in organic matter content. The potential for nitrifiable nitrogen production is almost equal in both soils.

Sampling

Soil samples were taken for moisture measurement to depths of 0-6, 6-12, 12-24, 24-36, and 36-48 inches from each plot. In 1957, four moisture samples were taken--at tillering, heading, dough, and harvest time. In 1958, samples were taken only at the three plant growth stages, harvest time being omitted. In both years, moisture samples were also taken at seeding.

Plant material samples were taken for yield and protein analyses at different plant growth stages, in addition to grain samples that were taken at harvest time.

The dates of sampling were different between the two seasons as they appear in table V. Yield measurements were not made on the July 8, 1958, sampling.

Table III. Mechanical analysis* for 0- to 6-inch depth for each site.

Sample	% Clay	% Silt	% Sand
1957	23.0	47.6	29.4
1958	17.4	63.4	19.2

*The hydrometer method was employed.

Table IV. Chemical analysis* for 0- to 6-inch depth for each site.

Sample	pH	Conductivity (20) mmhos $EC_e \times 10^3$	Total exchange capacity (9) me./100 gm.	Soluble P (6) lbs./acre	Organic matter (6) %	Nitrifiable nitrogen (15) ppm. in soil
1957	6.1	.46	23.94	224.75	1.85	11.70
1958	6.7	.42	22.60	210.25	2.15	10.50

*Beckman pH meter, Model H-2, was used for pH measurement on a saturated paste. Solu-Bridge, Model RD-15, was used for soluble salts measurement on a saturation extract.

Table V. Time of sampling.

Stage of growth	Date of sampling	
Tillering	June 12, 1957	May 28, 1958
Heading	July 12, 1957	July 8, 1958
Dough	August 1, 1957	August 4, 1958
Harvest	August 19, 1957	August 20, 1958

RESULTS OF FIELD EXPERIMENTS

The results of the two experiments are summarized in tables VI to XVII. Original data and statistical analyses are presented in tables XVIII to XXXVI in the Appendix.

Plant Data for 1957

Dry matter production is given in table VI. Analysis of variance shows significant differences in yield at tillering, heading, and harvest, but not at the dough stage. There were no significant decreases due to nitrogen at any stage of growth. The treatment which showed a significant increase was nitrogen applied with seed when sampled at the tillering stage. In the heading sampling, three treatments gave significantly higher yields than the check. These treatments were nitrogen applied with seed, on fallow, and on surface at seeding time. Although there were no statistically significant differences at the dough stage sampling, all treatments gave higher yields than the check. The highest production of dry matter at the dough stage was due to nitrogen applied with seed, on fallow, as ureaform, and on surface.

Analysis of variance of grain yields shows three treatments gave significantly higher yield than the check. These treatments are nitrogen with seed, nitrogen on fallow, and nitrogen at tillering time.

Analysis of variance of test weights shows that no significant difference occurred. It was found that the test weights were less than the standard figure in all treatments. The grain yield increased when the test weight decreased.

Analysis of variance of the straw:grain ratios shows no significant

Table VI. Agronomic data, 1957.

Treatment	Dry matter, lbs./A Tillering 6/12/57	Heading 7/12/57	Dough 8/1/57	Grain bu./A	Test weight lbs./bu.	Straw: grain ratio
Check	397	2,367	4,776	32.4	59.2	1.68
N on surface	501	3,388*	5,737	37.2	58.9	1.53
N with seed	740*	4,199*	6,828	42.8*	58.8	1.67
N on fallow	516	3,737*	6,780	42.0*	58.4	1.68
N at tillering	329	3,034	5,320	39.3*	58.8	1.19
N at early boot	397	2,450	5,588	33.2	59.6	1.80
Ureaform	464	2,811	6,164	38.1	59.4	1.70
L.S.D.$_{.05}$	± 159.5	± 850	N.S.	± 6.4	N.S.	N.S.

*Differs from the check by one L.S.D.

difference involved. Three treatments gave approximately the same result as the check treatment. Nitrogen at early boot and nitrogen on surface gave higher ratios than the check. The lowest ratio was due to applying nitrogen at tillering.

Plant Data for 1958

Plant material and grain yields of the 1958 trial are given in table VII. There were no statistically significant differences in any of the measurements except the straw:grain ratios. However, there were noticeable differences obtained between the treatments and the check which approached significance. At tillering stage, there was a 22% reduction due to nitrogen placement with seed. The production was higher than the check in the dough stage in all treatments except where nitrogen was applied at tillering.

The highest grain yield resulted from the treatments, nitrogen at 6 inches deep, followed by nitrogen on surface; nitrogen with seed; nitrogen on fallow, early; and nitrogen on fallow, late. There was not much difference between the check yield, ureaform, and nitrogen on tillering treatments. The nitrogen placement at early boot produced a lower yield than the check.

Test weights were higher than the standard figure used in the United States. Hardly any difference was obtained between the treatments, so a relationship between yield and test weight could not be established.

Straw:grain ratios indicated that the statistically significant differences decreased progressively with nitrogen at early boot, nitrogen with seed, nitrogen at 6 inches deep, and nitrogen on surface.

Table VII. Agronomic data, 1958.

Treatment	Dry matter, lbs./A Tillering 5/28/58	Dry matter, lbs./A Dough 8/4/58	Grain bu./A	Test weight lbs./bu.	Straw: grain ratio
Check	83.2	4,759.0	36.2	62.2	1.29
N on surface	85.6	6,083.8	42.5	62.0	1.20*
N with seed	65.2	5,451.4	42.3	61.7	1.19*
N at tillering	84.1	4,073.0	37.4	62.6	1.25
N at early boot	72.4	4,208.2	33.6	62.3	1.09*
Ureaform	90.5	5,327.3	37.5	62.7	1.26
N at 6 inches deep	90.5	5,263.3	43.9	62.2	1.19*
N on fallow, early	86.1	6,015.8	41.1	62.6	1.21
N on fallow, late	85.2	5,835.6	40.1	62.5	1.25
L.S.D. $_{.05}$	N.S.	N.S.	N.S.	N.S.	± .09

*Differs from the check by one L.S.D.

It was also found that the highest straw:grain ratio was obtained in the check, and the lowest ratio was obtained in the early boot treatment.

Tables VIII and IX present the amount of water used by the crop during both seasons. It appears that the stored and total water used at each stage of growth was higher in the 1957 season than in 1958. Although grain yields were comparable in the two years, straw yields were considerably higher in 1957 than in 1958.

