THE EFFECTS OF NITROGEN FERTILIZATION ON YIELD AND MALTING QUALITY OF A WINTER MALTING BARLEY GROWN IN OKLAHOMA

By

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CHAPTER I

INTRODUCTION

The amount of barley needed to satisfy the malting industry is ever increasing. Part of the barley needed to supply this demand may need to come from new areas of production. At the present time, most of the malting barley produced in the United States is from spring type varieties grown in the north-central and western areas. The irrigated region of the Oklahoma Panhandle is being considered as a possible new production area of malting barley.

At present no winter malting barley varieties exist that are adapted to this region. Winter type feed varieties that are well adapted to the area often exceed the desirable level of protein content and possess a large proportion of small kernels. In order for a winter malting barley to be acceptable, it must have a desirable protein level. The kernel size distribution must have either a large percentage of plump kernels or high uniformity from a large proportion of medium kernels. Yield levels must be comparable to those of adapted winter feed barleys. High yield must be obtained in such a way that the input of such growth factors as fertilizer and water are not prohibitive.

The primary objectives of this study were: (1) to investigate the effect of nitrogen fertilizer has upon the protein content of a potential winter malting barley under irrigated conditions, and (2) to examine the yield, yield components, and factors of malting quality as affected by this nitrogen fertilization.

CHAPTER II

REVIEW OF LITERATURE

Malting barley plays an important role in the total acreage of barley grown in the United States. The producer may receive higher prices for malting barley as opposed to barley used for feed. The quality of the barley for malting purposes determines the amount of premium offered by maltsters. Important physical characteristics affecting quality include kernel size and uniformity of kernels (2). A high percentage of plump kernels is desirable, but samples containing a high proportion of medium kernels may meet quality requirements. Good malting quality is also influenced by intermediate protein percentage, high extract percentage, and high diastatic power.

Recent expanded need for supplies of malting barley by maltsters have resulted in consideration of the south-central states as an alternative source of supply to the north-central states and Canada. The barley varieties currently grown in the southern United States are of a winter growth habit and were developed as feed barleys. Considerable work is underway in developing a winter malting barley having spring malting barley quality. Mader (22) and Gilchrist (13) concluded that year after year production of malting barley would be difficult in Oklahoma due to the uncertainty of existing weather conditions. The prime concern is moisture stress resulting in small kernel size and high protein content. A two-row winter malting barley has been successfully produced in

Missouri (8) where moisture stress was not a major problem. In the southern great plains at Lubbock, Texas (23), studies indicated that barley of acceptable malting quality could be produced providing an adapted variety was used and irrigation water was applied at the proper times.

Yield

The selection of a variety for production depends largely upon its yielding ability. In the case of malting barley production for Oklahoma, the variety grown must exhibit quality acceptable for malting and be comparable to adapted feed varieties in grain yield. High yields have been found to be associated with high kernel weight, high bushel weight, low protein, low diastatic power, and high extract (7). Other investigators have reported similar results with positive correlations between yield and test weight and yield and kernel weight with a negative correlation between yield and malt diastatic power (17,25). A negative correlation between yield and protein has been reported by Johnson and Aksel (17), Zubriski, Vasey, and Norman (30), and Hsi and Lambert (15).

Fertilization and Irrigation

In order to assure the highest possible yield, all possible limiting factors of growth should be eliminated. Application of macro- and micronutrients according to soil test is essential if top yield potential is to be realized. Nitrogen must be applied to assure a satisfactory crop if preceding crops have lowered the available supplies of nitrogen in the soil (5). Where nitrogen is limiting, added nitrogen is used largely for increased plant growth and grain production rather than for producing a higher protein content in the grain. However, nitrogen applied late in the season and in excess of the amount required for optimum growth often leads to increased protein content and decreased malting quality (11,16, 19).

Phosphorus and potassium are other major nutrients that affect malting quality as well as yield. Zubriski (30) found that phosphorus and potassium applied to deficient soils increased yield, reduced lodging, and improved malting quality by increasing kernel plumpness. This agrees with Atkin's conclusion (5) that the general effect of phosphorus applied to deficient soils was to improve malting quality. Gately (12) reported that a response to added phosphorus occurred only on soils with not more than 2 p.p.m. of phosphorus, and that little effect could be expected from the addition of phosphorus to well-fertilized soils.

Stone and Tucker (27) concluded, with supplemental irrigation in the Oklahoma Panhandle, that a relationship between decreased nitrogen content in the grain and increased yield did exist. Such a relationship has been determined to result from a "dilution effect". In such an instance, a treatment that increases yield tends to decrease the percentage of nitrogenous material in the grain.

Test Weight - Kernel Characteristics

Different samples of barley may differ considerably in percentage of plump and thin kernels. For this reason, test weight may not be an adequate measure of seed quality (21). Hsi and Lambert (15) and Den Hartog and Lambert (7) found positive relationships between test weight and yield, test weight and kernel weight, and test weight and barley extract. A negative relationship was reported between test weight and nitrogen content as well as test weight and diastatic power by Harris and Banasik (14).

Acceptable quality malting barley should possess a highly uniform distribution of medium kernels or a high percentage of plump kernels. Plump kernels are those remaining on a 6/64 inch sieve and thin kernels are those that pass through a 5/64 inch sieve after having been shaken for two minutes, as specified by Anheuser Busch, Inc. A high kernel weight and high extract have been shown to have a positive correlation (7,14,15).

Short, plump kernels are preferred over long and thin kernels. The activity of the various enzymes, which are released in the malting process, are related to kernel size. These enzymes are concentrated in the germ and the kernel's outer layer. Time is required for the enzymes to spread throughout the kernel. The enzymes take longer to penetrate the entire kernel as kernel size increases. With non-uniform kernel size, different rates of enzymatic activity occur during the malting process. The percentage of plump kernels should be as high as possible to obtain a high extract percentage. Also, kerenls should be uniform for proper enzyme activity during malting (2).

The hull of malting barley should be thin, tough, and closely held to the kernel. Little extractable material can be obtained from the hull, but the hull is useful in producing a filter bed used in the mash. A thick hull leads to a low yield of extract in the malt, while a thin but brittle hull will break up causing an inadequate filter bed.

Yield Components

The yield components of fertile tillers per unit area, kernels per spike, and kernel weight are of primary importance to the agriculturalist in attaining the highest possible yield. Grain yield components are determined at different stages in the development of the plant (1,10,24). The number of spikes per plant is determined at an early stage (6) with the number of kernels per spike being determined prior to spike emergence. Earlier formed tillers contribute most to grain yield. Kernel weight is partially determined during the period of vegetative growth, but the post-fertilization stage plays a greater role (29).

The tillering ability of a plant is determined by the genetic make-up in response to the environment. Plant competition also influences tillering indirectly through altered light intensity. With a lower seeding rate more light is available for the individual plant and more tillers are formed. Tillering exhibits a high dependence on the nitrogen supply. Reduced tillering will result when a plant with a high tiller potential receives a limited nitrogen supply. Increased tillering can be promoted by application of nitrogen at different phases of the plant's development (4,16).

High kernel weight may occur with both high and low nitrogen applications (16). Kernel weight can be attributed to a certain degree to hereditary factors. Environmental conditions influence kernel weight to a large degree and this yield component cannot be used alone as an indicator of malting quality. If nitrogen is deficient, the addition of nitrogen fertilizer will increase kernel weight, but excess nitrogen may lead to a decrease in kernel weight (12).

Number of kernels per spike decreases with increased seeding rate

(18). High yielding varieties in European barleys have resulted from selection for a high tillering capacity without any major reduction of kernels per spike or kernel weight (6).

Water supply has a direct relationship to tiller production. A diminished water supply leads to a reduced number of tillers. With reduced water supplies, the number of spikes per plant is determined primarily by the seeding rate; whereas, with adequate water, yield is related more to the number of tillers formed than the rate of seeding. Differences in yield components indicated the major response to irrigation was an increased number of spikes produced (19,20). Varieties that respond to irrigation produce a larger proportion of smaller spikes. Irrigation had no effect on the kernel size of the primary tiller, but stimulated the production of secondary spikes, which would contain smaller kernels. These secondary spikes would contribute to a decreased average kernel weight.

