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EFFECT OF RESIDUAL AND APPLIED N ON THE PROTEIN CONTENT AND YIELD OF WINTER WHEAT (*TRITICUM AESTIVUM* L.) UNDER THREE MOISTURE REGIMES

by

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EFFECT OF RESIDUAL AND APPLIED N ON THE PROTEIN CONTENT AND YIELD OF WINTER WHEAT (TRITICUM AESTIVUM L.) UNDER THREE MOISTURE REGIMES

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N.M.G.

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INTRODUCTION

Wheat is a staple food crop for people all over the world. It was grown on 19,608,000 hectares in 1972 in the USA alone. Production that year was 44,620,000 metric tons; second only to corn in cereal crop production (67). In Nebraska, wheat is grown on large acreages in the western areas. This western area is characterized by low rainfall (less than 500 mm/year) and therefore moisture storage during fallow and efficient use of the moisture during production are essential.

Because wheat is primarily consumed as a human food over the world, the protein content is extremely important. Production practices are constantly being altered so that higher yields of high protein wheat can be attained. Unfortunately, yield improvement has often occurred without equivalent improvements in protein content. Since improved varieties and new production practices increase yield, the wheat requires more N to maintain protein levels. High yields cause dilution of the available soil nitrogen supply which results in reduced grain protein.

Olson and Rhoades (47) concluded that the organic matter content of wheat producing soils in Nebraska declined 30 to 40% from 1916 to 1952. This resulted in a decreased soil N supply which accentuated the reduced protein levels as yields increased. Since little N fertilizer has been used in the wheat producing areas, the low protein problem continues to become greater.

On the basis of the previous discussion, it can be concluded that yield and soil N supply are major factors in wheat protein production. However, a third factor, soil moisture, is equally important. For

example, yield is dependent on soil moisture and therefore protein content is influenced on a dilution basis. But as one increases available water, N availability also increases at least to some extent. Therefore, soil moisture does not cause decreases in protein directly but cause indirectly by increasing the total dry matter production. Further examples could be cited to demonstrate that the interrelationships of moisture, yield and soil N supply are very intricate. The problem is one of being able to predict the amount of N fertilizer needed to produce desirable protein levels and optimum yields. This prediction must take into account the soils N supplying capacity, soil moisture level and the protein level the grower desires to attain.

The general objectives of a proposal to study the overall problem were published by Sander and Peterson (57). The objective was to study the effect of different levels of applied N on wheat yield parameters as influenced by different levels of the soil profile NO_3^--N and soil moisture. The parameters studied were on:

1. Grain yield.
2. Straw yield.
3. Grain protein content.
4. "1000" grain weight.
5. Number of kernels/head.
6. Number of heads/unit area.
7. N content of plants at three stages of growth.
8. Uptake of N by the plant at different stages of growth.
9. Soil NO_3^--N content.

The expected net result was an improvement in the calibration of the NO_3^--N soil test, in relation to soil moisture conditions.

REVIEW OF LITERATURE

Wheat is an important cereal crop all over the world. In the USA it ranks second only to corn in acreage and production. It is grown predominantly in areas where the average rainfall is less than 75 cm per year. In the Great Plains area of the USA where wheat is grown on a large scale, the production of wheat depends greatly upon the quantity of moisture and N available at the time of seeding. The quality of wheat is also affected by the amount of water and N stored in the soil.

A review of the literature concerning the effects of soil moisture level and soil N supply pertinent to yield and protein content of wheat is presented under the following topics:

1. Effects of soil moisture on wheat grain yield.
2. Effects of soil moisture on protein content of wheat grain.
3. Response of wheat to N fertilization under different moisture conditions.
4. Effects of N fertilization on uptake of N by the wheat plant.
5. Effects of N fertilization on grain yield of wheat.
6. Effects of N fertilization on protein content of wheat.
7. Effects of N fertilization and soil moisture on other agronomic characteristics of wheat.

Soil Moisture and Wheat Grain Yield

Call and Hallsted (5) reported a close relationship between available water at seeding and yield under Western Kansas conditions. Increases in stored water at planting increased the yield. Later

Hallsted and Mathews (18) and Hallsted and Cole (17) observed the relationship of yield and the depth to which water was stored. The greater the depth the higher the yield obtained.