The stored water used by the plants from five different depths during the plant growth stages in both years is given in tables X and XI. It was found that the water used from the 0- to 6-inch depth during the tillering stage in 1957 was lower than it was in 1958. This was because water used from this depth was replaced by rainfall. Practically no water was used in either season from the 24- to 36-inch and 36- to 48-inch depths at this stage, except that indicated by the ureaform treatment in 1958. The water used increased at the heading stage in 1957 at all depths. In 1958, there was not much difference between the first two stages at the 0- to 6-inch depth, but the differences increased with the others. In the dough stage, the water used increased from all depths in both years.

Tables XII and XIII present pounds of dry matter produced per acre-inch of water for both trials. The data indicate that, at the tillering stage, moisture efficiency was higher in 1957 than it was in 1958. In the dough stage, the moisture efficiency was higher in 1958. This difference will be explained later according to some climatic factors involved.

The averages of percentage of protein content in plant material and

Table VIII. Soil moisture data (inches of water for 4-foot depth of soil), 1957.

		Moisture used since seeding							
	Soil moisture	Tillering 6/12/57		Heading 7/12/57		Dough 8/1/57		Harvest	
Treatment	at seeding	Stored	Total	Stored	Total	Stored	Total	Stored	Total
Check	12.10	.59	3.74	2.56	8.15	5.55	11.36	6.18	11.99
N on surface	12.35	.53	3.68	2.98	8.57	6.83	12.64	6.58	12.39
N with seed	12.16	1.18	4.33	3.67	9.26	7.04	12.85	6.70	12.51
N on fallow	12.02	.46	3.61	3.63	9.22	6.92	12.73	6.77	12.58
N at tillering	12.23	.64	3.79	2.98	8.57	6.13	11.94	6.41	12.22
N at early boot	12.31	.44	3.59	2.44	8.03	6.24	12.05	6.19	12.00
Ureaform	12.31	.73	3.88	2.99	8.58	6.18	11.99	6.47	12.28

Table IX. Soil moisture data (inches of water for 4-foot depth of soil), 1958.

Treatment	Soil moisture at seeding 4/30/58	Moisture used since seeding					
		Tillering 5/28/58		Heading 7/8/58		Dough 8/4/58	
		Stored	Total	Stored	Total	Stored	Total
Check	12.02	1.07	1.19	2.58	6.52	5.41	10.35
Ureaform	12.44	1.92	2.04	3.60	7.54	6.71	11.65
N on surface	12.05	1.01	1.13	3.52	7.46	5.71	10.65
N at 6 inches deep	12.24	1.28	1.40	3.42	7.36	5.73	10.67
N at tillering	12.45	.94	1.06	2.82	6.76	5.20	10.14
N at early boot	12.40	1.28	1.40	1.72	5.66	4.72	9.66
N with seed	11.88	.96	1.08	3.01	6.95	5.35	10.29
N on fallow, early	12.26	1.14	1.26	2.56	6.50	5.35	10.29
N on fallow, late	12.05	1.09	1.21	3.20	7.14	5.78	10.72

Table X. Inches of stored water used since seeding, 1957.

Treatment	Depth in inches 0-6	6-12	12-24	24-36	36-48	Total
			June 12			
Check	.12	.17	.22	.14	-.06	.59
N on fallow	.09	.23	.13	.03	-.02	.46
N with seed	.24	.33	.58	.01	.02	1.18
N on surface	.16	.25	.23	-.15	.04	.53
Ureaform	.16	.27	.39	.01	-.10	.73
N at tillering	.14	.25	.34	.04	-.13	.64
N at early boot	.08	.23	.26	-.16	.04	.45
			July 12			
Check	.22	.44	.92	.62	.36	2.56
N on fallow	.29	.56	1.11	1.13	.54	3.63
N with seed	.37	.54	1.12	1.10	.54	3.67
N on surface	.28	.49	.93	.88	.48	2.98
Ureaform	.24	.52	1.01	.82	.40	2.99
N at tillering	.27	.60	.93	.79	.39	2.98
N at early boot	.22	.46	.80	.55	.41	2.44
			August 1			
Check	.84	.74	1.52	1.36	1.09	5.55
N on fallow	.94	.94	1.86	1.83	1.33	6.92
N with seed	.97	.81	1.87	1.93	1.44	7.04
N on surface	.99	.78	1.78	1.76	1.51	6.83
Ureaform	.93	.75	1.66	1.67	1.71	6.18
N at tillering	.86	.82	1.68	1.65	1.11	6.13
N at early boot	.96	.91	1.66	1.52	1.19	6.24

Table XI. Inches of stored water used since seeding, 1958.

Treatment	Depth in inches 0-6	6-12	12-24	24-36	36-48	Total
			May 28			
Ureaform	.60	.30	.24	.33	.45	1.92
N at tillering	.62	.07	.35	-.06	-.04	.94
N at early boot	.55	.23	.17	.39	-.06	1.28
Check	.58	.19	.21	.04	.05	1.07
N on fallow, late	.54	.20	.16	.02	.17	1.09
N on fallow, early	.55	.30	.28	.03	-.02	1.14
N at 6 inches deep	.51	.23	.15	.15	.24	1.28
N on surface	.56	.17	.29	.06	-.07	1.01
N with seed	.58	.21	.19	.02	-.04	.96
			July 8			
Ureaform	.63	.60	1.08	.76	.53	3.60
N at tillering	.59	.55	1.41	.39	-.12	2.82
N at early boot	.65	.64	.98	-.60	.05	1.72
Check	.62	.39	.99	.33	.25	2.58
N on fallow, late	.52	.58	1.03	.55	.52	3.20
N on fallow, early	.45	.58	.89	.42	.22	2.56
N at 6 inches deep	.60	.62	1.02	.70	.48	3.42
N on surface	.66	.46	1.30	.83	.27	3.52
N with seed	.59	.50	1.13	.59	.20	3.01
			August 4			
Ureaform	.92	.80	1.54	1.53	1.92	6.71
N at tillering	.91	.72	1.85	1.11	.61	5.20
N at early boot	.97	.87	1.55	1.05	.28	4.72
Check	.96	.79	1.68	1.35	.63	5.41
N on fallow, late	.90	.79	1.46	1.51	1.12	5.78
N on fallow, early	.94	.82	1.62	1.34	.63	5.35
N at 6 inches deep	1.03	.88	1.56	1.41	.85	5.73
N on surface	.94	.77	1.67	1.44	.89	5.71
N with seed	.93	.85	1.60	1.36	.61	5.35

Table XII. Mean dry matter in pounds (or bushels of grain) per inch of water, 1957.