Tillering is influenced more by a water-nitrogen interaction as opposed to water supply alone. Irrigation stimulated tillering, while the effect of nitrogen fertilizer was to maintain a high tiller number (20). Nitrogen fertilization increased the rate of nitrogen uptake, leading to increased growth and greater total nitrogen content.

Protein - Extract - Diastatic Power

The quality of malting barley must be considered from the brewer's point of view. Malting basically involves steeping and germinating the grain under controlled humidity, temperature, and atmosphere. The germinating kernels develop a high content of amylase and other enzymes, which are used for later digestion of starch in brewing. In brewing, malt is mixed with other grains to provide the mash. The enzymes of the malt reduce starch to simple sugars in the resulting wort, which is later fermented by yeast to make beer. The quantity and quality of the wort produced by a malt are thus the principle criteria of malt quality.

Protein content of barley influences the malting quality directly (3). Extremely low protein content causes a malt that is deficient in enzymatic activity. High protein gives a malt that, in the processes of mashing and extraction, yields worts high in soluble protein. Difficulties also arise from high protein because such malts produced possess undesirably high enzymatic activity. Small and thick kernels are associated with high protein content and yield a low extract percentage. Since extremes in protein affect diastatic power and extract to a large degree, through enzymatic activity, a medium protein content is preferred for malting purposes. Anderson, Meredith, and Sallans (2) found that environmental factors which affected the nitrogen content of the barley and malt also influence other malting characteristics, such as diastatic power and extract. Therefore, information concerning the general malting quality can be indicated by a determination of the protein content.

Extract percentage must be high in order for the maltster to produce an economical and desirable malt. The extract yield of a malt depends largely on the quantity of potentially extractable material in the barley. A second factor affecting extract yield involves the amount of potentially extractable material made available during the malting and mashing processes. Insoluble compounds, of which starch and proteins form a large proportion, compose a major portion of the grain. The enzymes which are active during mashing transform insoluble compounds into a soluble form. The quantity of solids in the wort, the extract yield, and wort quality are affected by the kind and extent of the hydrolytic processes taking place in the mash. If the extract yield of a variety is low it will generally be found that the grain is low in enzymatic activity or in potentially extractable material.

Malt diastatic power refers to the ability of the malt to convert the soluble starch of the malt and other grain added to the malt to fermentable sugars. The enzyme, beta-amylase, which is mainly responsible for converting starch to sugar is present in the barley in a partially combined or inactivated form.

High protein content has been found to be related with low extract percentage and high diastatic power (16,28). A positive correlation occurred between protein and malt diastic power and a negative correlation between protein and malt extract (30). Generally, high protein tends to be related with low malt extract and high diastatic power.

Not all relationships between protein content and other quality characteristics are totally genetic. Many environmental factors have a pronounced effect on the percent protein and quality factors (2). Environmental factors that may affect kernel weight and protein are water stress, nutrient supply, and inter- and intra-plant competition.

CHAPTER III

MATERIALS AND METHODS

Nature of Treatments

This study consisted of six levels of nitrogen fertilization selected to represent current fertilization practices. The rates of application varied from no nitrogen to 179.4 kg/ha of actual nitrogen applied. The six treatments were:

Treatment	Season: Fall (Actual N kg/ha)	Season: Spring (Actual N kg/ha)
1	89.7	89.7
2	89.7	44.8
3	89.7	22.4
4	89.7	00.0
5	44.8	00.0
6	00.0	00.0 .

Ammonium nitrate was used as the source of nitrogen for all treatments and was applied with a manually-operated Gandy spreader in all treatments. A soil test taken prior to planting indicated 82.9 kg/ha and 40.4 kg/ha of available nitrogen in the surface (0.0-15.2 cm) and subsurface (15.2-30.5 cm) soils, respectively. The total residual nitrogen available in the soil was 123.3 kg/ha.

The variety NY6005-18 selected for the study was developed at Cornell University from a cross involving the winter feed barley, Hudson, and the spring malting barley, Traill. NY6005-18 is relatively well adapted to Oklahoma for yield, and possesses desirable malting qualities.

Field Layout

The field design was a randomized complete block with four blocks and was located at the Panhandle Experiment Station at Goodwell. Each plot was 6.1 meters long and 4.3 meters wide--covering three beds with rows spaced 20.3 cm apart. Planting was done on October 4, 1973 with a 20 row x 8 inch deep furrow drill at the seeding rate of 107.6 kg/ha (2 bu/acre). Soil test indicated that the available soil supply of potassium was adequate, while phosphorus was deficient. A granular application of P_2O_5 was made on October 4, 1973 at the rate of 35.9 kg/ha. All plots received a furrow irrigation on six dates. Irrigations were applied as necessary to maintain adequate soil moisture and eliminate water stress. Approximately 5-6.4 cm of water were applied at each irrigation.

The soil was a Richfield clay loam (Typic Argiustoll), which is a deep, dark, clayey soil that is well drained. The surface soil is dark grayish-brown to a grayish brown silt loam and is generally about 15 cm deep. Beneath the surface soil is a dark, grayish-brown, compact clay that is 15 to 51 cm deep. The clay grades to light-colored, highly calcareous parent material of wind laid silt. This soil is slightly susceptible to erosion by wind and water.

Characters Investigated

The following characters were observed and measured on all plots: grain yield, test weight, protein percentage, tillers per unit area, kernels per spike, kernel weight, malt extract percentage, malt diastatic power, and per cent plump and thin kernels. The measurements on these characters were made as follows.

Grain Yield

Grain yield was determined as the weight in kilograms produced by the center 2.4 x 6.1 m of the plot. The area harvested per plot was 14.6 m^2.

Test Weight

This character was recorded in kilograms per hectoliter from a random sample from the harvested grain.

Protein Percentage

The percentage of kernel protein was determined by standard Kjeldahl methods. The analysis was performed in the cereal chemistry laboratory, Oklahoma State University.

Tiller Number

Tillers per 930 cm^2 was determined by counting the tillers in a random area of the plot.

Kernels per Spike

The average number of kernels per spike was determined by counting the kernels per spike from ten randomly selected spikes from each plot.

Kernel Weight

This character was the weight in grams of 100 kernels chosen at random from the yield sample of each plot.

Malt Extract Percentage and Malt Diastatic Power

The values used in the analysis were measured by the United States Department of Agriculture National Malt Laboratory, at Madison, Wisconsin.

Percentage of Plump and Thin Kernels

Measurements on these quality characteristics were determined by Anheuser Busch, Inc. at the company's quality laboratory in St. Louis, Missouri. A one hundred gram sample was used to determine kernel size. The weight of kernels remaining on a 6/64 inch sieve was the percentage of plump kernels. The weight of kernels passing through a 5/64 inch sieve directly below the larger sieve comprised the percentage of thin kernels. Medium kernels were those which remained on the 5/64 inch sieve. The sieves were shaken for two minutes.

Statistical Analysis

Analysis of variance for a randomized block design was conducted on all characters measured. Comparisons within seasons were made to determine if linear and quadratic effects were present and to determine if the effects were similar (26). Computational analyses were made by the Statistical Analysis Systems (SAS) at the Oklahoma State University Computer Center. The replication x treatment mean square was used as the error mean square.

CHAPTER IV

RESULTS AND DISCUSSION

Yield and Yield Components

Yield response to fall fertilization was similar to yield response for spring fertilization. The highest yield was obtained when 44.8 kg N/ha was applied (Table I, Figure 1). Within each season the high and low fertilizations gave essentially the same response. Although yields from spring fertilizations were higher than yields from fall fertilizations, the difference was not declared significant (Table II). The small difference between yields for fall and spring fertilization indicated the fall application of 89.7 kg N/ha had very little effect on plots that received a spring top dressing. With such high residual nitrogen, applications of nitrogen fertilizer were ineffective and unnecessary for increased grain yield. NY6005-18 was determined to be relatively well adapted to Oklahoma conditions for yield (13).

