# INFLUENCE OF NITROGEN AND PHOSPHORUS FERTILIZER ON MALTING CHARACTERISTICS OF RYE[1]

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## ABSTRACT

Rye grown for 2 years in Nebraska was fertilized with 9 rates of N (0 to 112 kg/hectare) and 7 rates of P (0 to 33.6 kg/hectare); the total number of N×P combinations was 18. The rye samples were malted under laboratory conditions. Kernel weight was positively correlated with fine-grind extract and soluble proteins. Increasing rye-grain protein decreased extract and increased wort protein and diastatic power in rye malt. Diastatic power was positively correlated with wort-N and α-amylase. Effects of nitrogen fertilization on malt characteristics were related to the effects of fertilization on grain protein. Phosphorus fertilization affected ratio of wort proteins to grain proteins.

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Malted rye is characterized by relatively large amounts of amylolytic enzymes (especially $\alpha$-amylase) and of soluble-nitrogenous compounds. However, malting of rye presents several problems that stem from the small size of the kernels and from the absence of husks. The rye kernels absorb water rapidly and pack densely in germinators. The latter results in intensive germination (per unit space) and leads to heat formation and rapid depletion of oxygen. The absence of hulls eliminates the mechanical protection afforded to germinating barley grains and enhances moldiness. Modern pneumatic conveying eliminates some of the difficulties in malting of rye.

Malted rye is used by the baking and distilling industries which can utilize its unique compositional characteristics. Several reports were published in recent years on malting of rye grown in Europe (1, 2), but no studies have been reported on rye grown in North America. This report concerns the effects of nitrogen-and phosphorus-fertilization on malting quality of rye; comparison of rye cultivars was reported elsewhere (3).

## MATERIALS AND METHODS

Rye fertilizer experiments were conducted in Logan County, Nebraska in 1969 and in Antelope County, Nebraska in 1970. Sites represent a range of conditions under which rye is grown in Nebraska. The Logan County site was a Holdrege loam with a much higher yield potential than the Thurman loamy sand in Antelope County.

The previous crop was fallow in Logan County and rye in Antelope County. Residual nitrate and available phosphorus determinations were made to a 183-cm depth. These data indicated a probability of response to N and P fertilizer application at both locations.

Pierre variety was planted in 1969 and Pearl in 1970. Experimental design was a composite with two factors; experiments were randomized complete-block designs with three replications in the field. Eighteen treatment combinations were evaluated each of the 2 years. Replicates were composited for laboratory evaluation. Treatment combinations included 9 rates of N and 7 rates of P. Phosphorus .fertilizer was applied with the seed at planting; N was spring topdressed. Lack of moisture reduced yields and affected fertilizer responses at both locations.

*Analytical Determinations.* The grains and malted grains were analyzed according to the methods of analysis of the American Society of Brewing Chemists (4).

*Malting.* The samples (170-g lots) were malted under uniform conditions (5,6). All were steeped to 45% moisture (about 18 hr) at 16° C and germinated in malting chambers at 16° C for 5 days. Final kiln temperature was 85° C for 2 hr.

## RESULTS AND DISCUSSION

In evaluating the results, each year was regarded as a replicate. All 36 samples were used in the estimation of an error term with 17 degrees of freedom. In addition to the normal use in the analysis of variance, the error term was also used to test N, P, and N×P effects using selected treatments from the 18 combinations which were malted. Average grain and malt characteristics of the ryes receiving applications of nitrogen and phosphorus are given in Table I.

## TABLE I

**Average Grain and Malt Characteristics of Rye Receiving Selected Applications of Nitrogen and Phosphorus and Harvested in 1969 and 1970[a]**