Treatment	Tillering 6/12/57	Heading 7/12/57	Dough 8/1/57	Grain
Check	106.1	331.0	420.4	2.70
N on fallow	142.8	405.3	532.6	3.34
N with seed	170.9	453.5	531.4	3.42
N on surface	136.0	395.3	453.9	3.00
Ureaform	119.5	327.6	514.1	3.10
N at tillering	86.7	354.0	445.6	3.22
N at early boot	110.6	305.1	463.7	2.77

Table XIII. Mean dry matter in pounds per inch of water, 1958.

Treatment	Tillering 5/28/58	Dough 8/4/58
Check	69.9	451.9
Ureaform	44.4	457.3
N on surface	75.6	571.2
N at 6 inches deep	64.6	493.3
N at tillering	55.0	440.8
N at early boot	68.0	526.2
N with seed	63.7	529.8
N on fallow, early	68.3	584.6
N on fallow, late	70.4	544.4

grain are given in tables XIV and XV. Analysis of variance shows significant differences due to plant material sampling in all stages of plant growth but not in grain in 1957. Three treatments in the tillering stage gave significantly lower protein percentages than the check. These treatments were: nitrogen with seed, nitrogen at tillering, and ureaform. There were no significant increases in this stage. At heading and at dough sampling, only nitrogen placement at tillering time gave significantly higher protein percentages over no-fertilizer treatments.

There were no significant differences in protein percentages appearing at either tillering or the dough stage in 1958, but they did appear at the heading stage and in the grain. At heading stage, the protein was increased by nitrogen applied at early boot, on surface, and with seed. The same treatments, along with nitrogen placement at 6 inches deep, also increased grain protein. Although there were no statistically significant differences in protein at the dough stage sampling, there were considerable differences in the percentage of protein content that approached significance. The treatments, nitrogen at 6 inches deep, nitrogen on surface, nitrogen with seed, and nitrogen at early boot, gave higher protein content than the check.

Tables XVI and XVII present pounds of nitrogen uptake per acre by plants during the growth seasons and grain development. Some difference appeared in nitrogen taken up by the check plots in the two trials. The data show that nitrogen taken up from the soil by the no-fertilizer treatment in 1958 is more than in 1957 in the dough stage and grain sampling. This was in contrast to the tillering stage, which shows that the nitrogen

Table XIV. Mean protein percentage of plant material and grain, 1957.

Treatment	Plant material: Tillering 6/12/57	Plant material: Heading 7/12/57	Plant material: Dough 8/1/57	Grain
Check	24.4	8.8	6.1	11.1
N on surface	23.0	8.7	6.1	11.6
N with seed	22.6*	8.5	6.1	11.8
N on fallow	24.2	9.0	6.6	12.1
N at tillering	22.2*	10.4*	7.3*	12.0
N at early boot	23.3	8.5	6.0	11.3
Ureaform	21.3*	7.7	5.5	10.7
$L.S.D._{.05}$	± 1.5	± 1.2	± .8	N.S.

*Differs from the check by one L.S.D.

Table XV. Mean protein percentage of plant material and grain, 1958.

Treatment	Plant material Tillering 5/28/58	Plant material Heading 7/8/58	Plant material Dough 8/4/58	Grain
Check	31.50	10.65	7.33	12.53
N on surface	31.05	12.33*	8.65	15.03*
N with seed	32.53	13.15*	8.58	15.40*
N at tillering	31.70	11.73	7.83	13.40
N at early boot	30.80	12.33*	8.15	14.48*
Ureaform	31.55	9.63	7.28	12.63
N at 6 inches deep	31.95	11.80	9.23	14.60*
N on fallow, early	30.68	10.70	6.85	13.15
N on fallow, late	31.78	11.15	7.23	12.95
$L.S.D._{.05}$	N.S.	± 1.31	N.S.	± 1.32

*Differs from the check by one L.S.D.

Table XVI. Pounds of nitrogen uptake by plants previous to different stages of plant growth, 1957.

Treatment	Tillering 6/12/57	Heading 7/12/57	Dough 8/1/57	Grain
Check	15.5	33.2	45.2	37.8
N at early boot	14.8	33.3	54.0	39.5
N on fallow	20.0	51.5	69.9	53.1
N on surface	18.9	47.9	56.1	45.1
Ureaform	15.4	34.6	54.2	42.6
N with seed	26.8	55.4	66.7	52.9
N at tillering	11.7	50.3	62.2	50.7

Table XVII. Pounds of nitrogen uptake by plants previous to different stages of plant growth, 1958.

Treatment	Tillering 5/28/58	Dough 8/4/58	Grain
Check	4.2	55.4	47.7
Ureaform	4.6	63.2	50.0
N on surface	4.5	82.5	66.9
N at 6 inches deep	4.7	81.8	66.9
N at tillering	4.4	59.4	52.9
N at early boot	3.5	66.2	51.0
N with seed	3.4	75.6	68.0
N on fallow, early	4.2	65.9	56.8
N on fallow, late	4.3	66.9	55.8

taken up in this stage is higher in 1957 than it is in 1958.

The calculation of correlation coefficients denotes that there is no relation between the yield of the plant materials and protein contents in all stages of growth on both trials. This was not the case with grain yields. It was found that there was a good correlation between percentage protein content and grain yield ($r = .663$) in 1957 but not in 1958 ($r = .142$).

DISCUSSION AND CONCLUSION

The results of the two trials indicate that nitrogen and moisture content in the soil are important factors limiting the yield of wheat. Moisture influences plant growth and grain development. Nitrogen becomes more efficient for plant use in adequate moisture. These influences appear evident in plant materials, grain yields, test weights, and straw:grain ratios.

Soil moisture was good in both years at seeding time. There was some difference in the amount and distribution of rainfall during the two growing seasons. Because of this difference, the results of both years varied. It is evident that the plant growth decreases as moisture in soil decreases. This behavior is illustrated by the results that were obtained in the tillering stage in 1958. Apparently the yield at tillering sampling in 1957 was higher because of the delay of sampling, but moisture is also a factor in increasing the yield of plant material. The treatment, nitrogen applied with seed, greatly increased the growth at this stage in 1957. The same treatment in 1958 showed a reduction of 22% below the check. This reduction was probably due to two reasons. First, it was the low precipitation received during the seedling period, which limited the moisture content in the soil. This caused damage by forming high concentration of salts around the seed. Second, it might be that the root system did not develop well as the moisture decreased, which, consequently, produced low yield. Since the yield measurements were not made on heading samples in 1958, it is difficult to discuss the results for this stage of plant development.

