# THE EFFECTS OF DIFFERENT FERTILIZERS ON THE PROTEIN, KERNEL SIZE DISTRIBUTION, AND YIELD OF HANNCHEN BARLEY

by

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# THE EFFECTS OF DIFFERENT FERTILIZERS ON THE PROTEIN, KERNEL SIZE DISTRIBUTION, AND YIELD OF HANNCHEN BARLEY

## INTRODUCTION

Hannchen barley is a crop well suited to the needs of Western Oregon farmers. It is, in addition to being a high yielding spring grain, readily accepted by the malting trade. However, this acceptance by the malting trade is based on the ability of Western Oregon producers to deliver uniform, high quality lots of barley.

Maintenance of uniformity in Oregon produced Hannchen barley is a difficult task. It is suspected by those interested in Hannchen barley that erratic use of commercial fertilizers, the great soil diversity, and the variance in rotational programs in the Willamette Valley have contributed to this difficulty. These factors apparently create undesirable heterogeneity of quality within as well as between commercial lots of barley. A knowledge of the basic variations caused by these several factors will make it possible to standardize management practices and to improve the malting quality of barley in this area.

It is generally conceded that injudicious rates of certain fertilizers have a deleterious effect on malting quality. Information on the incidence and magnitude of that effect is important if further research is to be done on malting quality maintenance. The relationship of quality and yield under fertilization is a factor of vital importance to the producer who is attempting to achieve the highest possible return from barley production.

Kernel size and barley protein were chosen as indicators of malting quality for this study. They have previously exhibited sensitivity to fertilization, may be determined with relative ease, and are accepted by the malting trade for the purpose of quality comparisons. Although these two factors are not perfect indicators of malting quality they will detect the magnitude of variation resulting from varying rates and kinds of fertilizers. It should be possible to gain insight into the amount of heterogeneity caused by fertilization by studying its effect on these chosen indices.

The purpose of the research conducted in preparing this thesis was:

(1) to ascertain, in a quantitative manner, the effects of certain fertilizers, and combinations of fertilizers, on yield and two indices of malting quality - kernel size and barley protein.

(2) to ascertain the degree of yield and quality variability which can be expected from fertilization under the extremes of soil management conditions in the Willamette Valley.

## REVIEW OF LITERATURE

Constant refinements in the technology of malting and brewing have caused great emphasis to be placed on the production of uniform, high quality malting barley. Consequently, research on this phase of production has gained steadily in scope and importance during the past several years.

### Malting Quality

> "Malting barley is barley of suitable mellow type—one which will yield a high percentage of extract (starch body) and does not have too high a nitrogen protein content. Barley for malting depends on germination to produce a high yield of extract and obtain proper reactions from its enzymes; therefore, barley must be fully mature and healthy . . . " (10, p.1)

This general statement focuses attention on three important quality measurements—protein, extract, and enzymatic activity[1]. The brewers and malsters use these three, plus a myriad of other, less revealing factors, to judge the relative quality of a given lot of barley or malt. Research workers, restricted by facilities, have attempted to find one or two values which will give an index by which the malting potentialities of any given lot of barley can be judged. Attempts to find this value or values have been at least partially successful.

[1] Reported as 'diastatic power' or 'saccharifying activity'.

Once a lot of barley has met the established governmental standards for malting barley (18, p.31), the most important criteria of quality is protein. Anderson has summarized the relationship of protein to malting quality by stating, "It is widely agreed . . . broad generalization . . . within any variety the malting quality of a sample can be stated roughly in terms of its protein content." (2, p.188)

In his study of the factors related to protein content of malting barley Anderson found, within a given variety, the following relationships (2, p.187):

Coefficient of Correlation

| Barley Protein | Barley |
|---|---|
| -.95** | Starch Content |
| .98** | Saccharifying Activity |
| | Malt |
| -.96** | Extract |
| .96** | Saccharifying Activity |
| .85** | Proteolytic Activity |

** Significant at 1% level of probability

Foote and Veblen (7, p.6) found the relationship between protein and extract, established by Anderson for six-row barley, applicable to Hannchen barley produced in the Willamette Valley. A correlation coefficient of -.975** was derived from samples obtained during a crop survey in 1952.

Hulton (9), in summarizing the effect of barley protein on malting quality, has pointed out that barleys of high nitrogen content produce low extract and bushel weight, cause defective maturation, steeliness, high density kernels, and sluggish modification, and produce a higher percentage of uncoagulated protein in beer wort. All these are, of course, undesirable characteristics. Hulton did, however, caution against the use of total protein content in the final evaluation of malting quality, particularly until there is more knowledge of the qualitative properties of different barley proteins.

It is apparent that barley protein content, though it may have limitations, provides a means of ascertaining the quality of malt which will be produced by a given lot of barley.

Kernel size is another measurement often used by malsters in judging barley. It is important principally because kernel uniformity is essential for uniformity of germination (2, p.189). A high percentage of large kernels is desired because large kernels have a higher percentage of extractable material (starch) than small kernels - for a given weight of grain. In preparing Hannchen barley for malting the kernels which pass through a 5½/64 screen are discarded. The larger this percentage the less barley is available for malting.

Although kernel size is conventionally ascertained in two ways - with sieves or by weight of 1000 kernels - Foote and Veblen (7, p.6) established a high positive association (correlation coefficient, .8917**) between the percent of kernels remaining on a 6/64 screen and the weight of 1000 kernels of Hannchen barley. The percentage of kernels remaining on a 6/64 screen appears to be an adequate estimate of relative kernel size.

In the final analysis the malsters and brewers are the arbiters of malting quality. Their specifications determine which lots of barley will be accepted into the malting trade. When it meets government specifications, exhibits the proper protein content, and has a large percentage of kernels remaining on a 6/64 screen, Hannchen barley will be accepted for malting.

## Protein and Environment

Hulton (9), Russel (17), and Anderson (2) have studied the influence of environment on the protein content of barley. The factors which have been found to affect protein are:

1. Soil texture
    a. soil moisture
    b. soil temperature
2. Air temperature
3. Fertilization
4. Spacing
5. Inherent genetic constitution
6. Date of planting
7. Date of cultivation
8. Soil organic matter

In each of these studies the importance of two factors has been emphasized. Seasonal conditions and soil texture determine, to a large degree, the absolute protein content of a given barley variety. The season, soil, and variety may be accentuated or moderated by fertilizer application but, as an example, an inherently high protein barley, produced during a dry hot season will have a high protein content regardless of the type and quantity of fertilizer applied. This is an important consideration if interpretation of fertilization results is to be made on one season's production.

These environmental factors undoubtedly have a marked effect on kernel size and yield.

## Effects of Fertilization

### Six Row Barley

The Midwest Barley Improvement Association has, over the past several years, sponsored malting barley trials throughout the barley producing areas of the Midwest. Lejeune and Parker (12, pp.5-13) have reported the results of these trials, a summary of which is presented in the following sections.

#### Yield

Workers in Michigan, Illinois, Iowa, Minnesota, and North Dakota have noted yield increases with the application of various fertilizers. Nitrogen, phosphorus, and combinations of nitrogen and phosphorus applications have produced significant increases over unfertilized plots. Phosphorus, when combined with nitrogen, has increased the yield over nitrogen or phosphorus alone. No responses have been obtained from the use of potassium, alone or in combination with other elements (12, p.5-6).