| Treatment | Fertilizer kg/ha N | Fertilizer kg/ha P | Kernel Weight (KWT) mg | Grain Nitrogen (GN) % | Malt Extract % Fine (FEX) | Malt Extract Fine-Coarse % | Extract Color srm[b] | Wort Nitrogen (WN) % | Wort/Total Nitrogen (S/T) % | Diastatic Power (DP) | $\alpha$-amylase (Alpha) 20° units | $\beta/\alpha$ Ratio (B/A) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 17.0 | 2.00 | 84.6 | 3.6 | 2.9 | 1.11 | 54.9 | 108 | 58.7 | 4.2 |
| 2 | 0 | 16.8 | 17.0 | 1.86 | 85.7 | 4.2 | 3.8 | 0.87 | 47.0 | 106 | 67.0 | 3.0 |
| 3 | 0 | 33.6 | 17.4 | 1.86 | 86.3 | 4.1 | 3.6 | 1.06 | 57.9 | 97 | 65.0 | 2.7 |
| 4 | 14 | 5.6 | 17.1 | 1.96 | 85.0 | 3.7 | 2.6 | 1.06 | 56.0 | 105 | 65.2 | 3.2 |
| 5 | 14 | 28.0 | 17.4 | 1.94 | 85.5 | 4.0 | 3.6 | 1.07 | 55.8 | 107 | 66.1 | 3.2 |
| 6 | 28 | 16.8 | 18.8 | 2.01 | 85.0 | 6.8 | 3.8 | 1.07 | 53.0 | 100 | 52.0 | 5.2 |
| 7 | 42 | 0 | 17.6 | 2.06 | 84.2 | 4.1 | 2.3 | 1.20 | 56.6 | 121 | 65.8 | 4.1 |
| 8 | 42 | 33.6 | 18.1 | 2.17 | 84.9 | 4.8 | 3.5 | 1.15 | 53.8 | 117 | 66.0 | 3.8 |
| 9 | 56 | 11.2 | 17.4 | 2.22 | 83.7 | 2.3 | 2.1 | 1.23 | 55.8 | 123 | 67.8 | 4.0 |
| 10 | 56 | 22.4 | 17.7 | 2.13 | 84.2 | 3.8 | 3.9 | 1.09 | 49.6 | 121 | 70.3 | 3.6 |
| 11 | 70 | 0 | 17.2 | 2.39 | 83.1 | 3.2 | 2.6 | 1.30 | 53.9 | 136 | 75.1 | 3.9 |
| 12 | 70 | 33.6 | 17.6 | 2.33 | 83.6 | 3.9 | 3.3 | 1.32 | 56.5 | 130 | 69.0 | 4.2 |
| 13 | 84 | 16.8 | 17.4 | 2.40 | 83.1 | 3.7 | 3.4 | 1.31 | 55.4 | 138 | 72.8 | 4.3 |
| 14 | 98 | 5.6 | 16.9 | 2.59 | 83.8 | 5.7 | 2.1 | 1.36 | 52.4 | 148 | 80.5 | 4.1 |
| 15 | 98 | 28.0 | 17.5 | 2.57 | 83.3 | 4.9 | 3.4 | 1.36 | 52.7 | 140 | 73.7 | 4.3 |
| 16 | 112 | 0 | 16.6 | 2.66 | 82.8 | 5.3 | 2.0 | 1.44 | 53.5 | 145 | 75.6 | 4.5 |
| 17 | 112 | 16.8 | 17.7 | 2.50 | 81.2 | 6.2 | 2.8 | 1.26 | 49.0 | 124 | 42.4 | 9.6 |
| 18 | 112 | 33.6 | 16.6 | 2.58 | 82.6 | 4.5 | 2.9 | 1.37 | 52.6 | 137 | 72.1 | 4.3 |

[a]Parenthesized abbreviations are used in Table II.
[b]Standard reference method, Lovibond Tintometer.

Simple correlations among the eight variables which were determined on rye grain and malt are summarized in Table II. Degrees of freedom for these correlations are 34; correlation coefficients of at least 0.330 are significant at the 0.05 level and of 0.426 at the 0.01 level.

Kernel weight was positively correlated with two important malting parameters: fine-grind extract and solubilized proteins (wort/malt N ratio). High-grain nitrogen resulted in malts of decreased fine-grind extract and increased wort-N and diastatic power. Fine-grind extract increased as the ratio of soluble-N to total-N increased. Diastatic power was positively correlated with wort-N and $\alpha$-amylase.