There was some difference in pounds of dry matter per inch of water between the two years, especially in the tillering stages. This difference was probably due to the rainfall distribution during the two growing seasons. In 1957, most of the rainfall came at the early part of the season, which increased the growth of foliage. There was no rainfall for 20 days preceding harvest, which affected the grain development. This was not the case in 1958; the amount of precipitation was less, but the distribution was entirely different. Most of the rainfall came late in the season and was prevalent until harvest time. This may explain the differences found in the straw:grain ratios and test weights in both trials (see tables VI and VII). It seems that a better yield could have been obtained if there had been uniform distribution of precipitation during the entire season. Nitrogen applied at tillering in 1957 provided fairly high yields without stimulating straw growth. Nitrogen at early boot in 1958 had much the same effect, producing a low straw:grain ratio.

It was mentioned before that nitrogen becomes more efficient for plant use under adequate moisture. Nitrogen also influences the quality of the crop when it is added at different times and methods of application. This was illustrated by the trial results presented. The treatments which caused higher protein content also gave a higher yield. Likewise, the treatments that produced relatively low protein content produced lower yield. This was true with both trials. Nitrogen applied at tillering, on fallow, and with seed had the same effect, so far as the yield and protein content were concerned, in 1957. In 1958, it was also found that nitrogen applied with seed, on surface, and at 6 inches deep gave higher yield and higher protein content, but nitrogen applied at early boot gave a different response. It produced higher protein content and lower yield. From these results, it might be concluded that nitrogen applied in the early part of the season was fairly effective in both years. Nitrogen placement below the seed was as effective as nitrogen placement with the seed.

Since there was a relationship between the grain yield and protein content, it may be concluded that adding nitrogen fertilizer to soil which is deficient in nitrogen increases nitrogen content in the crop and, consequently, the protein. This was indicated by the results of 1957, which showed approximately linear correlation between the protein content and the yield (figure 3). In 1958, the value of the correlation coefficient was only .142 (figure 4), which is not statistically significant. It seems the results of this year were quite variable.

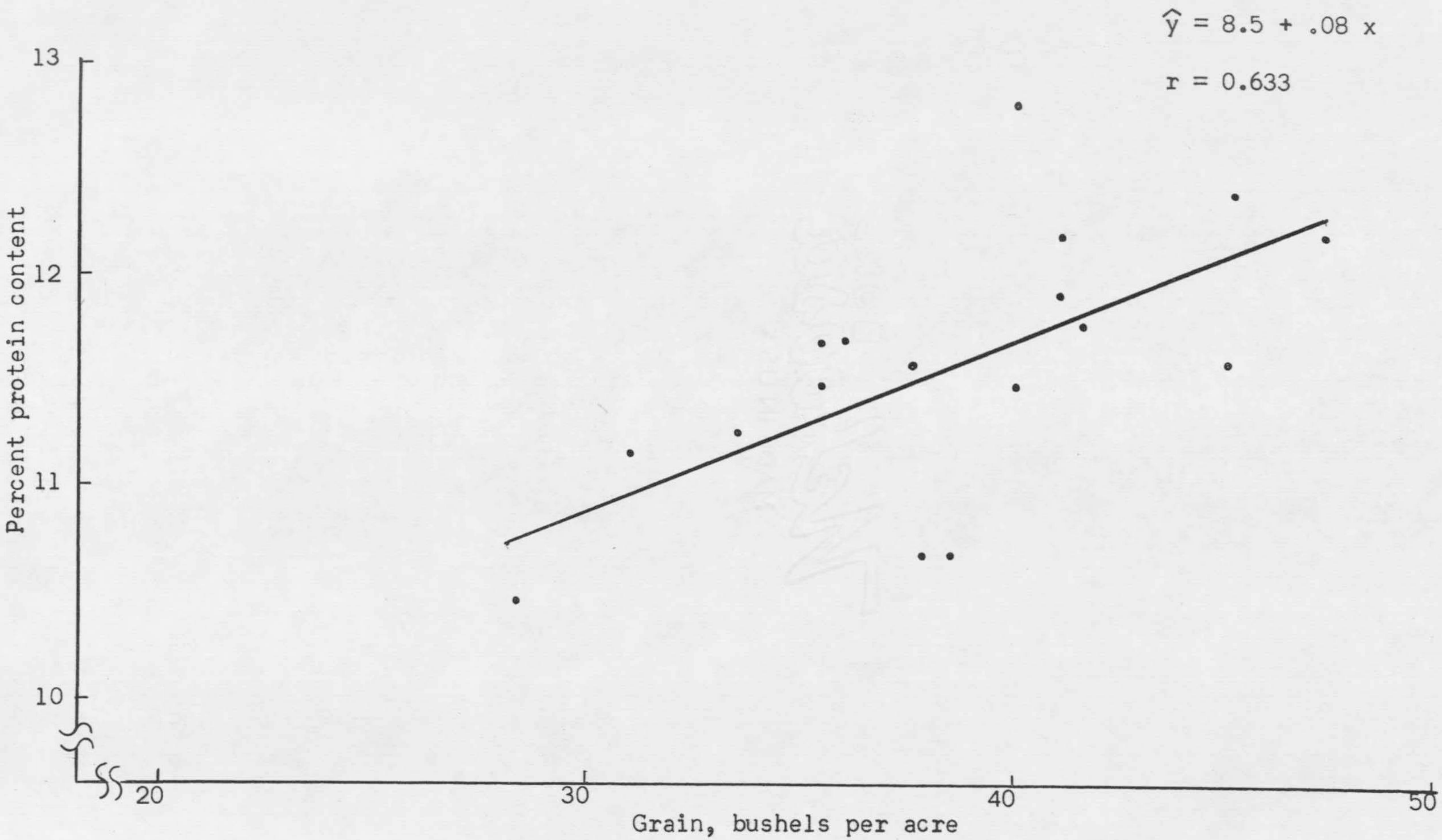

Figure 3. Regression line showing the correlation between the grain yields and percentage of protein content, 1957 trial.