Increased levels of nitrogen application had a different effect on plots receiving fall fertilization when compared to those receiving a spring top dressing (Table II). With fall fertilization, tiller production increased and then decreased as the level of nitrogen changed from 00.0 to 44.8 to 89.7 kg N/ha, respectively. Tiller production from spring fertilization decreased and then increased as the nitrogen level changed from 22.4 to 44.8 to 89.7 kg N/ha, respectively (Table I, Figure 2). Aspinall (4) reported the degree of tillering was highly dependent

TABLE I

TREATMENT MEANS FOR YIELD AND YIELD COMPONENTS OF SIX NITROGEN TREATMENTS ON NY6005-18 MALTING BARLEY

Treatment	Fall (kg N/ha)	Spring (kg N/ha)	Yield kg/ha	Tillers/ 930 cm^2	Kernels/ Spike	Weight/ Kernel (mg)
1	89.7	89.7	4063.4	78.5	47.3	25.6
2	89.7	44.8	4290.6	73.9	51.4	25.7
3	89.7	22.4	3927.8	86.2	47.9	25.7
4	89.7	00.0	3837.3	71.8	41.4	25.4
5	44.8	00.0	4586.5	81.0	47.0	25.5
6	00.0	00.0	3841.9	77.1	46.4	26.1
	Overall Mean		4091.2	78.1	46.9	25.7

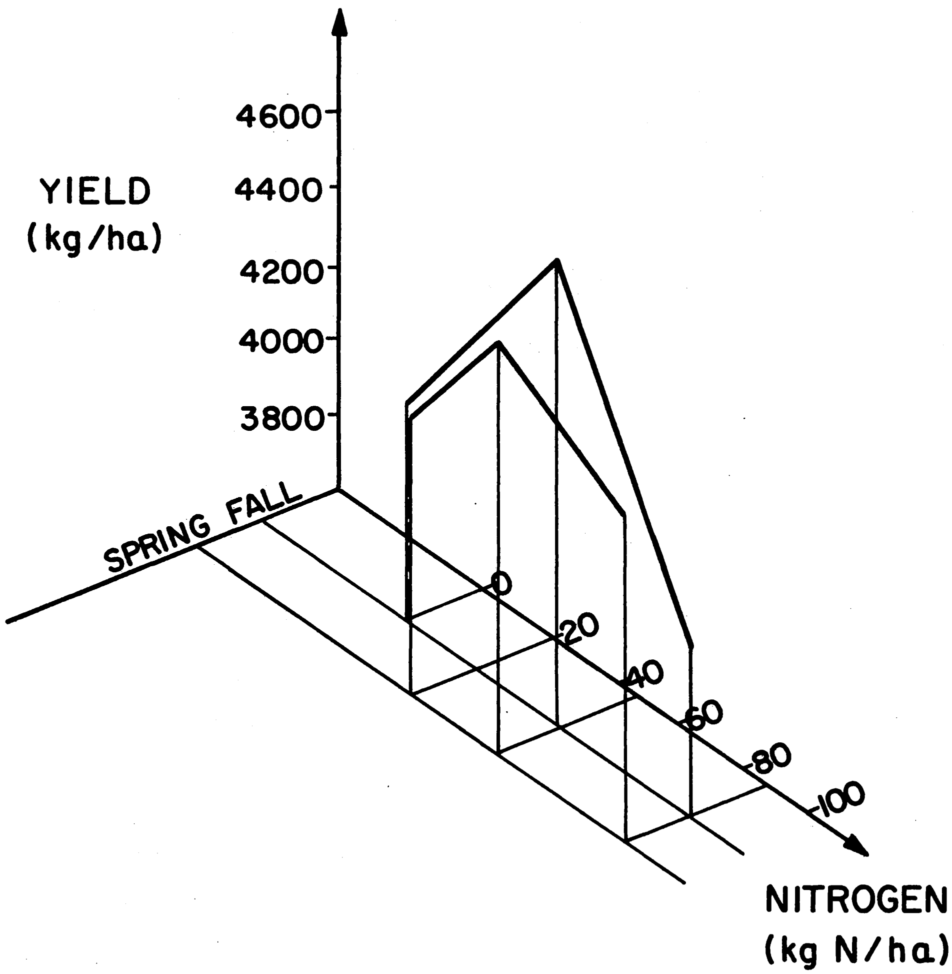

Figure 1. Yield in Response to Nitrogen Fertilization

TABLE II

MEAN SQUARES FROM AN ANALYSIS OF VARIANCE OF SIX NITROGEN TREATMENTS ON NY6005-18 MALTING BARLEY FOR YIELD AND YIELD COMPONENTS

Source of Variation	df	Grain Yield	Tillers/ 930 cm^2	Kernels/ Spike	Weight/ Kernel
Total	23	311715.7	83.210	21.33	0.200
Replications	3	566516.2	203.528	7.28	0.324
Treatments	5	351326.2	107.292	41.52	0.228
Seasons	1	172.8	51.042	92.83	0.020
Nitrogen Linear	1	2895.7	120.593	47.06	0.726*
Nitrogen Linear x Seasons	1	6608.1	3.440	7.11	0.209
Nitrogen Quadratic	1	1740467.9*	7.286	50.81	0.130
Nitrogen Quadratic x Seasons	1	6486.9	354.097**	9.76	0.056
Replications x Treatments	15	247552.2	51.119	17.41	0.166

*,**Significant at 0.05 and 0.01 levels of probability, respectively.

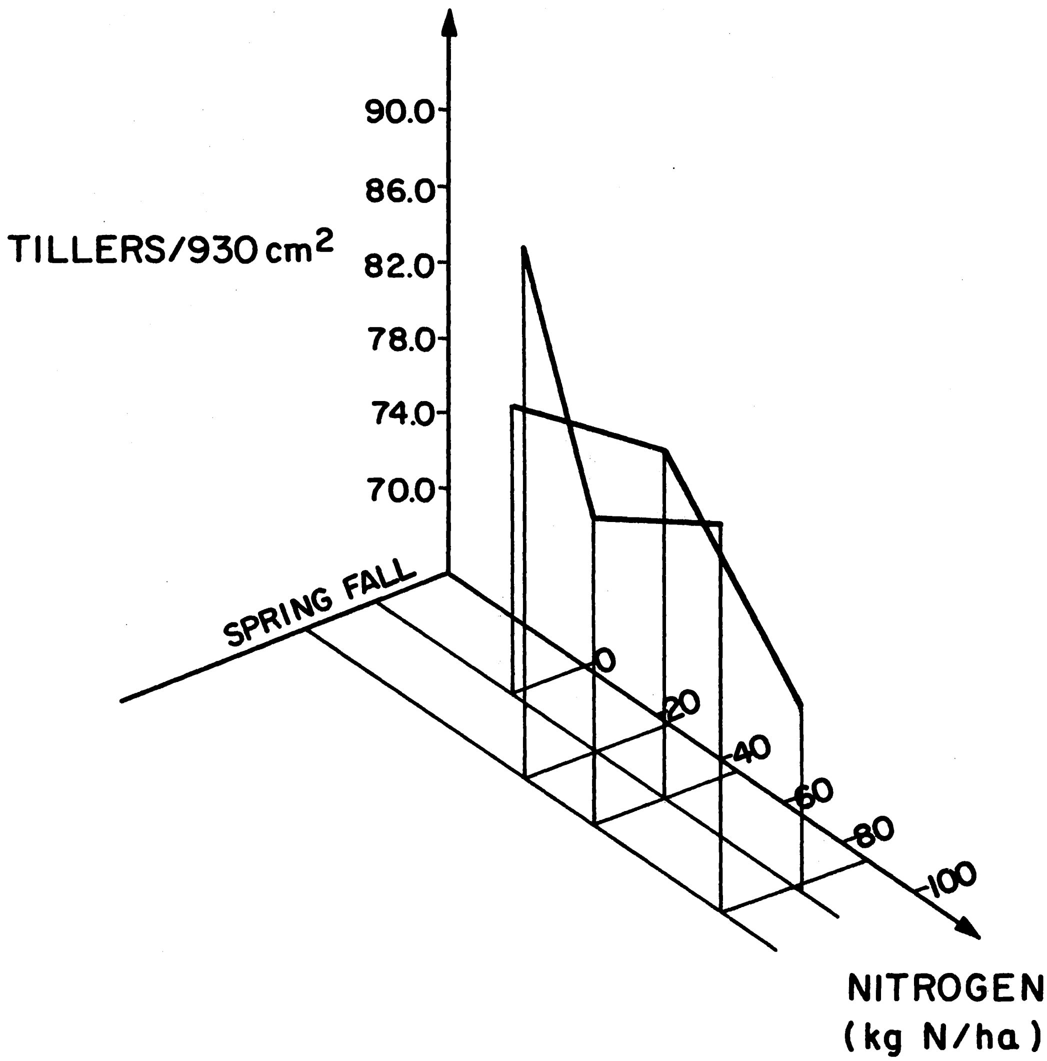

Figure 2. Tiller Production in Response to Nitrogen Fertilization

upon nutrient supply. Thorne (29) and Cannell (6) reported the number of tillers per plant was determined at an early stage of development. The number of fertile tillers per plant can be maintained at a higher level with increased and regular additions of nutrients (4,29).