Analyses of variance of the effects of fertilizer treatment on malting characteristics of rye are summarized in Table III. The results in Table III are arranged in three columns: a) all treatments; b) treatments 1, 3, 7, 8, 11, 12, 16, and 18 (from Table I) to evaluate effects of four levels of N applications and two levels of P; and c) treatments 1, 2, 3, 16, 17 and 18 to evaluate effects of two levels of N application and three levels of P. Examination of the summary indicates

**TABLE II**

**Simple Correlations Among Variables in 36 Samples of Rye (1969 and 1970 Fertilization Experiments)[a]**

| | KWT | GN | FEX | WN | S/T | DP | ALPHA | B/A |
|---|---|---|---|---|---|---|---|---|
| KWT | 1.000 | | | | | | | |
| GN | −.304 | 1.000 | | | | | | |
| FEX | .569 | −.780 | 1.000 | | | | | |
| WN | −.166 | .900 | −.586 | 1.000 | | | | |
| S/T | .459 | −.213 | .495 | .199 | 1.000 | | | |
| DP | .026 | .734 | −.264 | .780 | .126 | 1.000 | | |
| ALPHA | −.149 | .178 | .215 | .278 | .252 | .631 | 1.000 | |
| B/A | .314 | .296 | −.344 | .230 | −.171 | .028 | −.716 | 1.000 |

[a]See Table I for explanation of abbreviations. Correlation coefficients at or above 0.330 and 0.426 are significant, respectively, at the 0.05 and 0.01 level.

**TABLE III**

**F Value Significance Levels Observed Using 17 Degrees of Freedom for Error**

| Rye or malt characteristic | Analysis I[a] | Analysis II[b] | | | Analysis III[c] | | |
|---|---|---|---|---|---|---|---|
| | Fertilizer | N | P | N×P | N | P | N×P |
| Grain kernel weight | | | | | | | |
| Grain nitrogen | .01 | .01 | | | .01 | | |
| Fine grind extract | | .05 | | | .01 | | |
| Fine-coarse extract | | | | | | | |
| Extract color | | | .05 | | | | |
| Wort nitrogen | .01 | .01 | | | .01 | .05 | |
| Wort/total nitrogen | | | | | | .01 | |
| Diastatic power | .01 | .01 | | | .01 | | |
| Alpha amylase | | | | | | | .05 |
| Beta/alpha | | | | | .01 | .05 | .01 |

[a]Source of error term.
[b]Based on treatments 1, 3, 7, 8, 11, 12, 16 and 18 of Table I.
[c]Based on treatments 1, 2, 3, 16, 17 and 18 of Table I.

that nitrogen fertilization increased nitrogen in the rye grain. In the malt, it increased the soluble nitrogen and diastatic power, while decreasing malt extract. Phosphorus fertilization had a marginal effect on extract color and decreased (at the 16.8 kg P/hectare level) the ratio between soluble and total nitrogenous compounds. In addition, in four of the six samples grown on fields fertilized with 16.8 kg P/hectare $\alpha$-amylase levels were low; this led to an N×P interaction. No explanation can be offered, at this time, for this reduction in amylolytic activity.

These results are in general agreement with results of studies on the effects of N and P fertilization of barley. Lejeune and Parker (7) found that phosphorus had no adverse effects on malting quality; it, generally, increased kernel plumpness and malt extract. Phosphorus in combination with nitrogen, generally increased kernel plumpness and malt extract. Phosphorus was shown (7) under certain conditions to neutralize or counteract undesirable effects of excess nitrogen.

Atkins *et al.* (8) reported that malting quality characteristics of barley produced under conditions of high response to fertilization generally were not significantly altered, and those affected sufficiently to be of practical consequence in malting and brewing were improved. Nitrogen fertilizer, applied in excess of the amount required for maximum yield, increased protein content and decreased malt extract. Phosphorus fertilizer improved malting quality by increasing kernel weight and malt extract, and had no deleterious effects on other parameters of malting quality.

Reisenauer and Dickson (9) studied the effects of nitrogen and sulfur fertilization on yield and malting quality of barley grown in the Palouse area of eastern Washington. Barley yields were increased by nitrogen and sulfur fertilization with a significant nitrogen × sulfur yield interaction. The higher rates of nitrogen fertilization decreased kernel size and increased barley, malt, and wort nitrogen. While nitrogen fertilization increased amylolytic activities, it was regarded to have reduced overall-malting quality. More recently, Zubriski *et* al. (10) found that whereas kernel plumpness was not affected to a large degree by N fertilizer, grain protein increased with increase in fertilizer level. The effect of N fertilizer also depended on date of seeding and application of K fertilizer.

A survey of many investigations conducted in the Barley and Malt Laboratory points to three major and consistent effects of increased barley protein on malting parameters: increased wort nitrogen and diastatic power and decreased malt extract. The effects of protein content on malting characteristics of barley also are affected by variety. The results of this study indicate that in rye the effects on malting quality of nitrogen fertilization are similar to those in barley.

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