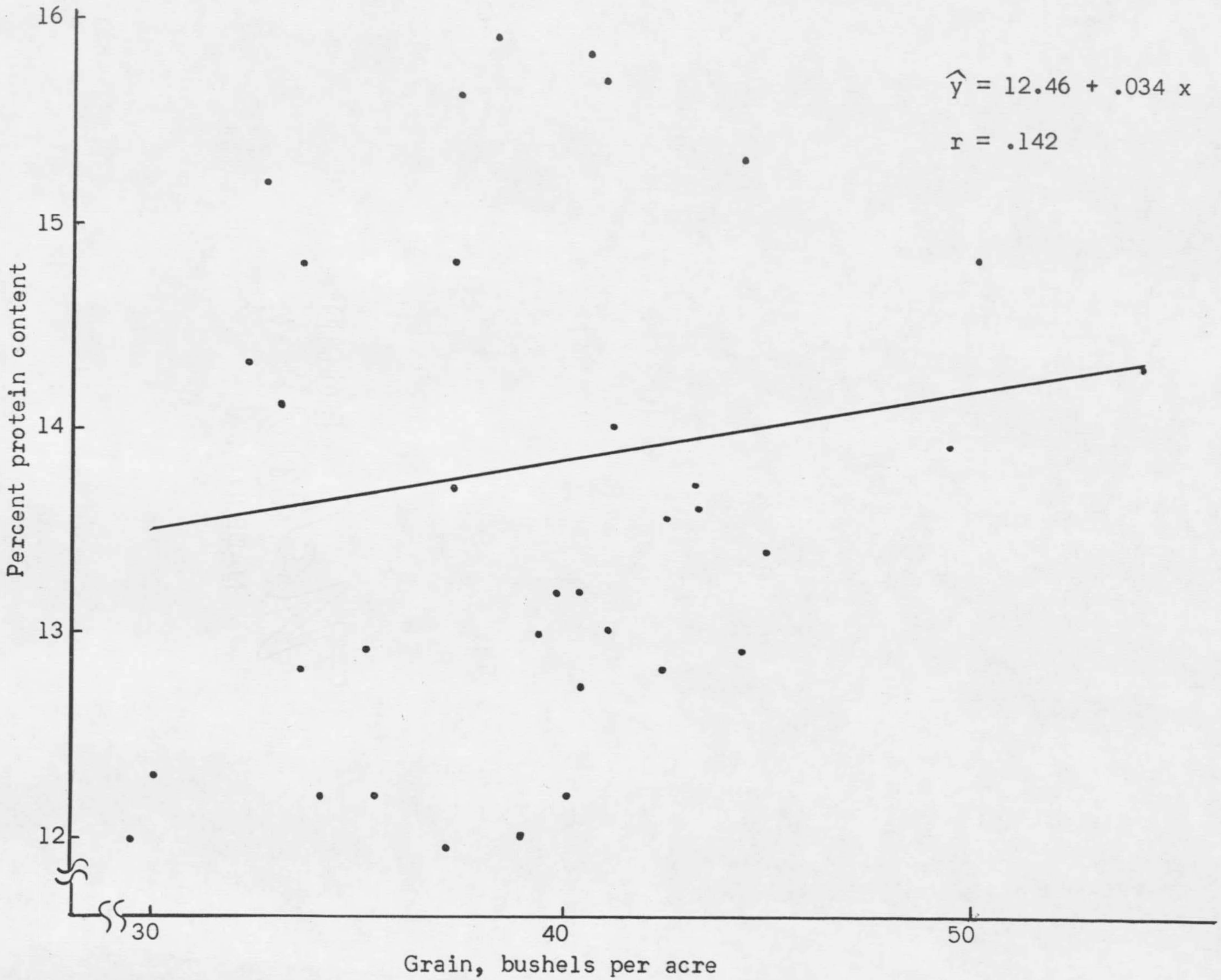

Figure 4. Regression line showing the correlation between the grain yields and percentage of protein content, 1958 trial.

LITERATURE CONSULTED

1. Black, C. A. Soil-Plant Relationships. John Wiley and Sons, Inc., New York. 1957.

2. Davidson, J., and LeClerc, J. A. The Effect of Na_2NO_3 Applied at Different Stages of Growth on Yield, Composition and Quality of Wheat. Jour. Amer. Soc. of Agron. 10:193-198. 1918.

3. DeYoung, W., and Smith, L. H. Soil Survey of the Gallatin Valley Area, Montana. USDA, Series 1931, No. 16.

4. Duley, F. L. Methods of Applying Fertilizers to Wheat. Jour. Amer. Soc. of Agron. 22:515-521. 1930.

5. Hunter, A. S., Gerard, J. C., Waddoups, H. M., Hall, W. E., Cushman, H. E., and Alban, L. A. The Effect of Nitrogen Fertilizers on the Relationship Between Increases in Yields and Protein Content of Pastry-Type Wheats. Agron. Jour. 50:311-314. 1958.

6. Jackson, M. L. Soil Chemical Analysis. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 1958.

7. Lyon, T. L., Buckman, H. O., and Brady, N. C. The Nature and Properties of Soils (5th Ed.). The Macmillan Company, New York. 1952.

8. Olson, R. A., and Dreier, A. F. Fertilizer Placement for Small Grain in Relation to Crop Stand and Nutrient Efficiency in Nebraska. Soil Sci. Soc. Amer. Proc. 20:19-24. 1956.

9. Peech, Michael, Alexander, L. T., Dean, L. A., and Reed, J. Fielding. Methods of Soil Analysis for Soil-Fertility Investigations. USDA Circular No. 757. 1947.

10. Russell, E. John. Soil Conditions and Plant Growth (8th Ed.). Longmans, Green and Company, New York. 1952.

11. Shaw, A. F., and Klages, M. G. Fertilizer Recommendations for Montana. Montana Extension Service, Circular 262. 1956.

12. Smith, F. W. The Effect of Time, Rate, and Method of Application of Fertilizer on the Yield and Quality of Hard Red Winter Wheat. Soil Sci. Soc. Amer. Proc. 12:262-265. 1947.

13. Smith, F. W., Ellis, B. G., and Grava, J. Use of Acid-Fluoride Solutions for the Extraction of Phosphorus in Calcareous Soils and in Soils to Which Rock Phosphate Has Been Added. Soil Sci. Soc. Amer. Proc. 21:400-405. 1957.

14. Snedecor, W. G. Statistical Methods (4th Ed.). Iowa State College Press, Ames. 1953.

15. Stanford, G., and Hanway, J. Predicting Nitrogen Fertilizer Needs of Iowa Soils: II. A Simplified Technique for Determining Relative Nitrate Production in Soils. Soil Sci. Soc. Amer. Proc. 19:74-77. 1955.

