AN ABSTRACT OF THE THESIS OF

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Title: **Nitrogen and Dry Matter Relationships for Winter Wheats Produced in Western Oregon**

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An understanding of nitrogen concentration patterns in above ground plant tissue of soft white (SWWW) and hard red winter wheat (*Triticum aestivum* L.) (HRWW) at specific growth stages is needed to facilitate current-season nitrogen management. Dry matter accumulation and N distribution patterns for SWWW and HRWW cultivars were compared. Two HRWW (OR 8313, 'Batum') and two SWWW ('Stephens', 'Dusty') were grown with a N fertilizer gradient of 0, 56, 112, and 168 kg/ha in western Oregon during 1987 to 1989. Dry matter accumulation and N uptake increased rapidly from Feekes growth stage (FS) 7 to FS 10.3. During this same period, plant total N concentration decreased rapidly with a gradual decrease to FS 11.4. Plant total N concentrations for Stephens and OR 8313 were relatively stable at specific growth stages across two dissimilar grain yield years. Clear market class separation for cultivar parameters did not occur until FS 11.4. Nitrogen fertilizer treatments produced wheat tissue N gradients measured by N uptake, plant total N, stem N and stem NO_3. At growth stages FS 4 to 7 plant total N and N uptake parameters were able to detect fertilizer treatment differences. Stem N and stem NO_3-N concentrations were only able to distinguish N sufficiency. Among parameters tested, plant total N concentration at FS 7 gave the highest correlations with grain yield, protein yield and grain protein. Plant total N at FS 4 and 7 produced predictive models most strongly correlated with yield parameters. Plant total N at FS 7 explained 62 and 72% of grain yield, and 67 and 75% of protein yield variability for HRWW and SWWW, respectively. The critical N range for both SWWW and HRWW cultivars compared in this study was determined by the Cate-Nelson method to be 27-37 g N/kg at FS 7. SWWW were more efficient at partitioning dry matter to grain than HRWW. Higher grain protein for HRWW occurred as a result of less grain protein dilution by reduced grain yield production, rather than more efficient partitioning of N to the grain.

Nitrogen and Dry Matter Relationships for Winter Wheats Produced in Western Oregon

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DEDICATED TO:

My wife Sally and sons,

Aaron and Justin

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INTRODUCTION

A requirement for N exists throughout plant development to maintain growth. In nonleguminous crops most N for vegetative growth is supplied by assimilation of N from the soil. Some N may be reassimilated several times during the growth cycle. During reproductive growth, much N is remobilized from vegetative tissues by hydrolysis of proteins to amino acids. Nitrogenous compounds are then transported to the developing seeds (Schrader, 1984).

Specific wheat (*Triticum aestivum* L.) grain protein concentrations are desired by the baking industry (Jackel, 1979). Premiums or dockage, based on grain protein concentrations, affect grower receipts. The acceptable protein concentration for hard red (HRWW) and soft white winter wheats (SWWW) is $>12\%$ and $<10\%$, respectively (Schlehuber and Tucker, 1967; PNW Crop Improvement Association, 1959). The emphasis in production of soft white wheats traditionally has focused only on yield with little or no attention to grain protein. Excessive use of N fertilizers can cause increased grain protein in SWWW and an increased risk of environmental pollution. A change in price structure to account for grain protein concentrations creates problems for growers, as specific protein concentrations can not always be achieved, due to environmental and genetic interactions.

The increasing sophistication of Asian markets has caused a demand for high protein grain. As a result, Pacific Northwest (PNW) grower interest in the production of hard red wheats has increased. Hard red winter wheat's desirability comes from the value of increased gluten protein for bread making (Finney, 1979). Protein derived from wheat contributes much of the dietary protein requirements for a large portion of the world's population, particularly in developing countries (Johnson and Mattern, 1976).

Nitrogen management for winter wheat production is becoming economically and environmentally crucial for PNW wheat growers who are working to produce high protein HRWW and low protein SWWW. Optimum N is necessary for maximum high quality yields. Excessive N results in an increased risk of high SWWW grain protein, increased plant disease and lodging, and increased environmental pollution.

The purchase of N fertilizer represents 20% of the total variable costs of production for western Oregon wheat producers (Taylor, 1990). A large amount of N applied in humid regions is lost through leaching (Huber, et al., 1977). Matching optimum N rates and timing for humid winter wheat production continues to be a major unresolved issue (Stanford, 1982).

Improving the efficiency of N utilization may increase storage proteins in the seed. Bhatia (1975) suggests greater N uptake of the root system and increased remobilization of nitrogenous compounds from the vegetative organs to the grain could influence storage proteins. Modification of growth and plant N metabolism to enhance grain productivity can be accomplished by altering the growth environment or genotype.

Plant tissue analysis is widely used in many PNW crops to determine plant N status. Roth (1989), and Fox and Piekielek (1984) suggest the use of plant tissue analysis as an alternative where soil testing for N has been ineffective. This method has the potential to be used in cereal crops to monitor plant N status during the season, which would allow growers greater flexibility in adjusting potential grain yield and grain protein concentrations, mid-season. The success of using tissue testing in wheat to predict fertilizer N necessary for maximum yields has been variable. Several techniques of analysis are available which give differing results. These methods need to be critically evaluated and compared under PNW field conditions. A strategy for N sufficiency testing and for prediction of grain yield and protein needs to be developed.

This study is concerned with manipulation of the N nutrient environment to aid in the understanding of mechanisms that affect wheat grain yield and protein concentrations. The objectives were:

1) to determine the distribution of N and dry matter in above ground plant tissues at specific growth stages of SWWW and HRWW cultivars for use in efficient N management;
2) to evaluate plant tissue testing procedures for their ability to predict current season grain yield and protein levels; and
3) to determine the critical N range and optimum N rate for humid winter wheat production during this study.

LITERATURE REVIEW

Nitrogen Relationships in the Wheat Plant

The major nutrient influencing wheat grain yield and grain protein concentration is nitrogen. Once the crop is planted, N fertilizer rate and timing are the main tools available for manipulation of protein yields. Plant response to N fertilizer applied to N-deficient soils initially increases plant dry matter resulting in increased grain yields. After grain yield is maximized increased grain N concentration results in increased grain protein. The kernel protein percentage increases most rapidly in response to N after crop yield potential has been reached (Deckard et al., 1984).

Knowles and Watkins (1931) monitored wheat nutrients from seven weeks before ear emergence until harvest. They found most of the N taken up was translocated to grain directly or remobilized from other plant parts. McNeal et al. (1968) showed a similar pattern of N remobilization with a close relationship between grain N content and amount of top growth. More than two-thirds of grain protein N is in the plant at anthesis (Deckard et al., 1984). Walters et al. (1980) found that soluble protein in the flag leaf declined rapidly with the onset of grain growth. They concluded that nearly all the soluble protein in the flag leaf and glumes was mobilized and that the flag leaf appeared to be a major contributor of grain N. Blacklow (1982) concluded that nitrate applied foliarly late in the season moved through the flag leaves, making a significant contribution to grain N; however, uptake by the flag leaves and plant metabolism of the nitrate-N exceeded the amount accumulated in the grain. This suggests that the rate of translocation, and the incorporation of assimilates, limited the utilization of the applied nitrate, or that the peduncle was an alternative sink to the grain.

Waldren and Flowerday (1979) determined the distribution of dry matter, N, P, and K for field grown wheat plants. They found that about 80% of the total plant N at maturity had been taken up by anthesis. About two-thirds of the N in the leaves, and less in the culms and heads, was translocated into the grain. At maturity, the grain contained 71% of the total plant N. The leaves and culms began remobilizing N at heading and continued through grain ripening.

Bauer et al. (1987a,b,c) measured N and P concentration and content in hard red spring wheat aerial components weekly from about the three-leaf to the kernel-hard stage, and determined their relationship to the Haun growth stage scale (Haun, 1973). They reported that leaf N decreased linearly by about 2.93 g/kg DM with each development stage from a maximum of 70.0 g/kg DM at tillering to a minimum of 28.0 g/kg DM at kernel-hard stage. Stem N decreased curvilinearly, most rapidly between the three-leaf and flag leaf extension stage, from a maximum of 72.0 g/kg DM to a minimum of 5.0 g/kg DM at kernel-hard stage. Spike N concentration increased linearly about 3.0 g/kg DM from anthesis to kernel-hard stage. Maximum leaf N content occurred at flag-leaf-extension through boot stage and in stems at anthesis. They calculated about 71% of the N and 57% of the P in spikes at kernel-hard stage was translocated from the leaves and stems.

Plant Tissue Analysis

A major role for plant analysis is to diagnose or monitor plant nutrient status during the growing season. If diagnosis is made early enough, deficiencies or declining levels can be corrected during the season. The monitoring of nitrate in potato petioles and the application of required N through sprinkler systems is an example (Gardner and Jones, 1975). This approach could be used in wheat to maintain grain yield and grain protein potentials during the growing season.

Macy (1936) defined the concept of critical concentration for plant nutrients as the concentration at the point that separates the zone of deficiency from the zone of adequacy. Munson and Nelson (1973) further defined the critical concentration for a nutrient as that point where crop yields equalled 95% of the maximum attainable for a particular environment. The sufficiency range for a nutrient begins at the point where maximum yield first occurs until yield starts to decline with further increases in concentration (Chapman, 1967).

Dow and Roberts (1982) recommend the use of a critical nutrient range (CNR) rather than critical nutrient concentration (CNC). CNR is defined as: that range of nutrient concentration above which we are reasonably confident the crop is amply supplied and below which we are reasonably confident the crop is deficient. They emphasize the need for an establishment of a range rather than a single point and the need to relate the CNR with a specific growth stage.

This approach assumes all other variables except one nutrient are nonlimiting. Higher N concentrations are known to be associated with deficiencies of other nutrients like P and S. Deficiencies of several nutrients are known to interfere with N metabolism in the plant (Tucker, 1984). Soil moisture stress can cause lower N concentrations in the plant by reducing uptake or it can result in higher N concentrations by reducing plant growth (Munson and Nelson, 1973).

Nitrogen occurs in plants in both inorganic and organic compounds. Nitrogen contained in the inorganic form (nitrate), and in reserve proteins and chlorophyll serves as the best indicator of the N status of the plant (Tucker, 1984). Inorganic N in the plant indicates the active supply available for metabolism at a given time. Organic reserves reflect N supply status to the plant prior to the time of fertilization. Nitrogen used in chlorophyll synthesis influences the plant color. These facts provide the rational basis for diagnosis of N deficiency in plants (Tucker, 1984).

Plant Total N Concentration

To determine total N in the aerial portion of the plant, the entire above-ground portion of the plant is excised at the soil surface, dried, ground and analyzed for N. Since all of the aerial portion of the plant is measured, it is an assay of the N supply to the plant over a long period of time (Tucker, 1984). Arkansas has implemented a statewide tissue monitoring program using this method for wheat that successfully predicts the N fertilization needs on more than 800 fields (Adams and Chapman, 1984). Donahue and Brann (1984) determined the critical N levels for three soft red winter wheat varieties in Virginia. The N concentrations at FS 4 are associated with a relative yield of 0.95 ranged from 37.8 to 40.7 g/kg in three varieties. The authors established a general sufficiency level for all varieties at 40.0 g/kg, due to sufficiency level similarity among cultivars, and because growers are often unable to sample at a precise growth stage.

Several scientists have rejected the total N approach because of inconsistent critical levels (Beringer and Hess, 1979; Touchton and Hargrove, 1983). Needham (1982) summarized the British experiences with total N and other tissue testing methods. He concluded measurements of plant N are not effective and that computer modeling holds the most promise for predicting N requirements of wheat. The plant N approach has not been consistently effective.

Flag Leaf Tissue Test

Flag leaf samples are most commonly analyzed using the Kjeldahl method. These values best indicate the cumulative N status to the time of sampling and do not necessarily reflect current status (Tucker, 1984). Petrie (1984a,b) has shown flag leaf N to be closely related to grain protein concentration in irrigated hard red spring wheat in southern Idaho. Brown (1986) reported that flag leaf N was closely related to N applied, grain protein and grain yield; however, he also found significant variety and location effects, which may hinder wide use of flag leaf N as an indicator of wheat N status at flowering. Pumphrey et al. (1986) found flag leaf nitrate concentration remained reasonably constant for irrigated hard red winter wheat at late jointing, heading and flowering. They concluded that a nitrate concentration of 60 mg/kg during these growth stages indicated a N deficiency. Nitrate levels of 100 to 150 mg/kg N were adequate for producing optimum yields. Since nitrate concentrations change rapidly over a short period of time and these concentrations are generally measured in g/kg, these small nitrate differences may be difficult to differentiate from an analytical sense for practical use as an indicator of N deficiency.

Stem Nitrate Tissue Test

Stem tissues contain higher concentrations of nitrate than leaf tissues. The nitrate ion is used as an indicator of N sufficiency because it is the predominant form of N in most well drained agricultural soils, and is readily taken up by the plant (Arbol et al., 1984). Pseudostems, consisting of basal tiller portions excluding leaf blades, and true stems after jointing are sampled for this test. The pseudostem and stems functions as a pipeline, translocating the majority of the nitrate absorbed by the roots to the leaves, where the nitrate is reduced and converted into amino-N for protein synthesis. The pseudostem and stem nitrate concentration is a relatively sensitive indicator of the amount of nitrate being absorbed by the root. Stem tissue thus appears the most suitable plant part to sample and analyze for evaluation of current N status of actively growing annual crops (Tucker, 1984). Papastylianou and Puckeridge (1984) found a correlation between stem nitrate and grain yield. At early tillering, a stem nitrate concentration of 8.0 g/kg indicated sufficient N for maximum grain yield.

Critical levels reported by various workers are quite variable among locations and change rapidly during the growing season. Pettygrove et al. (1981) found critical levels from 2.5 g/kg through the range of 5.0 to 10.0 g/kg of nitrate-N found by Gardner and Jackson (1976). Pettygrove et al. (1981) also observed critical level changes from 2.5 to 8.0 g/kg of nitrate-N within 10 days. They concluded that the major limitations to the stem nitrate test were "(1) rapid change over time and (2) large site to site variation."

Stem nitrate levels alone may not provide enough information to assess the N status of the plant. Identification of the most important factors influencing the critical levels will be necessary before this test can be useful in diagnosing N deficiency in PNW wheat.

Crop N Uptake

Total N uptake prior to sampling has been proposed to reflect accumulative plant nutrition. Crop N uptake is the product of [N concentration] X [dry weight of the crop]. Baethgen et al. (1985) were able to explain 80% of the variation in yield using N uptake. Sufficiency levels ranged from 80 to 100 kg/ha at Zadoks scale 5 (Zadoks et al., 1974) in their experiments. Batey (1984) showed a correlation ($r=0.67$) between the optimum N requirement and the rate of increase in uptake.

Other researchers have been less successful with the total N uptake method. The major disadvantage of this approach is that both dry matter yield and N concentration must be estimated instead of just one parameter. Researchers in Virginia are continuing to evaluate the crop N uptake approach. This test may have potential under PNW conditions to produce accurate N recommendations.

CHAPTER I

NITROGEN AND DRY MATTER ACCUMULATION IN SOFT WHITE AND HARD RED WINTER WHEAT CULTIVARS

ABSTRACT

An understanding of nitrogen concentration patterns in above ground plant tissue at specific growth stages for soft white (SWWW) and hard red winter wheat (*Triticum aestivum* L.) (HRWW) is needed to facilitate efficient nitrogen management. Limited work on N concentration patterns has been reported in the Pacific Northwest and none comparing SWWW and HRWW at different growth stages to investigate market class differences in grain and protein yield. Dry matter (DM) accumulation and N distribution patterns were compared during 1987-89 for two HRWW (OR 8313, 'Batum') and two SWWW ('Stephens', 'Dusty') grown in western Oregon with a N fertilizer gradient of 0, 56, 112, and 168 kg N/ha. Dry matter accumulation and N uptake increased rapidly from Feekes (Large, 1954) growth stage (FS) 7 to FS 10.3 during the vegetative phase. During this same period, plant total N concentration decreased rapidly. This demonstrated the dilution effect increased DM production had on plant total N concentration, and the importance of determining plant tissue parameters at specific growth stages. Plant total N concentration decreased gradually during the reproductive phase from FS 10.3 to FS 11.4 while DM accumulation gradually increased. Plant total N concentrations for 'Stephens' and OR 8313 were relatively stable at specific growth stages across two dissimilar grain yield years. Clear market class separation of cultivars for N uptake, dry matter, and plant total N concentration, at early growth stages was not detected until grain and protein

yield parameters were determined at FS 11.4. SWWW cultivars were more efficient at partitioning DM to grain than were HRWW cultivars. Higher grain protein concentration for HRWW cultivars occurred as a result of less grain protein dilution by reduced grain yield production, rather than more efficient partitioning of N to HRWW grain.

INTRODUCTION

Information concerning N concentration in above ground plant tissue at specific growth stages for SWWW and HRWW is needed to facilitate efficient nitrogen management in the Pacific Northwest (PNW). Dry matter accumulation and N distribution in winter wheat at specific growth stages have been studied in various parts of the U.S. (McNeal et al., 1968; Bauer et al., 1987a,b,c; McMullan et al., 1988). Limited work has been reported on this topic in the PNW (Brown and Stark, 1986), and none that compared SWWW and HRWW cultivars early in the growing season to explain differences in grain and protein yield production.

Nitrogen uptake (the product of plant N concentration and DM yield) reflects plan N status up to the time of sampling. Waldren and Flowerday (1979) measured distribution of DM, N and P over growth stages in HRWW. Nitrogen uptake was rapid during stem extension. Eighty percent of the N present in the plant at maturity was taken up prior to anthesis. Remobilization of vegetative N represented two-thirds of the grain N with the rest of the grain N coming directly from N uptake. At maturity, grain contained 71% of the total plant N. Leaves and culms began translocating N at heading and continued to remobilize N through ripening.

Harper et al. (1987) examined N cycling in HRWW. Plant total N concentration reached a maximum early in the vegetative stage; total N decreased during the remaining growth stages even though soil N uptake continued until plant maturity. Leaves translocated more total N to the grain than did stems.

After anthesis, 50% of the grain N came from redistribution, with the balance coming directly from the soil.

The emphasis in production of soft white wheats traditionally has focused only on yield with little or no attention to grain protein. Excessive use of N fertilizers can cause increased grain protein in SWWW and an increased risk of environmental pollution. A change in price structure to account for grain protein concentrations creates problems for growers, as specific protein concentrations can not always be achieved, due to environmental and genetic interactions.

Bauer et al. (1987a) reported that water and N changed plant mass, but did not shift development stages. Nutrient concentration data at specific growth stages is needed for improving N fertilizer management. This information can provide producers the capability to match crop N use to fertilizer rate and timing. Since nutrient concentrations change as the plant matures (Karlen and Whitney, 1980; Harper et al., 1987), relating growth stage with tissue nutrient concentration when analyzing research data is critical. Specific knowledge of different N parameters could also improve the precision of various wheat models.

This study was undertaken to determine N and DM distribution for SWWW and HRWW cultivars fertilized at different N rates in a humid PNW climate to explain market class differences for grain and protein yield production.

MATERIALS AND METHODS

Field experiments were conducted in 1987-88 and 1988-89 on a Woodburn silt loam soil (fine silty, mixed mesic Aquultic Argixerolls) at the Oregon State University Crop and Soil Science Hyslop Field Laboratory. The 1987-88 site had been cropped to winter wheat in 1986, and winter rapeseed in 1987. The 1988-89 site had been cropped to winter barley and oats in 1986, and was fallowed for two years. Crop residues (1987) were flail-chopped and spread before the soil was plowed, cultivated, and harrowed. Preplant fertilizer [$(NH_4)_2SO_4$] (30-0-0-6) was drilled in at a 4 cm depth at planting at a rate of 34 kg N/ha. Weed control consisted of postemergent applications of diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea + N'-(3,4-dichlorophenyl)-N,N-dimethylurea, 1.43 kg a.i./ha], chlorosulfuron {2-chloro-N[(4-methoxy-6-methyl-1,3,5 triazin-2-yl)aminocarbonyl]-benzenesulfonamide, 0.03 kg a.i./ha}, and bromoxynil (3,5-diromo-4-hydroxybenzonitrile, 0.21 kg a.i./ha). Fungicide applications consisted of benomyl [methyl 1-(butylcarbamoyl)-2-benzimi-diazolecarbamate, 0.56 kg a.i./ha] at Feekes scale (FS) 4 to 6, maneb (manganese ethylenebisdithiocarbamate) + benomyl (2.95 kg a.i./ha) at FS 6 to 8, and maneb + benomyl (2.95 kg a.i./ha) at FS 9 to 10. Soil testing the top 0.9 m indicated P and K were sufficient for winter wheat production while pH ranged from 5.8 to 6.0 (Hart et al., 1989). Wheat was planted at a depth of 4 cm in 20 cm rows on October 16 and 7 for 1988 and 1989. Seeding rate was adjusted on the basis of germination percentage to a rate of 323 viable seeds/m^2. Plots were harvested with a Hege plot combine on August 2 and July 25 in 1988 and 1989.

The experiments were designed as a randomized complete block factorial with two factors-cultivars, and N fertilizer rates and three blocks. In 1987-88, treatments consisted of two cultivars ('Stephens', a SWWW, and OR 8313, an experimental HRWW line) and four N fertilizer rates. Cultivars were planted in 1.2 x 7.6 m plots. Sulfur was applied as gypsum, ($CaSO_4 \cdot 2H_2O$) (0-0-0-18), at 33.6 kg S/ha in early March. Urea, [$CO(NH_2)_2$] (46-0-0), was used as a single N source applied in early March at rates of (0, 56, 112 and 168 kg N/ha). In 1988-89, two SWWW cultivars (Stephens, 'Dusty') and two HRWW cultivars (OR 8313, 'Batum') were used. These cultivars were planted in duplicate 1.2 x 10.9 m plots to allow for greater destructive tissue sampling and yield determination. Fertilizer treatments were the same as those used in 1987-88.

In 1988, random plant samples were cut at soil level from internal plot rows. Destructive sampling was limited and only enough plant material was collected to ensure 15 g of DM for each sample, to minimize the influence on grain yield. Collection of samples of sufficient size for biomass determination was not possible. Therefore, data dependent on unit area calculations for growth stages earlier than harvest are not available for the 1987-88 study. In 1989, plant material was collected from three randomly selected 0.3 m row sections, in plots designated for destructive sampling, and subsampled, to ensure 15 g of DM for each sample. Samples were taken at FS 3 (tillering), 4 (leaf sheath elongation), 5, 6 (first node), 7 (second node), 10.3 (heading), 11.2 (soft dough), and 11.4 (crop maturity). Plant (above ground), stems (stem sections cut at ground level and second node with leaf blade removed), and flag leaf blades were harvested when available. The samples were oven dried at 60^{o} C for 48 h, and ground first in a Wiley (1-mm screen) then a Udy mill (0.5 mm screen).