#### Protein

The effects of fertilization on barley protein were variable. In general, protein content appeared to be as dependent on factors other than fertilization as on fertilization itself. This reflects the findings of earlier workers as discussed in 'Protein and Environment'.

Lejeune and Parker offered an interesting observation on protein deposition (12, p.12):

> "These results indicate that protein content of barley is increased when nitrogen fertilizer is added to the soil in excess of the amount required for maximum yield in relation to other soil nutrients and environmental conditions."

Nitrogen applications produced substantial increases in barley protein only when rates exceeded 20 pounds per acre - with or without phosphorus.

Phosphorus, in several locations, decreased protein, while potassium produced no effect - alone or in combination with other fertilizer elements.

<u>Kernel Size</u>

Kernel plumpness (percent of kernels over 6/64 screen) was influenced greatly by nitrogen and phosphorus, alone or in combination. Phosphorus increased the percentage of plump kernels and counteracted the effect of nitrogen on the one location where nitrogen lowered the percentage. The percentage of thin kernels (kernels through a $5\frac{1}{2}/64$ screen) was decreased substantially by application of phosphorus. In one experiment nitrogen, at 20 pounds per acre, increased the percentage of 'thins'. Potassium had no effect on kernel size (12, pp.6-12).

## Effects of Fertilization

### Hannchen Barley

Foote, <u>et al.</u>, (8, pp.4-13) have reported the results of fertilizer trials in the Willamette Valley. At ten locations yield was increased with the application of 30 and 60 pounds of nitrogen per acre. At four of these locations phosphorus, in combination with nitrogen, gave significant yield increases. Sulphur increased yield at one location while potassium had no effect at any location. This agrees substantially with the work performed in the Midwest.

In Foote's report kernel size percentages are presented but not summarized. The effect of increasing rates (up to 60 pounds) of nitrogen is reflected in a steady increase in the percentage of thin kernels. This was apparent at all locations.

Batchelder (3, pp.23-26) applied 100 pounds of ammonium nitrate to Hannchen barley in 25 pound increments. He noted increasing yields, a decreasing percentage of plump kernels, an increasing percentage of thin kernels, and an increasing protein percentage as the nitrogen rate increased. The increase in protein percentage was matched by a correspondingly uniform decrease in total extract. When ammonium nitrate was applied at seeding diastatic power increased on the first increments but dropped on the last.

In certain respects the results reported for Hannchen and those from the Midwest appear to contradict each other. The higher rates of nitrogen used on the Hannchen trial, the great difference in initial protein content of the barleys studied, and a wide geographic separation can be used to account for this apparent contradiction. Although the particulars may not match, the outline is clear - barley protein, kernel size, and yield fluctuate as fertilizers are varied.

# METHODS AND MATERIALS

The experiment was designed as a factorial utilizing five rates of nitrogen, three rates of phosphorus, and two rates of potassium (Table 1). These various rates, in all combinations, were set in a randomized block and replicated three times at three locations - Camp Adair, 12 miles northwest of Corvallis; Hyslop Agronomy Farm, 7 miles northeast of Corvallis; East Farm, 1 mile east of Corvallis.

TABLE 1

FERTILIZER TREATMENTS ESTABLISHED IN A RANDOMIZED BLOCK WITH THREE REPLICATIONS AT CAMP ADAIR, HYSLOP FARM, AND EAST FARM - 1954

| | | | | | |
|---|---|---|---|---|---|
| N0 | P0 | K0 | N0 | P0 | K1 |
| N1 | P0 | K0 | N1 | P0 | K1 |
| N2 | P0 | K0 | N2 | P0 | K1 |
| N3 | P0 | K0 | N3 | P0 | K1 |
| N4 | P0 | K0 | N4 | P0 | K1 |
| N0 | P1 | K0 | N0 | P1 | K1 |
| N1 | P1 | K0 | N1 | P1 | K1 |
| N2 | P1 | K0 | N2 | P1 | K1 |
| N3 | P1 | K0 | N3 | P1 | K1 |
| N4 | P1 | K0 | N4 | P1 | K1 |
| N0 | P2 | K0 | N0 | P2 | K1 |
| N1 | P2 | K0 | N1 | P2 | K1 |
| N2 | P2 | K0 | N2 | P2 | K1 |
| N3 | P2 | K0 | N3 | P2 | K1 |
| N4 | P2 | K0 | N4 | P2 | K1 |

N0 - 0 pounds per acre of nitrogen (ammonium nitrate)
N1 - 30
N2 - 60
N3 - 90
N4 - 120
P0 - 0 pounds per acre of $P_2O_5$ (treble super phosphate)
P1 - 40
P2 - 80
K0 - 0 pounds per acre of $K_2O$ (muriate of potash)

On East and Hyslop Farms sulphur, in the form of gypsum, was applied uniformly to the experimental area at a twenty-pound-per-acre rate. At the Camp Adair location only the third replication received this treatment due to an error during treatment application.

The experimental plots measured eight by thirty-five feet at the East Farm location, eight by fifty feet at the Hyslop location, and eight by seventy-five feet at the Camp Adair location.

A composite soil sample was obtained from each location. An analysis of these samples is presented in Table 2.

TABLE 2

SOIL TEST VALUES FOR COMPOSITE SAMPLES FROM EXPERIMENTAL PLOT AREAS THIRTY SUB-SAMPLES PER COMPOSITE[2]

| Location | Depth | pH | Tons/ac. Lime req. | Pounds/Acre P | K | Ca | Mg | Soil Type[3] |
|---|---|---|---|---|---|---|---|---|
| Camp | 0- 8" | 5.9 | 2 | 4.2 | 362 | 5100 | 2700 | Melbourne |
| Adair | 8-16" | 5.9 | 2 | 3.2 | 285 | 6000 | 3680 | Clay Loam |
| Hyslop | 0- 8" | 5.7 | 2½ | 90.0 | 400 | 2900 | 1760 | Willamette |
| Farm | 8-16" | 5.7 | 2½ | 90.0 | 414 | 2760 | 560 | Silt Loam |
| East | 0- 8" | 5.9 | 1½ | 15.0 | 235 | 3320 | 2240 | Newberg |
| Farm | 8-16" | 6.0 | 1½ | 13.0 | 174 | 1760 | 880 | |

2 Analyzed by the Oregon State College Soil Testing Laboratory (1).

3 Described by W. L. Powers, *et al.*, in Identification and Productivity of Western Oregon Soils (16).

Powers, *et al.*, (16, pp.24-26) have rated the soils on which the experiment was located with an index giving their agricultural value. Newberg and Willamette are high and comparable in inherent productivity, while Melbourne is judged to be relatively low. The estimated acre yield of wheat for the soils rates Willamette, 35 bushels; Newberg, 30 bushels; Melbourne, 20 bushels. No comparative barley yields are given. Crops considered suited to these soils (16, pp.12-15) include legumes, fruit, grain, and grass seed for Willamette; potatoes, corn, alfalfa, truck, and fruits for Newberg; grain, vetch, and grass seed for Melbourne. Newberg, being of lighter texture than the other two soils, warms quickly in the spring and is adapted to a wider range of crops.

An investigation of previous cropping at Camp Adair revealed a history of small grain production for the three years preceding the experiment. The East Farm location was previously planted to Ladino Clover (three years) while the Hyslop location was plowed out of an established sod of Tall Fescue. The East Farm location was irrigated, by sprinkler, once during the crop season.