16. Stewart, Bobby A., and Eck, Harold V. The Movement of Surface-Applied Nitrate into Soils at Five Moisture Levels. Soil Sci. Soc. Amer. Proc. 22:260-262. 1958.

17. Thompson, L. M. Soil Fertility and Fertilizer (1st Ed.). McGraw-Hill Book Company, Inc., New York. pp. 187-206. 1952.

18. Thorne, D. W., and Peterson, H. B. Irrigated Soils, Their Fertility and Management (2nd Ed.). The Blakiston Company, Inc., New York. 1954.

19. Tisdale, S. L., and Nelson, W. L. Soil Fertility and Fertilizers. The Macmillan Company, New York. 1956.

20. United States Salinity Laboratory Staff. Diagnosis and Improvement of Saline and Alkali Soils. USDA Handbook No. 60. 1954.

APPENDIX

Table XVIII. Dry matter yields sampled on June 12, 1957, and analysis of variance.

Treatment					Average
			lbs./acre		
Check	547.2	256.2	387.4	----	396.9
Early boot	416.3	377.8	----	----	397.0
Fallow	555.4	497.9	648.4	360.2	515.5
Surface	579.6	579.6	342.6	----	500.6
Ureaform	456.3	470.7	----	----	463.5
With seed	635.6	683.6	854.9	786.1	740.1*
Tillering	328.2	307.4	350.6	----	328.7

Source of variance	df	SS	MS	F	$F_{.05}$
Total	20	529,683.2			
Treatments	6	374,892.2	62,482.04	5.65	2.85
Error	14	154,791.0	11,056.5		

$L.S.D._{.05} = \pm 159.5$

C.V. = 21.1%

Table XIX. Dry matter yields sampled on July 12, 1957, and analysis of variance.

Treatment					Average
			lbs./acre		
Check	2,491.2	2,239.8	2,371.1	----	2,367.4
Early boot	2,260.6	2,638.4	----	----	2,449.5
Fallow	2,953.8	4,153.0	4,077.7	3,056.3	3,736.7*
Surface	3,338.1	3,957.7	2,867.4	----	3,387.7*
Ureaform	2,644.9	2,976.3	----	----	2,810.6
With seed	3,227.6	4,886.3	4,357.9	4,325.9	4,119.4*
Tillering	2,961.9	2,345.5	3,794.4	----	3,033.9

Source of variance	df	SS	MS	F	$F_{.05}$
Total	20	12,698,976.0			
Treatments	6	8,187,358.0	1,364,559.67	4.23	2.85
Error	14	4,511,618.0	322,258.4		

$L.S.D._{.05} = 850.3$

C.V. = 18.1%

Table XX. Dry matter yields sampled on August 1, 1957, and analysis of variance.

Treatment					Average
			lbs./acre		
Check	4,642.9	5,715.6	3,970.5	---	4,776.3
Early boot	4,883.1	6,291.9	---	---	5,587.5
Fallow	5,283.3	7,236.5	6,468.0	8,133.1	6,780.2
Surface	4,658.9	6,836.3	5,715.6	---	5,736.9
Ureaform	5,171.2	7,156.5	---	---	6,163.8
With seed	6,484.1	6,532.1	8,501.3	5,795.6	6,828.3
Tillering	4,578.9	5,475.4	5,907.7	---	5,320.7

Source of variance	df	SS	MS	F	$F_{.05}$
Total	20	27,893,108.6			
Treatments	6	11,623,679.3	1,937,279.9	1.67	2.85
Error	14	16,269,429.3	1,162,102.1		

C.V. = 18.3%

Table XXI. Grain yields harvested on August 19, 1957, and analysis of variance.

Treatment					Average
			bu./acre		
Check	28.6	36.1	—	—	32.4
Early boot	30.9	35.4	—	—	33.2
Fallow	39.2	45.7	40.2	43.1	42.0
Surface	33.6	41.0	37.0	—	37.2
Ureaform	38.4	37.8	—	—	38.1
With seed	41.2	47.5	44.9	37.7	42.8
Tillering	35.5	41.1	41.6	—	39.4

Source of variance	df	SS	MS	F	$F_{.05}$
Total	19	433.62			
Treatments	6	263.84	43.97	3.37	2.92
Error	13	169.78	13.06		

$L.S.D._{.05} = \pm 6.4$

C.V. = 9.6%

Table XXII. Test weights, 1957, and analysis of variance.

Treatment					Average
			lbs./bushel		
Check	58.4	60.0	—	—	59.2
Early boot	59.6	59.6	—	—	59.6
Fallow	58.0	58.8	58.4	58.4	58.4
Surface	57.2	59.6	60.0	—	58.9
Ureaform	59.6	59.2	—	—	59.4
With seed	58.4	59.2	60.4	58.8	59.1
Tillering	59.1	59.2	59.2	—	58.9

Source of variance	df	SS	MS	F	$F_{.05}$
Total	19	11.27			
Treatments	6	2.73	.4550	.69	2.92
Error	13	8.54	.6569		

C.V. = 1.4%

Table XXIII. Straw:grain ratios, 1957, and analysis of variance.

Treatment					Average
Check	1.71	1.64	--	--	1.68
Early boot	1.63	1.96	--	--	1.80
Fallow	1.25	1.64	1.69	2.15	1.68
Surface	1.31	1.70	1.57	--	1.53
Ureaform	1.24	2.16	--	--	1.70
With seed	1.62	1.29	2.16	1.56	1.67
Tillering	1.15	1.22	1.19	--	1.19

Source of variance	df	SS	MS	F	$F_{.05}$
Total	19	2.0425			
Treatments	6	.6751	.112	1.07	2.92
Error	13	1.3674	.105		

C.V. = 20.3%

Table XXIV. Protein percentage of plant material sampled on June 12, 1957, and analysis of variance.

Treatment					Average
Check	24.4	24.8	24.1	—	24.4
Early boot	23.7	22.8	—	—	23.3
Fallow	25.2	25.9	22.8	22.8	24.2
Surface	22.2	26.1	20.8	—	23.0
Ureaform	19.7	23.0	—	—	21.3*
With seed	21.9	22.2	22.2	24.1	22.6*
Tillering	20.8	23.5	22.2	—	22.2*

Source of variance	df	SS	MS	F	$F_{.05}$
Total	20	55.45			
Treatments	6	44.73	7.455	9.73	2.85
Error	14	10.72	.766		

$L.S.D._{.05} = \pm 1.53$

C.V. = 3.9%

Table XXV. Protein percentage of plant material sampled on July 12, 1957, and analysis of variance.