A LECO CHN-600 carbon/hydrogen/nitrogen determinator (Englewood, CO) was used for dry chemical analysis of total N. Wet analysis for total N was determined using a modified macro Kjeldahl analysis method. Total N concentration in the H_2SO_4 digest was determined using an AlpChem autoanalyzer (Portland, OR). In 1988, both methods were used to determine total N concentration in ground plant samples. LECO N analysis data were regressed on Kjeldahl N analysis data. Both methods gave similar results with an r^2 value of 0.99 with 95 observations. The LECO method was used for plant analyses. Plant N uptake (kg N/ha) was calculated as the product of tissue N concentration by DM produced per unit area (kg/ha). Data were analyzed by analysis of variance (ANOVA). Protected least significant difference (PLSD) was used to test for significant differences among treatments means and interactions (SAS, 1987).

RESULTS AND DISCUSSION

Precipitation, though below normal, was 951 and 870 mm which represents 90 and 82% of normal for 1987-1988 and 1988-1989 crop years, respectively (Appendix Fig. 1). The coldest February in 100 years of Corvallis, OR weather records occurred abruptly during spike initiation in 1989 (Table I.1) (Appendix Fig. 2). The previous weather had been warm and mild. In 1988, cooler temperatures and more precipitation occurred during stem extension than in 1989. These facts may have contributed to higher grain yields and lower grain protein in 1988 than 1989 (Table I.2).

Table I.1. Monthly deviations from 30-yr means for temperatures and precipitation (1987-1988 and 1988-1989).

	Temperature Departures		Precipitation Departures	
Month	1987-1988	1988-1989	1987-1988	1988-1989
	C		mm	
October	+2.4	+2.4	-79.2	-82.6
November	+1.4	+1.1	-57.7	+119.4
December	-0.8	-0.3	+92.7	-96.5
January	0.0	+1.1	-10.9	-85.6
February	+0.4	-4.2	-80.3	-41.9
March	+0.8	+0.4	-18.5	+55.1
April	+1.4	+3.2	+22.1	-26.4
May	-0.4	+0.4	+48.8	-11.7
June	-0.2	+1.6	+16.0	-1.5
July	+0.8	-0.8	-5.6	+0.5

The following discussion was based on cultivar means averaged over N fertilizer treatments and blocks. Treatment interactions were either not significant, or they were significant at a level at least an order of magnitude less than the significance of the main effects. The N fertilizer treatment means will be presented in Chapter II.

Nitrogen Uptake

Cultivar N uptake in 1989 was rapid from FS 7 to 10.3 with a gradual decline for Batum and Dusty to FS 11.4 (Fig. I.1). Over the same period a trend for Stephens N uptake to decrease rapidly while OR 8313 maintained N uptake occurred. At FS 7, N uptake for OR 8313 was lower than the other three cultivars. There was no market class separation for N uptake as a plant tissue parameter. General decline in rate of N uptake from FS 10.3 to 11.4 underscores the importance of applying N fertilizer in phase with early N uptake for subsequent remobilization of N to grain. Baethgen and Alley (1989a) reported maximum daily N uptake rate occurred shortly after FS 5. They found the largest range in N uptake, highest N use efficiency, and largest grain yield response to N fertilizer applications at FS 5. These observations are consistent with the results of this study.

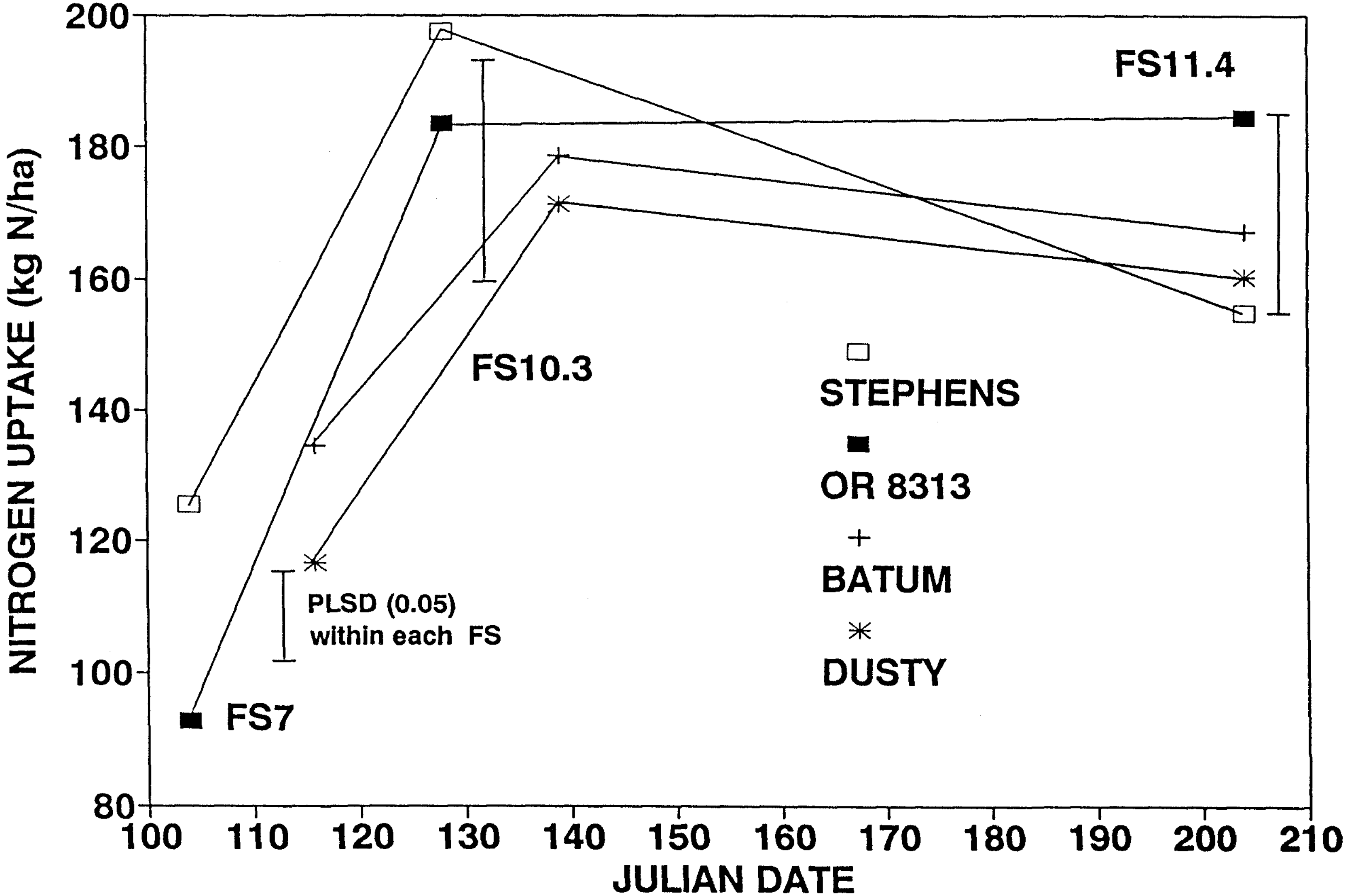

Fig. I.1 Cultivar N uptake means at specific growth stages during 1989.

Dry Matter Accumulation

Dry matter accumulation doubled during the vegetative phase from FS 7 to 10.3 with a gradual increase in DM accumulation over the reproductive phase to FS 11.4, during 1989 (Fig. I.2). This was observed by Karlen and Whitney (1980), and Waldren and Flowerday (1979). Batum and Dusty produced significantly more DM than Stephens and OR 8313 at FS 7. Cultivar DM accumulation was not statistically different at FS 10.3 and FS 11.4. Since SWWW had a one Mg/ha grain yield advantage over the HRWW cultivars (Table I.2), this indicates more efficient partitioning of DM to grain for the SWWW cultivars tested. Again, there was no market class separation for DM accumulation.

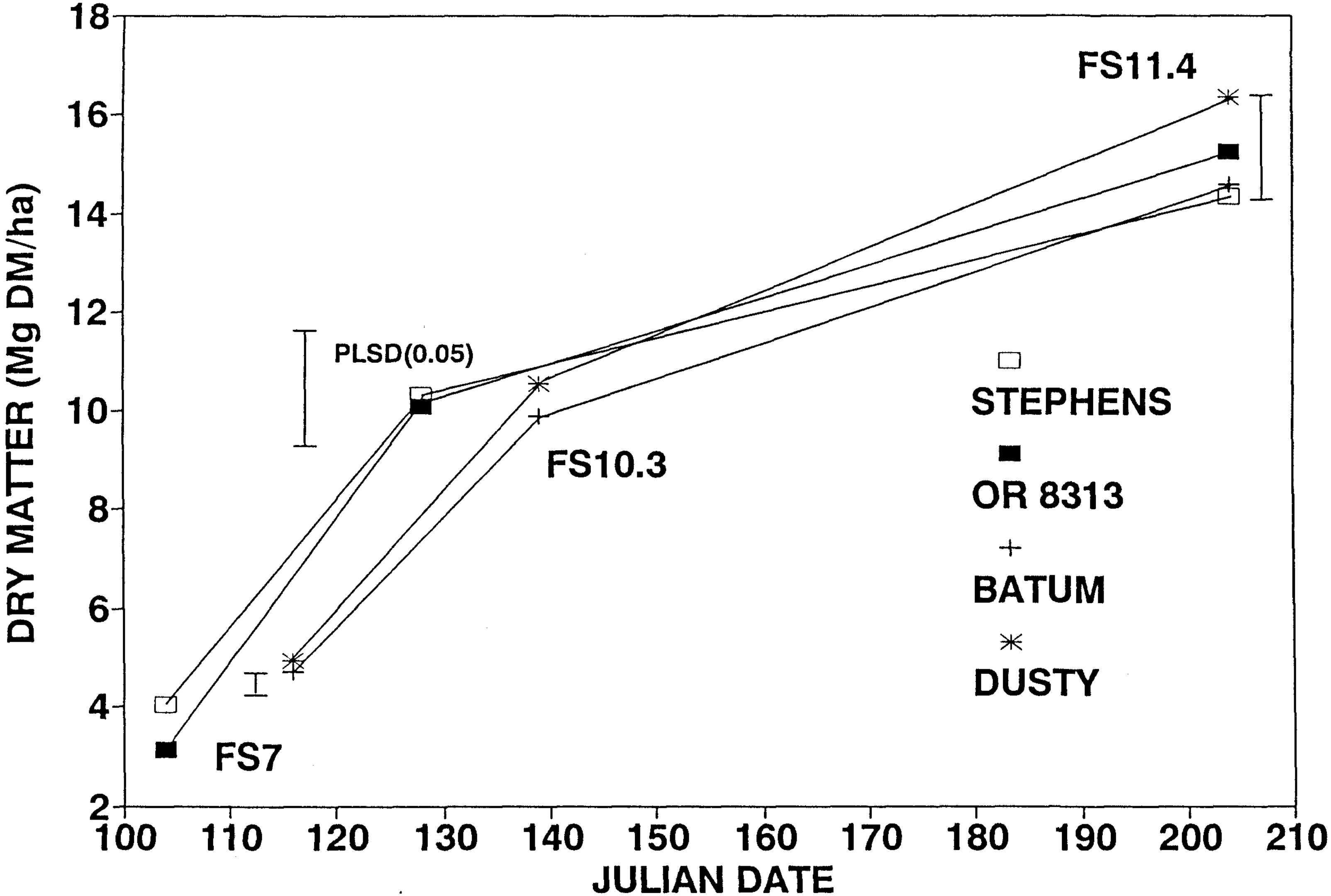

Fig. I.2 Cultivar dry matter accumulation means at specific growth stages during 1989.

Plant Total N Concentration

In 1989, a lower grain yield year than 1988 (Table I.2), maximum plant total N concentration occurred at early growth stages, FS 5 to 6 (Fig. I.3), and decreased rapidly until FS 10.3, when the rate of DM accumulation began to stabilize. This curvilinear relationship supports the work of Engel and Zubriski (1982). However, Karlen and Whitney (1980) reported a linear relationship from FS 4 to 11.2 for plant total N concentration. A rapid decline in total N concentration during a rapid increase in DM production demonstrated the dilution effect DM production had on plant N concentration. There was a gradual reduction in total plant N concentration from FS 10.3 to 11.4. Cultivars differed in total N concentration at early growth stages, FS 6 to 7, with no market class difference. Engel and Zubriski (1982) observed cultivar differences, but they reported cultivar influence for N plant tissue analysis was secondary to accurate determination of growth stage.

Stephens and OR 8313 were similar in total N concentration at specific growth stages for two years in which grain yield differed markedly (Fig. I.4). The fact these cultivars maintained relatively constant total N concentrations at specific growth stages from year-to-year with no market class separation, indicates plant total N concentration was not responsible for the year-to-year fluctuations in market class grain protein concentration (Table I.2). This agrees with McNeal et al. (1968) that cultivar percent grain N differences could not be attributed to differences in plant total N translocation to the grain. Stability for plant total N concentration over years and cultivars would make this a useful plant tissue testing parameter if it is sensitive to plant N status.

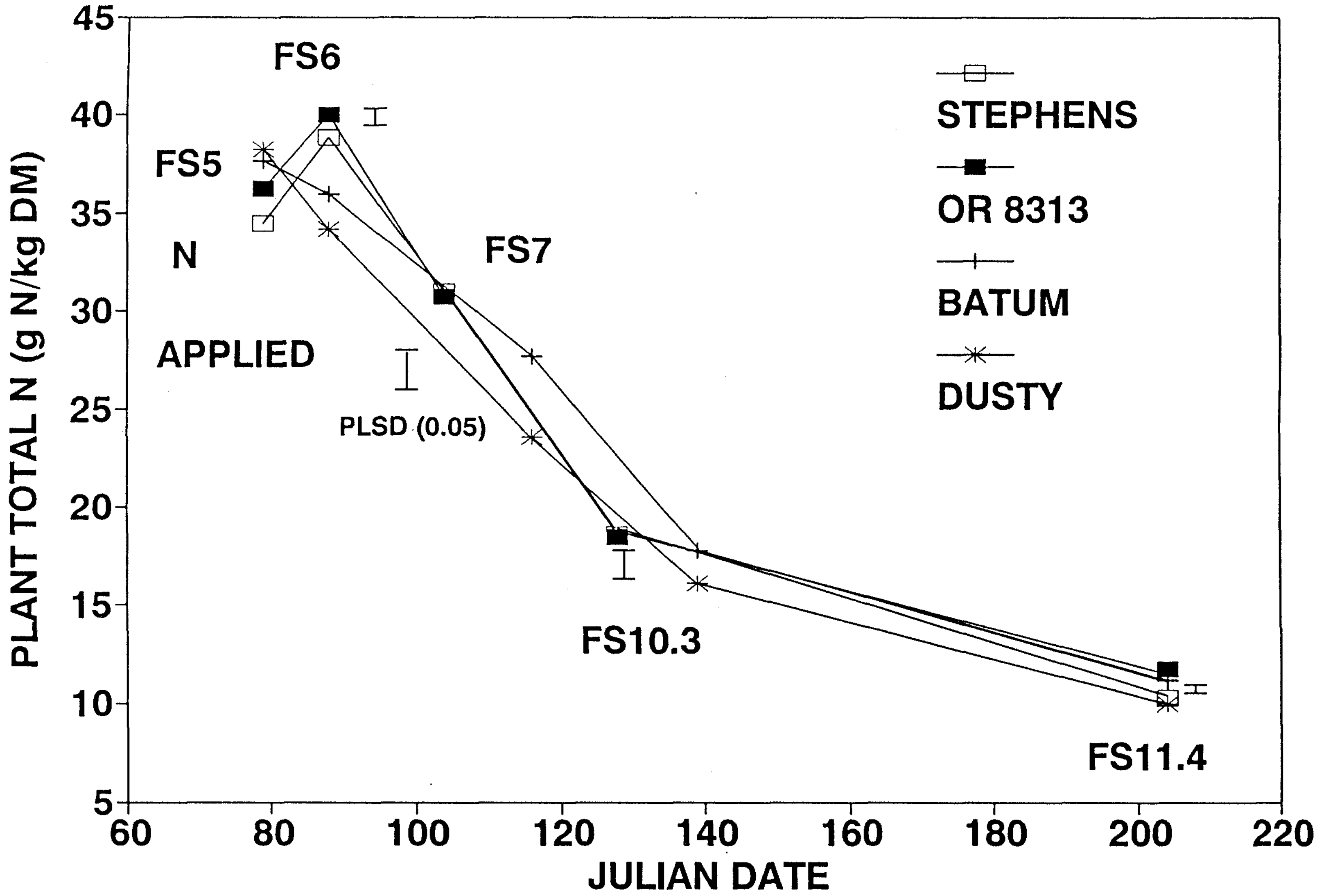

Fig. I.3 Cultivar plant total N concentration means at specific growth stages during 1989.

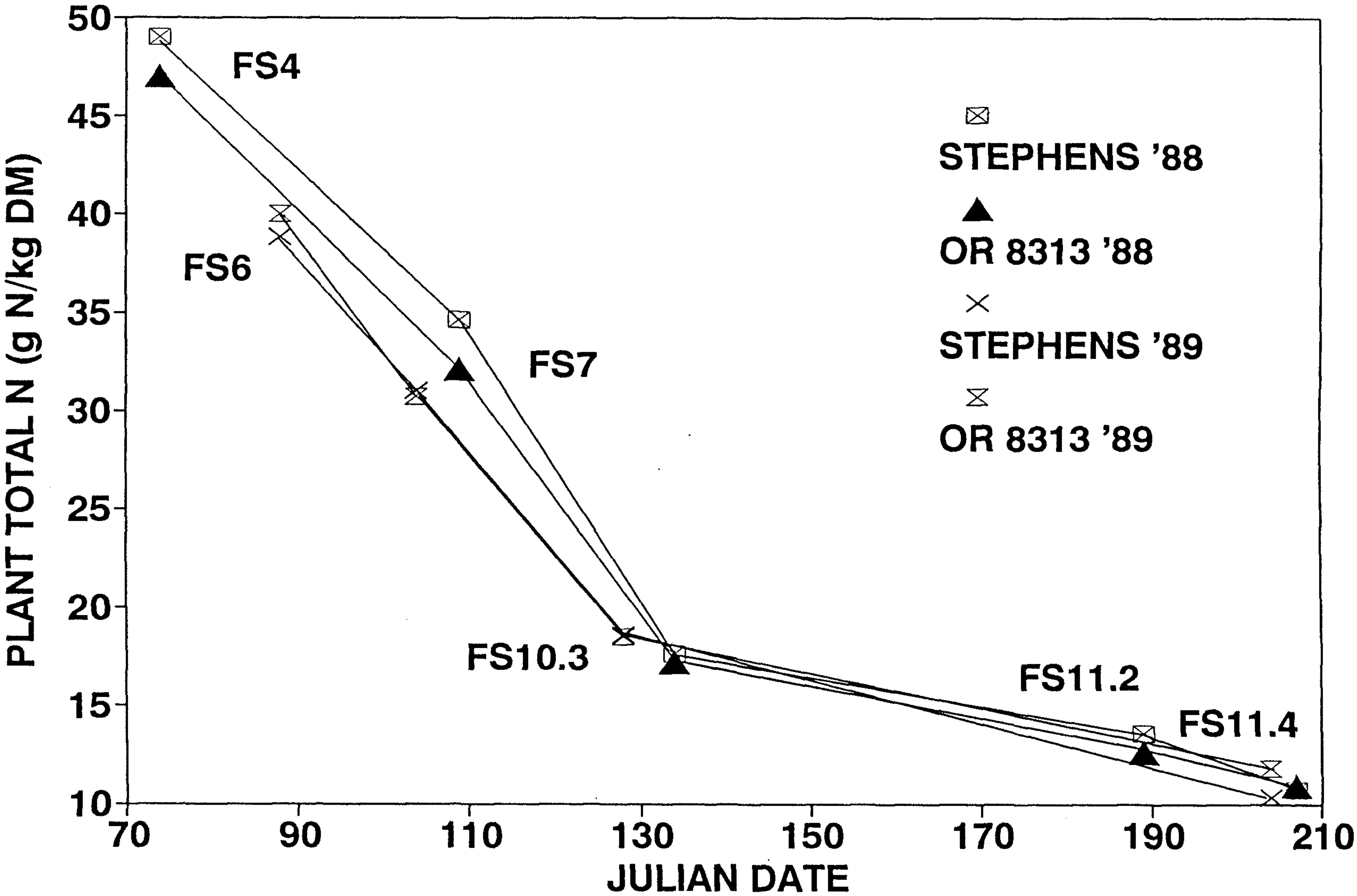

Fig. I.4 Cultivar plant total N concentration means at specific growth stages during 1988 and 1989.

Yield Parameters

Dry matter production was 33 and 16% higher in 1988 than 1989 for Stephens and OR 8313, respectively. Environmental factors (temperature, soil available N, and soil moisture) during critical growth stages (Bauer, 1987b) contributed to an imbalanced reproductive sink/source ratio (Dhugga, 1989) with the resulting grain and protein yield differences. In 1988, daily temperatures were normal during January and February (Table I.1) during spike initiation (FS 2 to 5, after vernalization, and increased day length). This may have allowed for initial increase in sink, increased soil N mineralization, and more rapid early growth. In contrast, during this same period in 1989, the minimum temperature was -28 C (Table I.1) with an extended cold period to follow. This may have caused a reduced sink, slower soil N mineralization, and delayed early spring growth. Also, cool wet weather during stem extension (April and May) in 1988, extended the growing season. This was not the case in 1989, where increased temperatures and reduced precipitation shortened the growing season.

Cultivar means for protein yield (the product of grain yield and grain protein), grain protein and NHI (nitrogen harvest index; grain N divided by total above ground plant N) were not different in 1988 (Table I.2). Grain yields were high, and grain protein concentrations were low. This indicated more N was needed to maximize grain protein. Stephens was most efficient in conversion of DM to grain, as evidenced by a harvest index (HI; grain yield divided by total above ground DM yield) that was significantly higher than those for other cultivars in both years. Nitrogen harvest index for OR 8313 in 1989 was significantly lower than the other cultivars. In 1989, OR 8313 had a large N uptake, high plant total N concentration, and low grain yield. Thus, it was less efficient than the other cultivars in converting plant N to grain protein. Batum had a significantly lower protein yield than the other cultivars because both the grain yield and grain protein concentration were low. There was a significant market class separation for grain yields in both years with a yield advantage for SWWW.

No market class difference before harvest for N uptake, DM, and plant total N concentration was evident from the cultivars studied over two markedly different grain yield years. Since HRWW had lower or equal NHI (Table I.2) they were not more efficient at partitioning N to grain than SWWW. One could conclude that increased DM in SWWW grain diluted grain protein concentration, or conversely, high grain protein for HRWW came at the expense of lower grain yield for these cultivars.

Table I.2. Yield parameter means for 1988 and 1989.

Cultivar	Year	Dry Matter	Grain Yield	Protein Yield	Grain Protein	NHI	HI
		—— Mg/ha——		kg/ha	g/kg		
	1988						
Stephens		21.4	9.49	826.3	87	.67	.42
OR 8313		18.3	8.65	825.8	90	.62	.38
PLSD (0.01)		2.4	0.61	NS	NS	NS	.02
	1989						
Stephens		14.4	6.78	654.6	99	.70	.39
Dusty		16.2	6.75	638.6	94	.67	.34
OR 8313		15.3	5.73	660.9	114	.55	.34
Batum		14.5	5.43	514.4	97	.67	.33
PLSD (0.01)		2.0	0.56	66.5	3	.08	.04

NHI = nitrogen harvest index; HI = harvest index.