Johnson (26) in the Great Plains area of Texas estimated the average contribution of an inch of stored water to be 2.44 bu/acre for spring and 2.74 bu/acre for winter wheat. Mathews and Barnes (41) working on winter wheat at Delhart, Texas, showed that the yield potential in low rainfall areas was related to the amount of stored water at planting time. They observed that in an area where the average precipitation was about 17.5 inches the wheat crop seldom failed when the quantity of stored water at planting was above normal. When the stored water was low, below average precipitation was not sufficient to produce a good crop. Compton (9) compiled data from 2,451 Kansas Experiments and observed the relationship of stored water at planting and rainfall during the growing season. The relationship was described by the following equation:

$$Y = 0.3552\, X + 1.133\, X_1 - 10.5$$

where Y = yield

X = stored water at planting in inches

X_1 = rainfall during October to May 31 in inches.

Laude _et al_. (32) observed variable responses of wheat to N fertilization in Western Kansas because of moisture. Hallsted _et al_. (18) working with winter wheat in Kansas reported a correlation coefficient of 0.78 with quantity of water stored at seeding and grain yield. It was noted that when available soil moisture at seeding was less than

1.5 inches, the chances of failure of the crop were large. When the available soil moisture was about 1.5 to 2.9 inches at seeding, it was enough to give the wheat a good start but not sufficient to enable the crop to survive any long periods of drought. Available soil moisture above 3 inches produced good crops. Mathews and Brown (42) in 1938 reported on the combined effect of rainfall and stored water at planting on yield of winter wheat at the Garden City and Colby, Kansas Experiment Stations. They expressed the relationship by the equation

$$\text{Yield} = \frac{\text{water used} - 7.37}{0.51}$$

Where yield was in bu/acre, the water used was the precipitation in inches during the growing season plus the loss of soil water in inches during the growing season (evapotranspiration). It required 7.37 inches of water to produce the first bushel and an additional 0.51 inch of water was needed to produce each additional bushel of grain.

Smika *et al*. (58) in 1969 found a positive correlation between grain yield and stored water at seeding for all years at Akron, Colorado, two out of five years at North Platte, Nebraska, and two out of three years at Sidney, Montana.

Lahane and Staple (29) studied the influence of meterological factors over a period of 31 years on spring wheat production in a Canadian Prairie Province. They found that the stored soil moisture at seeding and seasonal precipitation were the most important factors affecting yield and were of equal importance. A linear regression of wheat yield on evapotranspiration showed that 5 to 6 inches of water were needed to produce the first increment of 4 bushels of wheat and each additional inch of water increased the grain yield 4 bu/acre.

Spring wheat yields in the Canadian Prairie Province were usually more highly correlated with seasonal precipitation than annual precipitation and even more highly correlated with seasonal plus stored soil moisture than seasonal plus annual precipitation.

A summarization of 1,107 records from the Southern High Plains in 1948 by Finnell (13) showed the relationship between soil moisture at seeding and yield of winter wheat. He observed that increases in the soil moisture at seeding increased the grain yield.

In 1953, Locke and Mathews (37) reported that winter wheat yields at Woodward, Oklahoma, were correlated with April rainfall and February-April rainfall. The rainfall for the three month period (February-April) was extremely critical in determining the magnitude of the wheat yields. There was no significant correlation between yield and stored soil moisture at seeding.

Warder et al. (66) working with spring wheat in Southwestern Saskatchewan in Canada observed no direct relationship between amount of available moisture at seeding or the seasonal precipitation with yield during 1963 under their climatic conditions.

Olson et al. (49) observed a 2.87 bushel yield increase per inch of water used with fertilized wheat compared to nonfertilized which represented an increase in water use efficiency due to N averaged over 24 locations. On five other fallow locations that had high N supplies and produced high yields without treatments, they observed a yield decrease of 3.38 to 2.71 bushels per inch of water used as N was applied. These sites even had a substantial amount of available water in the

lower part of the soil profile.