Treatment					Average
Check	8.0	8.9	9.4	---	8.8
Early boot	8.6	8.4	---	---	8.5
Fallow	10.0	8.9	9.4	7.8	9.0
Surface	8.3	9.7	8.2	---	8.7
Ureaform	7.2	8.1	---	---	7.7
With seed	8.4	8.2	8.3	9.1	8.5
Tillering	10.2	11.0	10.1	---	10.4*

Source of variance	df	SS	MS	F	$F_{.05}$
Total	20	17.85			
Treatments	6	11.30	1.88	4.02	2.85
Error	14	6.55	.468		

$L.S.D._{.05} = \pm 1.2$

C.V. = 7.7%

Table XXVI. Protein percentage of plant material sampled on August 1, 1957, and analysis of variance.

Treatment					Average
Check	5.8	6.5	6.0	---	6.1
Early boot	5.7	6.3	---	---	6.0
Fallow	6.7	7.0	6.9	5.7	6.6
Surface	5.8	6.6	6.0	---	6.1
Ureaform	5.2	5.7	---	---	5.5
With seed	6.5	5.8	5.9	6.3	6.1
Tillering	7.7	7.3	7.0	---	7.3*

Source of variance	df	SS	MS	F	F.05
Total	20	8.01			
Treatments	6	5.34	.89	4.66	2.85
Error	14	2.67	.191		

$L.S.D._{.05} = \pm .77$

C.V. = 6.9%

Table XXVII. Protein percentage of grain harvested on August 19, 1957, and analysis of variance.

Treatment					Average
Check	10.5	11.7	—	—	11.1
Early boot	11.2	11.5	—	—	11.3
Fallow	11.0	12.4	12.8	12.0	12.1
Surface	11.3	11.9	11.5	—	11.6
Ureaform	10.7	10.7	—	—	10.7
With seed	11.8	12.2	11.6	11.6	11.8
Tillering	11.7	12.4	11.8	—	12.0

Source of variance	df	SS	MS	F	$F_{.05}$
Total	19	6.89			
Treatments	6	3.61	.602	2.39	2.92
Error	13	3.28	.252		

C.V. = 4.3%

Table XXVIII. Dry matter yields sampled on May 28, 1958, and analysis of variance.

Treatment	Rep. I	Rep. II	Rep. III	Rep. IV	Average
			lbs./acre		
Check	81.6	92.9	88.1	70.4	83.2
Ureaform	70.4	102.5	94.5	94.5	90.5
Surface	84.9	70.4	78.4	108.9	85.6
6 inches deep	86.5	89.7	116.9	68.8	90.5
Tillering	81.7	92.9	73.6	88.1	84.1
Early boot	80.1	80.1	67.2	62.4	72.4
With seed	68.8	56.0	73.6	62.4	65.2
Fallow, early	88.1	92.9	76.8	86.5	86.1
Fallow, late	62.4	80.1	86.4	112.1	85.2

Source of variance	df	SS	MS	F	$F_{.05}$
Total	35	7,157.21			
Treatments	8	2,243.14	280.39	1.43	2.36
Replications	3	219.10	73.03	.37	3.01
Error	24	4,694.97	195.62		

C.V. = 16.9%

Table XXIX. Dry matter yields sampled on August 4, 1958, and analysis of variance.

Treatment	Rep. I	Rep. II	Rep. III	Rep. IV	Average
			lbs./acre		
Check	5,091.2	4,146.6	4,578.9	5,219.3	4,759.0
Ureaform	3,970.5	5,315.3	6,372.0	5,651.5	5,327.3
Surface	5,491.4	5,315.3	6,243.9	7,284.6	6,083.8
6 inches deep	4,658.9	4,018.5	6,932.3	5,443.4	5,263.3
Tillering	4,274.7	4,562.9	4,274.7	5,699.6	4,703.0
Early boot	4,507.4	3,810.4	4,459.4	4,055.5	4,208.2
With seed	6,179.9	5,939.7	3,890.4	5,795.6	5,451.4
Fallow, early	5,811.6	5,987.7	6,083.8	6,179.9	6,015.8
Fallow, late	4,546.8	6,291.9	5,283.3	7,220.5	5,835.6

Source of variance	df	SS	MS	F	$F_{.05}$
Total	35	30,182,223.7			
Treatments	8	8,238,198.2	1,029,774.8	1.51	2.36
Replications	3	5,519,057.0	1,839,685.7	2.69	3.01
Error	24	16,424,968.5	684,373.6		

C.V. = 15.1%

Table XXX. Grain yields harvested on August 20, 1958, and analysis of variance.

Treatment	Rep. I	Rep. II	Rep. III	Rep. IV	Average
			bu./acre		
Check	40.16	29.58	35.03	39.94	36.18
Ureaform	30.54	38.98	35.40	45.18	37.52
Surface	38.55	37.43	44.38	49.82	42.54
6 inches deep	41.06	37.59	54.06	42.72	43.85
Tillering	33.21	33.70	43.31	39.46	37.42
Early boot	35.35	32.25	32.79	33.91	33.57
With seed	40.69	36.10	41.44	50.84	42.27
Fallow, early	43.31	40.26	40.16	40.48	41.05
Fallow, late	44.85	37.38	37.22	44.43	40.97

Source of variance	df	SS	MS	F	$F_{.05}$
Total	35	1,070.81			
Treatments	8	238.61	29.81	1.58	2.36
Replications	3	379.29	126.42	6.70	3.01
Error	24	453.1	18.88		

C.V. = 10.9%

Table XXXI. Test weights, 1958, and analysis of variance.

Treatment	Rep. I	Rep. II	Rep. III	Rep. IV	Average
			lbs./bushel		
Check	62.4	62.4	61.6	62.4	62.2
Ureaform	62.8	63.2	62.0	62.8	62.7
Surface	61.2	62.0	62.0	62.8	62.0
6 inches deep	62.0	62.0	62.0	62.8	62.2
Tillering	62.8	62.8	62.4	62.4	62.6
Early boot	62.4	62.0	62.4	62.4	62.3
With seed	62.0	61.0	62.0	61.6	61.7
Fallow, early	62.8	62.4	63.2	62.0	62.6
Fallow, late	62.0	62.0	63.2	62.8	62.5

Source of variance	df	SS	MS	F	F.05
Total	35	9.00			
Treatments	8	3.40	.425	1.91	2.36
Replications	3	.25	.083	.37	3.01
Error	24	5.35	.2229		

C.V. = .76%

Table XXXII. Straw:grain ratios, 1958, and analysis of variance.