The different levels of nitrogen fertilization had little or no effect on changing the number of kernels per spike (Table II). Kernels per spike for the treatments studied are shown (Table I, Figure 3). The overall treatment mean was 46.9 kernels per spike (Table I). Gilchrist (13) reported the variety NY6005-18 ranked first at two locations for kernels per spike. The residual nitrogen appeared to be sufficient for maximum production of kernels per spike over all treatments.

Weight per kernel indicated a similar and significant linear effect to nitrogen application in both seasons (Table II). As nitrogen application increased, weight per kernel decreased (Figure 4). Low kernel weigh weight decreased malting quality. The highest kernel weight occurred for treatment six (Table I).

Over the range of treatments studied, additional nitrogen had an effect for increasing grain yield and affected tiller production while lowering kernel weight. However, residual soil nitrogen appeared to have been sufficient to realize a good grain yield potential.

Protein Content

A significant difference was found for protein percentage between seasons (Table III). Treatments having a spring topdressing resulted in higher protein percentages. The highest protein percentage in the grain (13.72 per cent) was observed in the plots which had received the highest rate of total nitrogen (179.4 kg/ha), while the lowest protein percentage

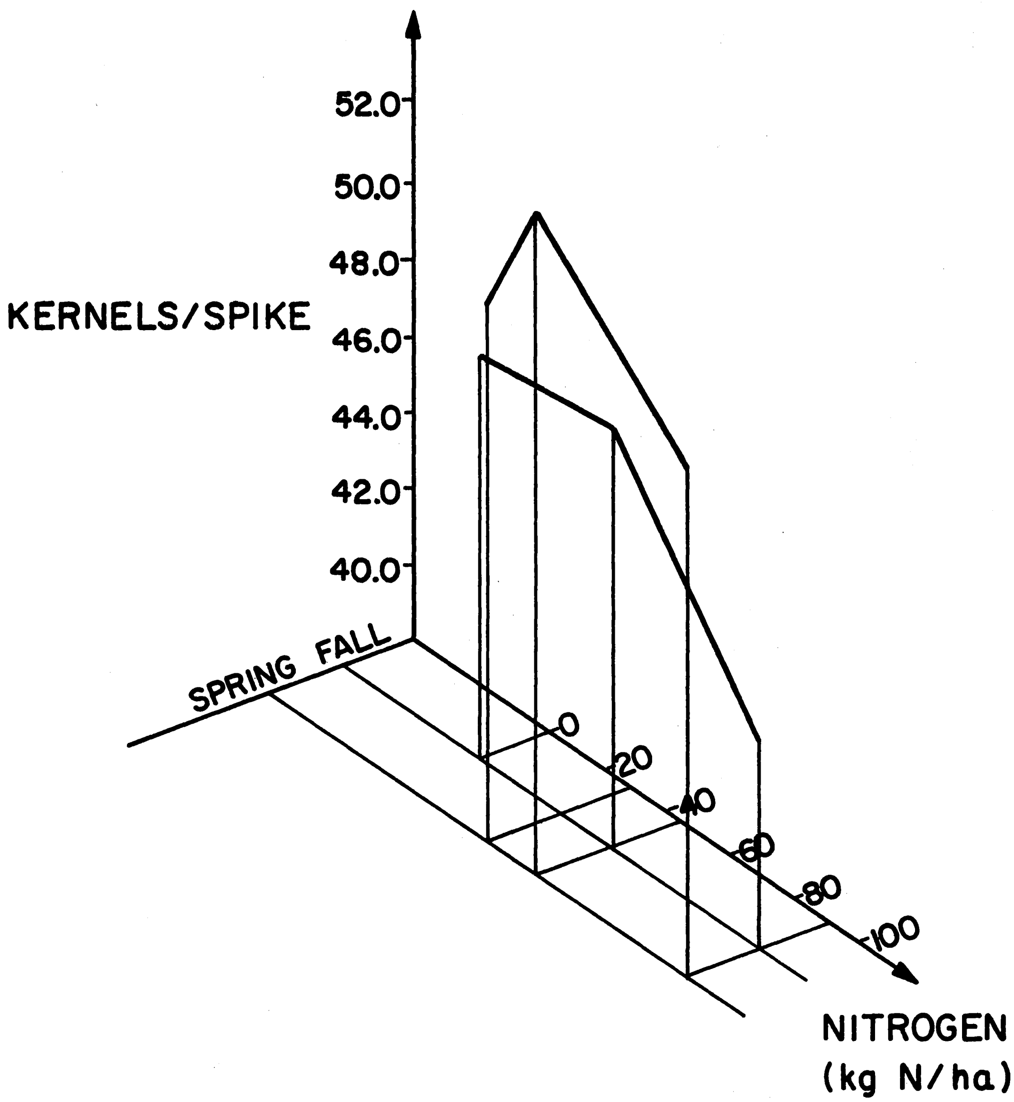

Figure 3. Kernels per Spike in Response to Nitrogen Fertilization

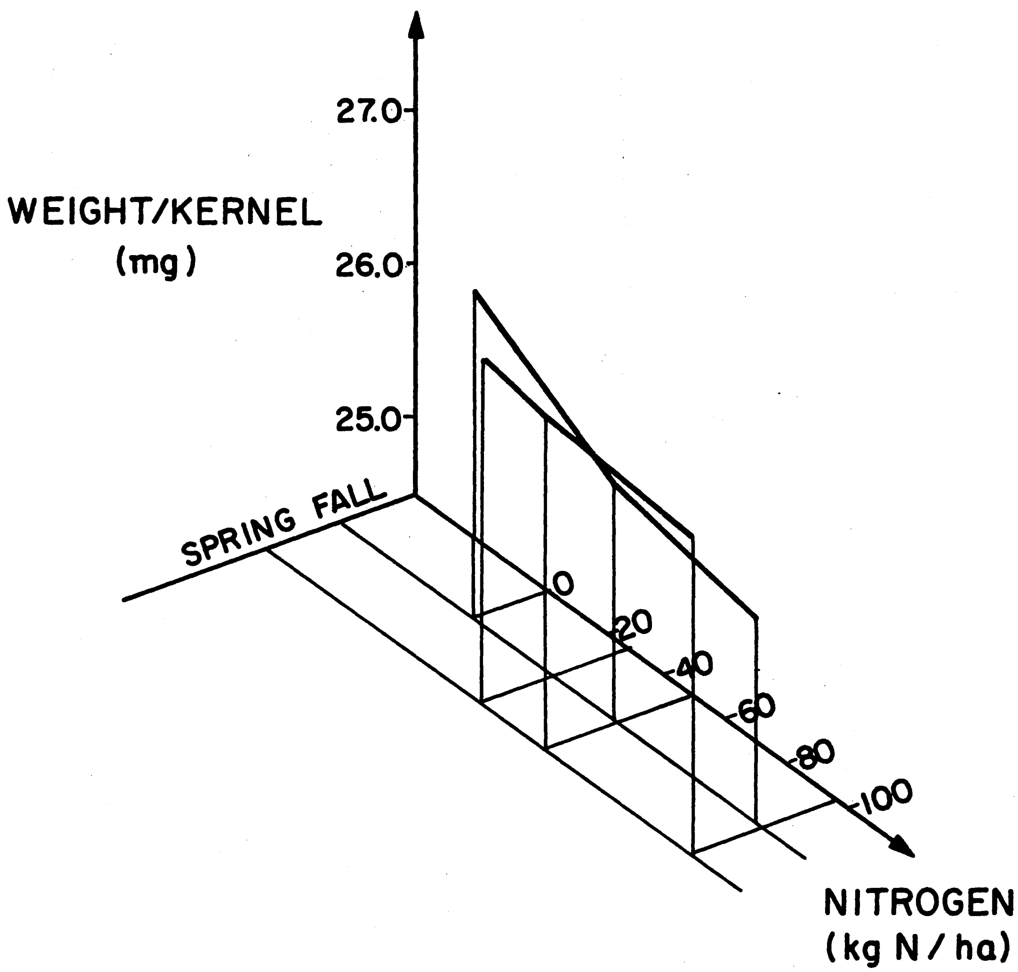

Figure 4. Weight per Kernel in Response to Nitrogen Fertilization

TABLE III

MEAN SQUARES FROM AN ANALYSIS OF VARIANCE OF SIX NITROGEN TREATMENTS ON NY6005-18 MALTING BARLEY FOR PROTEIN PERCENTAGE

Source of Variation	df	Protein Percentage
Total	23	1.359
Replications	3	1.600
Treatments	5	3.538
Seasons	1	5.704*
Nitrogen Linear	1	9.495**
Nitrogen Linear x Seasons	1	1.652
Nitrogen Quadratic	1	0.619
Nitrogen Quadratic x Seasons	1	0.223
Replications x Treatments	15	0.584

*,**Significant at the 0.05 and 0.01 levels of probability, respectively.

of 10.85 occurred in the plots that received no nitrogen (Table IV). A linear effect of nitrogen application on protein percentage existed (Table III, Figure 5). As nitrogen application increased protein percentage increased in both seasons.