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CHAPTER II

PLANT TISSUE ANALYSIS FOR NITROGEN SUFFICIENCY IN SOFT WHITE AND HARD RED WINTER WHEATS

ABSTRACT

The ability to monitor and adjust a nitrogen fertilizer program during the current growing season has economic and environmental advantages. Early determination of crop N status allows more options in N fertility management. Two hard red winter wheats (OR 8313', 'Batum') and two soft white winter wheats ('Stephens', 'Dusty') were studied with a N fertility gradient of 0, 56, 112, and 168 kg N/ha in western Oregon during 1987-89. The following discussion was based on N treatment means averaged over blocks and cultivars. Nitrogen fertilizer treatments produced wheat tissue N gradients measured by N uptake, plant total N, stem N and stem NO_3. At Feekes (Large, 1954) growth stages (FS) 4 to FS 7 plant total N and N uptake parameters were able to detect fertilizer treatment differences. Stem N and stem NO_3-N concentrations were not; however, these parameters were able to distinguish N sufficiency.

Among parameters tested, plant total N concentration at FS 7 gave the highest correlation with grain yield, protein yield and grain protein. In high grain yield years dependency of grain protein on grain yield made the use of plant tissue analysis at early growth stages ineffective for correlating plant tissue parameters and grain protein. In low grain yield years there was a moderate but, highly significant correlation for all plant tissue parameters, except N uptake, with grain

protein . Plant total N at FS 4 and 7 was the plant tissue analysis which produced predictive models most strongly correlated with yield parameters. Plant total N at FS 7 explained 62 and 72% of grain yield, and 67 and 75% of protein yield variability for hard red winter wheat (HRWW) and soft white winter wheat (SWWW), respectively.

Optimum fertilizer N rate for soft white winter wheat production during this study was 112 kg N/ha. The potential benefit of higher grain protein for hard red winter wheat production, particularly in a lower grain yield year, may warrant a higher N rate. The critical N level for both SWWW and HRWW cultivars compared in this study was determined by the Cate-Nelson method to be 27 g N/kg at FS 7. The critical nutrient range for plant total N at FS 7 was 27-37 g N/kg.

INTRODUCTION

In humid regions during winter and spring soil N concentration varies too much to be a useful indicator of crop N requirement (Fox and Piekielek, 1978; Fox and Piekielek, 1984). Other N indicators are needed. Plant tissue testing is used to determine plant N status for some Pacific Northwest (PNW) crops. This method has been suggested as an alternative to soil N testing for estimating fertilizer N requirements for winter wheat production (Roth et al., 1989).

Three plant tissue test parameters have been suggested as indicators of N fertilizer requirements for wheat: stem nitrate concentration (Gardner and Jackson, 1976), plant N concentration (Engel and Zubriski, 1982), and crop N uptake (Baethgen et al., 1985). Roth et al. (1989) evaluated these plant tissue tests at FS 3 to 6 as indicators of plant N requirements for soft red winter wheat production in Pennsylvania. Plant N concentration accounted for the most temporal variation in relative yields, and had the lowest spatial variability, making it the best suited plant tissue test. Critical plant N concentrations for 90% of maximum yield were 39.0, 35.0 and 26.5 g N/kg at FS 4, 5 and 6, respectively. Stem nitrate tissue test was most sensitive to short term soil N changes with a critical level of 2.15 g NO_3-N/kg. N uptake was the weakest N deficiency predictor and had the largest spatial variability, due to factors limiting crop dry matter (DM) production.

Baethgen and Alley (1989a,b), working with soft red winter wheat in Virginia, found a large range in N uptake at FS 4-5, high expected N use after FS 4-5 (rapid growth), and large grain yield response to N fertilization at FS 4-5. They concluded that plant N concentration or N uptake at this growth stage could be useful indicators of crop N needs and possibly be good predictors for optimum grain yields. Calculated critical N levels at FS 4-5 for plant N concentration and N uptake were 39.5 g N/kg and 95 kg N/ha, respectively, with R^2 values of 0.87 and 0.79.

Critical N levels for wheat at different growth stages and plant parts was published by Vaughan et al. (1990). The list points out discrepancies between critical N values reported in the literature and the fact that most of the critical N levels were determined at growth stages too late to be of early season use. Their report demonstrates the need to develop critical N levels based both on a specific early growth stage and a particular plant tissue. Thus, they determined critical plant tissue N and NO_3-N concentrations at FS 3, 5 and 7 for hard red winter wheat in Colorado. Plant N concentrations at FS 5 and 7 gave the best results with critical N levels of 32.0 and 27.0 g N/kg, respectively.

If growth stage and plant tissue are matched for a comparison of the literature reporting critical N levels, a strong similarity for critical N levels, which were developed for different cultivars, years, and environments, is revealed. This overall stability of plant tissue N levels has important implications for developing sound current season N management recommendations. A reliable strategy for N sufficiency testing and for prediction of grain yield and grain protein concentration needs to be developed for winter wheat production in the PNW. The objectives of this study were: (i) to investigate dry matter accumulation and N distribution patterns in plant tissues for different N fertilizer rates and winter wheat cultivars in PNW for differences which may be useful for grain and protein yield prediction, (ii) to identify optimum N rates and critical plant tissue N levels at growth stages early enough for current season correction of N deficiency, and (iii) to propose models for predicting grain and protein yield based on early season parameter measurements.

MATERIALS AND METHODS

Field experiments were conducted in 1987-88 and 1988-89 on a Woodburn silt loam soil (fine silty, mixed mesic Aquultic Argixerolls) at the Oregon State University Crop and Soil Science Hyslop Field Laboratory. Details of the procedures used are given in Chapter I, Materials and Methods. The Cate-Nelson method (Cate and Nelson, 1971) was used to determine critical plant N levels. Scatter plots of data points were quartered to maximize data points in the lower left and upper right quadrants while minimizing data points in the upper left and lower right quadrants. Stepwise linear and quadratic models were developed for the variables measured in this study using Statistical Analyses Systems, regression procedure with MAXR forward selection, and general linear model procedure for multiple regression (SAS, 1987).

RESULTS AND DISCUSSION

Precipitation, though below normal, was 951 and 870 mm which was 90 and 82% of normal for 1987-1988 and 1988-1989 crop years, respectively (Table I.1) (Appendix Fig. 1). The coldest February in 100 years of Corvallis, OR weather records occurred abruptly during spike initiation in 1989 (Table I.1) (Appendix Fig. 2). The previous weather had been warm and mild. In 1988, cooler temperatures and more precipitation occurred during stem extension than in 1989. This may have contributed to higher grain yields and lower grain protein in 1988 than 1989 (Table I.2).

The following discussion was based on N fertilizer treatment means averaged over cultivars. Treatment interactions were either not significant, or were at a significance level at least an order of magnitude less than that of the main effects.

Nitrogen Uptake

Nitrogen uptake patterns for fertilizer treatment means averaged over cultivars in 1989 (Fig. II.1), showed a distinct separation for fertilizer rates at each growth stage (FS 7, 10.3 and 11.4). Treatment means separation at FS 7 supports use of early growth stages for monitoring plant N status. Nitrogen uptake increased rapidly from FS 7 to FS 10.3 followed by a gradual decline in kg N/ha to FS 11.4, underscoring the importance of applying fertilizer N in phase with rapid crop uptake. All fertilizer treatments displayed similar N uptake patterns with an average increase of 45 kg N/ha in uptake for each 56 kg N/ha increment of N fertilizer applied.

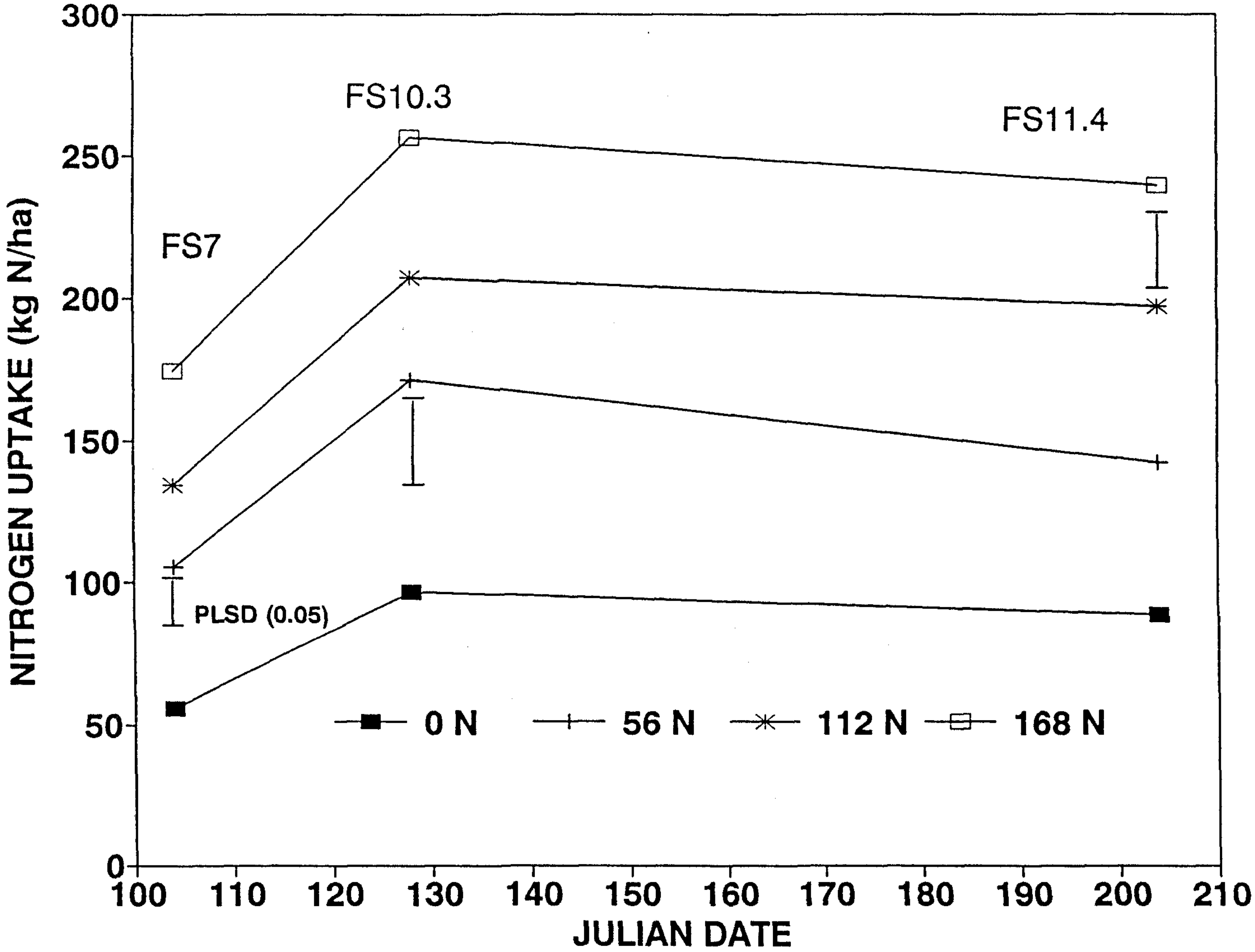

Fig. II.1 Nitrogen fertilizer treatment effects on N uptake means at specific growth stages during 1989.

Dry Matter Accumulation

In 1989, dry matter accumulated rapidly from FS 7 to 10.3 with a gradual increase to FS 11.4 (Fig. II.2). Dry matter accumulation for the 0 N treatment was significantly less than the other N fertilizer rates at all growth stages. The 56 kg N/ha rate was adequate for dry matter production to FS 10.3, but this N rate produced significantly less dry matter than the 112 and 168 kg N/ha treatments at FS 11.4. There was no significant difference between the 112 and 168 kg N/ha treatments for dry matter accumulation at any growth stage. Since there was no increase in dry matter accumulation at the higher N rate, and the 56 kg N/ha rate limited dry matter accumulation, the 112 kg N/ha rate, of the rates tested, appeared optimum for dry matter accumulation in 1989.

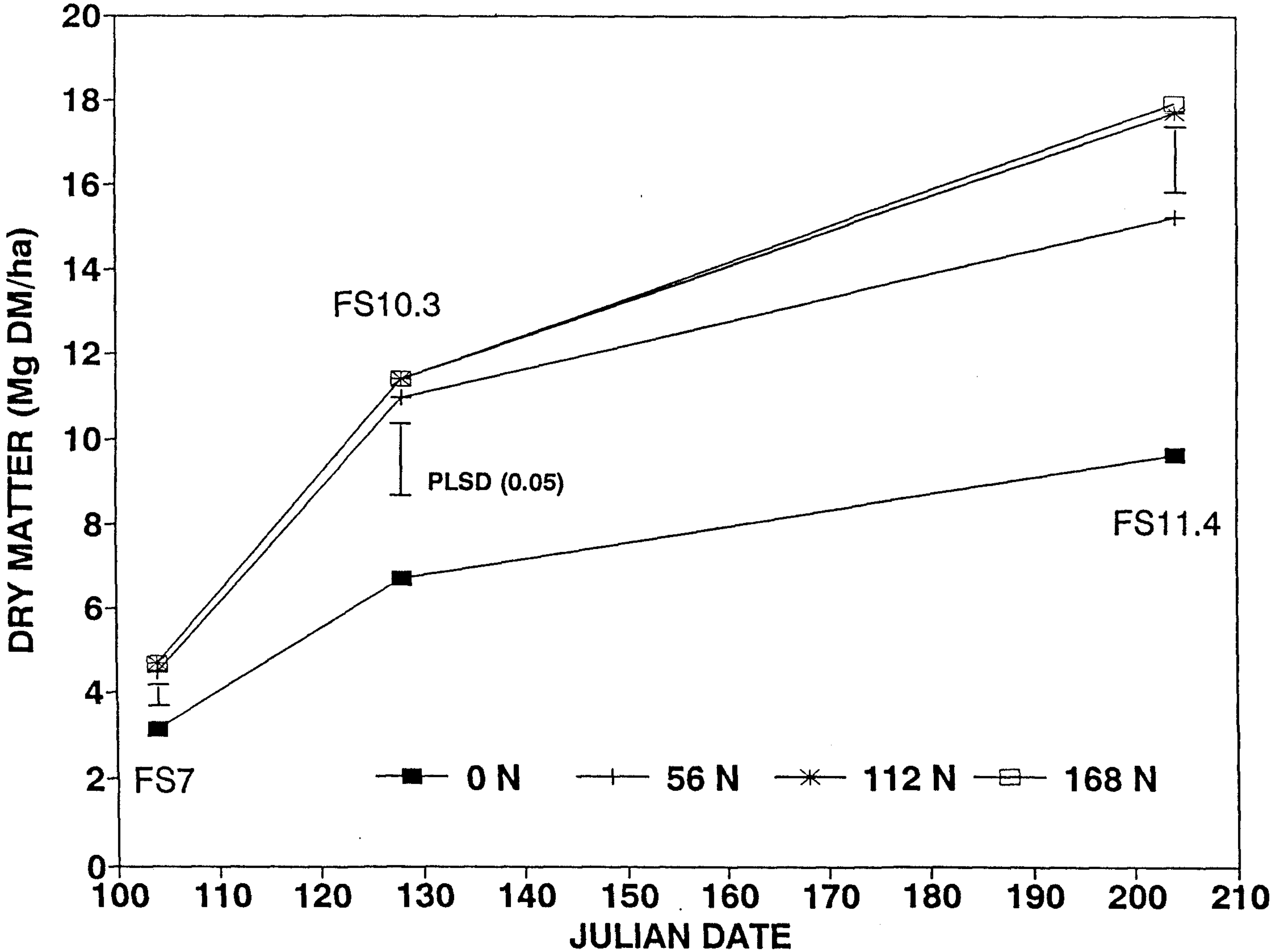

Fig. II.2 Nitrogen fertilizer treatment effects on dry matter accumulation means at specific growth stages during 1989.

Plant Total N Concentration

Means for plant total N concentration at specific growth stages averaged over cultivars for different N fertilizer rates in 1988 are shown in Fig. II.3. In general, total N decreased from a high at FS 3 or 4 to a low at FS 11.4. This trend and range of total N is consistent with reports by McNeal et al. (1966, 1968), Bauer et al. (1987a,b,c), Harper et al. (1987) and McMullan (1988). High total N at early growth stages was consistent with the rapid N uptake at early growth stages shown in this study.

At each growth stage, each increment of fertilizer N increased total N concentration. All N fertilizer treatments at FS 7 and 11.2 produced significantly different total N means. The 0 and 56 kg N/ha treatments produced significantly different total N means for all growth stages except FS 11.4. The largest range in total N concentration for the N fertilizer treatments occurred during FS 7 which facilitates the use of this parameter for predictive and corrective purposes. Distinct total N mean separation allows for reliable tissue analysis of plant N status. The sharp decline in total N concentration ends at FS 10.3 during heading when dry matter accumulation begins to stabilize.

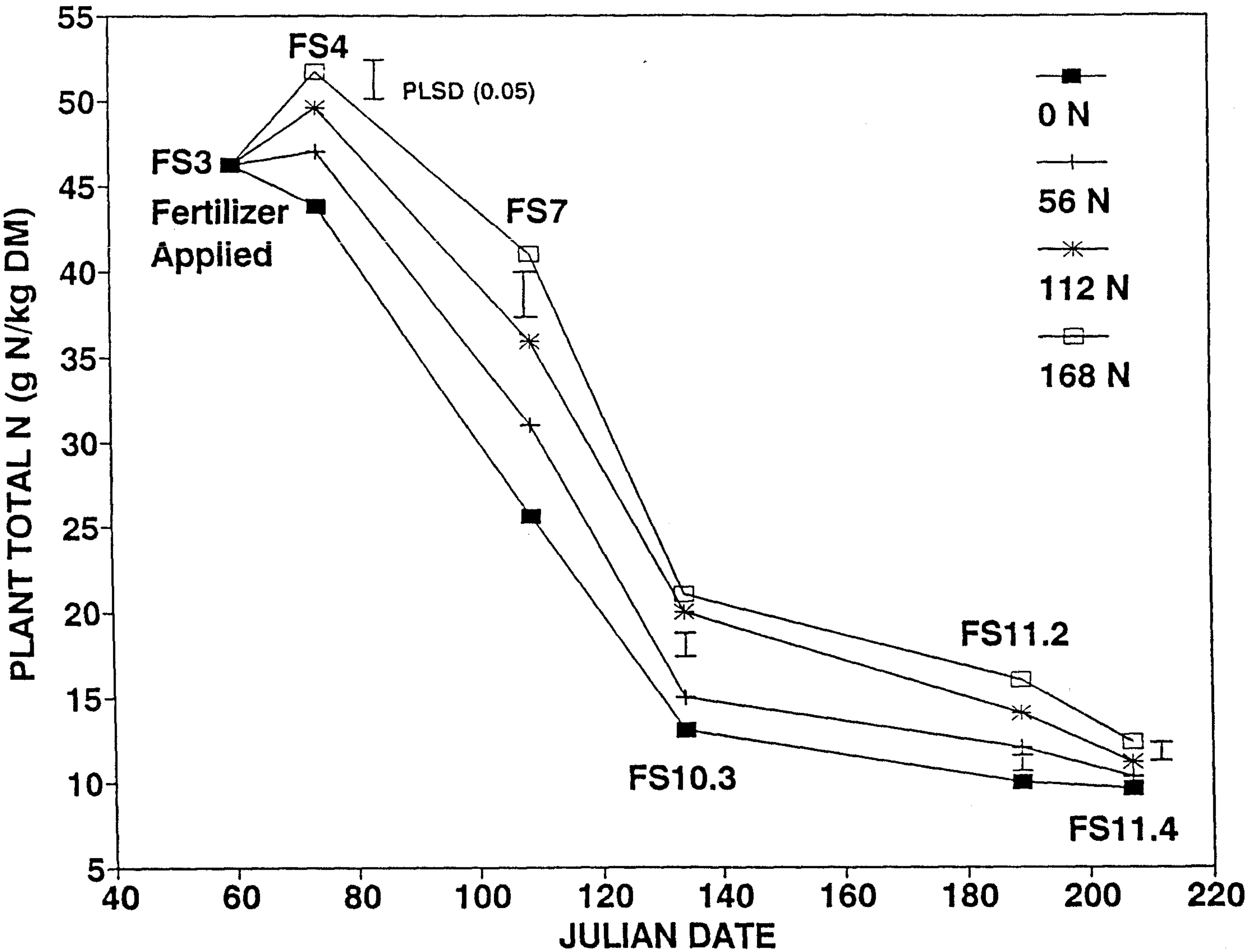

Fig. II.3 Nitrogen fertilizer treatment effects on plant total N concentration means at specific growth stages during 1988.

In 1988, plant parts were separated and tissue analysis performed to determine if these tissues reflected N fertilizer rates at FS 11.2. Table II.1. shows total N concentration in different plant parts at FS 11.2 for 1988. Total N means for plant samples were significantly different for N fertilizer treatments. This was the only sampled variable sensitive enough to be different for all N fertilizer treatments. The 56 and 112 kg N/ha N fertilizer treatments were significantly different for all plant parts. However, the range in plant N concentration for parts at this late growth stage was too narrow and came too late to be of practical use for current season N sufficiency adjustment.

Table II.1. Nitrogen fertilizer treatment effects on total N concentration means for plant tissues at Feekes stage 11.2 in 1988.

N Rate	Plant	Flag Leaf	Stem Section	Head
kg N/ha	g N/kg			
0	10.2	10.4	2.3	14.1
56	11.6	12.5	2.0	15.9
112	14.3	16.6	3.6	15.3
168	16.4	17.9	5.6	14.1
PLSD (0.05)	1.3	2.9	1.3	2.9

In 1989, the same general decline in plant total N concentration from FS 6-11.4 occurred (Fig. II.4), even though grain yields were lower than 1988 (Table I.2). High total N occurred at FS 5 or 6 with the lowest total N at FS 11.4. Again, the sharp decline in concentration to FS 10.3 becomes a gradual decline in total N to FS 11.4, maturity. Each N fertilizer treatment produced significantly different total N means for each growth stage except at FS 11.4. The range of total N within growth stages was 21.0, 19.0 and 8.3 g N/kg at FS 6, 7 and 10.3, respectively. The distinct separation of total N means for two different grain yield years with a wide range during early growth stages (FS 4-7) suggests development of a data base for current season correction of N deficiency and prediction of grain yield (Baethgen and Alley, 1989b) and protein is possible. The use of N tissue testing at early growth stages (FS 4-7) has the advantage of allowing growers time to adjust their fertility program during the current season (Baethgen and Alley, 1989b).