Treatment	Rep. I	Rep. II	Rep. III	Rep. IV	Average
Check	1.29	1.29	1.28	1.30	1.29
Ureaform	1.30	1.23	1.26	1.25	1.26
Surface	1.13	1.20	1.18	1.28	1.20
6 inches deep	1.12	1.25	1.19	1.21	1.19
Tillering	1.26	1.23	1.18	1.33	1.25
Early boot	1.12	.97	1.26	1.00	1.09
With seed	1.08	1.15	1.22	1.30	1.19
Fallow, early	1.18	1.28	1.11	1.27	1.21
Fallow, late	1.27	1.33	1.21	1.18	1.25

Source of variance	df	SS	MS	F	$F_{.05}$
Total	35	.2211			
Treatments	8	.1096	.0137	3.55	2.36
Replications	3	.0189	.0063	1.63	3.01
Error	24	.0926	.00386		

$L.S.D._{.05} = \pm .09$

C.V. = 5.13%

Table XXXIII. Protein percentage of plant material sampled on May 28, 1958, and analysis of variance.

Treatment	Rep. I	Rep. II	Rep. III	Rep. IV	Average
Check	32.5	31.8	31.5	30.2	31.50
Ureaform	31.8	31.3	31.3	31.8	31.55
Surface	29.6	30.4	31.8	32.4	31.05
6 inches deep	32.2	32.6	31.5	31.5	31.95
Tillering	31.1	31.3	31.8	32.6	31.70
Early boot	30.0	30.6	31.1	31.5	30.80
With seed	33.1	33.3	32.4	31.3	32.53
Fallow, early	33.1	29.6	32.0	28.0	30.68
Fallow, late	32.2	31.8	31.1	32.0	31.78

Source of variance	df	SS	MS	F	$F_{.05}$
Total	35	41.49			
Treatments	8	10.98	1.373	1.13	2.36
Replications	3	1.21	.403	.33	3.01
Error	24	29.30	1.221		

C.V. = 3.5%

Table XXXIV. Protein percentage of plant material sampled on July 8, 1958, and analysis of variance.

Treatment	Rep. I	Rep. II	Rep. III	Rep. IV	Average
Check	10.2	9.4	10.8	12.2	10.65
Ureaform	9.6	9.7	9.6	9.6	9.63
Surface	11.9	11.7	12.7	12.6	12.33
6 inches deep	11.2	12.0	12.3	11.7	11.80
Tillering	12.2	10.5	12.7	11.5	11.73
Early boot	11.8	11.8	12.0	13.7	12.33
With seed	12.2	14.8	12.0	13.6	13.15
Fallow, early	9.2	10.4	10.5	12.7	10.70
Fallow, late	9.9	10.9	10.7	13.1	11.15

Source of variance	df	SS	MS	F	$F_{.05}$
Total	35	65.44			
Treatments	8	36.58	4.573	5.63	2.36
Replications	3	9.38	3.127	3.85	3.01
Error	24	19.48	.812		

L.S.D.$_{.05}$ (treatments) = $\pm$ 1.31

C.V. = 7.8%

Table XXXV. Protein percentage of plant material sampled on August 4, 1958, and analysis of variance.

Treatment	Rep. I	Rep. II	Rep. III	Rep. IV	Average
Check	6.6	7.0	7.6	8.1	7.33
Ureaform	6.0	6.2	7.8	9.1	7.28
Surface	8.2	6.5	11.5	8.4	8.65
6 inches deep	10.9	8.2	8.4	9.5	9.23
Tillering	8.3	8.2	6.8	8.0	7.83
Early boot	7.5	8.3	8.1	8.7	8.15
With seed	7.0	10.5	7.4	9.4	8.58
Fallow, early	6.5	7.3	7.2	6.4	6.85
Fallow, late	7.6	8.4	6.9	6.0	7.23

Source of variance	df	SS	MS	F	$F_{.05}$
Total	35	60.29			
Treatments	8	21.75	2.72	1.76	2.36
Replications	3	1.46	.49	.32	3.01
Error	24	37.08	1.55		

C.V. = 15.8%

Table XXXVI. Protein percentage of grain yields harvested on August 20, 1958, and analysis of variance.

Treatments	Rep. I	Rep. II	Rep. III	Rep. IV	Average
Check	12.2	12.0	12.9	13.0	12.53
Ureaform	12.3	12.0	12.2	14.0	12.63
Surface	15.9	14.8	15.5	13.9	15.03
6 inches deep	15.7	15.6	14.3	12.8	14.60
Tillering	14.1	12.8	13.6	13.1	13.40
Early boot	13.6	14.3	15.2	14.8	14.48
With seed	15.8	17.0	14.0	14.8	15.40
Fallow, early	13.7	13.2	13.0	12.7	13.15
Fallow, late	13.4	13.7	11.8	12.9	12.95

Source of variance	df	SS	MS	F	$F_{.05}$
Total	35	59.1			
Treatments	8	37.87	4.73	5.82	2.36
Replications	3	1.71	.57	.70	3.01
Error	24	19.52	.813		

$L.S.D._{.05} = \pm 1.32$

C.V. = 6.5%

Table XXXVII. Precipitation, recorded in inches, from Belgrade Airport Record.

	Daily precipitation																		Total for month
1957																			
May	3	9	11	12	13	16	19	20	21	22	23	31							
	.11	.08	.03	.16	.04	.04	.32	.97	.36	.07	.02	.06							2.26
June	2	6	7	8	10	12	14	15	16	20	21	27	30						
	.12	.27	.01	.31	.14	.12	.07	.33	.45	.37	.45	.01	.03						3.28
July	1	2	3	14	18	19	30												
	.09	.04	.04	.01	.07	.11	.02												.38
August	None																		
1958																			
April	28																		
	T																		
May	5	6	7	11	12	19	21	23	24	25	27	28	30	31					
	T	T	T	T	.02	T	T	.08	T	T	T	.02	.09	.75					.96
June	1	2	3	6	7	8	9	11	12	13	14	19	20	21	23	24	29	30	
	.03	.06	.21	T	.34	.08	.07	.24	.05	T	.05	T	T	.06	T	.42	.08	.29	1.98
July	2	3	4	6	7	8	9	23	26	29	30								
	.51	.01	T	.12	.29	.07	.26	.08	.16	.19	.09								1.78
August	2	3	8	9	11	17	18	19	21										
	.01	.21	T	.17	.05	.01	.06	.20	.06										.77