Nitrogen applied in the spring probably was not used as much for growth as that applied in the fall. Spring nitrogen may have been incorporated into increased protein in the grain. Kirby (19) and Hunter (16) reported that nitrogen in excess of that required for optimum yield increased protein content and decreased malting quality.

Anheuser-Busch, Inc. has specified that in order to be of an acceptable quality for malting the protein content of the grain must be between 9.0 and 12.5 per cent (8). Only the plots receiving the highest application of nitrogen exceeded the limits of this range (Table IV). The plots which received a spring topdressing of 44.8 kg/ha approached the upper limit of acceptability. The percentage of protein obtained from the zero nitrogen treatment was within the acceptable range for malting barley, and would be most economical under the existing test conditions. This data suggested the possibility of varying the amount of applied nitrogen to alter protein percentage.

Test Weight

No significant difference was determined between seasons for test weight. Increased nitrogen application indicated no linear or quadratic effects (Table V, Figure 6). Grade No. 1 malting barley must have a test weight greater than 60.5 kg/hl. The lowest acceptable value to meet requirements as malting barley is 55.3 kg/hl as specified in the Official Grain Standards of the United States (28). All treatments resulted in

TABLE IV

TREATMENT MEANS FOR PROTEIN OF SIX NITROGEN TREATMENTS ON NY6005-18 MALTING BARLEY

Treatment	Fall (kg N/ha)	Spring (kg N/ha)		Protein Percentage
1	89.7	89.7		13.72
2	89.7	44.8		12.34
3	89.7	22.4		11.73
4	89.7	00.0		12.03
5	44.8	00.0		12.00
6	00.0	00.0		10.85
			Overall Mean	12.11

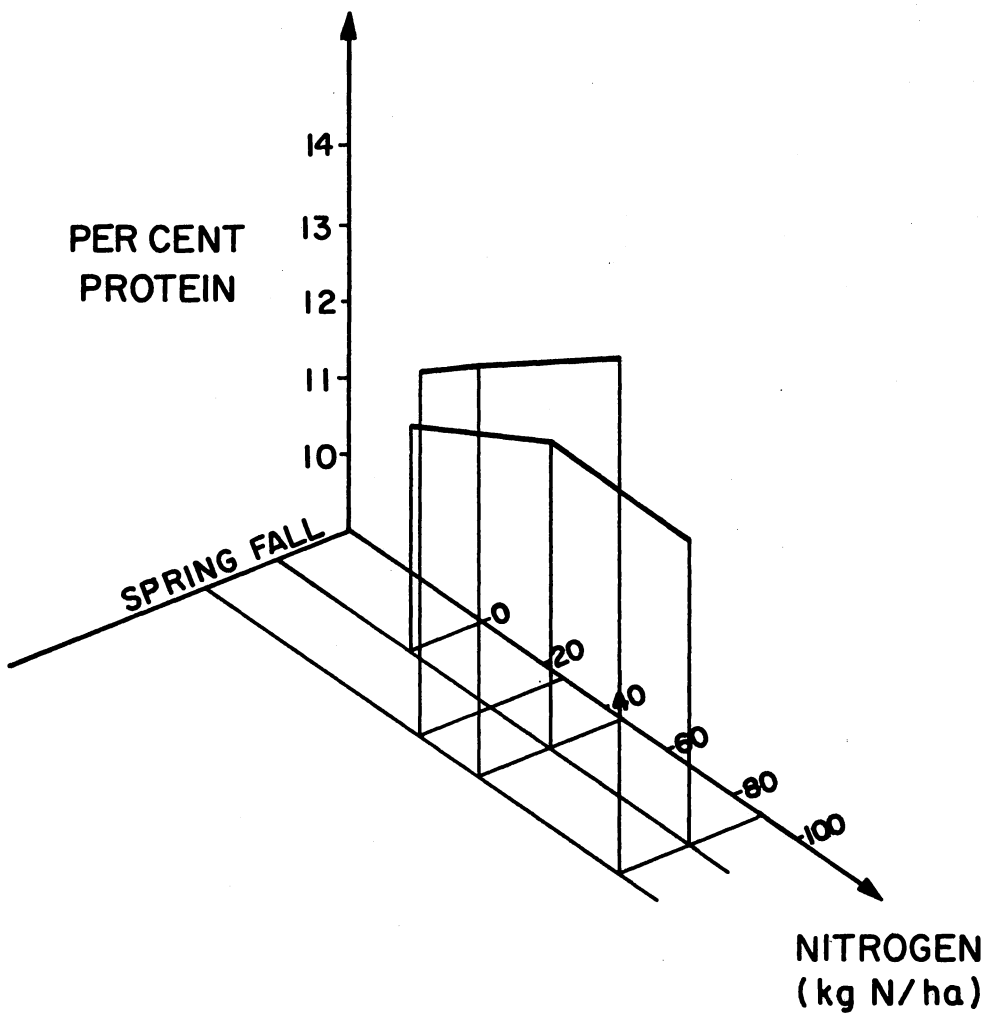

Figure 5. Protein Percentage in Response to Nitrogen Fertilization

TABLE V

MEAN SQUARES FROM AN ANALYSIS OF VARIANCE OF SIX NITROGEN TREATMENTS ON NY6005-18 MALTING BARLEY FOR TEST WEIGHT

Source of Variation	df	Test Weight
Total	23	1.360
Replications	3	5.002
Treatments	5	1.179
Seasons	1	1.654
Nitrogen Linear	1	3.051
Nitrogen Linear x Seasons	1	0.550
Nitrogen Quadratic	1	0.616
Nitrogen Quadratic x Seasons	1	0.026
Replications x Treatments	15	0.691