Total N concentration means in different plant parts at FS 10.3 for 1988 and 1989 are shown in Table II.2. The widest range of total N at this growth stage occurred in flag leaves. Flag leaves were the only plant part at FS 10.3 for 1988 and 1989 with significant difference among all N fertilizer treatment means. Flag leaf analysis may be useful for grain and protein yield prediction. This agrees with Engel and Zubriski (1982). These data support the work by others who suggest the use of flag leaves during heading as an indicator for plant N status (Petrie, 1984a,b; Donohue and Brann, 1984; Brown and Stark, 1986). Flag leaves and plants would be sensitive plant tissues to use as an indicator of plant N status at FS 10.3. However, sampling at this late growth stage may not allow for effective current season adjustments of N fertilizer management.

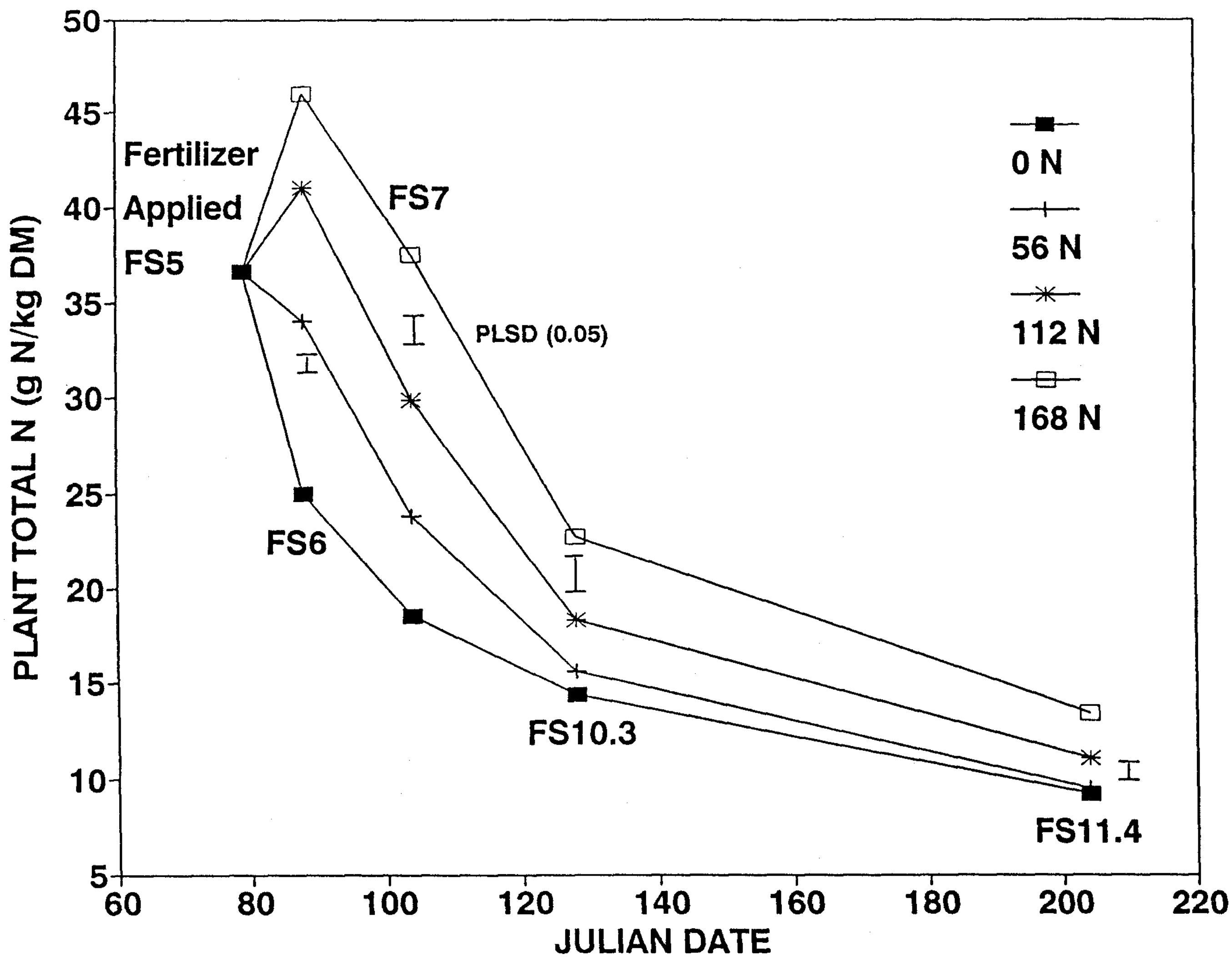

Fig. II.4 Nitrogen fertilizer treatment effects on plant total N concentration means at specific growth stages during 1989.

Table II.2. Nitrogen fertilizer treatment effects on total N concentration means for plant tissues at Feekes stage 10.3 in 1988 and 1989.

N Rate	Year	Plant	Flag Leaf	Stem Section
kg N/ha	1988		g/kg	
0		13.2	32.3	3.8
56		15.4	35.6	4.7
112		20.0	38.3	6.9
168		21.0	40.0	10.8
PLSD (0.05)		2.0	1.6	1.4
kg N/ha	1989			
0		14.4	28.1	2.8
56		15.6	30.3	3.1
112		18.3	34.4	4.6
168		22.7	38.9	8.2
PLSD (0.05)		1.2	1.4	1.4

Stem Total N Concentration

Stem total N concentration means for N fertilizer treatments are shown in Fig. II.5 for specific growth stages in 1988. Like plant total N, stem total N declines from high concentrations at FS 7 to low concentrations at later growth stages. The widest range in stem total N (16.8 g N/kg) occurred at the earliest growth stage FS 7 with a significant difference produced between 56 and 112 kg N/ha fertilizer treatments. Unlike plant total N, there was no growth stage which showed distinct separation of stem total N means for all fertilizer treatments. However, there was a significant difference between the 56 kg N/ha and 112 kg N/ha N rates. This distinction maybe useful for separation of N sufficiency from N deficiency. Use of stem total N as an indicator parameter to determine critical N level and optimum N fertilizer rates may be more difficult than use of plant total N.

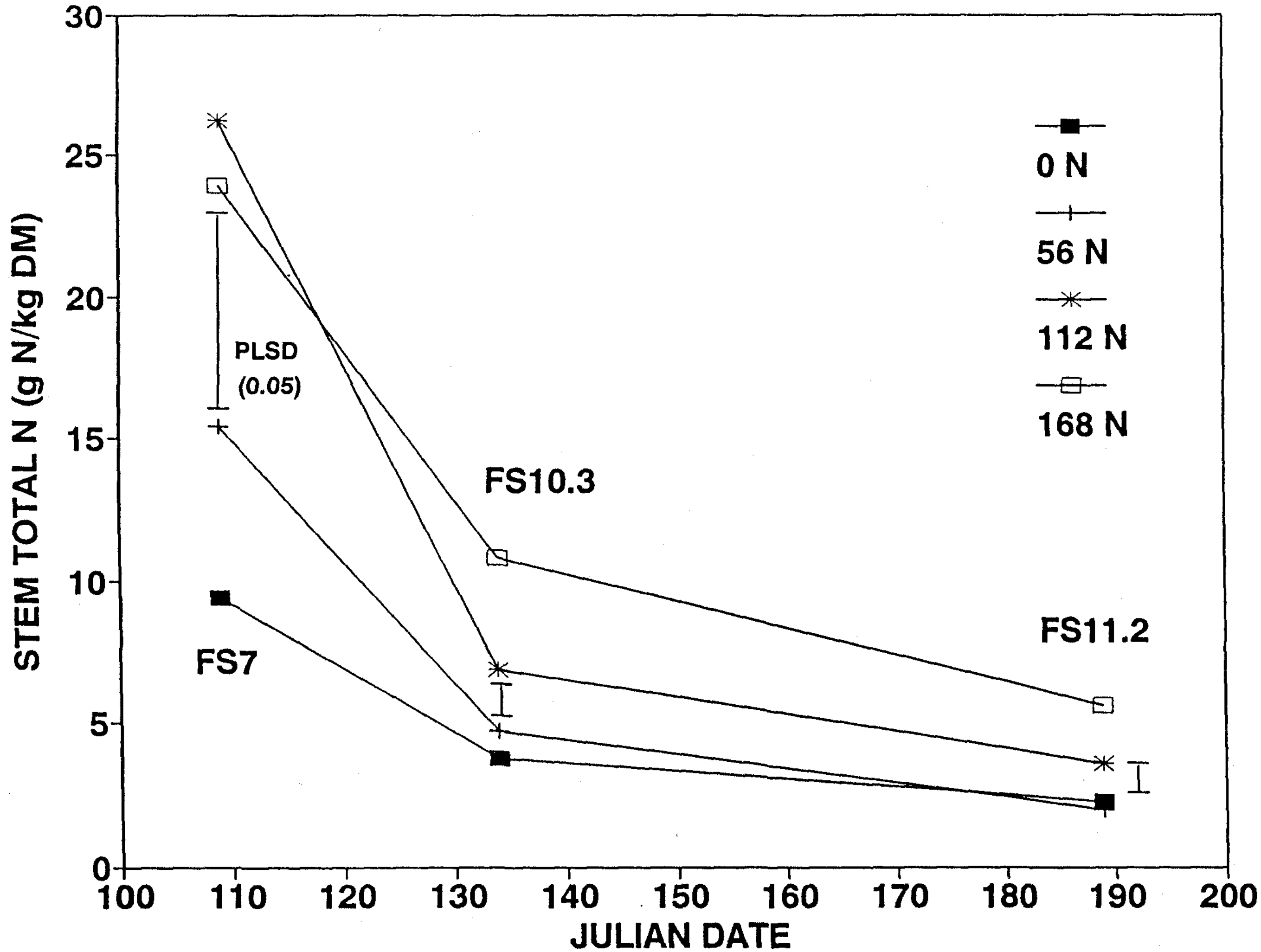

Fig. II.5 Nitrogen fertilizer treatment effects on stem total N concentration means at specific growth stages during 1988.

Stem Nitrate Concentration

Stem NO_3-N means for fertilizer treatments are shown in Fig. II.6 for specific growth stages in 1988. Stem NO_3-N declined from a high concentration at FS 7 to a low concentration at FS 11.2 which agrees with the results of Gardner and Jackson (1976). Stem NO_3-N concentration increased with increased N fertilizer treatments. This agrees with results by Papastylianou (1984) and Gardner and Jackson (1976). The widest range (8183 mg NO_3-N/kg) occurred at FS 7, but like stem total N all N fertilizer treatment means were not distinctly separated. Again, the significant difference between the 56 kg N/ha and 112 kg N/ha rates would allow for detection of N sufficiency. The inability to clearly separate all N fertilizer treatments using stem total N and stem NO_3-N concentration would make their use as sensitive parameters for determining critical N levels and optimum N fertilizer rates more difficult. Pettygrove et al. (1981) reported that critical NO_3-N levels changed rapidly over time with large site to site variation limiting its usefulness.

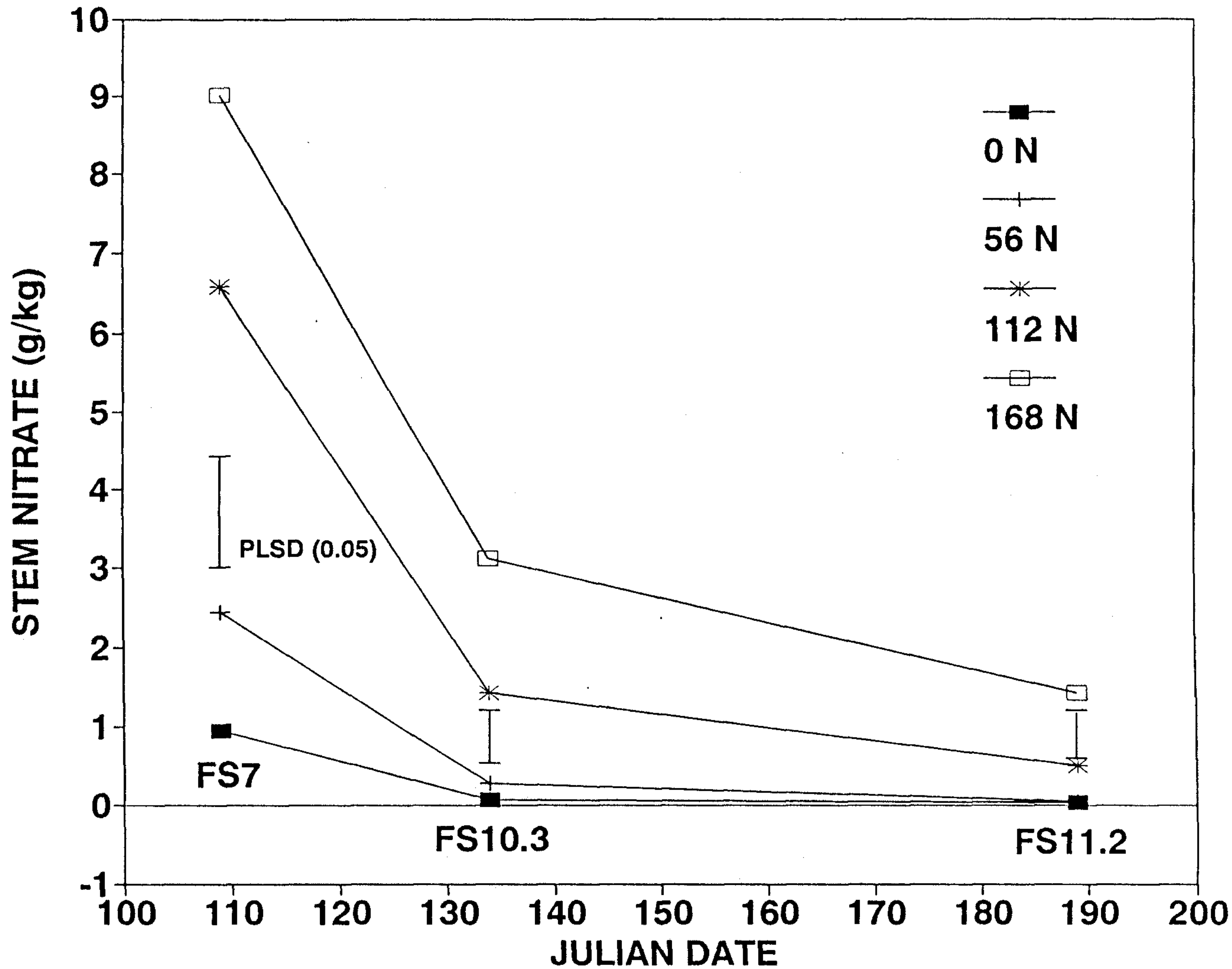

Fig. II.6 Nitrogen fertilizer treatment effects on stem NO_3-N concentration means at specific growth stages during 1988.

Yield Parameters

Grain yield means and grain protein means for N fertilizer treatments averaged over cultivars in 1988 and 1989 are shown in Fig. II.7. The N fertilizer rate of 112 kg N/ha produced optimum grain yield per increment of N fertilizer in both years. However, maximum grain protein per increment of N fertilizer in both years occurred with the 168 kg N/ha rate. In 1989, the lower grain yield year, more fertilizer N was available for grain protein production (Table I.2). The optimum fertilizer N rate for soft white winter wheat production during the study was 112 kg N/ha which produced nearly maximum yields before incurring a sharp rise in grain protein. The potential benefit of higher grain protein for hard red winter wheat production, particularly in a lower grain yield year, may warrant a higher N rate.

The Cate-Nelson method (Cate and Nelson, 1971) was used to determine critical plant N levels. The relationship of plant total N at FS 7 over two very different grain yield years, 1988 and 1989, with grain and protein yield was plotted. Figures II.8 and 9 show the relationship soft white winter wheat and hard red winter wheat plant total N at FS 7 had with grain yield. The critical N levels for both SWWW and HRWW grain yield was 27 g N/kg at FS7. Roberts et al. (1972) reported 26 g N/kg at FS 7 was the minimum total N concentration for optimum grain yields. The optimum N rate of 112 kg N/ha for this study maintains plant N above this critical N level (Fig. II.10) for both years. When both high and low yield years are considered the critical nutrient range was 27-37 g/kg at FS 7.

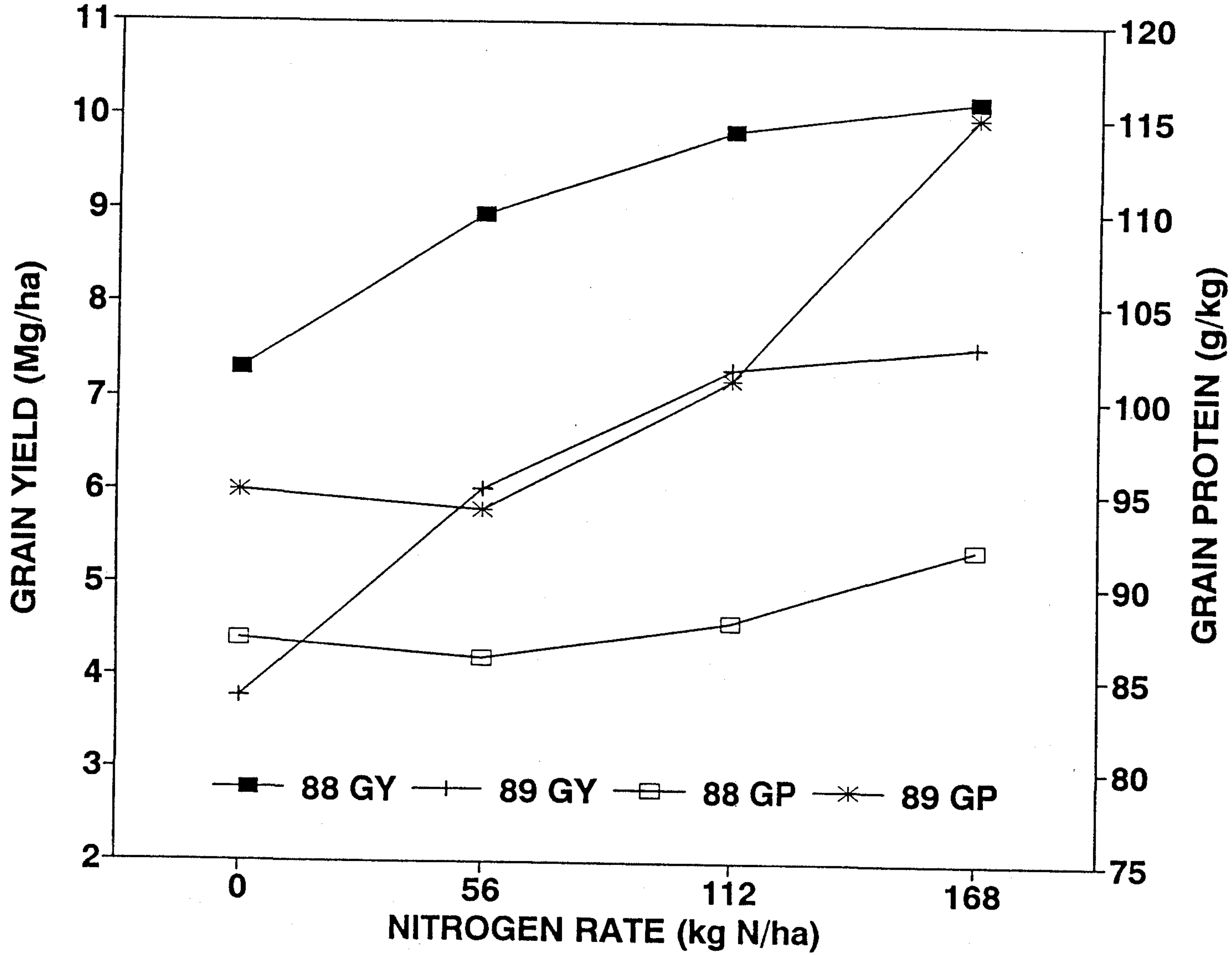

Fig. II.7 Nitrogen fertilizer treatment effects on grain yield and grain protein means for 1988 and 1989.

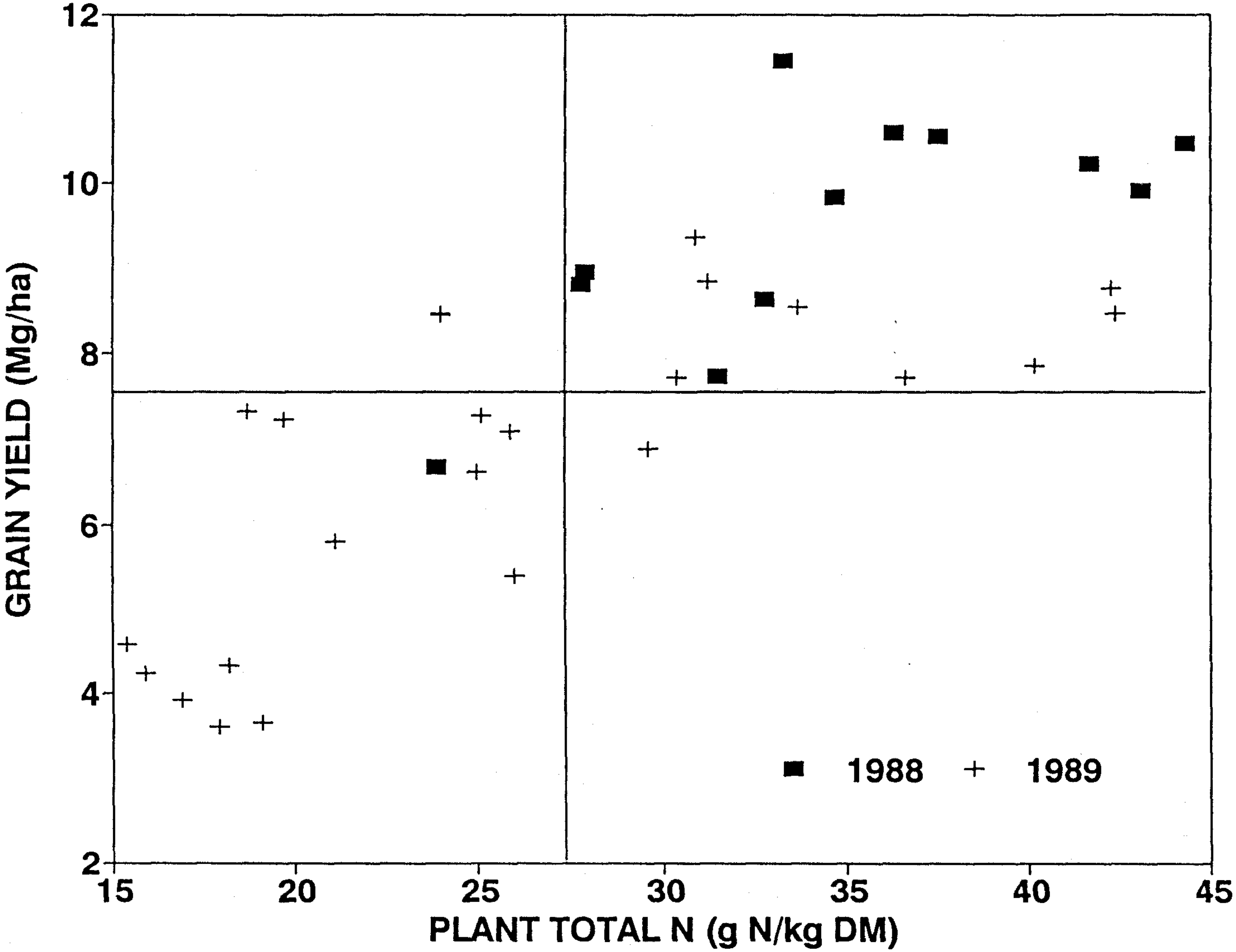

Fig. II.8 Plant total N relationship with grain yield at Feekes stage 7 for soft white winter wheats in 1988 and 1989.