Fertilizer application was completed one day prior to seeding at all locations. The fertilizer was drilled into the prepared seed-bed at eight inch intervals, to a depth of four inches. Application was made with a trailer mounted, belt fed, tractor drawn, fertilizer drill. Predetermined amounts of each fertilizer were spread and mixed on the belt to assure uniform application. Each area was then seeded at approximately 100 pounds per acre with a standard grain drill.

The plots at East and Hyslop Farms were harvested with an experimental plot combine. A three foot swath was taken the length of each plot, yield was determined, and a representative sample was obtained for laboratory analysis. Yields were determined, and a sample obtained, at Camp Adair with a three foot quadrat. Four quadrats were cut from each plot with the quadrats spaced equally the length of the plot. The grain obtained in this manner was then threshed in a small nursery thresher.

The field samples were removed to the laboratory, run through a coarse screen and blower, passed over a 4 1/4/64 x 3/4 inch screen, and hand picked for broken kernels. To determine kernel size, two 200 gram samples of barley from each cleaned field sample were shaken by hand on a series of calibrated screens. Percentage determinations were made on the weight of kernels remaining on screens with slots measuring 7/64 x 3/4, 6/64 x 3/4, and 5½/64 x 3/4 inches, and that percentage, by weight, which passed through the smallest screen.

A randomly selected 300 gram sub-sample, obtained from each cleaned field sample, was sent to the Jos. Schlitz Brewing Company for protein analysis in their laboratory. All protein determinations were made following standardized laboratory procedures (14, p.5), and reported as percent protein, dry basis.

Figure I. Experimental Plot Combine.

Figure II. Experimental Fertilizer Spreader.

# EXPERIMENTAL RESULTS

The results from experimentation varied widely from location to location. This variation is presented in graphic and tabular form at the end of the following sections. An Analysis of Variance, including a testing of regression deviations, was derived for each observation at each location.

Table 3 illustrates the great effect location has on the factors studied. Average protein analysis varied from 8.7 at Hyslop Farm to 11.5 at East Farm. Yield differences were even more striking, 29.3 bushels at Camp Adair to 73.2 bushels at East Farm. While the variations in size were somewhat less, they nevertheless were significant these variations due to location become more important when an attempt is made to determine the absolute effect of fertilizer application on yield and quality factors.

In presenting Table 4, potassium x nitrogen and phosphorus x nitrogen interactions (Tables 6 and 7) necessitated the presentation of nitrogen responses at the various levels of potassium and phosphorus.

The response of the factors studied to phosphorus and potassium applications (Table 5) is of less magnitude than the responses from applications of nitrogen (Table 4). The nature of these responses is summarized in the Analyses of Variance (Tables 6, 7, 8, and 9).

The magnitude of the responses (Table 4), even where statistically significant, indicates the minor effect phosphorus and potassium applications, when not combined with other fertilizers, have on barley quality and yield in this area.

Bushel Yield

Summary Table 4 and Analyses of Variance Table 6 indicate the magnitude of responses achieved from the use of nitrogen fertilizers.

Nitrogen increased yield over the check or no nitrogen plot at all locations. The highest proportionate yield increase resulting from nitrogen application was noted on the first nitrogen increment at Hyslop Farm. At two locations there were significant nitrogen x phosphorus interactions.

At the East Farm the highest yield on the no nitrogen plots was produced with eighty pounds of phosphorus. It is interesting to note, however, that forty pounds of phosphorus apparently changed the character of the yield curve resulting from nitrogen increments. At both zero and eighty pounds of phosphorus the yield on successive increments of nitrogen did not deviate from linearity. Essentially there was no increase over the no nitrogen plots. However, with forty pounds of phosphorus, yield was extended to the maximum obtained at the location. At this rate of phosphorus yield was effectively increased on the first two nitrogen increments.

Graph 1 illustrates the possibility of a nitrogen x phosphorus x sulphur yield interaction at the Camp Adair location. The experiment does not allow statistical isolation of this effect but a comparison of the Analyses of Variance for yield, with and without sulphur, adds weight to the assumption that it is real, rather than apparent.

## Protein

The effect of nitrogen on protein is presented in Table 4.

Successive increments of nitrogen increased the protein content at all locations. At the Hyslop Farm the first and second increments lowered protein content. Succeeding rates raised the protein content above the no nitrogen plot with acceptable protein (acceptable for malting) produced on the 120 pound rate.

At the East Farm (Tables 4 and 5) the level of potassium determined the rate of change in the linear response of protein to nitrogen ($K_0 = 1.18$; $K_{40} = 1.28$). In effect, this represents a more rapid increase of protein under successive nitrogen increments where potassium was applied.

Potassium increased protein percent at Camp Adair irrespective of sulphur application (Tables 5 and 7). Neither of these increases were as substantial as those created by nitrogen.

## Kernel Size

Analyses of Variance Tables 8 and 9 and summary Table 4 indicate the response of kernel size to nitrogen applications.

The apparent response of kernel size to sulphur (Table 4, Graph 2) can not be isolated statistically.

Percent Through $5\frac{1}{2}/64$ Screen

The percentage of thin kernels was increased by nitrogen at all locations. At East Farm and Camp Adair (with sulphur) there occurred a linear response to nitrogen. Hyslop and Camp Adair (without sulphur) produced a curvilinear effect. Sulphur effectively increased kernel size at Camp Adair.

Percent Over 6/64 Screen

The percentage of plump kernels was decreased by nitrogen at all locations. An odd effect was noted on the with and without sulphur replications at Camp Adair. In the presence of sulphur, potassium increased the plump kernel percentage, but without sulphur, potassium decreased the percentage.

TABLE 3

A COMPARISON OF LOCATION EFFECT ON FACTORS INVESTIGATED, AND THE RANGE OF RESPONSE AS A RESULT OF NITROGEN APPLICATIONS

| Means<br>Locations | Percent Protein | Bushel Yield | Percent Kernels<br>Over 6/64 | <br>Through 5½/64 |
|---|---|---|---|---|
| East Farm | 11.5 | 73.2 | 79.1 | 10.7 |
| Hyslop Farm | 8.7 | 47.3 | 90.1 | 5.0 |
| Camp Adair ($S_{20}$) | 11.1 | 39.4 | 82.4 | 6.3 |
| Camp Adair ($S_0$) | 11.3 | 29.3 | 75.2 | 9.3 |
| Range of treatment means (nitrogen increments) | | | | |
| East Farm | 9.3 - 14.0 | 64.8 - 85.2 | 91.1 - 68.2 | 4.2 - 17.0 |
| Hyslop Farm | 8.7 - 10.2 | 20.3 - 59.7 | 94.2 - 84.0 | 2.7 - 8.2 |
| Camp Adair ($S_{20}$) | 8.4 - 13.7 | 24.2 - 60.6 | 94.3 - 71.5 | 2.0 - 11.1 |
| Camp Adair ($S_0$) | 8.4 - 13.8 | 25.7 - 29.4 | 94.9 - 61.3 | 1.8 - 14.8 |

