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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Approved:

A. H. Post
Head, Major Department

Murray Klages
Chairman, Examining Committee

Leon H. Johnson
Dean, Graduate Division

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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

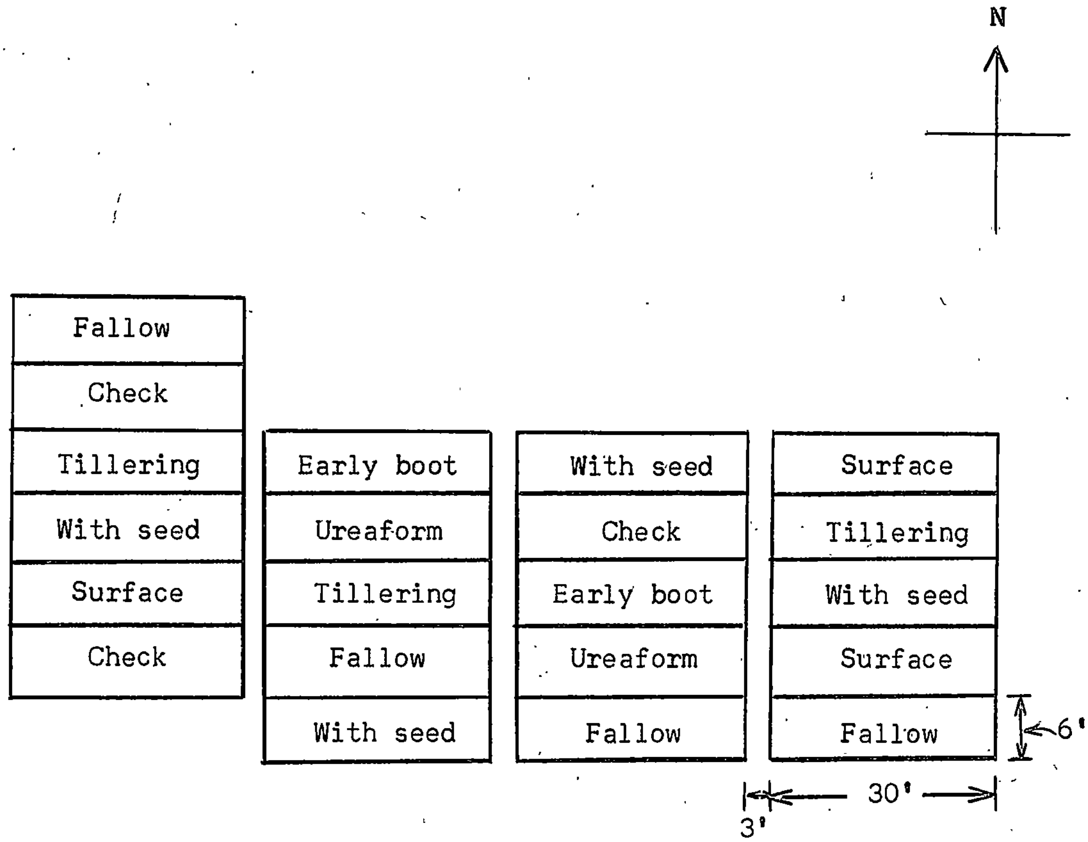

Figure 1. Field plot diagram of 1957 trial—completely randomized design.

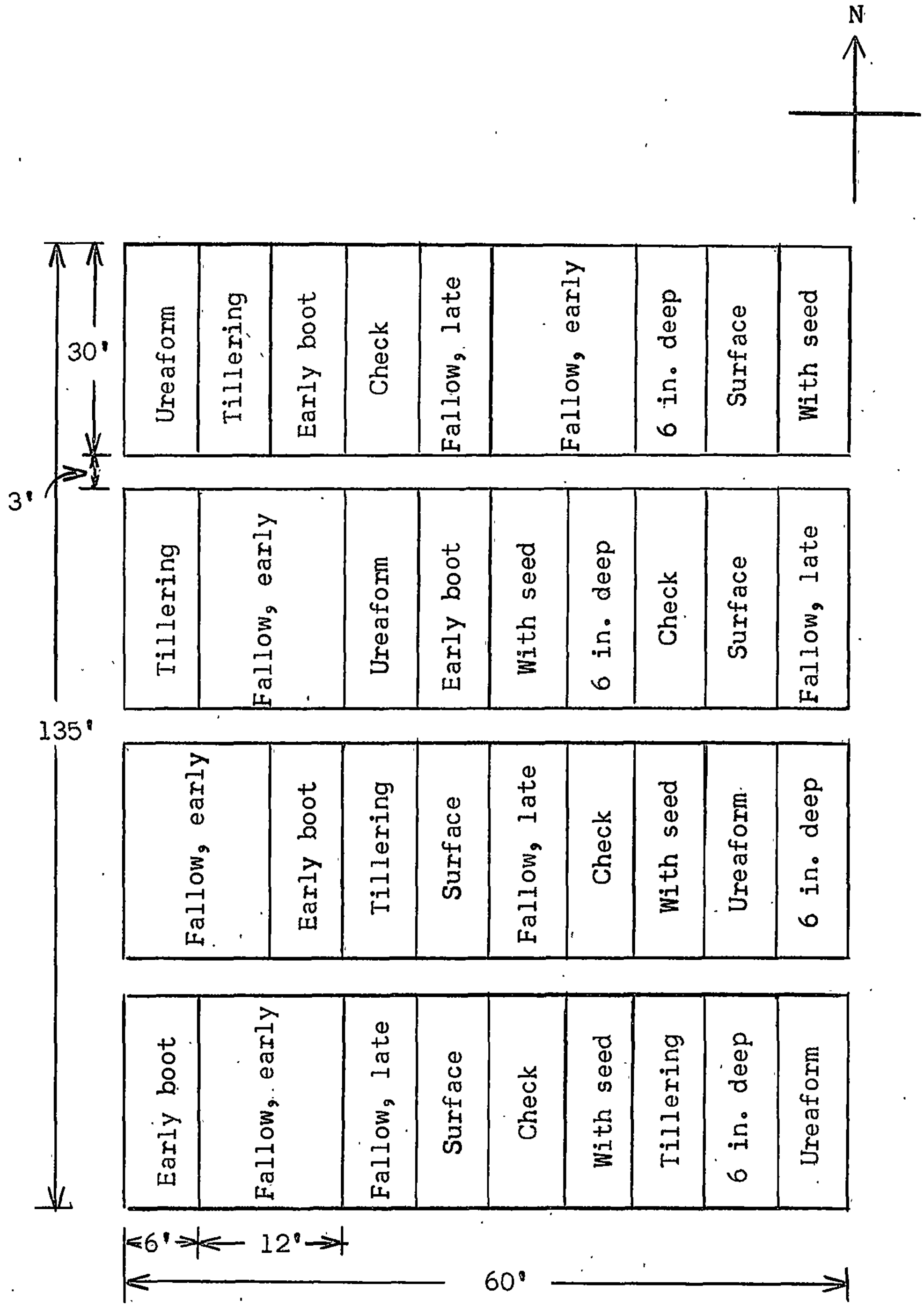

Figure 2. Field plot diagram of 1958 trial--randomized block design.

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.

<u>Soil Description</u> (3)

<u>Classification</u>

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