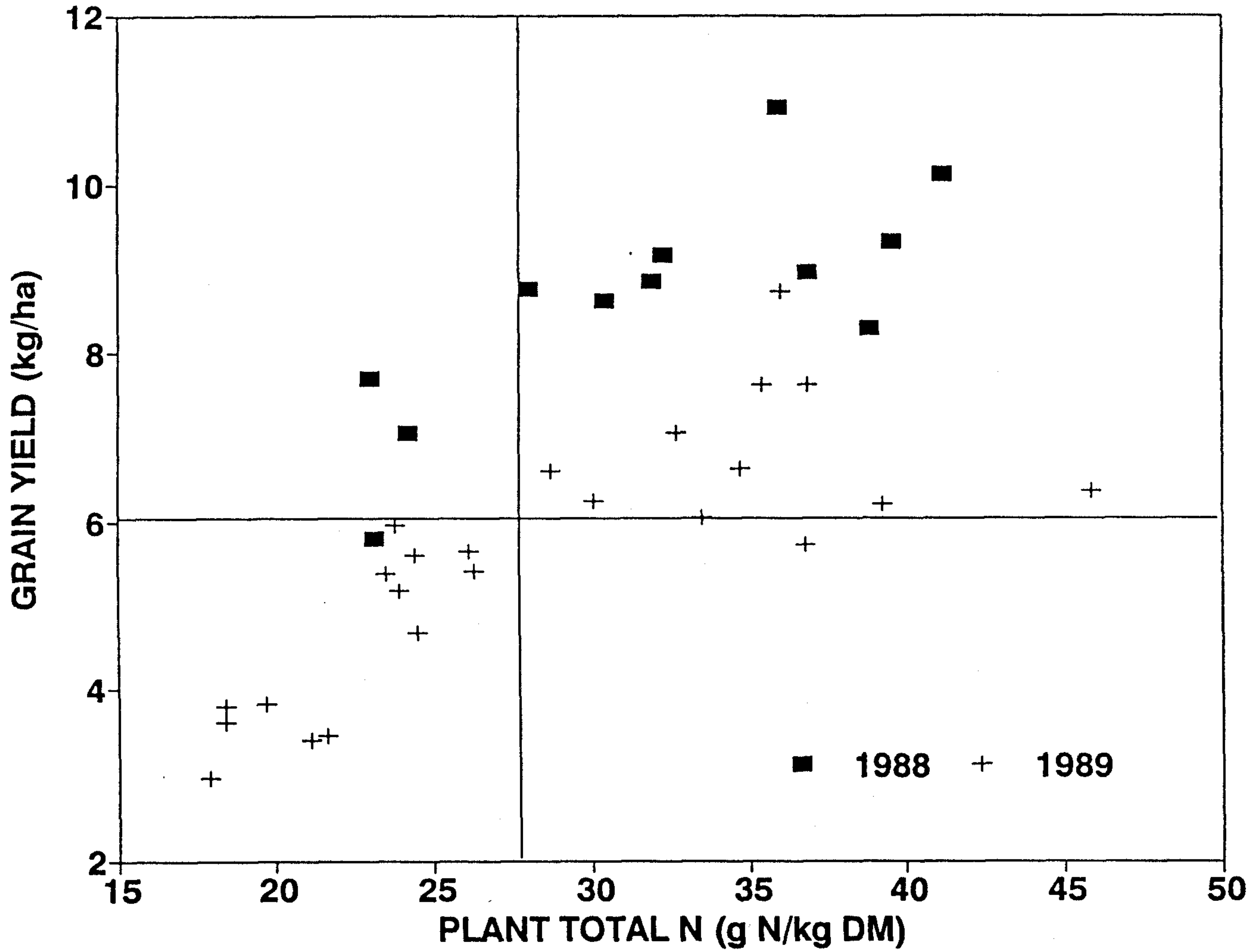

Fig. II.9 Plant total N relationship with grain yield at Feekes stage 7 for hard red winter wheats in 1988 and 1989.

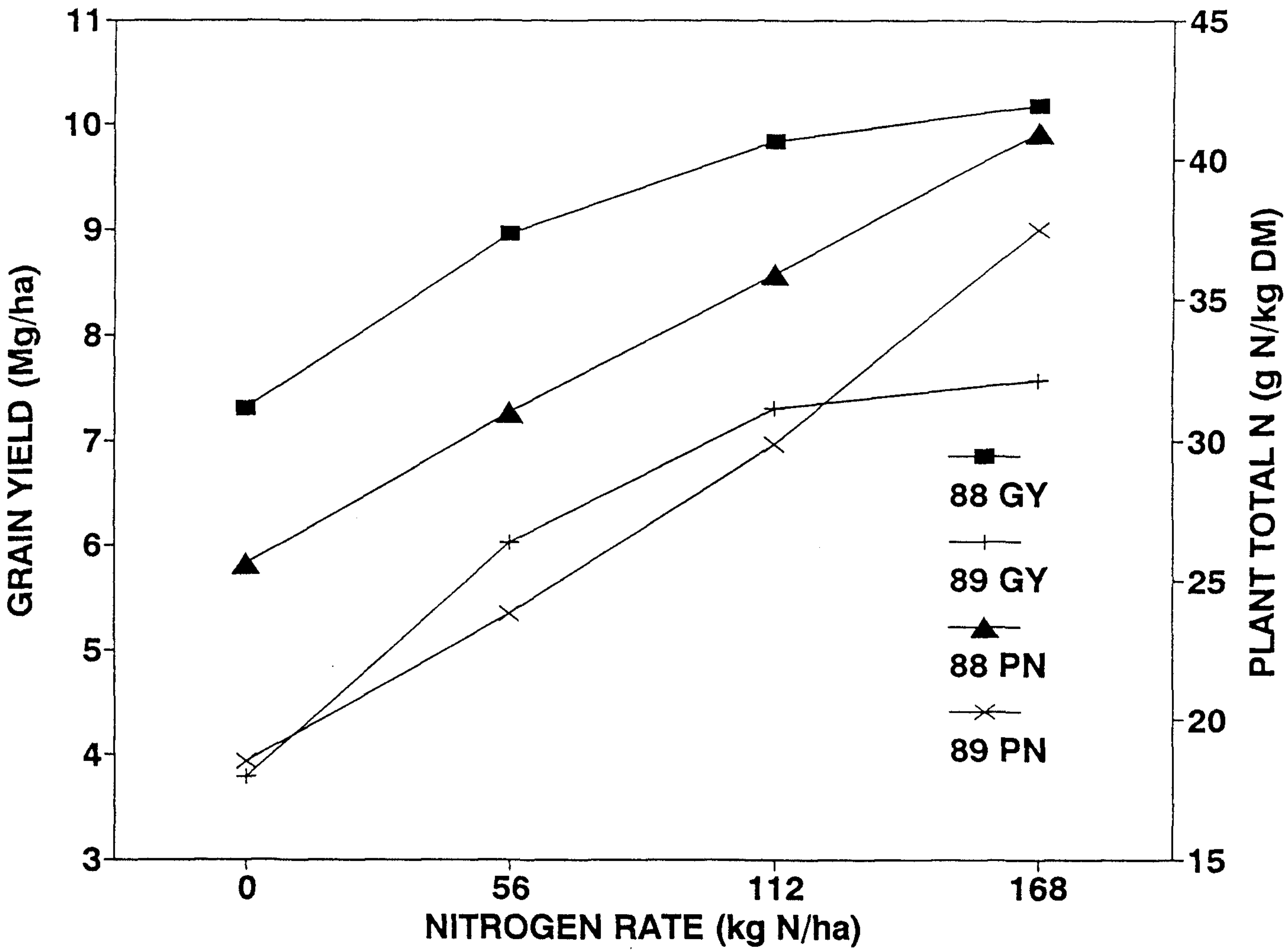

Fig. II.10 Nitrogen fertilizer treatment effects on grain yield and Feekes stage 7 plant total N means for 1988 and 1989.

Grain and Protein Yield Prediction

Distinct N fertilizer treatment differences detected by the plant tissue parameters presented support the use of early growth stages (FS 4-7) for determination of plant N status. Table II.3 shows Pearson correlation coefficients for plant tissue analysis with grain yield, protein yield and grain protein. In 1988, a high yield year (Table I.2), all correlations were highly significant except for those with grain protein. Grain and protein yield were moderately correlated with all plant tissue analyses. In 1989, a low yield year (Table I.2), all correlations were highly significant. Grain and protein yield were moderately correlated with all plant tissue analyses. Plant total N at FS 7 and protein yield were highly correlated in 1989. Grain protein was weakly correlated with FS 7 N uptake. The dependence of grain protein on grain yield was reflected by the correlations for these two very different grain yield years. When grain yield was not limited by the environment (1987-88), tissue analysis parameters were not correlated with grain protein. When the environment restricted grain yield (1988-89), tissue analysis parameters were highly significant and moderately correlated with grain protein (Fig. II.11). Plant total N at FS 7 was the plant tissue analysis best correlated with these yield variables in this study.

Table II.3. Pearson correlation coefficients for plant total N, stem total N, stem NO_3-N, and N uptake means with grain yield, protein yield and grain protein means at three Feekes stages in 1988 and 1989.

Feekes Stage Tissue Analysis	Year	n†	Grain Yield	Protein Yield	Grain Protein
	1988			r	
4 Plant total N		24	0.73***	0.68***	0.18
7 Plant total N		24	0.73***	0.77***	0.30
7 Stem total N		24	0.69***	0.76***	0.37
7 Stem NO_3-N		24	0.71***	0.79***	0.32
	1989				
6 Plant total N		60	0.73***	0.79***	0.61***
7 Plant total N		48	0.67***	0.81***	0.73***
7 Stem total N		48	0.61***	0.74***	0.65***
7 Stem NO_3-N		48	0.55***	0.72***	0.72***
7 N uptake		48	0.68***	0.66***	0.38**

, * Significance at the 0.01 and 0.001 probability level, respectively.
† Number of observations used in correlations.

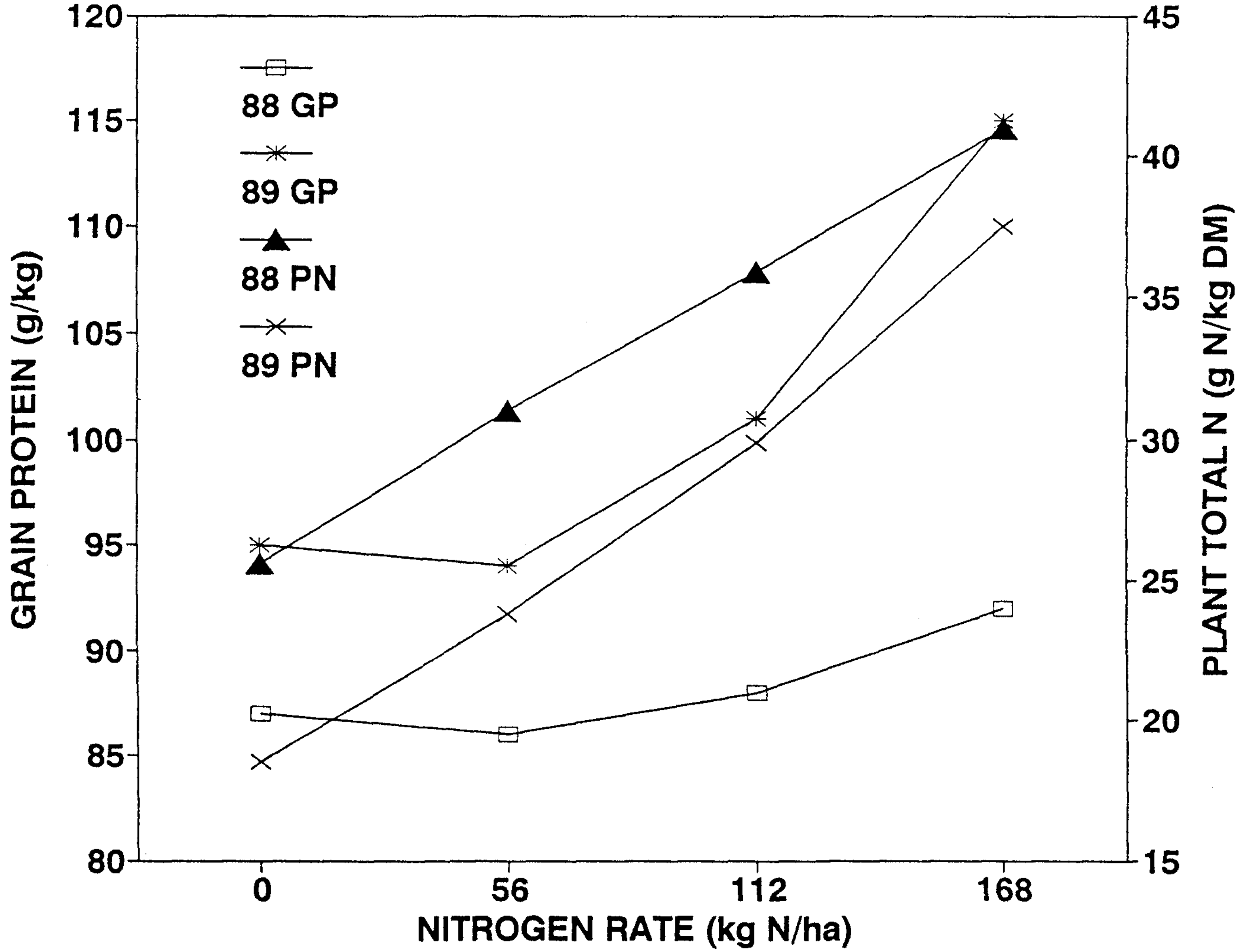

Fig. II.11 Nitrogen fertilizer treatment effects on grain protein and Feekes stage 7 plant total N means for 1988 and 1989.

When these correlations are made over years (Table II.4) all grain and protein yield correlations were at least moderate and highly significant. Plant total N at FS 7 was highly correlated with protein yield. Stem total N and stem NO_3-N were not significantly correlated with grain protein. Plant total N had a highly significant and weak correlation with grain protein. The dependence of grain protein on grain yield confounds the plant tissue parameters used for reliable, early determination of grain protein in high grain yield years. When compared across years, plant total N at FS 7 gave the best correlations with grain yield, protein yield and grain protein.

Table II.4. Pearson correlation coefficients for plant total N, stem total N and stem NO_3-N concentration means with grain yield, protein yield and grain protein means at Feekes stage 7 over 1988 and 1989.

Tissue Analysis	n	Grain Yield	Protein Yield	Grain Protein
		r		
Plant total N	72	0.72***	0.83***	0.36**
Stem total N	72	0.71***	0.75***	0.16
Stem NO_3-N	72	0.70***	0.75***	0.17

, * Significance at the 0.01 and 0.001 probability level, respectively.
Number of observations used in correlations.

Stepwise linear and quadratic models (not shown) were developed for the variables measured in this study using SAS, regression procedure with MAXR forward selection, and general linear model procedure for multiple regression (SAS, 1987). The coefficients of determination were not sufficiently improved over those of simple models to warrant their use. Therefore, coefficients of simple determination were used to describe the relationship of plant tissue analyses with grain yield, protein yield and grain protein by market class (Table II.5). Plant tissue analyses for both market classes were not well correlated with grain protein. There were highly significant correlations for plant tissue analyses and grain and protein yield. Soft white winter wheat and HRWW plant total N were moderately correlated with grain and protein yield using a simple quadratic and simple linear model, respectively.

Table II.5. Coefficients of determination for regression models to describe the relationship of plant tissue analysis by market class with grain yield, protein yield and grain protein at Feekes stage 7 over 1988 and 1989.

Tissue Analysis	Market Class	n	Grain Yield	Protein Yield	Grain Protein
	SWWW			r^2	
Plant total N		36	Q 0.72**	L 0.75***	L 0.11*
Stem total N		36	Q 0.66***	Q 0.77***	0.09
Stem NO_3-N		36	L 0.54***	Q 0.70**	Q 0.20*
	HRWW				
Plant total N		36	Q 0.62**	L 0.67***	L 0.18**
Stem total N		36	L 0.61***	L 0.61***	0.04
Stem NO_3-N		36	L 0.60***	L 0.60***	0.07

*, **, *** Significance at the 0.05, 0.01 and 0.001 probability level, respectively.
Number of observations used in correlations.
Soft white winter wheat - SWWW, hard red winter wheat - HRWW, linear - L, quadratic - Q.

From the plant tissue parameters tested, plant total N concentration (PN) gave the best correlation with grain yield (GY) and protein yield (PY) for both market classes. The curvilinear relationship for GY with PN at FS 7 over 1988-89 is shown in Fig. II.12. Maximum GY for SWWW of 9.5 Mg/ha was associated with a PN of 40 g N/kg. A maximum GY of 8 Mg/ha for HRWW was reached with a PN of 37 g N/kg. These relationships when considered with the critical N levels previously discussed, gave a CNR for SWWW and HRWW PN of 27-37 g N/kg. Figure II.13 depicts the linear relationship PY has with PN.

This study suggests plant total N concentration at early growth stages (FS 4-7) would be reliable for current season grain and protein yield prediction. Further work is needed to test these models and techniques for their early season ability to correctly predict unknown grain and protein yield data.

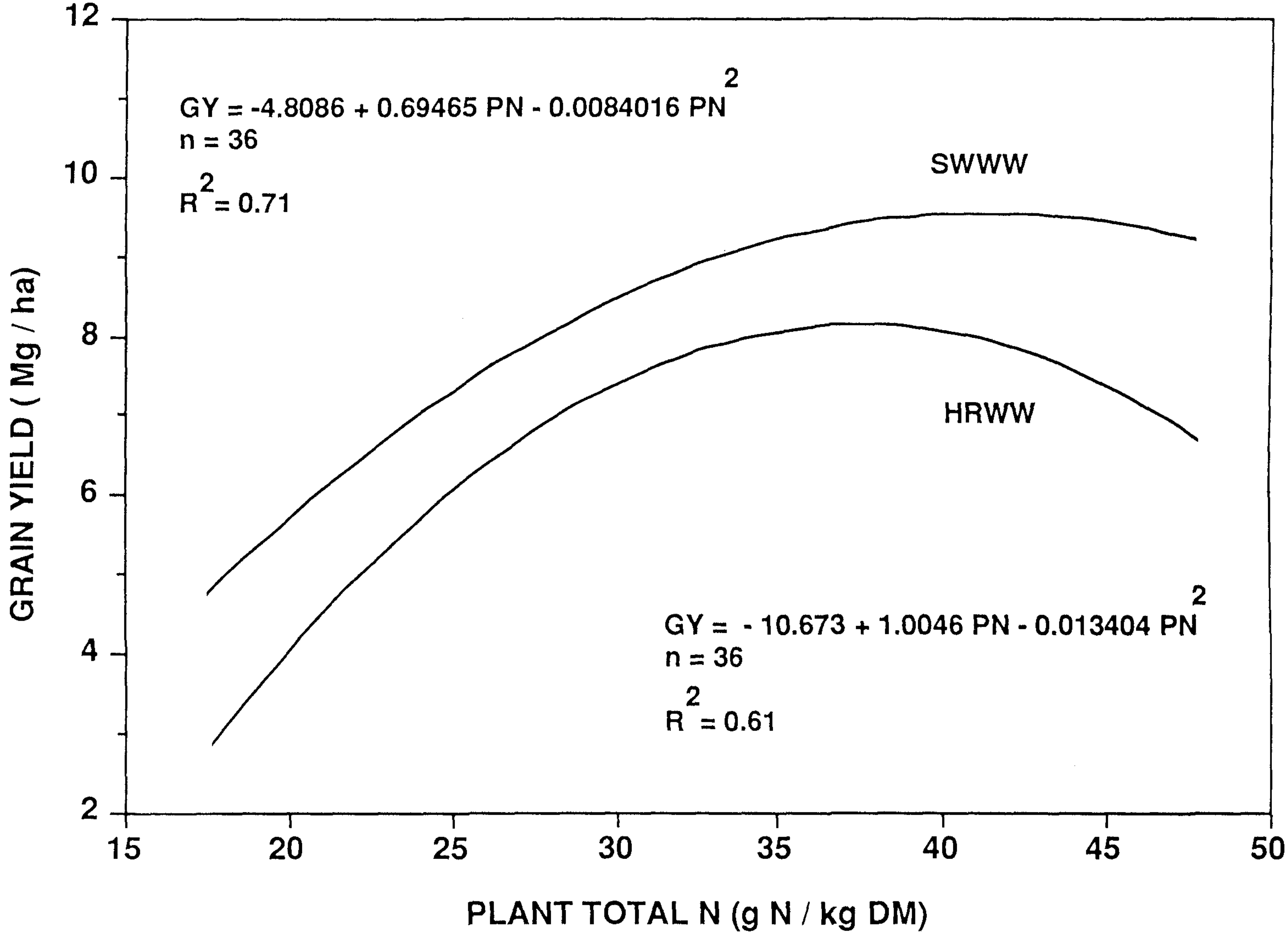

Fig. II.12 Grain yield relationship with market class plant total N at Feekes stage 7 over 1988 and 1989.