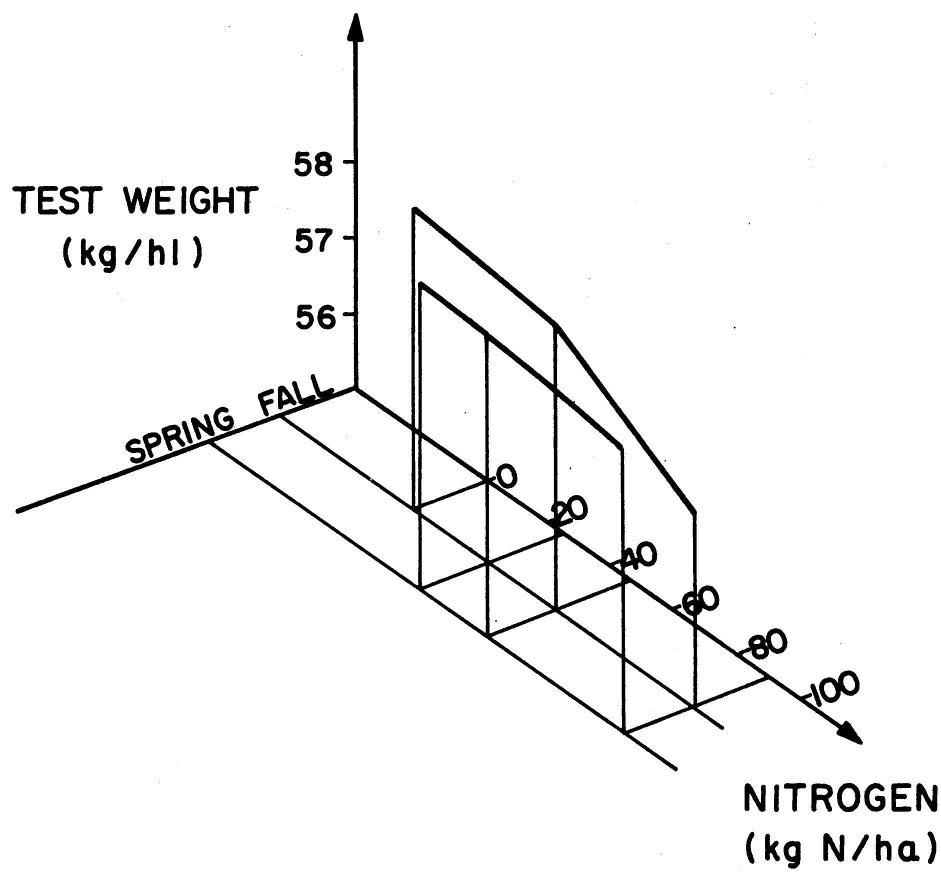

Figure 6. Test Weight in Response to Nitrogen Fertilization

test weights above 55.3 kg/hl, but none equaled 60.5 kg/hl (Table VI).

Malt Extract Percentage

The percentage of extractable material was influenced to a large degree by the amount of nitrogen fertilization. The difference between seasons was highly significant (Table VII). Treatments involving only fall fertilization resulted in greater extract percentage than those having a spring topdressing. The highest extract percentage occurred when no nitrogen was applied (Table VIII). A high percentage of extractable material was desired for malting. Both seasons indicated highly significant linear effects of decreased malt extract percentage with increased nitrogen application (Table VII, Figure 7).

In both seasons with increased nitrogen application, protein percentage increased and malt extract percentage decreased. Other investigators reported similar results of low protein content related to high extract percentage (7,15,25). Rutger, Schaller, and Dickson (25), observed a negative correlation between grain protein content and malt extract. If additional nitrogen was needed for maximum yield, it would be best if added during the fall. Nitrogen taken up by the plant during that time would be used to a greater degree for increased growth and productivity.

Malt Diastatic Power

Application of nitrogen as a spring topdressing resulted in greater diastatic power over the range of treatments studied (Table VII). Evidence was highly significant that a linear effect occurred with diastatic power as nitrogen application increased (Table VII). As nitrogen

TABLE VI

TREATMENT MEANS FOR TEST WEIGHT OF SIX NITROGEN TREATMENTS ON NY6005-18 MALTING BARLEY

Treatment	Fall (kg N/ha)	Spring (kg N/ha)	Test Weight kg/hl
1	89.7	89.7	56.6
2	89.7	44.8	57.0
3	89.7	22.4	56.9
4	89.7	00.0	56.5
5	44.8	00.0	57.7
6	00.0	00.0	58.8
		Overall Mean	57.0

TABLE VII

MEAN SQUARES FROM AN ANALYSIS OF VARIANCE OF SIX NITROGEN TREATMENTS ON NY6005-18 MALTING BARLEY FOR MALT EXTRACT AND DIASTATIC POWER

Source of Variation	df	Malt Extract Percentage	Malt Diastatic Power
Total	23	1.171	145.52
Replications	3	1.440	126.15
Treatments	5	2.925	497.74
Seasons	1	6.100**	1027.04**
Nitrogen Linear	1	7.050**	1351.37**
Nitrogen Linear x Seasons	1	0.434	1.90
Nitrogen Quadratic	1	1.035	88.43
Nitrogen Quadratic x Seasons	1	0.006	19.96
Replications x Treatments	15	0.532	31.99

**Significant at the 0.01 level of probability.

TABLE VIII

TREATMENT MEANS FOR MALT EXTRACT AND DIASTATIC POWER OF SIX NITROGEN TREATMENTS ON NY6005-18 MALTING BARLEY

Treatment	Fall	Spring	Malt Extract Percentage	Diastatic Power
	kg N/ha			
1	89.7	89.7	71.78	159.0
2	89.7	44.8	72.00	149.2
3	89.7	22.4	72.60	144.2
4	89.7	00.0	72.42	146.2
5	44.8	00.0	72.78	142.0
6	00.0	00.0	74.20	125.0
		Overall Mean	72.63	144.3

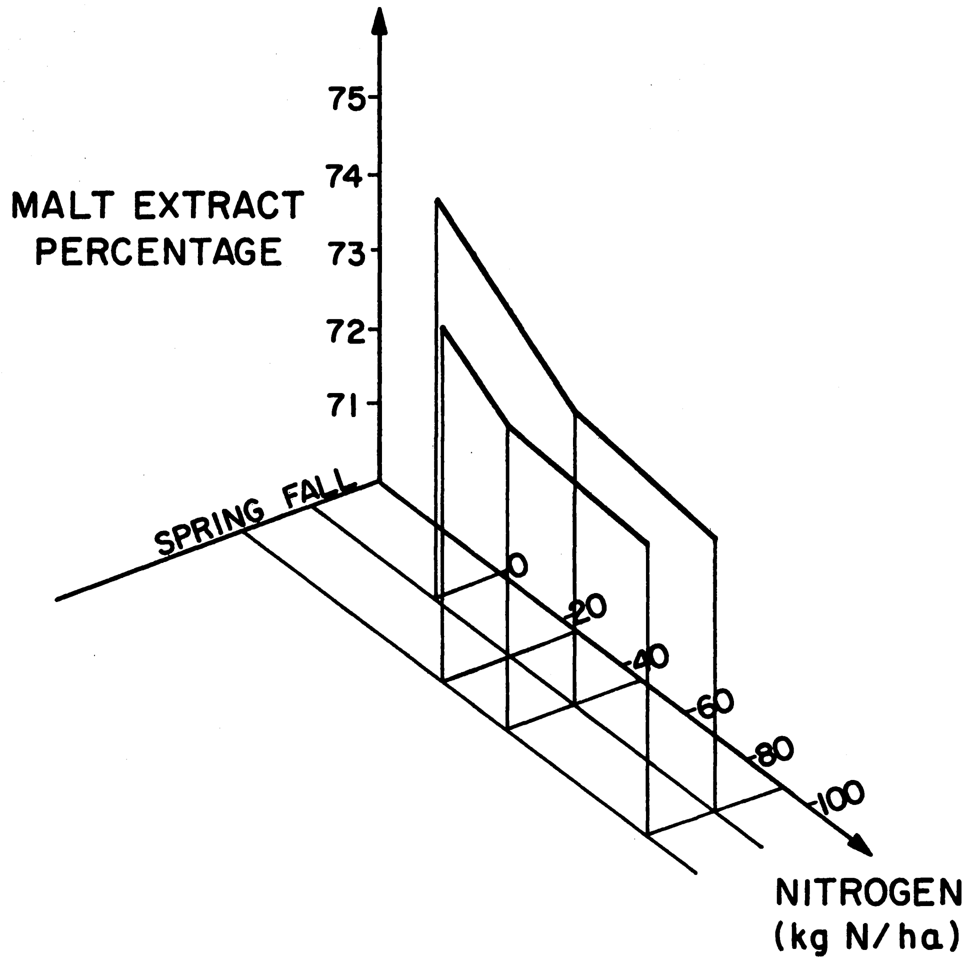

Figure 7. Malt Extract Percentage in Response to Nitrogen Fertilization

fertilization increased the malt diastatic power increased similarly in both seasons (Figure 8). The highest diastatic power occurred with the highest total nitrogen application and the lowest diastatic power occurred when no nitrogen was applied (Table VIII). A high diastatic power is desired for malting quality. Diastatic power appeared to be unfavorably related with protein percentage. High protein content has been found to be related with high diastatic power and low extract percentage (16,28).