Effects of Soil Moisture on Protein Content of Wheat Grain

Dubetz (11) in 1960 working on spring wheat under greenhouse conditions on loam and loamy sand soils at the Lethbridge Station, Alberta, Canada, found a significant decrease in the percent protein of grain with increasing moisture levels on the loamy soils but not on the sandy loam. He attributed this difference to the texture of the soil because the coarse textured soil exhibited less change in the moisture tension within the moisture range studied, compared to fine textured soil. Second, the coarser soil was watered more frequently so that the higher tension was of shorter duration in this soil. Sosulski et al. (60) working with Thatcher wheat in Canada in a growth chamber observed that the protein content increased by reducing the supply of water, increasing N fertilization and high temperature. Soil moisture condition had a greater influence on increasing protein content at higher temperature, while the largest response in protein to the fertilization was obtained at the medium moisture level. Under a high moisture regime, in which the soil moisture content was never less than 17%, an application of up to 200 lb N/acre failed to increase the protein content of the grain above 12.7%. However, the grain from treatments subjected to periodic wilting contained in excess of 20% protein. Stone and Tucker (61) studied the N content of wheat as influenced by the water supplied to the plant. They observed that the N content of the grain decreased generally as the amount of water applied increased. These results were

consistent on all the three locations for all 7 years. Their explanation for these results was:

1. N movement below the active root zone.
2. Reduction in the soil N concentration.
3. The dilution effect of increased yield.

Peterson (51) studied the effect of annual precipitation on winter wheat quality. He observed yield increases with increases in annual precipitation but decreases in the protein content. Though he did not give the reason for this, it was probably due to the high yield causing a dilution of the protein.

Smika and Greb (59), while studying the effects of climatic factors on protein content of winter wheat at Akron, Colorado; North Platte, Nebraska; and several other Southwest Nebraska locations, observed that wheat protein content was negatively correlated with soil moisture at seeding time. They explained this result as being due to an increase in yield which was due to high moisture which ultimately diluted the grain protein. They also observed a significant negative correlation between protein and total precipitation. They attributed this to a dilution of N in the plant which was the result of an increase in the number of heads. Smika and Greb (59) reported that protein contents greater than 12% were obtained with increasing amounts of NO_3^--N in the soil and decreasing amounts of available soil water. Thus, limiting water affected only yield, whereas limiting NO_3^--N affected both yield and protein. They stated that with 28 cm of available soil water, at least 106 Kg/ha of NO_3^--N would have been seeded to produce grain with 12% protein at the highest yield levels.

Response of Wheat to N Fertilization Under Different Moisture Conditions

Ramig and Rhoades (53) worked with winter wheat in Central Nebraska on continuous cropped low N soils; that received approximately 12 inches of October to June rainfall. They observed that these soils produced maximum yields of wheat if approximately 20 lb N/acre were applied for every 2.5 to 3 inches of preplant available soil moisture in the six foot profile. They observed highly significant effects of preplant soil moisture levels, rate of N application and the positive interaction of these variables on yields of grain and straw during the three year period. They also observed that an additional 1 to 2 inches of water was removed from the soil when N was applied compared to plots that had no N applied.

Hunter et al. (22) working with wheat in the Columbia Basin of Oregon, observed that in low rainfall areas a yield increase was obtained up to 60 lb N/acre applied in fall while spring application increased the yield up to 100 lb N/acre. In higher rainfall areas response to fall application of N was obtained up to 90 lb N/acre while spring application increased yield up to 120 lb N/acre. In intermediate rainfall areas of Washington, Jacquot reported that from 2.3 to 5.7 lb of N were required to produce one bushel grain under a wheat-fallow system.

Wagner and Vasey (64) based their fertilizer recommendations for North Dakota on soil test data, soil moisture stored at seeding time, crop to be grown, and probable growing season rainfall in relation to yield potentials. They observed that when the stored soil moisture was less than 2 inches and the growing season precipitation was less than

6 inches, that high levels of N were not needed. An increase in the stored soil moisture of 2 to 4 inches increased the response to N fertilization to economical levels. When stored moisture was greater than 4 inches, crop responses were more assured.