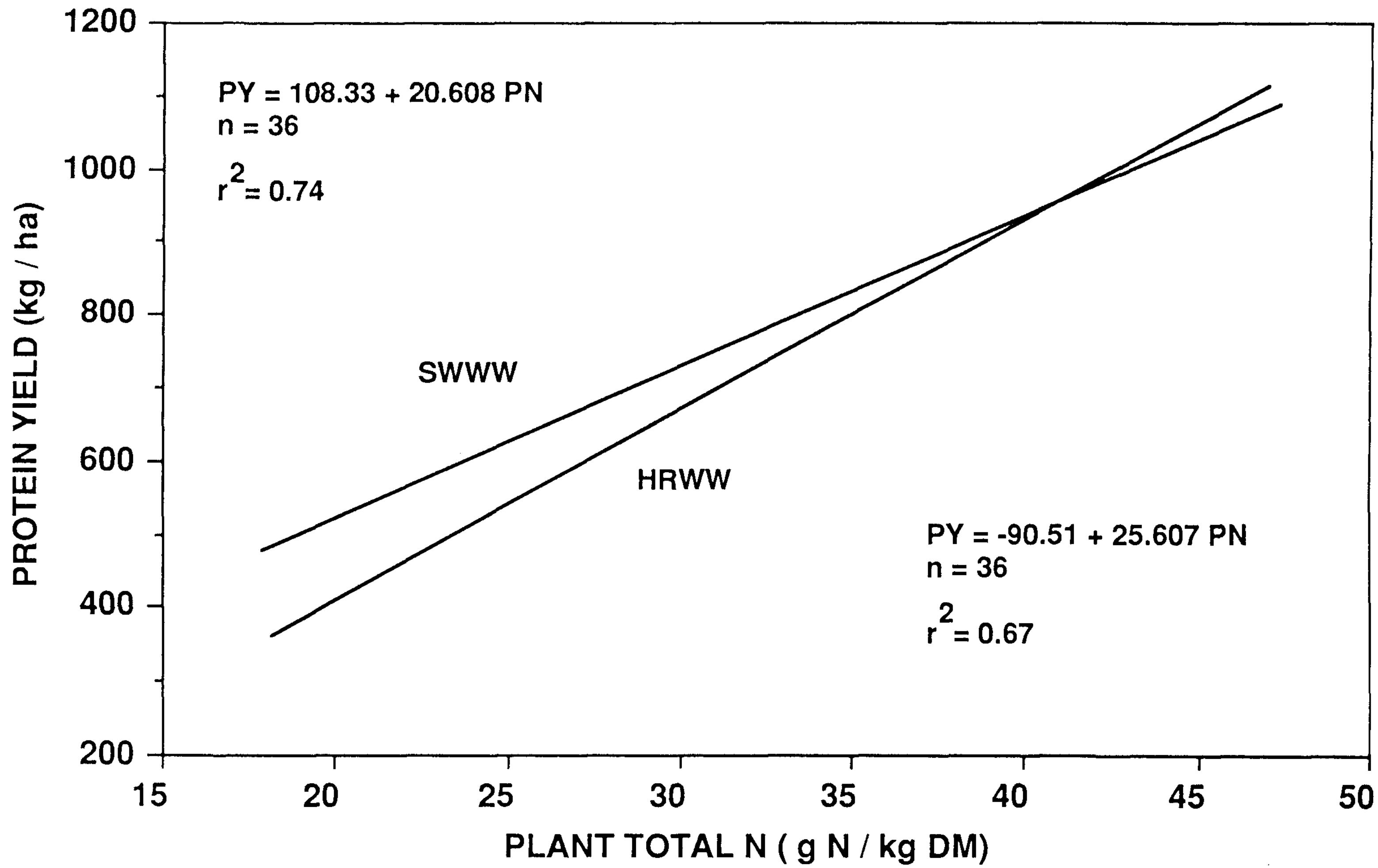

Fig. II.13 Protein yield relationship with market class plant total N at Feekes stage 7 over 1988 and 1989.

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SUMMARY AND CONCLUSIONS

Wheat cultivars have been developed with the potential for high grain yield and desired quality factors. The cultivars chosen for this study represent wide genetic diversity from two different breeding programs. Stephens and OR 8313 are from Oregon State University, and Dusty and Batum are from Washington State University.

General patterns for N uptake, dry matter accumulation and plant N over all Feekes stages were similar for all cultivars. SWWW and HRWW cultivars were not differentiated by market class for the parameters measured at early growth stages until FS 11.4 (maturity). The patterns and levels for cultivar plant N were relatively stable over two different grain yield and grain protein years. Though there were significant parameter differences at early Feekes stages (FS 4-7), they were due to cultivars, not market class. Plant tissue analysis of cultivar differences in this study at early growth stages was not a major factor explaining market class grain yield and grain protein differences. Thus, the use of plant tissue analysis at early growth stages for determination of plant N status and predictive purposes of winter wheats was more influenced by cultivar than market class.

In humid winter wheat producing areas N fertilizer management is a key factor influencing grain yield and grain protein. The ability to monitor plant N status at growth stages early enough to allow for current season correction of N deficiency would be beneficial to both growers and the environment. Efficient management converts genetic potential to the reality of high yields with desirable quality.

The N fertilizer treatments (0, 56, 112 and 168 kg N/ha) produced distinct differences measured by N uptake, dry matter accumulation plant N, stem N, and stem NO_3-N. The general patterns over growth stages were similar. At early growth stages FS 4-7 plant total N and N uptake parameters are sensitive enough to distinctly detect fertilizer treatment differences. Stem N and stem NO_3-N concentrations were not sensitive enough to provide clear distinctions between all fertilizer treatments, but they were able to distinguish N sufficiency.

Plant total N concentration at FS 7 gave the highest correlations with grain yield, protein yield and grain protein. The confounding effect of grain yield on grain protein made the use of plant tissue analysis at early growth stages during high grain yield years ineffective for correlating plant tissue parameters and grain protein. There was a highly significant, moderate correlation for all plant tissue parameters, except N uptake, with grain protein during low grain yield years. Plant total N at FS 4 and 7 was the plant tissue analysis which produced predictive models most strongly correlated with yield parameters for this study. Plant total N at FS 7 explained 62 and 72% of grain yield, and 67 and 75% of protein yield variability for HRWW and SWWW, respectively.

Optimum fertilizer N rate for SWWW production during this study was 112 kg N/ha. The potential benefit of higher grain protein for HRWW production, particularly in a lower grain yield year, may warrant a higher N rate. The critical plant total N level at FS 7 for both SWWW and HRWW cultivars compared in this study was determined by the Cate-Nelson method to be 27 g N/kg. The critical nutrient range for plant total N at FS 7 was 27 to 37 g N/kg. SWWW were more efficient at partitioning dry matter to grain than HRWW.

Higher grain protein for HRWW may be due to reduced carbohydrate dilution of grain N, rather than more efficient partitioning of N to the grain.

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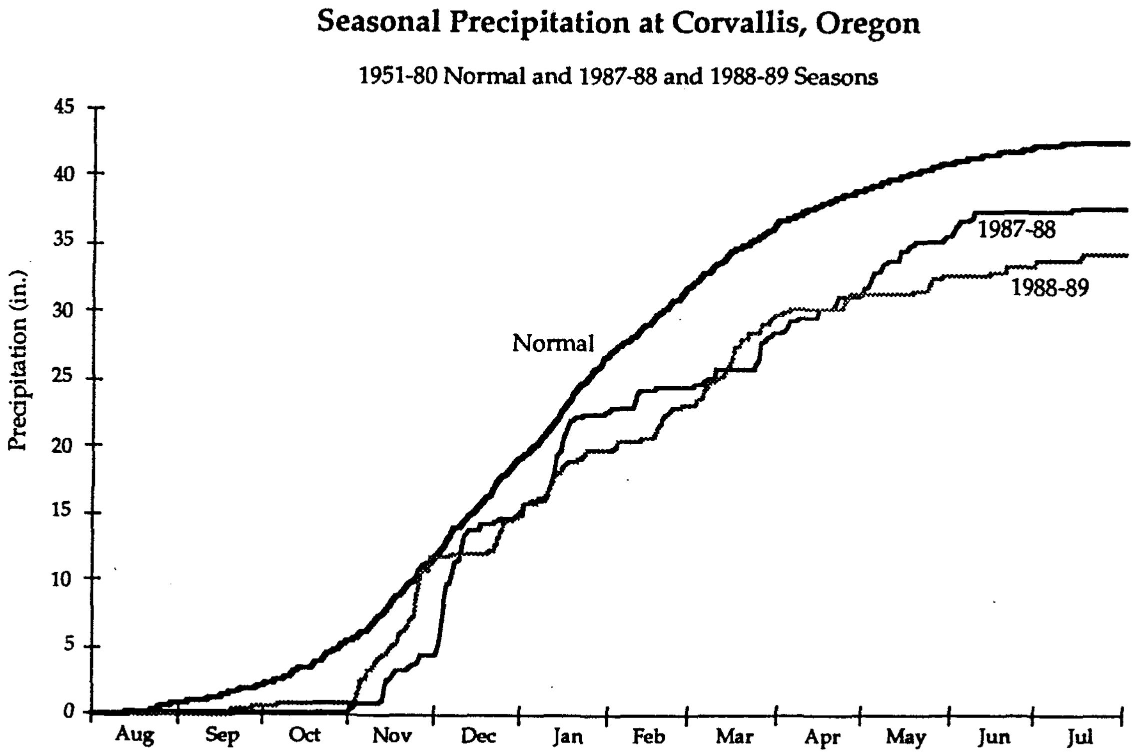
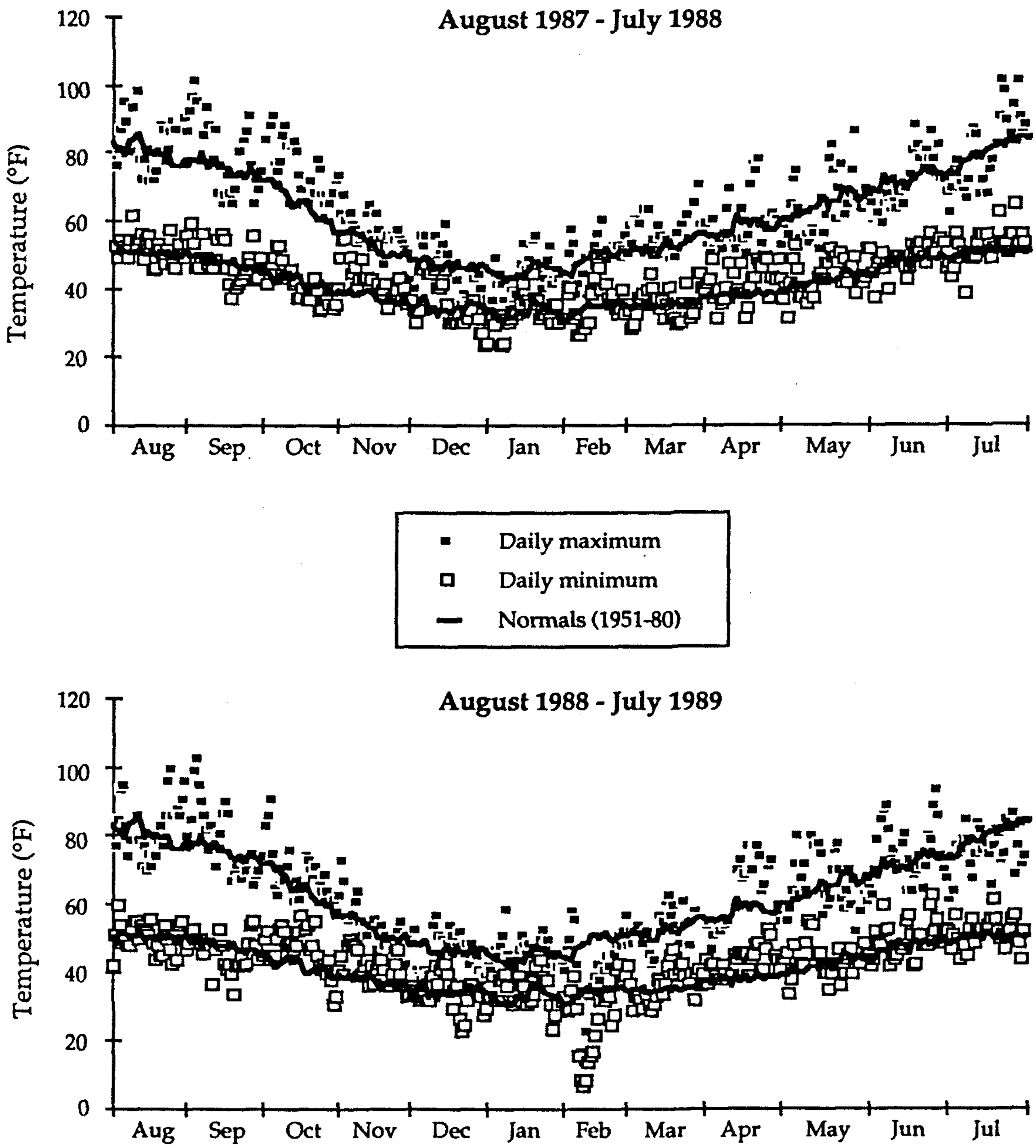
APPENDIX



Appendix Fig 1. Seasonal precipitation at Oregon State University Crop and Soil Science Hyslop Field Laboratory for 1988 and 1989.

Daily Maximum and Minimum Observed and Normal Temperatures at Hyslop Experimental Station, Corvallis



Appendix Fig 2. Daily maximum and minimum observed and normal temperatures at Oregon State University Crop and Soil Science Hyslop Field Laboratory for 1988 and 1989.

Appendix Table 1. Analysis of variance mean squares for cultivar and nitrogen rate dependent variables at different growth stages during 1988.

Source of Variation	Degrees of Freedom	Mean Squares					
		Feekes Stage 4		Feekes Stage 7			
		Plant N	Kjeldahl N	Plant N	Kjeldahl N	Stem N	Stem NO_3-N
Total	23						
Block	2	0.035	0.000	0.075	0.109	0.174	1011481.7
C	1	0.246*	0.051	0.360*	0.393*	1.025	1254968.4
N	3	0.687****	0.672****	2.609****	2.419****	3.604**	82864635.3****
C*N	3	0.034	0.107*	0.073	0.039	0.622	766960.7
Error	14	0.043	0.025	0.070	0.071	0.425	17127548.1
C.V. (%)		4.3	3.3	7.9	8.8	34.8	27.7
S.E.		0.208	0.158	0.264	0.266	0.652	1314.362
		%					PPM
Grand Mean		4.80	4.74	3.33	3.02	1.87	4750.5

C = cultivar (Stephens, OR 8313); N = nitrogen fertilizer (0, 56, 112 and 168 kg N/ha); C.V. = coefficient of variation; S.E. = standard error; *,**,***,**** Significant at the 0.05, 0.01, 0.001 and 0.0001 probability levels, respectively.

Appendix Table 2. Summary of treatment means for cultivar and nitrogen rate dependent variables at different growth stages during 1988.

		Feekes Stage 4		Feekes Stage 7			
		Plant N	Kjeldahl N	Plant N	Kjeldahl N	Stem N	Stem NO_3
Main Effect Means							
1 = STEPHENS		4.90	4.79	3.46	3.15	2.08	4521.9
2 = OR 8313		4.70	4.70	3.21	2.89	1.67	4979.2
LSD (0.05)		0.18	0.14	0.23	0.23	0.57	1150.9
1 = 0 N		4.38	4.30	2.56	2.26	0.94	945.0
2 = 56 N		4.70	4.74	3.10	2.82	1.54	2448.2
3 = 112 N		4.96	4.83	3.59	3.23	2.62	6580.7
4 = 168 N		5.17	5.11	4.10	3.76	2.39	9028.3
LSD (0.05)		0.26	0.20	0.33	0.33	0.81	1627.6
Level of Cultivar	Level of Nitrogen						
1	1	4.44	4.34	2.77	2.42	1.10	816.77
1	2	4.87	4.74	3.18	2.90	1.53	1689.33
1	3	4.98	4.75	3.57	3.27	3.30	6567.00
1	4	5.33	5.34	4.30	3.99	2.39	9014.33
2	1	4.33	4.27	2.34	2.11	0.79	1073.13
2	2	4.54	4.75	3.01	2.73	1.55	3207.00
2	3	4.94	4.90	3.60	3.19	1.94	6594.33
2	4	5.00	4.88	3.89	3.53	2.38	9042.33

N = nitrogen fertilizer (0, 56, 112 and 168 kg N/ha).

Appendix Table 3. Analysis of variance mean squares for cultivar and nitrogen rate dependent variables at different growth stages during 1988.

Source of Variation	Degrees of Freedom	Mean Squares					
		Feekes Stage 10				Feekes Stage 11.2	
		Plant N	Leaf N	Stem N	Stem NO_3	Head N	Leaf N
Total	23						
Block	2	0.036	0.035	0.006	212335.50	0.015	0.216*
C	1	0.011	0.657****	0.001	1468.75	0.073*	0.905**
N	3	0.834****	0.681****	0.578****	11777440.83****	0.102***	0.739***
C*N	3	0.048	0.024	0.005	72210.90	0.013	0.063
Error	14	0.026	0.016	0.013	510139.10	0.009	0.054
C.V. (%)		9.2	3.5	17.6	58.4	6.0	16.1
S.E.		0.160	0.128	0.115	714.240	0.094	0.231
		%			PPM	%	
Grand Mean		1.74	3.65	0.65	1222.39	1.56	1.44

C = cultivar (Stephens, OR 8313); N = nitrogen fertilizer (0, 56, 112 and 168 kg N/ha); C.V. = coefficient of variation; S.E. = standard error; *,**,***,**** Significant at the 0.05, 0.01, 0.001 and 0.0001 probability levels, respectively.

Appendix Table 4. Summary of treatment means for cultivar and nitrogen rate dependent variables at different growth stages during 1988.

		Feekes Stage 10				Feekes Stage 11.2	
		Plant N	Leaf N	Stem N	Stem NO_3	Head N	Leaf N
Main Effect Means							
1 = STEPHENS		1.76	3.82	0.66	1230.2	1.51	1.63
2 = OR 8313		1.72	3.49	0.65	1214.6	1.62	1.24
LSD (0.05)		0.14	0.11	0.10	625.39	0.08	0.20
1 = 0 N		1.32	3.23	0.38	66.9	1.41	1.04
2 = 56 N		1.54	3.56	0.47	273.3	1.53	1.25
3 = 112 N		2.00	3.83	0.69	1426.7	1.59	1.66
4 = 168 N		2.10	4.00	1.08	3122.7	1.72	1.79
LSD (0.05)		0.20	0.16	0.14	884.44	0.12	0.29
Level of Cultivar	Level of Nitrogen						
1	1	1.42	3.44	0.41	86.87	1.40	1.29
1	2	1.50	3.63	0.46	184.01	1.41	1.43
1	3	1.93	4.01	0.66	1369.97	1.54	1.95
1	4	2.19	4.20	1.10	3280.00	1.68	1.85
2	1	1.21	3.02	0.35	46.86	1.42	0.79
2	2	1.57	3.48	0.47	362.67	1.65	1.06
2	3	2.07	3.65	0.71	1483.40	1.64	1.38
2	4	2.01	3.81	1.05	2965.33	1.76	1.74

N = nitrogen fertilizer (0, 56, 112 and 168 kg N/ha).

Appendix Table 5. Analysis of variance mean squares for cultivar and nitrogen rate dependent variables at different growth stages during 1988.

Source of Variation	Degrees of Freedom	Mean Squares: Feekes Stage 11.2 Stem N	Feekes Stage 11.2 Stem NO_3	Feekes Stage 11.2 Plant N	Feekes Stage 11.4 Plant N	Feekes Stage 11.4 Dry Matter	Feekes Stage 11.4 HI	Feekes Stage 11.4 N Uptake	Feekes Stage 11.4 NHI
Total	23								
Block	2	0.021	211579.059	0.069*	0.005	5.054	0.000	153.254	0.004
C	1	0.016	26765.425	0.064*	0.004	58.270*	0.009***	2751.165	0.015*
N	3	0.160****	2562122.503***	0.462****	0.076**	65.620**	0.000	13809.117****	0.011*
C*N	3	0.008	98019.924	0.019	0.018	7.606	0.003**	1437.040	0.004
Error	14	0.011	216134.341	0.011	0.008	7.543	0.000	695.105	0.003
C.V. (%)		31.4	92.9	8.0	8.5	13.8	5.0	13.6	8.8
S.E.		0.105	464.903	0.105	0.091	2.747	0.020	26.365	0.057
		——%——	——PPM——	—————	%—————	—Mg/ha—		——lb/a——	
Grand Mean		0.34	500.38	1.31	1.08	19.89	0.40	193.70	0.64

C = cultivar (Stephens, OR 8313); N = nitrogen fertilizer (0, 56, 112 and 168 kg N/ha); HI = harvest index; NHI = nitrogen harvest index; C.V. = coefficient of variation; S.E. = standard error; *,**,***,**** Significant at the 0.05, 0.01, 0.001 and 0.0001 probability levels, respectively.

Appendix Table 6. Summary of treatment means for cultivar and nitrogen rate dependent variables at different growth stages during 1988.

		Feekes Stage 11.2			Feekes Stage 11.4				
		Stem N	Stem NO_3	Plant N	Plant N	Dry Matter	HI	N Uptake	NHI
Main Effect Means									
1 = STEPHENS		0.31	467.0	1.36	1.07	21.44	0.42	204.40	0.67
2 = OR 8313		0.36	533.8	1.26	1.09	18.33	0.38	182.99	0.62
LSD (0.05)		0.09	407.07	0.09	0.08	2.40	0.02	23.09	0.05
1 = 0 N		0.23	52.3	1.02	0.96	15.65	0.40	136.53	0.70
2 = 56 N		0.20	33.6	1.16	1.03	18.88	0.40	172.94	0.65
3 = 112 N		0.36	486.6	1.43	1.11	22.77	0.40	223.41	0.62
4 = 168 N		0.56	1429.0	1.64	1.23	22.24	0.40	241.90	0.60
LSD (0.05)		0.13	575.69	0.13	0.11	3.40	0.02	32.65	0.07
Level of Cultivar	Level of Nitrogen								
1	1	0.19	19.29	1.09	1.03	18.41	0.45	169.74	0.73
1	2	0.19	30.55	1.19	1.00	19.30	0.40	171.65	0.65
1	3	0.37	592.17	1.55	1.05	25.03	0.42	231.45	0.68
1	4	0.48	1225.93	1.63	1.20	23.04	0.40	244.78	0.61
2	1	0.26	85.35	0.94	0.90	12.90	0.35	103.33	0.66
2	2	0.21	36.75	1.13	1.06	18.46	0.39	174.24	0.65
2	3	0.34	381.00	1.32	1.17	20.51	0.38	215.37	0.56
2	4	0.63	1632.00	1.65	1.25	21.44	0.39	239.01	0.59

N = nitrogen fertilizer (0, 56, 112 and 168 kg N/ha); HI = harvest index; NHI = nitrogen harvest index.

Appendix Table 7. Analysis of variance mean squares for cultivar and nitrogen rate dependent variables at different growth stages during 1988.

Source of Variation	Degrees of Freedom	Mean Squares				
		Feekes Stage 11.4				
		1000 KWT	Grain Yield	Test Wt	Grain Protein	Protein Yield
Total	23					
Block	2	52.932	67.305	3.252	1.039	2204.292
C	1	47.320	955.082**	67.670****	0.770	1.500
N	3	62.938	2187.525****	1.390	0.646	97419.278****
C*N	3	42.297	245.356	3.627	0.074	14703.278
Error	14	42.955	105.073	2.385	0.502	5092.435
C.V. (%)		12.9	7.6	2.5	8.0	9.7
S.E.		6.554	10.251	1.544	0.709	71.361
		——g——	———bu/a———	——lb/bu——	——%——	———lb/a———
Grand Mean		50.95	134.96	61.83	8.84	737.58

C = cultivar (Stephens, OR 8313); N = nitrogen fertilizer (0, 56, 112 and 168 kg N/ha); KWT = kernel weight; C.V. = coefficient of variation; S.E. = standard error; *,**,***,**** Significant at the 0.05, 0.01, 0.001 and 0.0001 probability levels, respectively.

Appendix Table 8. Summary of treatment means for cultivar and nitrogen rate dependent variables at different growth stages during 1988.