TABLE 4

MEAN VALUES FOR RESPONSES TO NITROGEN FERTILIZER AT ALL LOCATIONS

| Location | N0 | N30 | N60 | N90 | N120 |
|---|---|---|---|---|---|
| **Percent Protein (Dry Basis)** | | | | | |
| East Farm | | | | | |
| K0 | 9.5 | 10.4 | 11.1 | 13.2 | 14.0 |
| K40 | 9.0 | 9.5 | 11.8 | 12.4 | 14.0 |
| Hyslop Farm | 8.7 | 7.4 | 8.1 | 9.2 | 10.2 |
| Adair (S20) | 8.4 | 9.4 | 11.4 | 12.7 | 13.7 |
| Adair (S0) | 8.4 | 9.8 | 11.7 | 12.6 | 13.8 |
| **Bushel Yield** | | | | | |
| East Farm | | | | | |
| P0 | 68.3 | 76.6 | 77.1 | 64.0 | 76.7 |
| P40 | 64.8 | 81.7 | 85.2 | 57.7 | 56.2 |
| P80 | 77.3 | 78.5 | 70.8 | 76.3 | 69.0 |
| Hyslop Farm | 20.3 | 45.7 | 54.4 | 56.2 | 59.7 |
| Adair (S20) | | | | | |
| P0 | 24.2 | 35.2 | 29.8 | 29.9 | 25.9 |
| P40 | 26.5 | 45.0 | 51.9 | 51.4 | 47.8 |
| P80 | 26.3 | 49.8 | (56.0)* | 60.6 | 48.2 |
| Adair (S0) | 25.7 | 35.4 | 29.4 | 27.7 | 28.6 |
| **Percent Kernels Through 5½/64** | | | | | |
| East Farm | 4.2 | 6.5 | 10.8 | 14.8 | 17.0 |
| Hyslop Farm | 2.7 | 3.2 | 4.3 | 6.5 | 8.2 |
| Adair (S20) | 2.0 | 4.5 | 6.3 | 7.7 | 11.1 |
| Adair (S0) | 1.8 | 6.1 | 10.5 | 13.3 | 14.8 |
| **Percent Kernels Over 6/64** | | | | | |
| East Farm | 91.1 | 86.4 | 78.1 | 71.8 | 68.2 |
| Hyslop Farm | 94.2 | 93.8 | 91.4 | 87.2 | 84.0 |
| Adair (S20) | 94.3 | 88.1 | 79.8 | 78.3 | 71.5 |
| Adair (S0) | 94.9 | 82.3 | 71.4 | 66.0 | 61.3 |

* The two values obtained for this treatment were 56.0 and 20.3. The plot with 20.3 value did not receive sulphur.

TABLE 5

MEAN VALUES FOR RESPONSES TO PHOSPHORUS AND POTASSIUM FERTILIZER AT ALL LOCATIONS

| Location | P0 | P40 | P80 | K0 | K40 |
|---|---|---|---|---|---|
| **Percent Protein, Dry Basis** | | | | | |
| East Farm | 11.7 | 11.3 | 11.5 | * | * |
| Hyslop Farm | 8.7 | 8.7 | 8.8 | 8.7 | 8.7 |
| Adair (S20) | 11.3 | 10.8 | 11.2 | 10.9 | 11.3 |
| Adair (S0) | 11.5 | 11.0 | 11.3 | 11.1 | 11.4 |
| **Bushel Yield** | | | | | |
| East Farm | * | * | * | 71.9 | 74.4 |
| Hyslop Farm | 45.8 | 48.2 | 47.9 | 45.0 | 49.5 |
| Adair (S20) | * | * | * | 38.4 | 40.3 |
| Adair (S0) | 28.6 | 29.8 | 29.7 | 30.4 | 28.4 |
| **Percent Kernels Through 5½/64** | | | | | |
| East Farm | 11.2 | 10.3 | 10.5 | 10.8 | 10.6 |
| Hyslop Farm | 5.2 | 5.1 | 4.7 | 5.1 | 4.9 |
| Adair (S20) | 5.7 | 5.9 | 7.4 | 6.7 | 6.0 |
| Adair (S0) | 10.3 | 8.6 | 9.0 | 8.3 | 10.2 |
| **Percent Kernels Over 6/64** | | | | | |
| East Farm | 78.6 | 79.7 | 79.0 | 78.7 | 79.6 |
| Hyslop Farm | 89.8 | 90.0 | 90.6 | 89.9 | 90.3 |
| Adair (S20) | 83.6 | 84.8 | 78.8 | 80.5 | 84.3 |
| Adair (S0) | 73.0 | 76.5 | 76.0 | 76.6 | 73.8 |

* Indicates Significant Nitrogen x Phosphorus or Nitrogen x Potassium Interaction. See Preceding Table.

TABLE 6

ANALYSES OF VARIANCE - EFFECT OF NITROGEN, PHOSPHORUS, AND POTASSIUM ON BUSHEL YIELD

| Source of Variation | Hyslop Farm | | East Farm | | Camp Adair | |
|---|---|---|---|---|---|---|
| | d.f. | Mean Square | d.f. | Mean Square | d.f. | Mean Square |
| | | | | | Without Sulphur | |
| Total | 89 | | 89 | | 89 | |
| Replications | 2 | 509.4750** | 2 | 62.5870 | 1 | 239.2006** |
| Treatments | 29 | 678.8356** | 29 | 250.5769* | 29 | 47.1230 |
| Nitrogen | 4 | 4,570.1867** | 4 | 451.6485* | 4 | 159.9106** |
| Regression | | | | | | |
| Linear | 3 | 1,316.0299** | | | 3 | 212.5363** |
| Quadratic | 4 | 154.6254* | | | 4 | 119.9450* |
| Cubic | 3 | 0.0765 | | | 3 | 26.7017 |
| Phosphorus | 2 | 48.6060 | 2 | 70.1876 | 2 | 10.0362 |
| Potassium | 1 | 461.4931** | 1 | 69.6526 | 1 | 61.2059 |
| N x P | 8 | 23.1414 | 8 | 367.5830** | 8 | 58.9422 |
| Regression | | | | | | |
| N at P0 | | | | | | |
| Linear | | | 3 | 286.7046 | | |
| N at P40 | | | | | | |
| Linear | | | 3 | 1,029.2160** | | |
| Quadratic | | | 4 | 6.8852 | | |
| N at P80 | | | | | | |
| Linear | | | 3 | 71.2848 | | |
| N x K | 4 | 49.9317 | 4 | 206.8415 | 4 | 11.6989 |
| P x K | 2 | 61.7414 | 2 | 137.4048 | 2 | 8.1376 |
| N x P x K | 8 | 42.3051 | 8 | 151.1578 | 8 | 13.8798 |
| Reps x Treatments | 58 | 51.8386 | 58 | 125.8239 | 29 | 30.8454 |

TABLE 6 (CONT.)