For diastatic power, increased nitrogen application improved the quality factor. Increased nitrogen fertilization had the effect of decreasing quality of some of the factors discussed previously. The problem linking desirable diastatic power with undesirable high protein was apparently part of the inherent constitution of the plant. Manipulation of nitrogen fertilizer alone to cause high levels of diastatic activity appears unlikely at this time due to the unfavorable relationship of the character to protein content and extract percentage.

Kernel Size

Plump kernel percentage indicated a strong positive response to increasing nitrogen fertilization. The observed difference for treatment effects between seasons on percentage plump kernels was highly significant (Table IX). Plots which received no nitrogen had the greatest average percentage of plump kernels with 33.5 per cent (Table X). Plots receiving the highest topdressing had the lowest percentage of plump kernels.

Plump kernel percentage in both seasons decreased as applied nitrogen increased (Figure 9). The evidence for such a linear effect was

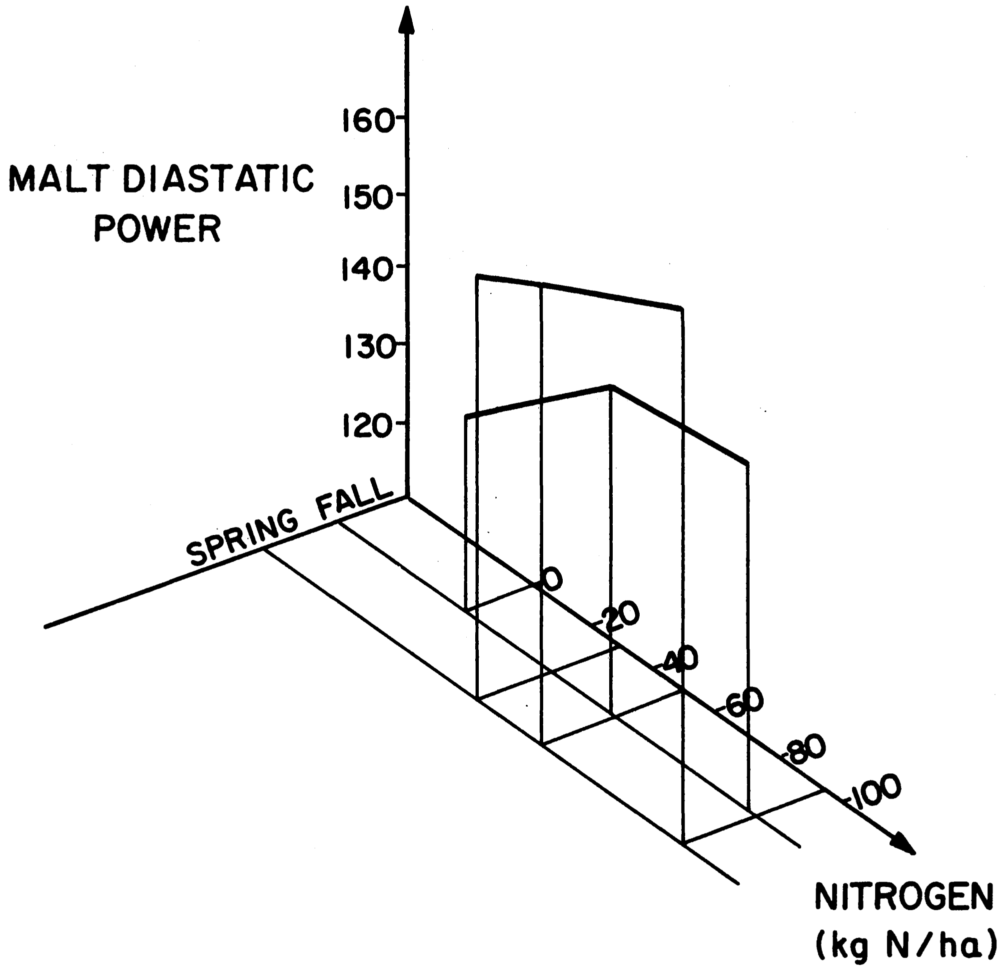

Figure 8. Malt Diastatic Power in Response to Nitrogen Fertilization

TABLE IX

MEAN SQUARES FROM AN ANALYSIS OF VARIANCE OF SIX NITROGEN TREATMENTS ON NY6005-18 MALTING BARLEY FOR KERNEL SIZE

Source of Variation	df	Plump Kernel Percentage	Thin Kernel Percentage
Total	23	21.88	2.35
Replications	3	39.88	2.92
Treatments	5	52.88	4.60
Seasons	1	73.15**	2.04
Nitrogen Linear	1	149.27**	17.10**
Nitrogen Linear x Seasons	1	22.46	3.71
Nitrogen Quadratic	1	0.46	0.05
Nitrogen Quadratic x Seasons	1	19.06	0.07
Replications x Treatments	15	7.94	1.49

**Significant at the 0.01 level of probability.

TABLE X

TREATMENT MEANS FOR KERNEL SIZE OF SIX NITROGEN TREATMENTS ON NY6005-18 MALTING BARLEY

Treatment	Fall (kg N/ha)	Spring (kg N/ha)	Plump Kernel Percentage	Thin Kernel Percentage
1	89.7	89.7	23.2	4.3
2	89.7	44.8	26.8	3.9
3	89.7	22.4	25.2	3.6
4	89.7	00.0	24.6	5.0
5	44.8	00.0	27.5	3.2
6	00.0	00.0	33.5	1.8
		Overall Mean	26.8	3.6