		Feekes Stage 11.4				
		1000 KWT	Grain Yield	Test Wt	Grain Protein	Protein Yield
Main Effect Means						
1 = STEPHENS		52.36	141.27	60.15	8.66	737.83
2 = OR 8313		49.55	128.65	63.51	9.02	737.33
LSD (0.05)		5.74	8.98	1.35	0.62	62.48
1 = 0 N		54.92	108.70	61.58	8.68	577.50
2 = 56 N		46.98	133.30	62.12	8.58	709.83
3 = 112 N		50.95	146.48	61.28	8.77	783.17
4 = 168 N		50.97	151.35	62.33	9.32	879.83
LSD (0.05)		8.12	12.69	1.91	0.88	88.37
Level of Cultivar	Level of Nitrogen					
1	1	59.20	115.23	59.73	8.47	585.00
1	2	44.87	136.17	59.80	8.27	672.00
1	3	53.03	161.67	60.73	8.70	850.67
1	4	52.33	152.00	60.33	9.20	843.67
2	1	50.63	102.17	63.43	8.90	570.00
2	2	49.10	130.43	64.43	8.90	747.67
2	3	48.87	131.30	61.83	8.83	715.67
2	4	49.60	150.70	64.33	9.43	916.00

N = nitrogen fertilizer (0, 56, 112 and 168 kg N/ha); *,**,***,**** Significant at the 0.05, 0.01, 0.001 and 0.0001 probability levels, respectively.

Appendix Table 9. Analysis of variance mean squares for cultivar and nitrogen rate dependent variables at different growth stages during 1989.

		Mean Squares							
		Feekes Stage 7					Feekes Stage 10		
Source of Variation	Degrees of Freedom	Plant N	Stem N	Stem NO_3	Dry Matter	N Uptake	Leaf N	Stem N	Stem NO_3
Total	47								
Block	2	0.007	0.001	108792.9	0.055	304.988	0.077	0.018	210617.49
C	3	1.058****	0.233***	2160859.6**	1.623****	3056.235****	0.258***	0.071	1004062.83
N	3	8.021****	3.824****	60184155.1****	1.449****	24022.116****	2.690****	0.755****	12534402.09****
C*N	9	0.104*	0.067*	851706.9	0.120	621.433*	0.044	0.026	766228.72
Error	30	0.040	0.028	471708.5	0.097	234.531	0.029	0.029	575190.85
C.V. (%)		7.3	15.0	42.3	16.5	14.6	5.2	36.7	125.1
S.E.		0.199	0.168	686.810	0.311	15.314	0.171	0.171	758.413
		———%———		——PPM——	——t/a——	——lb/a——	———%———		——PPM——
Grand Mean		2.74	1.11	1623.20	1.89	104.80	3.29	0.466	606.42

C = cultivar (Stephens, OR 8313, Batum, Dusty); N = nitrogen fertilizer (0, 56, 112 and 168 kg N/ha); DM = dry matter; C.V. = coefficient of variation; S.E. = standard error; *,**,***,**** Significant at the 0.05, 0.01, 0.001 and 0.0001 probability levels, respectively.

Appendix Table 10. Summary of treatment means for cultivar and nitrogen rate dependent variables at different growth stages during 1989.

		Feekes Stage 7					Feekes Stage 10		
		Plant N	Stem N	Stem NO_3	Dry Matter	N Uptake	Leaf N	Stem N	Stem NO_3
Main Effect Means									
1 = STEPHENS		2.96	1.27	1980.4	1.83	112.13	3.41	0.50	634.3
2 = OR 8313		2.96	1.12	1967.1	1.39	82.87	3.39	0.51	857.4
3 = BATUM		2.72	1.15	1428.4	2.12	119.93	3.29	0.50	739.4
4 = DUSTY		2.33	0.93	1116.9	2.21	104.28	3.09	0.35	194.6
LSD (0.05)		0.17	0.14	572.63	0.26	12.77	0.14	0.14	632.33
1 = 0 N		1.85	0.62	49.1	1.37	49.65	2.81	0.28	18.4
2 = 56 N		2.38	0.78	168.9	2.01	93.89	3.03	0.31	29.5
3 = 112 N		2.99	1.16	1424.5	2.04	119.64	3.44	0.46	246.5
4 = 168 N		3.75	1.89	4850.3	2.13	156.03	3.89	0.82	2131.4
LSD (0.05)		0.17	0.14	572.63	0.26	12.77	0.14	0.14	632.33
Level of Cultivar	Level of Nitrogen								
1	1	1.84	0.62	62.13	1.39	51.37	2.77	0.27	22.74
1	2	2.57	0.79	178.30	1.94	99.98	3.15	0.36	32.35
1	3	3.26	1.34	1738.33	1.97	128.67	3.62	0.52	294.23
1	4	4.16	2.31	5943.00	2.02	168.51	4.09	0.86	2188.00
2	1	1.93	0.64	75.99	1.08	41.22	2.88	0.29	19.88
2	2	2.47	0.74	346.73	1.61	80.15	3.17	0.28	25.73
2	3	3.39	1.29	2554.33	1.54	104.20	3.52	0.45	287.10
2	4	4.04	1.80	4891.33	1.33	105.90	3.97	1.02	3096.73
3	1	1.97	0.70	23.07	1.31	51.35	2.92	0.30	17.59
3	2	2.41	0.90	65.20	2.13	102.49	2.91	0.34	38.28
3	3	2.87	1.16	1033.90	2.40	135.84	3.35	0.49	331.70
3	4	3.61	1.83	4591.33	2.63	190.05	4.00	0.88	2570.00
4	1	1.64	0.54	35.34	1.70	54.66	2.68	0.25	13.24
4	2	2.07	0.69	85.32	2.35	92.94	2.91	0.26	21.76
4	3	2.43	0.86	371.47	2.25	109.83	3.26	0.36	72.80
4	4	3.17	1.63	3975.33	2.53	159.68	3.50	0.54	670.67

N = nitrogen fertilizer (0, 56, 112 and 168 kg N/ha).

Appendix Table 11. Analysis of variance mean squares for cultivar and nitrogen rate dependent variables at different growth stages during 1989.

Source of Variation	Degrees of Freedom	Mean Squares						
		Feekes Stage 10			Feekes Stage 11.4			
		Plant N	Dry Matter	N Uptake	Plant N	Dry Matter	HI	N Uptake
Total	47							
Block	2	0.006	1.702	2082.374	0.012	8.235	0.000	684.448
C	3	0.163***	0.210	1178.202	0.095	8.874	0.009*	1577.542
N	3	1.624****	12.840****	43337.294****	0.448***	179.924****	0.001	41607.159****
C*N	9	0.043	0.951	2012.077	0.021****	5.833	0.002	593.913
Error	30	0.019	1.051	1200.122	0.010	5.674	0.002	881.508
C.V. (%)		7.8	22.7	21.2	9.3	15.8	13.3	19.9
S.E.		0.138	1.025	34.643	0.101	2.382	0.046	29.690
		——%——	——t/a——	——lb/a——	——%——	——Mg/ha——		——lb/a——
Grand Mean		1.78	4.52	163.17	1.08	15.09	0.35	148.86

C = cultivar (Stephens, OR 8313, Batum, Dusty); N = nitrogen fertilizer (0, 56, 112 and 168 kg N/ha); HI = harvest index; C.V. = coefficient of variation; S.E. = standard error; *,**,***,**** Significant at the 0.05, 0.01, 0.001 and 0.0001 probability levels, respectively.

Appendix Table 12. Summary of treatment means for cultivar and nitrogen rate dependent variables at different growth stages during 1989.

		Feekes Stage 10			Feekes Stage 11.4			
		Plant N	Dry Matter	N Uptake	Plant N	Dry Matter	HI	N Uptake
Main Effect Means								
1 = STEPHENS		1.86	4.60	176.43	1.03	14.39	0.39	138.34
2 = OR 8313		1.85	4.48	163.79	1.18	15.25	0.34	164.72
3 = BATUM		1.78	4.35	159.53	1.12	14.47	0.33	149.15
4 = DUSTY		1.61	4.65	152.92	0.99	16.24	0.34	143.21
LSD (0.05)		0.12	0.85	28.88	0.08	1.99	0.04	24.75
1 = 0 N		1.44	2.98	85.88	0.92	9.60	0.34	78.46
2 = 56 N		1.56	4.89	152.98	0.95	15.14	0.34	126.86
3 = 112 N		1.83	5.10	185.33	1.11	17.73	0.36	176.43
4 = 168 N		2.27	5.12	228.48	1.34	17.89	0.35	213.67
LSD (0.05)		0.12	0.85	28.88	0.08	1.99	0.04	24.75
Level of Cultivar	Level of Nitrogen							
1	1	1.42	2.93	83.85	0.82	8.13	0.35	59.30
1	2	1.65	5.19	170.60	0.89	13.66	0.38	108.65
1	3	1.93	4.77	182.66	1.06	17.32	0.42	163.34
1	4	2.44	5.50	268.62	1.35	18.46	0.39	222.05
2	1	1.48	2.82	83.62	1.05	8.94	0.35	82.47
2	2	1.61	5.21	166.90	1.06	16.75	0.29	159.10
2	3	1.87	5.82	216.44	1.21	17.97	0.36	197.69
2	4	2.45	4.07	188.19	1.42	17.32	0.33	219.63
3	1	1.50	3.13	94.48	0.84	10.81	0.34	81.40
3	2	1.47	4.14	121.95	1.04	12.68	0.32	116.01
3	3	1.80	4.74	170.45	1.16	17.97	0.30	185.71
3	4	2.33	5.39	251.25	1.45	16.43	0.35	213.49
4	1	1.35	3.02	81.57	0.98	10.49	0.32	90.66
4	2	1.52	5.00	152.47	0.80	17.48	0.35	123.69
4	3	1.70	5.05	171.77	1.02	17.64	0.36	158.99
4	4	1.87	5.52	205.87	1.15	19.35	0.32	199.52

N = nitrogen fertilizer (0, 56, 112 and 168 kg N/ha); HI = harvest index.

Appendix Table 13. Analysis of variance mean squares for cultivar and nitrogen rate dependent variables at different growth stages during 1989.

Source of Variation	Degrees of Freedom	Mean Squares					
		Feekes Stage 11.4					
		NHI	Grain Yield	Test Wt	Grain Protein	Protein Yield	1000 KWT
Total	47						
Block	2	0.002	707.079**	3.090**	0.407	26387.437*	13.270
C	3	0.057**	1284.470****	33.899****	9.860****	45740.722***	351.792****
N	3	0.026	7909.769****	0.484	12.074****	451723.722****	45.371**
C*N	9	0.024*	75.847	1.191	0.583**	5152.370	11.778
Error	30	0.009	98.961	0.580	0.155	5070.282	9.306
C.V. (%)		14.6	10.8	1.3	3.9	12.9	7.0
S.E.		0.095	9.948	0.761	0.394	71.206	3.051
			———bu/a———	———lb/bu———	———%———	———lb/a———	———g———
Grand Mean		0.65	91.82	58.63	10.11	551.00	43.356

C = cultivar (Stephens, OR 8313, Batum, Dusty); N = nitrogen fertilizer (0, 56, 112 and 168 kg N/ha); NHI = nitrogen harvest index; KWT = kernel weight; C.V. = coefficient of variation; S.E. = standard error; *,**,***,**** Significant at the 0.05, 0.01, 0.001 and 0.0001 probability levels, respectively.

Appendix Table 14. Summary of treatment means for cultivar and nitrogen rate dependent variables at different growth stages during 1989.

		Feekes Stage 11.4					
		NHI	Grain Yield	Test Wt	Grain Protein	Protein Yield	1000 KWT
Main Effect Means							
	1 = STEPHENS	0.70	100.87	57.31	9.89	584.50	50.70
	2 = OR 8313	0.55	85.18	59.48	11.43	590.08	43.98
	3 = BATUM	0.67	80.82	57.16	9.74	459.25	40.36
	4 = DUSTY	0.67	100.43	60.59	9.37	570.17	38.39
	LSD (0.05)	0.08	8.29	0.63	0.33	59.37	2.64
	1 = 0 N	0.69	56.33	58.52	9.47	312.33	43.91
	2 = 56 N	0.67	89.75	58.42	9.35	489.25	45.64
	3 = 112 N	0.64	108.66	58.75	10.08	641.92	42.88
	4 = 168 N	0.59	112.55	58.85	11.53	760.50	40.99
	LSD (0.05)	0.08	8.29	0.63	0.33	59.37	2.54
Level of Cultivar	Level of Nitrogen						
1	1	0.77	57.57	56.17	9.13	296.00	48.50
1	2	0.75	98.13	56.93	9.23	515.33	54.70
1	3	0.70	123.17	57.60	9.97	708.00	49.90
1	4	0.59	124.60	58.53	11.23	818.67	49.70
2	1	0.57	50.67	59.70	10.80	329.33	43.57
2	2	0.49	81.37	59.10	10.30	495.33	47.30
2	3	0.60	102.90	59.77	11.47	707.33	44.53
2	4	0.53	105.77	59.33	13.13	828.33	40.50
3	1	0.85	53.80	57.37	8.57	264.33	41.73
3	2	0.64	78.43	56.87	8.93	397.00	41.73
3	3	0.58	91.77	56.90	9.90	516.67	38.73
3	4	0.61	99.27	57.50	11.57	659.00	39.23
4	1	0.59	63.27	60.83	9.37	359.67	41.83
4	2	0.79	101.07	60.77	8.93	549.33	38.83
4	3	0.70	116.80	60.73	8.97	635.67	38.37
4	4	0.61	120.57	60.03	10.20	736.00	34.53

N = nitrogen fertilizer (0, 56, 112 and 168 kg N/ha); KWT = kernel weight.

Appendix Table 15. Field data for parameters measured in 1988.

			FS 4		FS 7				FS 10.3				FS11.2	
B	C	N	Plant N	KJN	Plant N	KJN	Stem N	Stem NO_3	Plant N	Leaf N	Stem N	Stem NO_3	Plant N	Head N
			%					PPM	%			PPM	%	
1	1	1	4.61	4.54	3.15	2.60	1.23	1263.0	1.55	3.65	0.44	183.30	1.22	1.42
1	1	2	4.92	4.87	3.47	3.10	1.64	1732.0	1.58	3.68	0.47	163.80	1.40	1.49
1	1	3	4.79	4.70	3.33	3.22	1.92	4680.0	1.87	3.97	0.52	463.90	1.52	1.39
1	1	4	5.31	5.30	4.17	3.97	2.29	8835.0	2.37	4.17	1.30	4827.00	1.70	1.72
1	2	1	4.37	4.30	2.30	1.95	0.87	2717.0	1.34	3.04	0.33	35.99	0.93	1.41
1	2	2	4.07	4.57	3.04	2.79	1.53	2717.0	1.65	3.54	0.47	458.70	1.23	1.80
1	2	3	4.97	4.87	3.89	3.56	1.94	6732.0	1.85	3.64	0.59	840.20	1.42	1.73
1	2	4	5.04	4.80	4.12	3.66	2.68	11229.0	2.19	4.02	1.15	3485.00	1.91	1.93
2	1	1	4.45	4.37	2.78	2.54	1.13	983.8	1.40	3.45	0.45	35.51	1.09	1.40
2	1	2	4.79	4.70	2.79	2.51	1.20	1008.0	1.56	3.42	0.43	98.73	1.07	1.34
2	1	3	4.94	4.90	3.63	3.22	5.22	5746.0	2.20	3.97	0.69	1623.00	1.71	1.57
2	1	4	5.09	5.13	4.31	3.78	2.32	8287.0	2.08	4.08	0.89	1980.00	1.64	1.69
2	2	1	4.37	4.30	2.42	2.23	0.71	318.1	1.11	2.94	0.29	52.34	0.93	1.44
2	2	2	4.73	4.80	2.80	2.54	1.55	3627.0	1.45	3.41	0.44	161.90	1.06	1.54
2	2	3	4.79	4.87	3.23	2.60	1.93	6725.0	2.29	3.65	0.71	1223.00	1.28	1.58
2	2	4	5.00	4.90	3.96	3.66	2.26	8039.0	1.88	3.75	1.07	3102.00	1.49	1.72
3	1	1	4.25	4.10	2.39	2.11	0.93	203.5	1.32	3.23	0.34	41.80	0.97	1.37
3	1	2	4.89	4.64	3.28	3.10	1.75	2328.0	1.35	3.78	0.48	289.50	1.10	1.39
3	1	3	5.21	4.64	3.75	3.38	2.75	9275.0	1.72	4.09	0.77	2023.00	1.41	1.67
3	1	4	5.60	5.60	4.43	4.21	2.57	9921.0	2.11	4.35	1.12	3033.00	1.54	1.63
3	2	1	4.25	4.20	2.31	2.14	0.78	184.3	1.18	3.08	0.43	52.26	0.97	1.41
3	2	2	4.81	4.87	3.19	2.85	1.57	3277.0	1.62	3.50	0.50	467.40	1.10	1.60
3	2	3	5.06	4.97	3.69	3.41	1.96	6326.0	2.08	3.65	0.84	2387.00	1.25	1.60
3	2	4	4.96	4.93	3.59	3.28	2.21	7859.0	1.95	3.65	0.92	2309.00	1.56	1.64

B = block; C = cultivar, 1 = Stephens, 2 = OR 8313; N = nitrogen fertilizer, 1 = 0 kg N/ha, 2 = 56 kg N/ha, 3 = 112 kg N/ha, 4 = 168 kg N/ha; KJN = Kjeldahl nitrogen.

Appendix Table 16. Field data for parameters measured in 1988.

			FS 11.2			FS 11.4									
B	C	N	Leaf N	Stem N	Stem NO_3	Plant N	Dry Matter	HI	N Uptake	NHI	1000 KWT	Grain Yield	Test Wt	Grain Protein	Protein Yield
			%		PPM	%	Mg/ha		lb/a		g	bu/a	g	%	lb/a
1	1	1	1.56	0.23	25.32	1.06	19.8	0.44	187.81	0.68	59.9	115.2	60.2	8.3	576
1	1	2	1.89	0.25	41.05	0.89	19.4	0.39	154.28	0.68	55.1	146.5	60.2	8.0	705
1	1	3	2.19	0.25	192.30	0.90	29.4	0.41	236.61	0.67	50.9	170.3	61.0	7.5	779
1	1	4	1.70	0.73	2465.00	1.17	22.1	0.39	230.50	0.59	49.6	152.4	60.3	9.1	837
1	2	1	0.78	0.29	8.90	0.92	13.8	0.38	112.99	0.56	50.8	114.8	64.2	7.0	516
1	2	2	1.13	0.21	37.39	1.13	16.3	0.41	164.08	0.63	49.3	128.5	64.6	8.9	739
1	2	3	1.50	0.48	749.50	1.23	23.6	0.37	258.85	0.54	48.9	123.5	64.3	9.1	722
1	2	4	2.15	0.65	1966.00	1.33	20.6	0.39	244.16	0.56	50.0	150.7	64.9	9.7	949
2	1	1	1.34	0.16	16.84	1.03	20.2	0.45	185.79	0.77	60.2	131.1	59.7	8.9	696
2	1	2	1.22	0.14	24.04	1.05	20.9	0.42	196.12	0.64	55.4	133.4	59.8	8.2	654
2	1	3	2.19	0.56	1151.00	1.14	20.4	0.42	207.82	0.71	53.5	157.6	61.0	9.8	941
2	1	4	1.96	0.37	706.70	1.30	20.6	0.41	239.48	0.59	51.6	147.7	60.5	9.4	840
2	2	1	0.76	0.31	212.40	0.89	12.5	0.35	99.63	0.77	54.1	105.2	63.6	10.1	675
2	2	2	1.01	0.20	32.45	1.10	20.1	0.37	197.01	0.61	49.2	130.7	64.1	9.1	762
2	2	3	1.35	0.27	205.20	1.06	17.1	0.37	162.05	0.59	49.7	136.7	56.9	8.7	677
2	2	4	1.43	0.66	1124.00	1.29	20.4	0.38	235.17	0.53	50.2	139.1	63.9	9.1	809
3	1	1	0.98	0.19	15.71	1.00	15.2	0.46	135.61	0.74	57.5	99.4	59.3	8.2	483
3	1	2	1.18	0.17	26.55	1.05	17.6	0.38	164.55	0.61	24.1	128.6	59.4	8.6	657
3	1	3	1.47	0.31	433.20	1.11	25.2	0.42	249.92	0.65	54.7	157.1	60.2	8.8	832
3	1	4	1.88	0.35	506.10	1.12	26.4	0.41	264.35	0.65	55.8	155.9	60.2	9.1	854
3	2	1	0.83	0.18	34.74	0.88	12.4	0.31	97.38	0.65	47.0	86.5	62.5	9.6	519
3	2	2	1.05	0.22	40.41	0.95	19.1	0.40	161.64	0.72	48.8	132.1	64.6	8.7	742
3	2	3	1.28	0.28	188.30	1.21	20.8	0.39	225.23	0.55	48.0	133.7	64.3	8.7	748
3	2	4	1.63	0.58	1806.00	1.14	23.4	0.41	237.72	0.67	48.6	162.3	64.2	9.5	990

B = block; C = cultivar, 1 = Stephens, 2 = OR 8313; N = nitrogen fertilizer, 1 = 0 kg N/ha, 2 = 56 kg N/ha, 3 = 112 kg N/ha, 4 = 168 kg N/ha; HI = harvest index; NHI = nitrogen harvest index; KWT = kernel wt.

Appendix Table 17. Field data for parameters measured in 1989.

B	C	N	FS 7 Plant N	FS 7 Stem N	FS 7 Stem NO_3	FS 7 Dry Matter	FS 7 N Uptake	FS 10 Plant N	FS 10 Stem N	FS 10 Stem NO_3	FS 10 Leaf N	FS 10 Dry Matter	FS 10 N Uptake
			%	%	PPM	t/a	lb/a	%	%	PPM	%	t/a	lb/a
1	1	1	1.82	0.60	22.76	1.56	56.75	1.27	0.32	20.79	2.67	2.49	63.15
1	1	2	2.59	0.73	129.10	2.17	112.45	1.63	0.27	36.51	3.09	5.30	172.93
1	1	3	3.09	1.30	1203.00	1.86	114.88	1.84	0.51	242.70	3.69	6.48	238.41
1	1	4	4.24	2.30	6425.00	1.56	132.22	2.42	0.75	2175.00	4.11	5.80	281.35
1	2	1	2.16	0.74	105.00	0.78	33.68	1.51	0.33	17.91	2.76	2.11	63.89
1	2	2	2.35	0.79	493.00	1.52	71.59	1.61	0.27	19.79	3.19	4.85	155.91
1	2	3	3.54	1.43	3411.00	1.28	90.86	1.79	0.35	129.70	3.40	7.82	279.89
1	2	4	3.60	1.23	2401.00	1.42	101.90	2.08	0.58	895.20	3.63	5.90	244.90
1	3	1	2.11	0.74	15.54	0.90	37.96	1.60	0.32	12.52	3.27	2.97	95.39
1	3	2	2.38	0.88	58.94	2.23	106.18	1.54	0.41	74.33	2.99	4.34	134.14
1	3	3	3.01	1.22	1103.00	2.28	137.18	1.85	0.65	497.20	3.29	4.63	171.64
1	3	4	3.69	2.03	4777.00	2.52	185.87	2.51	1.12	3938.00	4.22	5.45	273.01
1	4	1	1.65	0.51	21.64	2.15	66.12	1.30	0.21	11.29	2.60	3.38	88.07
1	4	2	2.22	0.73	99.37	2.75	108.21	1.54	0.34	33.72	3.09	6.36	195.54
1	4	3	2.40	0.81	314.00	1.95	93.84	1.66	0.35	66.63	3.23	4.85	161.00
1	4	4	3.12	1.63	4235.00	2.35	146.68	1.93	0.55	620.20	3.66	5.09	195.80
2	1	1	1.91	0.67	133.50	1.21	46.27	1.49	0.24	26.43	2.80	3.24	96.70
2	1	2	2.60	0.77	157.60	2.15	111.63	1.62	0.44	18.67	2.98	5.85	189.91
2	1	3	3.04	1.25	1544.00	2.21	134.17	1.92	0.49	238.50	3.43	4.29	164.57
2	1	4	4.02	2.25	5696.00	2.43	195.75	2.44	0.86	2014.00	4.02	6.50	317.86
2	2	1	1.84	0.51	31.71	1.10	40.60	1.47	0.25	14.95	2.86	3.84	113.09
2	2	2	2.44	0.67	181.30	1.72	83.69	1.57	0.27	37.18	3.01	7.20	225.35
2	2	3	3.35	1.15	2162.00	1.82	122.14	1.91	0.57	436.60	3.57	4.56	173.85
2	2	4	4.59	2.14	6500.00	0.92	84.78	2.91	1.65	6036.00	4.19	2.09	121.32

B = block; C = cultivar, 1 = Stephens, 2 = OR 8313, 3 = Batum, 4 = Dusty; N = nitrogen fertilizer, 1 = 0 kg N/ha, 2 = 56 kg N/ha, 3 = 112 kg N/ha, 4 = 168 kg N/ha.