ANALYSES OF VARIANCE - EFFECT OF NITROGEN, PHOSPHORUS, AND POTASSIUM ON BUSHEL YIELD

| Source of Variation | Camp Adair d.f. | Camp Adair Mean Square |
|---|---|---|
| | With Sulphur | |
| Nitrogen vs. Check | 1 | 1,410.4164** |
| Phosphorus vs. Check | 1 | 1,616.1660** |
| Potassium vs. Check | 1 | 41.8867 |
| N x P | 3 | 99.3094* |
| Regression | | |
| N at P0 | | |
| Linear | 3 | 47.7752 |
| N at P40 | | |
| Linear | 3 | 131.0418* |
| Quadratic | 4 | 3.7420 |
| N at P80 | | |
| Linear | 3 | 248.0885** |
| Quadratic | 4 | 134.3592** |
| Cubic | 3 | 179.1440* |
| Quartic | 4 | 0.0000 |
| Error (from without sulphur replications) | 29 | 30.8454 |

** F value significant at 1% level
* F value significant at 5% level

TABLE 7

ANALYSES OF VARIANCE - EFFECT OF NITROGEN, PHOSPHORUS, AND POTASSIUM ON PERCENT PROTEIN DRY BASIS

| Source of Variation | Hyslop Farm d.f. | Hyslop Farm Mean Square | East Farm d.f. | East Farm Mean Square | Camp Adair d.f. | Camp Adair Mean Square |
|---|---|---|---|---|---|---|
| | | | | | Without Sulphur | |
| Total | 89 | | 89 | | 59 | |
| Replications | 2 | 0.7524** | 2 | 7.4230** | 1 | 0.0281 |
| Treatments | 29 | 2.7585** | 29 | 10.3136** | 29 | 8.1087** |
| Nitrogen | 4 | 19.5136** | 4 | 69.0751** | 4 | 56.9845** |
| Regression | | | | | | |
| Linear | 3 | 39.5051** | | | 3 | 0.9034** |
| Quadratic | 4 | 1.8940** | | | 4 | 0.3604 |
| Cubic | 3 | 0.0447 | | | | |
| Phosphorus | 2 | 0.0388 | 2 | 1.1710 | 2 | 1.5166** |
| Potassium | 1 | 0.0216 | 1 | 2.3040* | 1 | 1.3391** |
| N x P | 8 | 0.0684 | 8 | 0.7630 | 8 | 0.1315 |
| N x K | 4 | 0.0898 | 4 | 1.8857* | 4 | 0.1034 |
| Regression | | | | | | |
| N at K0 | | | | | | |
| Linear | | | 3 | 1.5894 | | |
| N at K40 | | | | | | |
| Linear | | | 3 | 1.5227 | | |
| P x K | 2 | 0.0880 | 2 | 0.3670 | 2 | 0.1412 |
| N x P x K | 8 | 0.0951 | 8 | 0.4712 | 8 | 0.1368 |
| Reps x Treatments | 58 | 0.0689 | 58 | 0.5461 | 29 | 0.1691 |

TABLE 7 (CONT.)

ANALYSES OF VARIANCE - EFFECT ON NITROGEN, PHOSPHORUS, AND POTASSIUM ON PERCENT PROTEIN, DRY BASIS

| Source of Variation | Camp Adair d.f. | Camp Adair Mean Square |
|---|---|---|
| | With Sulphur | |
| Nitrogen vs. Check | 1 | 56.3011** |
| Regression | | |
| Linear | 3 | 0.6229* |
| Quadratic | 4 | 0.4042 |
| Phosphorus vs. Check | 1 | 0.6827 |
| Potassium vs. Check | 1 | 1.2814* |
| N x P | 3 | 0.0031 |
| Reps x Treatment (from without sulphur replications) | 29 | 0.1691 |

** F value significant at 1% level
* F value significant at 5% level

TABLE 8

ANALYSES OF VARIANCE - EFFECT OF NITROGEN, PHOSPHORUS, AND POTASSIUM ON THE PERCENT OF KERNELS THROUGH A $5\frac{1}{2}/64$ SCREEN

| Source of Variation | Hyslop Farm d.f. | Hyslop Farm Mean Square | East Farm d.f. | East Farm Mean Square | Camp Adair d.f. | Camp Adair Mean Square |
|---|---|---|---|---|---|---|
| | | | | | Without Sulphur | |
| Total | 89 | | 89 | | 58 | |
| Replication | 2 | 5.6573 | 2 | 46.9622** | 1 | 22.0827* |
| Treatments | 29 | 14.6820** | 29 | 82.6102** | 29 | 52.2460** |
| Nitrogen | 4 | 98.3144** | 4 | 523.4442** | 4 | 343.3283** |
| Regression | | | | | | |
| Linear | 3 | 5.9007* | 3 | 9.5291 | 3 | 15.5461** |
| Quadratic | 4 | 0.8064 | | | 4 | 0.7048 |
| Phosphorus | 2 | 1.7590 | 2 | 6.6791 | 2 | 15.3162* |
| Potassium | 1 | 0.8410 | 1 | 1.2018 | 1 | 55.6807** |
| N x P | 8 | 0.4305 | 8 | 15.5618 | 8 | 1.4728 |
| N x K | 4 | 2.6777 | 4 | 13.4809 | 4 | 5.6065 |
| P x K | 2 | 0.6223 | 2 | 5.4271 | 2 | 0.8552 |
| N x P x K | 8 | 1.5952 | 8 | 12.2609 | 8 | 2.4485 |
| Reps x Treatments | 58 | 1.3785 | 58 | 9.7145 | 28 | 3.7574 |
| | | | | | With Sulphur | |
| Nitrogen vs. Check | | | | | 1 | 137.6021** |
| Regression | | | | | | |
| Linear | | | | | 3 | 1.8520 |
| Phosphorus vs. Check | | | | | 1 | 6.2082 |
| Potassium vs. Check | | | | | 1 | 4.0334 |
| N x P | | | | | 3 | 1.0151 |
| Error (from without sulphur replications) | | | | | 28 | 3.7574 |