Bauer et al. (1) reported from North Dakota that as the stored soil moisture at seeding increased, there was an increase in the amount of N and P fertilizer needed to produce the maximum yield.

Mathers et al. (40) working with sorghum observed the highest correlation values of NO_3^--N in the soil and the yield of grain N at their highest moisture levels. The data indicate that the NO_3^--N content of the soils was reflected in the yield whenever other factors were not limiting. From this they concluded that without irrigation, soil tests for N were of limited value for semi-arid or arid regions.

Leubs and Laag (35) working with barley in California illustrated how moderately high rates (45 Kg N/ha) of N, applied to N deficient soils with limited water, could result in severe water stress at critical growth periods and thereby depress grain yield. They observed that 45 Kg and 90 Kg N/ha applied at emergence increased the leaf area index 44 and 109% and evapotranspiration 14 and 43%, respectively.

Brown and Campbell (4) working with spring and winter wheat at Huntley, Montana, on Thurlow clay loam under a wheat-fallow system reported a wheat yield response to N fertilization. They observed that spring grain yield increased significantly only one year out of 8 years by N fertilization and decreased one year. During the three year period, winter wheat yields were not increased by fertilization but decreased

significantly in one year. Fertilizers caused accelerated growth and soil moisture use during the spring. Soil moisture use was at a lower rate from heading to maturity because of decreased moisture supply.

Effects of N Fertilization on Uptake of N by Wheat

Carpenter et al. (6) observed that the uptake of N by plants on a low N soil decreased rapidly after the wheat reached the heading stage. Uptake continued on high N soils through the dough stage. They also observed that the uptake of N at different stages of plant growth was correlated with total N content of the top 6 inches of soil, except at heading, which was correlated with the total N content of the 6 to 12 inches soil layer. They also reported high correlations between grain yields and the quantity of N either in the soil or plant. Munson and Stanford (45) in Iowa observed a linear relationship between total N uptake by the crop and levels of applied N at heading in all soils. Hucklesby et al. (20) reported depletion of soil N due to plant removal at low rates of N fertilization. At the 224 Kg N/ha rate, however, there was a net gain in soil N.

Leubs and Laag (35) in California reported an increase in N uptake by the barley crop with increased applied N. However, for a given N level, N content was highest at the lower moisture level.

Effect of N Fertilization on Grain Yield of Wheat

In relation to all the plant nutrients, N has been given more attention with regards to crop requirement than all other nutrients during the last 2 to 3 decades. Thousands of experimental findings are

available from all corners of the world on all crops. A selected amount of work on winter and spring wheat fertilization is being considered here.

Gingrich and Smith (15) in Kansas observed that on relatively low N soils (0.094, 0.11 and 0.125 N%) yields increased with N fertilization up to 100 lb N/acre. When soil N content was relatively high (0.150% N), yield increased up to 50 lb N/acre and then with high rates (100 lb N/acre) the yield declined. At each location the efficiency of 100 lb N/acre was less than with the lower rates.

While working on winter wheat and rye fertilization in the Panhandle area of Western Nebraska from 1961 to 1968, Drier et al. (10) observed an increase in grain yield with an increase in applied N levels. The soils contained on an average of 73 lb of NO_3^--N in a 4 foot profile. On these soils, yield increases averaged 4, 6, and 6 bu/acre with 20, 40, and 60 lb N/acre, respectively. In West Central Nebraska increases of 2, 6, 8, and 9 bu/acre were obtained with 0, 20, 40, and 60 lb N/acre.

Olson and Rhoades (47) summarized experimental results from 1916 to 1952 and observed a decline in the organic matter content of the cultivated soils. They also observed widespread N deficiency of crops throughout Nebraska at that time. They found a consistent response to N applications of 40 lb/acre in all parts except the Panhandle area.

Laopirojana et al. (31) in Corvallis, Oregon, reported an increase in grain yield of winter wheat with N fertilization. They observed the highest yield with 114 Kg N/ha, but there was no significant difference between the 84 and 224 Kg N/ha treatments.