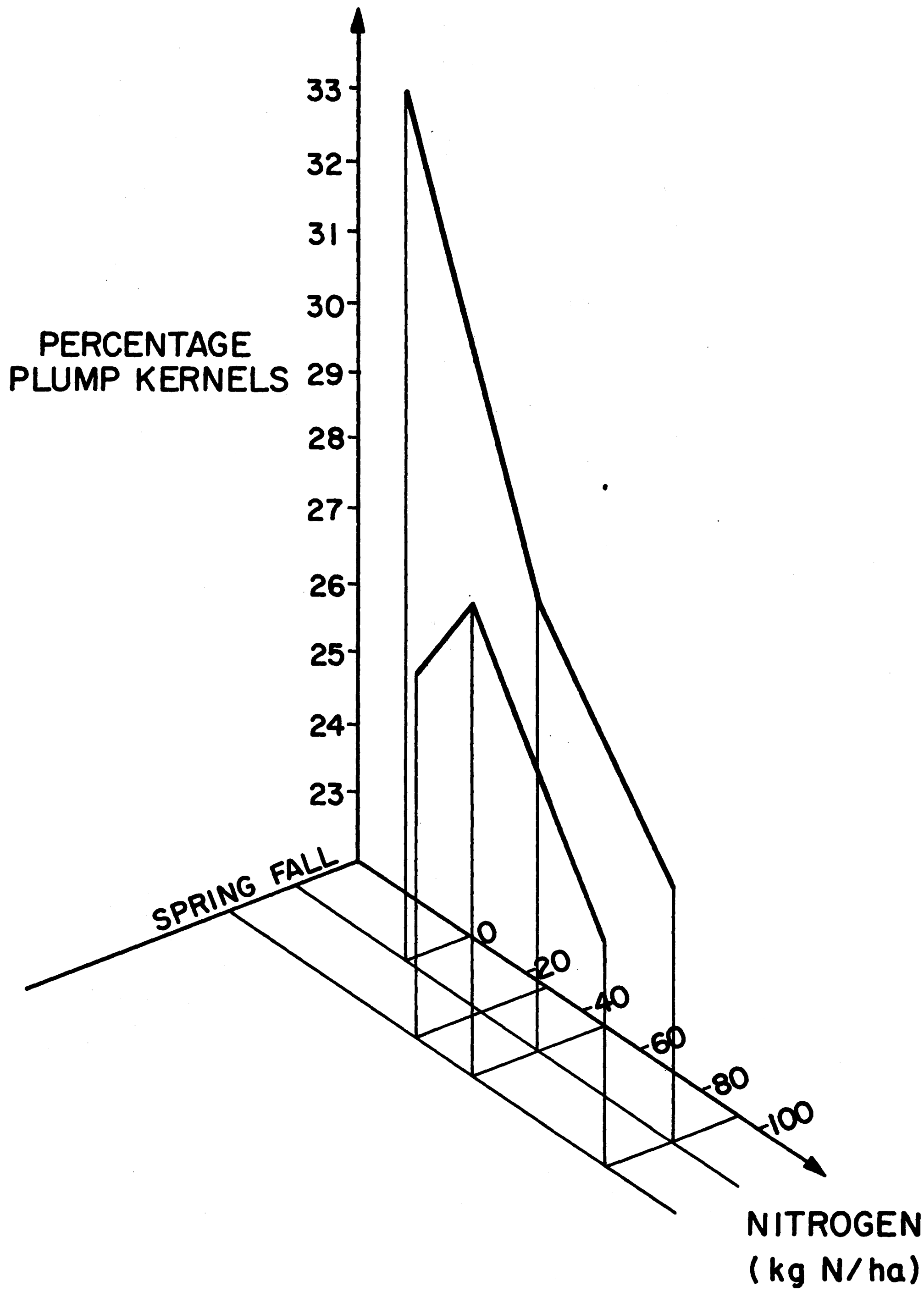

Figure 9. Plump Kernel Percentage in Response to Nitrogen Fertilization

highly significant and similar for both seasons (Table IX).

Evidence of a linear effect between nitrogen application and thin kernel percentage was highly significant (Table IX). Similar decreases in thin kernel percentage occurred with increased nitrogen in both seasons (Figure 10). High nitrogen levels could have caused excessive vegetative growth. Such growth would lead to an over production of potential kernels. With increased sink size, available photosynthate would be distributed among more kernels, leading to a higher percentage of thin kernels.

Generally, with increased nitrogen fertilization the percentages of plump and thin kernels decreased and increased, respectively.

Barley to be used for malting should have a plump kernel percentage greater than 60 per cent. None of the nitrogen treatments resulted in this high of percentage of plump kernels. However, barley having a lower percentage of plump kernels may be accepted if a high degree of uniformity is present. All treatments yielded small percentages of thin kernels and intermediate percentages of plump kernels with a large percentage of medium kernels. Even though the percentage of plump kernels was lower than desired, the very small percentage of thin kernels and uniformity of kernel size allowed all treatments to produce grain which met the requirements for malting barley. Considering kernel size, the zero nitrogen treatment appeared to produce the best quality malting barley.

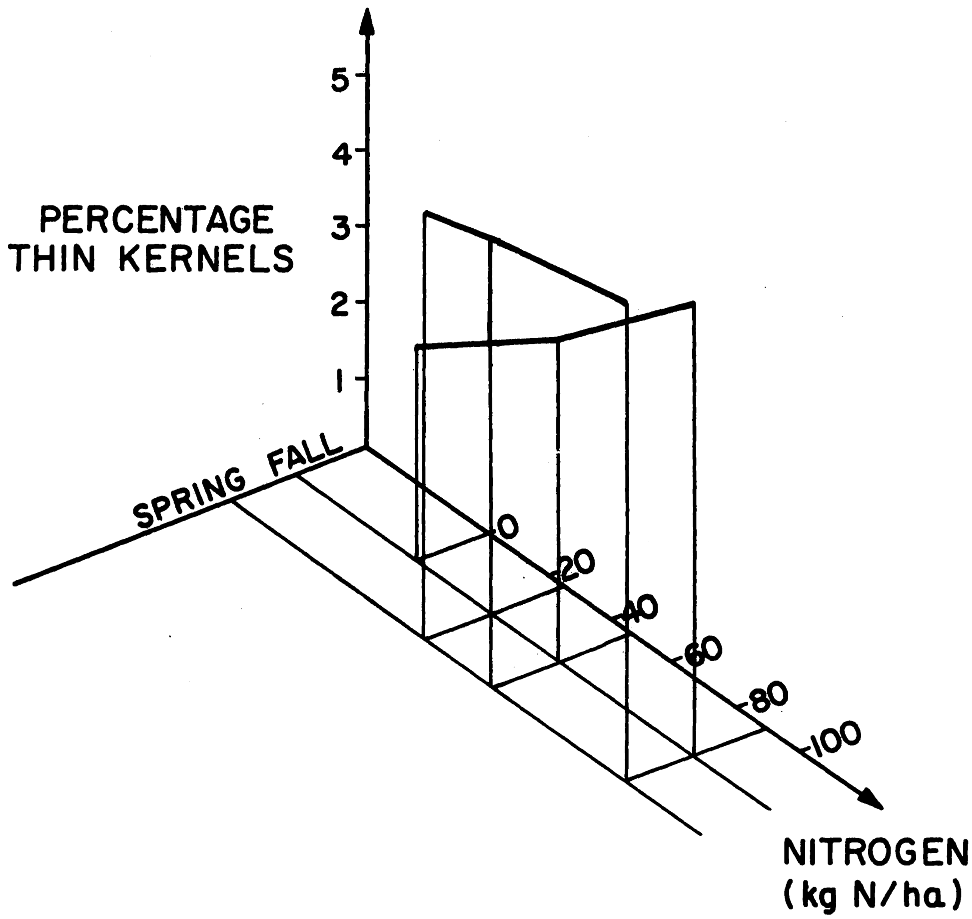

Figure 10. Thin Kernel Percentage in Response to Nitrogen Fertilization

CHAPTER V

SUMMARY AND CONCLUSIONS

Six different levels of nitrogen fertilizer were used to investigate the effects of nitrogen fertilizer upon the protein content, yield and yield components, other factors of malting, and quality of a potential winter malting barley under irrigated conditions.

Agronomic and malting characteristics were evaluated for each of the six nitrogen treatments. Characters analyzed were: yield and yield components; tiller number; kernels per spike, and weight per kernel, and quality factors; test weight; protein percentage; malt extract percentage; malt diastatic power; and percentages of plump and thin kernels. Analyses of variance were conducted for each character. Season effects and comparisons for linear and quadratic nitrogen effects were examined for the characters studied.

Yield indicated a highly significant quadratic effect to nitrogen and the effect was similar in the fall and spring seasons. Fertile tillers per unit area were not different between seasons, but showed an interaction with rate and date of fertilization. Kernels per spike gave no significant difference between seasons and no significant linear or quadratic effect with nitrogen application. Weight per kernel was similar in both seasons and indicated a significant linear decrease with increased nitrogen fertilization.

Protein percentage was different between the two seasons. A linear effect of increased protein content with increased nitrogen application occurred. Test weights obtained indicated no linear or quadratic effects from increased nitrogen application. Fall and spring nitrogen applications gave similar test weights. Malt extract percentage and malt diastatic power were significantly different between seasons. These quality factors indicated highly significant linear effects with increased nitrogen application; malt extract decreased and diastatic power increased. Plump kernel percentages were significantly different at the 0.01 level between seasons, while thin kernel percentage was not. Linear effects were significant and percentages of plump and thin kernels decreased and increased, respectively, with increased nitrogen application.

The most acceptable malting quality for the characteristics malt extract and kernel size occurred when no nitrogen was applied. Protein percentage was also at an acceptable level for this treatment. The lowest and least desirable diastatic power occurred with no nitrogen fertilization. The results indicate that when a sufficient residual nitrogen level exists, maximum yield can be realized without addition of nitrogen fertilizer. Efficiency of use of applied nitrogen was higher for fall than spring fertilization. An example of the efficiency of nitrogen use occurred with treatment five which had the highest grain yield of 4586 kg/ha and received 44.8 kg N/ha. With the 123.3 kg/ha of residual nitrogen, 168.1 kg N/ha was available to the crop. Total nitrogen present in the grain on this treatment was 88.0 kg N/ha for a use efficiency of 52.4 per cent.

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