** F value significant at 1% level
" F value significant at 5% level

## TABLE 9

### ANALYSES OF VARIANCE - EFFECT OF NITROGEN, PHOSPHORUS, AND POTASSIUM ON THE PERCENT OF KERNELS OVER A 6/64 SCREEN

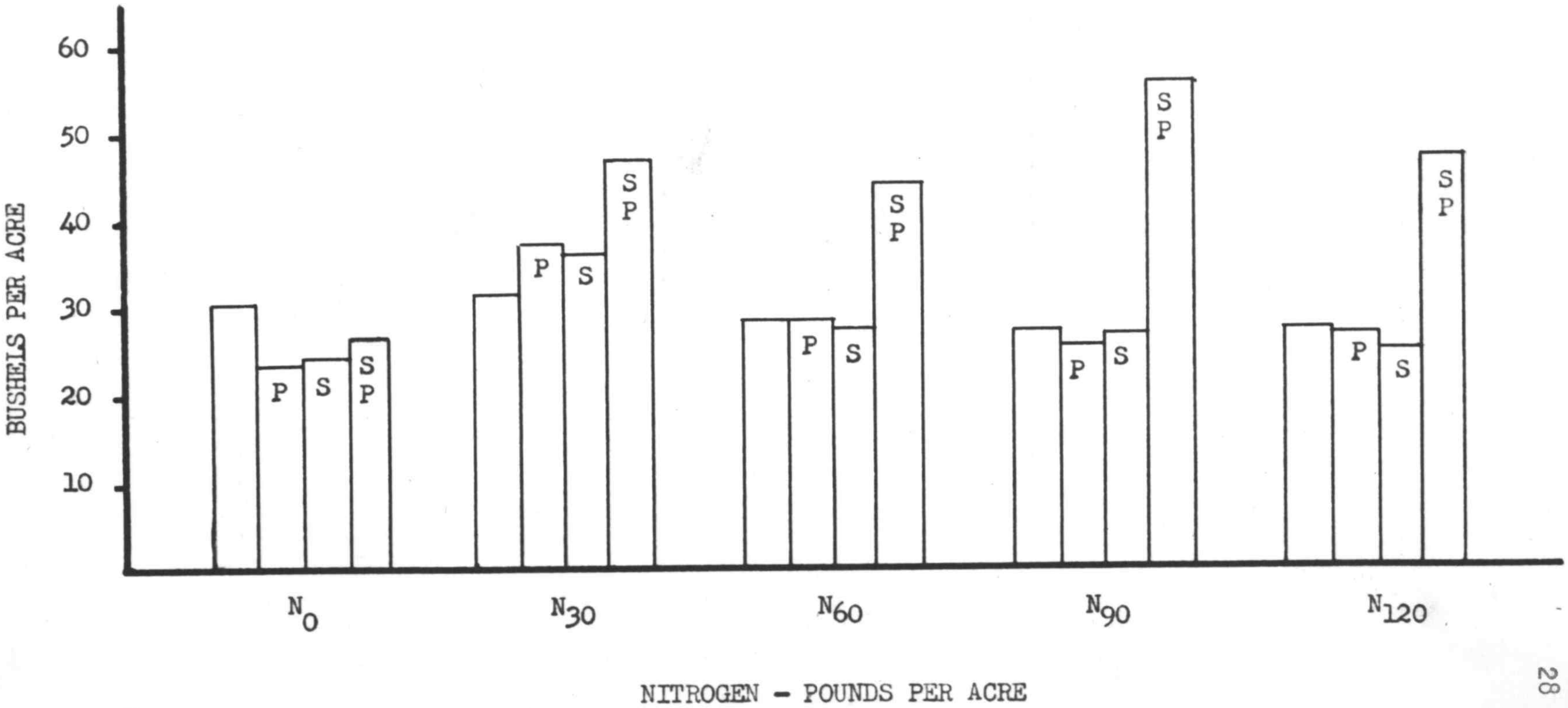
| Source of Variation | Hyslop Farm d.f. | Hyslop Farm Mean Square | East Farm d.f. | East Farm Mean Square | Camp Adair d.f. | Camp Adair Mean Square |
|---|---|---|---|---|---|---|
| | | | | | Without Sulphur | |
| Total | 89 | | 89 | | 59 | |
| Replications | 2 | 16.2608** | 2 | 197.0874** | 1 | 87.3626 |
| Treatments | 29 | 50.9571** | 29 | 253.6101** | 29 | 323.7876** |
| Nitrogen | 4 | 351.2830** | 4 | 1,660.1493** | 4 | 2,192.8269** |
| Regression | | | | | | |
| Linear | 3 | 28.8147** | 3 | 33.4861 | 3 | 134.3125* |
| Quadratic | 4 | 3.9567 | | | 4 | 3.5912 |
| Phosphorus | 2 | 5.4404 | 2 | 8.4618 | 2 | 70.6212 |
| Potassium | 1 | 3.6000 | 1 | 19.2284 | 1 | 124.4160* |
| N x P | 8 | 1.2545 | 8 | 33.2219 | 8 | 12.2562 |
| N x K | 4 | 4.9308 | 4 | 40.1124 | 4 | 28.2439 |
| P x K | 2 | 1.5774 | 2 | 7.1752 | 2 | 10.3835 |
| N x P x K | 8 | 3.1536 | 8 | 29.6711 | 8 | 15.1352 |
| Reps x Treatment | 58 | 3.1281 | 58 | 26.6689 | 29 | 25.6316 |
| | | | | | With Sulphur | |
| Nitrogen vs. Check | | | | | 1 | 1,066.2440** |
| Regression | | | | | | |
| Linear | | | | | 3 | 21.9229 |
| Phosphorus vs. Check | | | | | 1 | 20.0682 |
| Potassium vs. Check | | | | | 1 | 108.4144* |
| N x P | | | | | 3 | 5.3734 |
| Error (from without sulphur replications) | | | | | 29 | 25.6316 |

** F value significant at 1% level

* F value significant at 5% level

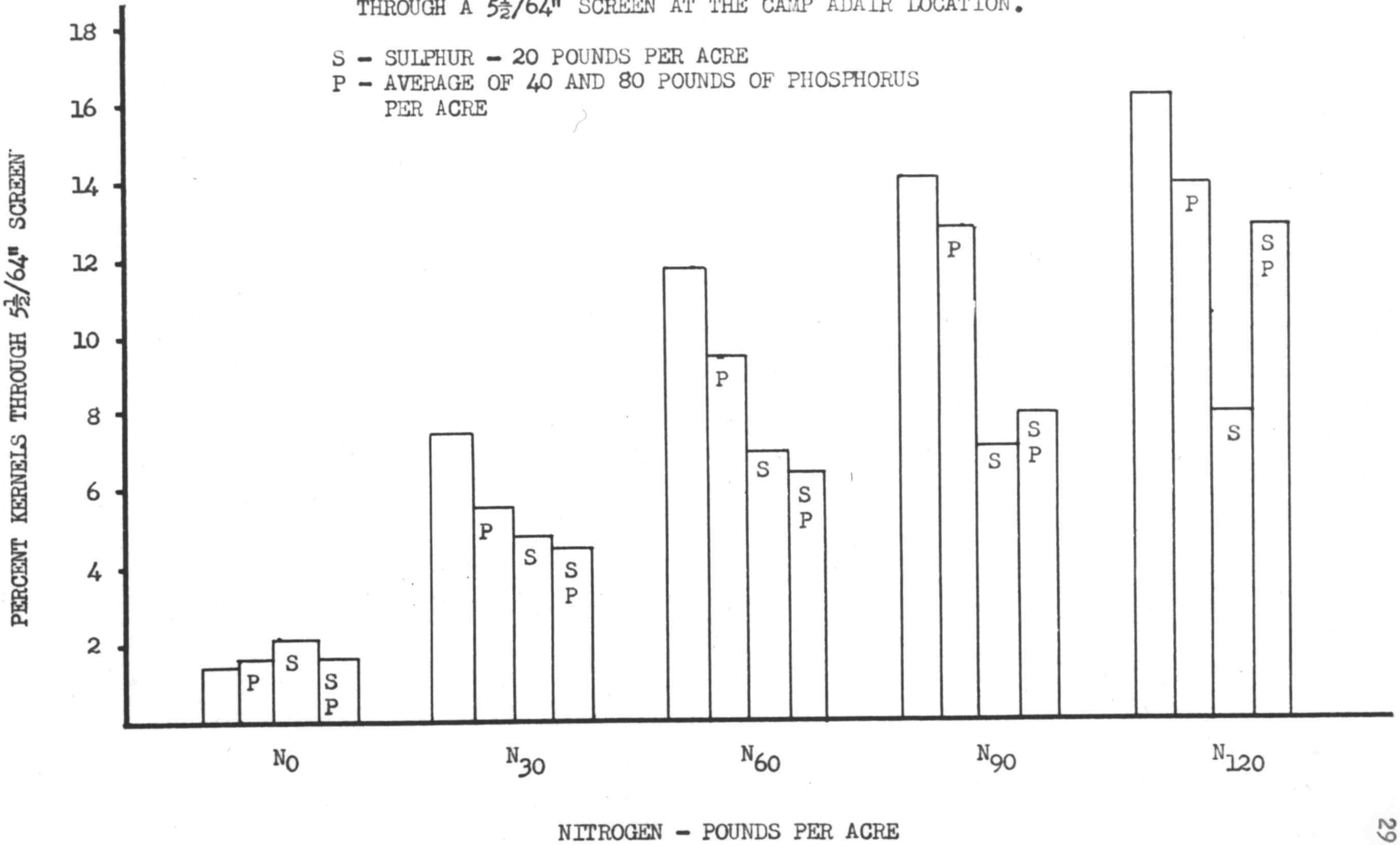
GRAPH 1. A COMPARISON OF TREATMENT EFFECT ON BUSHEL YIELD AT THE CAMP ADAIR LOCATION.

S - SULPHUR, 20 POUNDS PER ACRE
P - AVERAGE OF 40 AND 80 POUNDS OF PHOSPHORUS PER ACRE

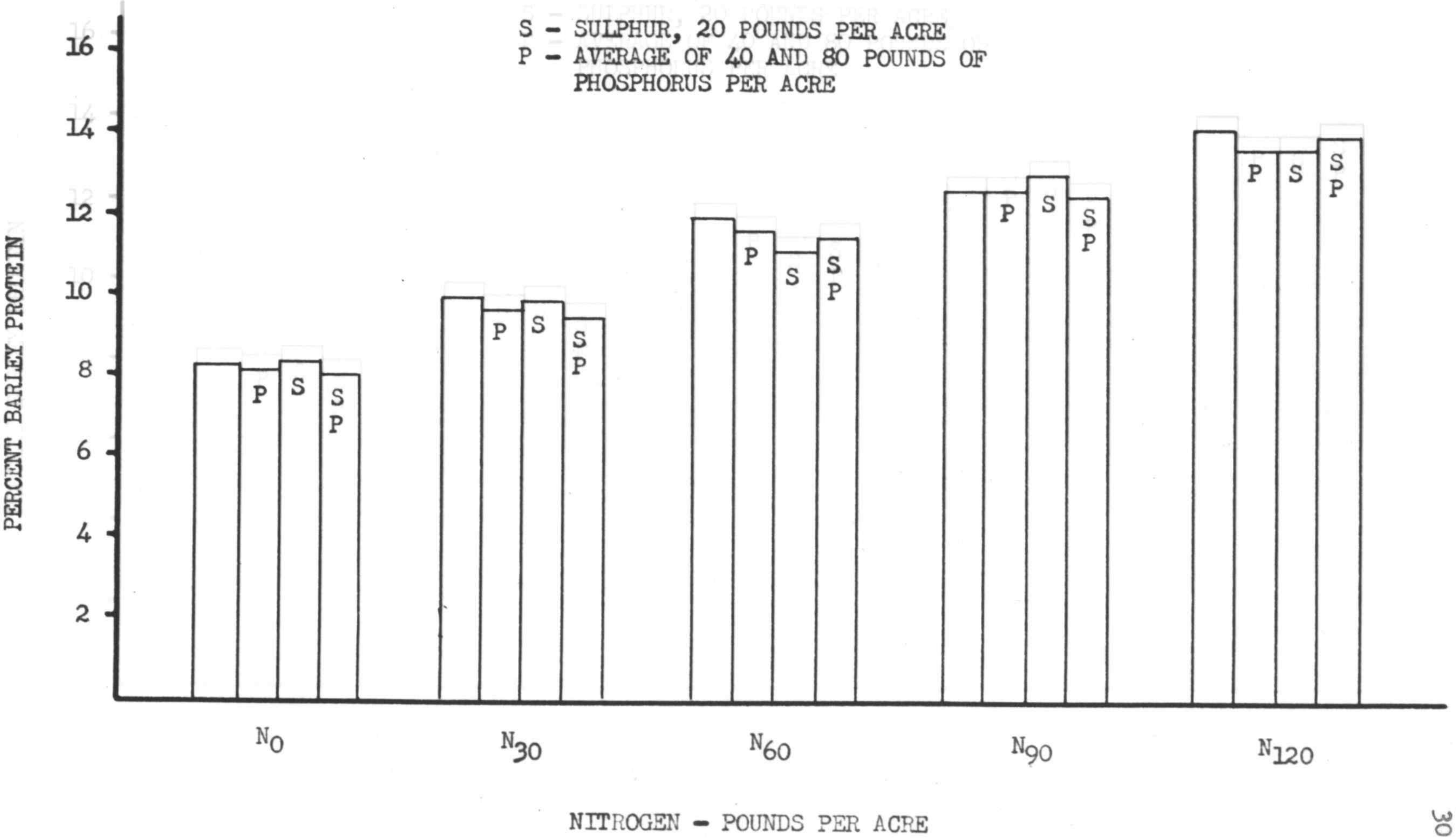


GRAPH 2. A COMPARISON OF TREATMENT EFFECT ON THE PERCENT OF KERNELS THROUGH A $5\frac{1}{2}/64"$ SCREEN AT THE CAMP ADAIR LOCATION.

S - SULPHUR - 20 POUNDS PER ACRE
P - AVERAGE OF 40 AND 80 POUNDS OF PHOSPHORUS PER ACRE



GRAPH 3. A COMPARISON OF TREATMENT EFFECT ON PERCENT BARLEY PROTEIN AT THE CAMP ADAIR LOCATION.



## Lodging

Extreme lodging was observed at East Farm on plots receiving sixty or more pounds of nitrogen. Neither phosphorus nor potassium had a visible effect on the intensity of this lodging. East Farm was the only location to exhibit lodging.

## Color and Height

A heavy concentration of anthocyanin in the culms, leaves, and awns occurred at Camp Adair. This was particularly pronounced in the replication receiving sulphur, but was evident to a lesser degree throughout the experimental area.

The barley in plots receiving heavy rates of nitrogen (sixty pounds and up) was noticeably taller and greener at all locations. The height effect was most pronounced at Hyslop Farm and on the Camp Adair sulphur replication.

## Maturity

High rates of nitrogen delayed maturity at all locations. At Camp Adair the sulphur replication matured approximately two weeks later than the unsulphured replications.

# DISCUSSION

The locations used for this experiment were chosen because they represented the extremes under which barley is produced in the Willamette Valley. These conditions gave a diversity of environments which readily illustrate the importance of local conditions on yield and the factors of malting quality. Perhaps the most striking illustration of this is a comparison of the check plot yield at East Farm and the top mean yields from the other locations. In no instance do the latter exceed the East Farm check.

A combination of irrigation and a high nitrogen level from previous clover crops produced high yields at East Farm. The reduction in yield and the extreme increase in thin kernel percentage on the high nitrogen plots at this location can be attributed in part to lodging. The inherent structural weakness of Hannchen barley appears to be accentuated under conditions of high fertility and moisture. Through an inhibition of kernel development and a decrease in harvesting efficiency, lodging can be expected to emphasize the deleterious effects of heavy fertilization on both yield and the physical factors affecting malting quality.

The abnormally low check plot yields at Camp Adair and Hyslop Farm indicated extreme plant nutrient deficiencies. From observations made during the growing season it appeared that both low fertility and moisture were the limiting factors at these locations. Had moisture been available at these locations prior to kernel development, through supplemental irrigation or increased rainfall, higher yields would have resulted from more efficient utilization of the fertilizer applied, particularly on the high nitrogen plots.

The apparent sulphur deficiency detected at Camp Adair was not unexpected. Foote (8, pp.4-13) has indicated that sulphur deficiencies occur, though infrequently, in the Willamette Valley. Many inherent sulphur deficiencies probably go undetected in this area when producers use sulphur containing fertilizers, such as ammonium sulphate. The data indicates that sulphur deficiencies, if overlooked, will result in both quality and yield losses.

Hannchen barley will not be accepted by malsters if its protein content exceeds 13.0 percent or falls below 9.5 percent. Much of the barley produced on the experimental trials failed to come within this range. Although fertilization varied protein content considerably, its effects must be considered in relation to location.

The unacceptable barley produced at Hyslop Farm appears to be the result of previous cropping practices. Ellis (6, p.495) observed that wheat produced on land newly broken out of cultivated grass sod invariably was of low protein content. The unavailability of nitrogen due to an unfavorable carbon-nitrogen ratio is perhaps the salient factor in a depression of this sort. A depression such as this can be expected in barley which follows any crops creating an extremely high carbon to nitrogen ratio. The Hyslop Farm experiment shows that applied nitrogen will overcome this inbalance.

Lejeune and Parker (12, p.12) indicated that nitrogen not used in making growth in barley is used in making protein. This is substantiated by the results obtained at East Farm. Although there was no apparent increase in plant growth on plots receiving over sixty pounds of nitrogen, the protein content continued to rise. The nature of the protein increase indicates further that maximum protein was not achieved, while the yield curve, indicative of total plant growth, had leveled off. No further increases in yield or plant growth could be expected from heavier applications of nitrogen.

The responses of protein to nitrogen applications, with and without potassium, indicate a relationship between potassium and protein assimilation at this location. Although this effect is quite noticeable at the lower rates of nitrogen, it has apparently been confounded with lodging or is non-operative at the higher rates. The inconsistency and small difference in the responses noted indicate their relative unimportance.

With wheat there has been some work, and much speculation, on the effect of protein constitution on baking quality. It is recognized that both quality and quantity of wheat protein influences baking properties (11, p.14). Recent unpublished work by the U. S. D. A. laboratory in Albany, California has pointed to new methods for establishing the extent of this influence. It is anticipated that by fractionation and reconstitution of proteonaceous matter in wheat the problem of protein quality, as it affects baking quality, can be isolated.

Cereal proteins contain varying amounts of carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus (11, p.11). The various effects of fertilization on yield, protein quantity, and kernel size of barley cause speculation about possible changes in the makeup of its protein, particularly as fertilizer applications are varied. In comparing yield, kernel size, and protein responses at Camp Adair (graphs 1, 2, and 3) it is difficult not to imagine various treatments causing a change in the constitution of proteins. Changes in the enzymatic activity and the behavior of coagulable protein in malts of high protein content may be as dependent on quality changes as quantity changes. If this is true, the type of fertilizer would be as important as quantity of fertilizer in creating variations in malting and brewing quality.

The high correlation between protein and diastatic power, found under natural cropping conditions, may not be valid where fertilizer elements are varied drastically. Batchelder (3, p.25) found protein increased steadily as nitrogen was increased. This increase was matched by an increase in diastatic power <u>up to the last increment</u>. But on this high rate (100 pounds) of nitrogen it dropped substantially. Something had affected the trend in enzymatic activity but had not affected the trend in protein content.

A method is needed to ascertain the changes, if any, brought about in barley protein constitution by varying environmental conditions, particularly fertilization. If this phenomenon should be established, a method would then be needed to relate protein constitution to enzymatic activity, maturation, extract, modification, and steeliness. Perhaps Hulton's caution (9) in using protein content to judge malting quality of barley will be proved valid when these relationships have been established.

Hannchen kernel size is a factor which shows consistent responses to fertilization. With an increase in nitrogen level, kernel size is decreased - thin kernel percentage increases, plump kernel percentage decreases. This predictability of relative response is attested to by all previous work in which nitrogen applications have exceeded twenty pounds per acre.

Only on Camp Adair was a kernel size response elicited from the use of fertilizer elements other than nitrogen. Apparently the Camp Adair location was an area of extreme nutrient deficiencies. This location, a representative of marginal grain production areas, indicates the sensitivity of both quality factors and yield to fertilization under sub-optimum conditions in soil productivity.

When producing barley on land not particularly suited to the production of malting barley, the producer is faced with an enigma. Though the relationship between the factors investigated in this study are not perfect, the trends have been established - yield and protein increase with the application, while kernel size decreases. Imposed on this nitrogen effect is the modifying influence of phosphorus, potassium, and sulphur, which varies from location to location in this area. Under these conditions an attempt to achieve malting quality may either be unsuccessful or cause the producer to sacrifice yield. But, if a high yield is achieved, at the expense of malting quality, the premium offered for malting barley is lost. This study, though extremely limited in scope, readily illustrates the existence of variations of this type.

If these variations, and the possible combinations indicated by the data collected, are extended over an area the size of the Willamette Valley, the magnitude of the problem becomes apparent. Table 10 has been prepared to illustrate the problems which arise in attempting to balance yield and quality on locations such as the ones studied in this problem.

It is evident that fertilization is but one of the factors contributing to the quality variations found in the Willamette Valley. Soil, moisture, rotation, and fertilization all have a profound effect on the absolute protein percentage and kernel size of barley produced in this area. Extremes in soil fertility, no matter how created, will produce barley of poor quality. Throughout the Willamette Valley this contribution to variation will be either modified or accentuated by the conditions under which it is found. The data collected in this study indicates the magnitude of variation possible in this area and illustrates the necessity for localized experimentation if recommendations for the control of this variation are to be effective.

TABLE 10

A COMPARISON OF MEAN VALUES FOR VARIOUS FERTILIZER TREATMENTS AT ALL LOCATIONS

| Location | Pounds Per Acre N | P | K | S | Percent Protein | Yield | Percent Over 6/64 | Percent Through 5½/64 |
|---|---|---|---|---|---|---|---|---|
| East Farm | 30 | 40 | - | 20 | 10.4 | 81.7 | 86.4 | 6.5 |
| | - | 80 | - | 20 | 9.5 | 77.3 | 91.1 | 4.2 |
| Hyslop Farm | 120 | - | - | 20 | 10.2 | 59.7 | 84.0 | 8.2 |
| | 60 | - | - | 20 | 8.1 | 54.4 | 91.4 | 4.3 |
| | 0 | - | - | 20 | 8.7 | 20.3 | 94.2 | 2.7 |
| Camp Adair | 60 | 40 | - | 20 | 11.4 | 51.9 | 79.8 | 6.3 |
| | 30 | - | - | 0 | 9.8 | 35.4 | 82.3 | 1.8 |

## SUMMARY AND CONCLUSIONS

To ascertain the effect of fertilization on Hannchen barley's malting quality and yield, various rates of nitrogen, phosphorus, and potassium, in all combinations, were applied at three locations in the Willamette Valley. At two locations sulphur was applied uniformly to the experimental area, while on the third location sulphur was applied to one of the three replications.

Observations were taken on yield, kernel size, protein content, and lodging.

Nitrogen increases yield and protein content but decreases kernel size. The effects of phosphorus and potassium are variable and appear to be dependent on localized conditions.

Sulphur, where its effects could be observed, contributed to increased yield and kernel size. A possible nitrogen x phosphorus x sulphur interaction (for yield) was observed.

Lodging occured when excessive nitrogen and adequate moisture combined to accentuate the inherent structural weakness of Hannchen barley. This lodging accentuated the deleterious effects of heavy fertilization on yield and kernel size.

Conclusions:

1. Fertilization, though it contributes to variations in quality, is only one factor contributing to the variations observed in Willamette Valley Hannchen barley.

2. The absolute effect of nitrogen fertilization on quality and yield is dependent on local environment.
3. There is no simple index by which the malting quality of barley may be judged.
4. The possibility of qualitative changes in the protein content of barley should be studied. If these changes are real, a study of their relation to malting quality may provide methods which will control quality variation in malting barley.
5. To control quality variations which result from fertilization, recommendations must be specific for soil type and previous soil management.

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