Appendix Table 18. Field data for parameters measured in 1989.

			FS 7					FS 10						
B	C	N	Plant N	Stem N	Stem NO_3	Dry Matter	N Uptake	Plant N	Stem N	Stem NO_3	Leaf N	Dry Matter	N Uptake
			%		PPM	t/a	lb/a	%		PPM	%	t/a	lb/a
2	3	1	1.97	0.67	26.16	1.54	60.49	1.38	0.35	29.03	2.68	3.02	83.56
2	3	2	2.45	1.00	105.00	1.97	96.38	1.45	0.27	13.97	2.87	3.79	109.66
2	3	3	2.72	1.16	729.70	2.69	140.24	1.87	0.41	312.20	3.55	4.63	172.91
2	3	4	3.68	1.78	4749.00	2.71	199.49	2.18	0.76	1449.00	3.79	5.23	228.33
2	4	1	1.59	0.48	17.68	1.55	49.20	1.32	0.31	14.47	2.60	3.02	79.85
2	4	2	2.11	0.76	110.40	1.81	76.42	1.44	0.19	15.80	2.76	4.29	124.07
2	4	3	2.40	0.85	423.00	2.11	101.32	1.65	0.31	95.06	3.18	4.97	163.66
2	4	4	3.37	1.84	4841.00	2.52	169.75	1.81	0.69	1064.00	3.22	5.21	188.54
3	1	1	1.79	0.59	30.12	1.43	51.09	1.50	0.24	20.99	2.85	3.05	91.69
3	1	2	2.51	0.88	248.20	1.51	75.86	1.69	0.38	41.87	3.38	4.41	148.97
3	1	3	3.66	1.48	2468.00	1.87	136.95	2.04	0.56	401.50	3.74	3.55	145.00
3	1	4	4.23	2.38	5708.00	2.10	177.56	2.46	0.97	2375.00	4.13	4.20	206.63
3	2	1	1.79	0.66	91.25	1.38	49.38	1.47	0.28	26.79	3.03	2.52	73.87
3	2	2	2.63	0.76	365.90	1.62	85.17	1.66	0.3	20.23	3.30	3.60	119.43
3	2	3	3.27	1.28	2090.00	1.52	99.61	1.92	0.43	295.00	3.60	5.09	195.58
3	2	4	3.93	2.02	5773.00	1.67	131.03	2.35	0.83	2359.00	4.10	4.22	198.34
3	3	1	1.84	0.69	27.51	1.51	55.61	1.53	0.23	11.21	2.81	3.41	104.50
3	3	2	2.39	0.81	31.67	2.19	104.91	1.42	0.34	26.53	2.86	4.29	122.04
3	3	3	2.87	1.10	1269.00	2.27	130.11	1.68	0.42	185.70	3.22	4.97	166.82
3	3	4	3.47	1.67	4248.00	2.66	184.78	2.30	0.76	2323.00	3.98	5.49	252.42
3	4	1	1.69	0.63	66.71	1.44	48.65	1.44	0.23	13.95	2.84	2.66	76.79
3	4	2	1.87	0.58	46.20	2.52	94.20	1.58	0.25	15.75	2.88	4.37	137.80
3	4	3	2.50	0.93	377.40	2.69	134.33	1.79	0.41	56.71	3.37	5.33	190.64
3	4	4	3.03	1.41	2850.00	2.75	162.59	1.86	0.37	327.80	3.61	6.28	233.26

B = block; C = cultivar, 1 = Stephens, 2 = OR 8313, 3 = Batum, 4 = Dusty; N = nitrogen fertilizer, 1 = 0 kg N/ha, 2 = 56 kg N/ha, 3 = 112 kg N/ha, 4 = 168 kg N/ha.

Appendix Table 19. Field data for parameters measured in 1989.

B	C	N	Plant N	Dry Matter	HI	N Uptake	NHI	Grain Yield	Test Wt	Grain Protein	Protein Yield	1000 KWT
			FS 11.4									
			%	Mg/ha		lb/a		bu/a	g	%	lb/a	g
1	1	1	0.83	8.29	0.42	61.46	0.90	64.5	56.8	9.2	337	48.7
1	1	2	0.86	13.90	0.37	106.77	0.77	105.5	57.6	9.0	547	48.8
1	1	3	1.07	18.30	0.48	174.78	0.73	139.5	58.4	10.0	815	46.0
1	1	4	1.41	19.27	0.36	242.61	0.49	126.1	58.7	11.2	829	48.3
1	2	1	0.88	10.00	0.37	78.58	0.66	51.3	59.8	10.7	328	43.1
1	2	2	1.17	17.32	0.30	180.93	0.43	80.1	59.6	10.1	482	55.1
1	2	3	1.00	14.39	0.38	128.50	0.74	113.5	60.2	11.9	813	46.5
1	2	4	1.38	18.78	0.33	231.43	0.54	130.1	60.3	13.4	1051	40.8
1	3	1	0.89	10.73	0.34	85.29	0.81	50.7	58.6	8.1	240	44.5
1	3	2	0.95	17.32	0.36	146.91	0.76	88.8	56.7	8.5	428	44.6
1	3	3	1.14	17.32	0.31	176.29	0.62	92.9	57.2	9.8	521	39.0
1	3	4	1.54	17.32	0.33	238.14	0.57	113.6	58.6	11.3	753	40.4
1	4	1	0.86	12.68	0.30	97.40	0.62	68.3	60.7	9.1	377	42.3
1	4	2	0.74	20.00	0.29	132.16	0.68	107.7	61.0	9.1	598	38.5
1	4	3	1.06	17.56	0.32	166.22	0.60	125.8	61.3	8.4	648	39.5
1	4	4	1.16	21.47	0.35	222.33	0.67	131.8	60.7	10.0	799	35.2
2	1	1	0.79	8.05	0.32	56.78	0.73	54.5	56.7	9.3	288	48.6
2	1	2	0.93	11.22	0.38	93.17	0.72	80.4	55.7	9.5	425	59.6
2	1	3	0.97	18.05	0.41	156.34	0.77	115.0	57.1	9.8	644	52.1
2	1	4	1.30	19.27	0.37	223.68	0.55	117.1	57.8	11.6	785	50.9
2	2	1	1.28	8.05	0.42	92.00	0.57	56.5	60.0	11.8	400	42.8
2	2	2	1.14	16.83	0.29	171.32	0.45	83.4	59.3	10.7	529	46.9
2	2	3	1.37	21.95	0.38	268.55	0.55	90.1	58.9	11.2	594	45.5
2	2	4	1.49	19.03	0.34	253.13	0.54	94.8	59.5	13.1	740	40.3

B = block; C = cultivar, 1 = Stephens, 2 = OR 8313, 3. = Batum, 4 = Dusty; N = nitrogen fertilizer, 1 = 0 kg N/ha, 2 = 56 kg N/ha, 3 = 112 kg N/ha, 4 = 168 kg N/ha; HI = harvest index; NHI = nitrogen harvest index; KWT = kernel wt.

Appendix Table 20. Field data for parameters measured in 1989.

B	C	N	FS 11.4									
			Plant N	Dry Matter	HI	N Uptake	NHI	Grain Yield	Test Wt	Grain Protein	Protein Yield	1000 KWT
			%	Mg/ha		lb/a		bu/a	g	%	lb/a	g
2	3	1	0.84	10.73	0.32	80.50	0.89	57.1	56.1	8.9	285	39.9
2	3	2	1.02	9.27	0.30	84.42	0.62	69.5	57.4	9.1	363	41.2
2	3	3	1.16	15.61	0.22	161.69	0.42	84.0	55.9	10.2	479	37.3
2	3	4	1.45	17.81	0.38	230.54	0.67	85.3	57.1	12.1	589	38.3
2	4	1	1.00	7.81	0.36	69.70	0.66	63.0	60.6	9.3	355	45.4
2	4	2	0.79	16.34	0.35	115.28	0.83	86.5	60.6	8.9	467	37.6
2	4	3	1.05	14.15	0.40	132.64	0.72	126.1	61.2	9.3	718	40.1
2	4	4	1.20	20.49	0.32	219.54	0.61	127.4	61.0	9.8	762	36.4
3	1	1	0.83	8.05	0.30	59.66	0.68	53.7	55.0	8.9	263	48.2
3	1	2	0.89	15.86	0.40	126.00	0.77	108.5	57.5	9.2	574	55.7
3	1	3	1.14	15.61	0.37	158.91	0.59	115.0	57.3	10.1	665	51.6
3	1	4	1.33	16.83	0.45	199.88	0.72	130.6	59.1	10.9	842	49.9
3	2	1	0.98	8.78	0.27	76.84	0.47	44.2	59.3	9.9	260	44.8
3	2	2	0.87	16.10	0.29	125.06	0.59	80.6	58.4	10.1	475	39.9
3	2	3	1.25	17.56	0.33	196.02	0.51	105.1	60.2	11.3	715	41.6
3	2	4	1.38	14.15	0.33	174.33	0.52	92.4	58.2	12.9	694	40.4
3	3	1	0.80	10.98	0.35	78.41	0.86	53.6	57.4	8.7	268	40.8
3	3	2	1.14	11.46	0.31	116.70	0.53	77.0	56.5	9.2	400	39.4
3	3	3	1.17	20.98	0.37	219.15	0.70	98.4	57.6	9.7	550	39.9
3	3	4	1.36	14.15	0.33	171.80	0.61	98.9	56.8	11.3	635	39.0
3	4	1	1.07	10.98	0.30	104.87	0.49	58.5	61.2	9.7	347	37.8
3	4	2	0.86	16.10	0.41	123.62	0.85	109.0	60.7	8.8	583	40.4
3	4	3	0.94	21.22	0.37	178.12	0.78	98.5	59.7	9.2	541	35.5
3	4	4	1.09	16.10	0.28	156.69	0.54	102.5	58.4	10.8	647	32.0

B = block; C = cultivar, 1 = Stephens, 2 = OR 8313, 3 = Batum, 4 = Dusty; N = nitrogen fertilizer, 1 = 0 kg N/ha, 2 = 56 kg N/ha, 3 = 112 kg N/ha, 4 = 168 kg N/ha; HI = harvest index; NHI = nitrogen harvest index; KWT = kernel wt.

Appendix Table 21. Beginning soil test results, 3/18/89.

Sample Depth	NO_3	NH_4	NO_3 + NH_4	6" Profile	Total 3' Profile
——inch——		——PPM——		——lb/a——	
0-6	1.7	2.7	4.4	8.8	71.6
6-12	1.7	3.2	4.9	9.8	
12-18	1.7	3.8	5.5	11	
18-24	1.7	3.8	5.5	11	
24-30	2.3	4.9	7.2	14.4	
30-36	2.9	5.4	8.3	16.6	

Appendix Table 22. Ending soil test results, 1989.

B	C	N	Sample ID #	Sample Depth	NO_3	NH_4	$NO_3 + NH_4$
				inch	PPM		
1	2	1	805	0-6	2.5	1.5	4.0
			805	6-12	0.9	2.7	3.6
			805	12-24	0.5	3.4	3.9
			805	24-36	3.0	2.1	5.1
1	2	2	702	0-6	2.6	1.3	3.9
			702	6-12	1.7	1.7	3.4
			702	12-24	0.7	3.6	4.3
			702	24-36	0.5	3.0	3.5
1	2	3	753	0-6	3.0	3.1	6.1
			753	6-12	2.0	1.2	3.2
			753	12-24	0.5	2.7	3.2
			753	24-36	0.5	6.0	6.5
1	2	4	853	0-6	2.5	2.0	4.5
			853	6-12	1.1	4.0	5.1
			853	12-24	0.5	1.9	2.4
			853	24-36	0.5	3.1	3.6
1	2	5	803	0-6	10.0	1.9	11.9
			803	6-12	2.5	2.8	5.3
			803	12-24	0.5	2.6	3.1
			803	24-36	0.7	4.2	4.9
1	1	1	854	0-6	2.0	1.9	3.9
			854	6-12	1.0	2.5	3.5
			854	12-24	0.5	3.1	3.6
			854	24-36	0.5	2.8	3.3
			854	36-48	0.5	2.3	2.8
			854	48-60	1.0	2.3	3.3
1	1	2	802	0-6	2.3	1.7	4.0
			802	6-12	1.9	1.7	3.6
			802	12-24	0.5	2.3	2.8
			802	24-36	0.5	4.2	4.7
1	1	3	804	0-6	4.3	2.8	7.1
			804	6-12	2.5	1.6	4.1
			804	12-24	0.5	2.5	3.0
			804	24-36	0.5	5.0	5.5
1	1	4	755	0-6	4.0	2.0	6.0
			755	6-12	2.0	1.2	3.2
			755	12-24	0.5	1.3	1.8
			755	24-36	0.5	4.3	4.8
			755	36-48	1.0	2.1	3.1
			755	48-60	2.0	1.6	3.6

B = block; C = cultivar, 1 = Stephens, 2 = OR 8313, 3 = Batum, 4 = Dusty; N = nitrogen fertilizer, 1 = 0 kg N/ha, 2 = 56 kg N/ha, 3 = 112 kg N/ha, 4 = 168 kg N/ha, 5 = 112 + 56 kg N/ha.

Appendix Table 23. Ending soil test results, 1989.

B	C	N	Sample ID #	Sample Depth	NO_3	NH_4	NO_3 + NH_4
				inch	PPM		
1	1	5	851	0-6	8.6	2.3	10.9
			851	6-12	2.4	2.1	4.5
			851	12-24	0.6	2.5	3.1
			851	24-36	0.5	4.1	4.6
1	3	1	701	0-6	3.9	2.7	6.6
			701	6-12	1.7	2.1	3.8
			701	12-24	0.5	2.6	3.1
			701	24-36	0.5	2.6	3.1
1	3	2	752	0-6	3.8	1.7	5.5
			752	6-12	2.1	2.4	4.5
			752	12-24	0.5	2.3	2.8
			752	24-36	0.5	3.2	3.7
1	3	3	754	0-6	3.9	1.9	5.8
			754	6-12	2.5	1.6	4.1
			754	12-24	0.5	3.1	3.6
			754	24-36	0.5	4.6	5.1
1	3	4	852	0-6	4.9	1.4	6.3
			852	6-12	2.1	1.6	3.7
			852	12-24	0.6	2.9	3.5
			852	24-36	0.5	2.9	3.4
1	3	5	751	0-6	11.6	2.6	14.2
			751	6-12	1.9	2.0	3.9
			751	12-24	0.5	2.1	2.6
			751	24-36	0.5	3.2	3.7
1	4	1	704	0-6	3.4	1.9	5.3
			704	6-12	1.3	2.1	3.4
			704	12-24	0.5	2.7	3.2
			704	24-36	0.5	4.3	4.8
			704	36-48	0.5	2.1	2.6
			704	48-60	1.2	2.1	3.3
1	4	2	703	0-6	2.8	3.2	6.0
			703	6-12	2.0	2.3	4.3
			703	12-24	0.5	3.4	3.9
			703	24-36	0.5	2.6	3.1
1	4	3	855	0-6	1.0	1.8	2.8
			855	6-12	0.5	2.1	2.6
			855	12-24	0.5	3.3	3.8
			855	24-36	0.5	1.7	2.2

B = block; C = cultivar, 1 = Stephens, 2 = OR 8313, 3 = Batum, 4 = Dusty; N = nitrogen fertilizer, 1 = 0 kg N/ha, 2 = 56 kg N/ha, 3 = 112 kg N/ha, 4 = 168 kg N/ha, 5 = 112 + 56 kg N/ha.

Appendix Table 24. Ending soil test results, 1989.

B	C	N	Sample ID #	Sample Depth	NO_3	NH_4	NO_3 + NH_4
				inch	PPM		
			801a	0-6	3.9	2.9	6.8
			801a	6-12	1.9	2.8	4.7
			801a	12-24	0.7	3.9	4.6
			801a	24-36	0.6	5.1	5.7
			801a	36-48	1.3	4.0	5.3
			801a	48-60	3.2	3.1	6.3
1	4	4	801	0-6	4.7	2.1	6.8
			801	6-12	2.1	1.8	3.9
			801	12-24	0.5	2.8	3.3
			801	24-36	0.5	6.3	6.8
1	4	5	705	0-6	14.0	1.8	15.8
			705	6-12	2.6	2.0	4.6
			705	12-24	0.5	1.8	2.3
			705	24-36	0.5	3.0	3.5
2	2	1	856	0-6	1.6	2.0	3.6
			856	6-12	5.4	1.7	7.1
			856	12-24	0.5	2.3	2.8
			856	24-36	0.5	3.0	3.5
2	2	2	857	0-6	8.6	2.1	10.7
			857	6-12	2.5	3.1	5.6
			857	12-24	0.7	3.1	3.8
			857	24-36	0.5	3.6	4.1
2	2	3	708	0-6	4.3	2.4	6.7
			708	6-12	2.0	2.7	4.7
			708	12-24	0.9	2.7	3.6
			708	24-36	0.6	4.3	4.9
2	2	4	808	0-6	0.5	2.1	2.6
			808	6-12	2.5	2.1	4.6
			808	12-24	0.5	3.1	3.6
			808	24-36	0.5	4.0	4.5
2	2	5	756	0-6	1.7	2.3	4.0
			756	6-12	0.6	1.4	2.0
			756	12-24	0.5	2.0	2.5
			756	24-36	0.5	3.1	3.6

B = block; C = cultivar, 1 = Stephens, 2 = OR 8313, 3 = Batum, 4 = Dusty; N = nitrogen fertilizer, 1 = 0 kg N/ha, 2 = 56 kg N/ha, 3 = 112 kg N/ha, 4 = 168 kg N/ha, 5 = 112 + 56 kg N/ha.

Appendix Table 25. Ending soil test results, 1989.

B	C	N	Sample ID #	Sample Depth	NO_3	NH_4	NO_3 + NH_4
				inch	PPM		
2	1	1	758	0-6	3.4	2.3	5.7
			758	6-12	1.7	2.2	3.9
			758	12-24	0.9	3.0	3.9
			758	24-36	0.5	4.7	5.2
			758	36-48	0.9	3.0	3.9
			758	48-60	1.7	2.4	4.1
2	1	2	707	0-6	6.3	2.1	8.4
			707	6-12	2.6	2.1	4.7
			707	12-24	0.5	3.1	3.6
			707	24-36	0.5	3.6	4.1
2	1	3	759	0-6	4.3	3.5	7.8
			759	6-12	2.9	2.6	5.5
			759	12-24	0.6	3.1	3.7
			759	24-36	0.5	4.2	4.7
2	1	4	710	0-6	6.2	2.8	9.0
			710	6-12	3.1	2.7	5.8
			710	12-24	0.9	3.6	4.5
			710	24-36	0.8	4.5	5.3
			710	36-48	1.3	3.2	4.5
			710	48-60	2.0	3.3	5.3
2	1	5	806	0-6	2.3	1.4	3.7
			806	6-12	0.5	2.3	2.8
			806	12-24	0.5	2.0	2.5
			806	24-36	0.5	3.3	3.8
2	3	1	760	0-6	6.1	2.7	8.8
			760	6-12	3.2	2.2	5.4
			760	12-24	0.8	3.7	4.5
			760	24-36	0.8	4.3	5.1
2	3	2	807	0-6	4.0	2.1	6.1
			807	6-12	2.0	1.6	3.6
			807	12-24	0.5	3.6	4.1
			807	24-36	0.5	2.6	3.1
2	3	3	709	0-6	4.4	2.6	7.0
			709	6-12	2.0	2.0	4.0
			709	12-24	0.7	3.2	3.9
			709	24-36	0.7	5.6	6.3

B = block; C = cultivar, 1 = Stephens, 2 = OR 8313, 3 = Batum, 4 = Dusty; N = nitrogen fertilizer, 1 = 0 kg N/ha, 2 = 56 kg N/ha, 3 = 112 kg N/ha, 4 = 168 kg N/ha, 5 = 112 + 56 kg N/ha.

Appendix Table 26. Ending soil test results, 1989.

B	C	N	Sample ID #	Sample Depth	NO_3	NH_4	NO_3 + NH_4
				inch	PPM		
2	3	4	757	0-6	8.3	2.1	10.4
			757	6-12	2.5	1.6	4.1
			757	12-24	0.5	3.1	3.6
			757	24-36	0.5	3.6	4.1
2	3	5	706	0-6	12.7	1.6	14.3
			706	6-12	2.3	1.6	3.9
			706	12-24	0.6	1.6	2.2
			706	24-36	0.9	2.6	3.5
2	4	1	810	0-6	2.0	2.9	4.9
			810	6-12	1.7	2.1	3.8
			810	12-24	0.6	2.5	3.1
			810	24-36	0.6	3.2	3.8
			810	36-48	0.6	2.5	3.1
			810	48-60	1.6	2.3	3.9
2	4	2	809	0-6	3.3	2.6	5.9
			809	6-12	2.0	3.0	5.0
			809	12-24	0.5	2.8	3.3
			809	24-36	0.5	4.1	4.6
2	4	3	859	0-6	3.0	2.6	5.6
			859	6-12	1.6	2.7	4.3
			859	12-24	0.5	3.6	4.1
			859	24-36	0.5	3.7	4.2
2	4	4	858	0-6	4.5	2.6	7.1
			858	6-12	2.1	3.6	5.7
			858	12-24	0.5	2.6	3.1
			858	24-36	0.5	3.6	4.1
			858	36-48	2.0	2.1	4.1
			858	48-60	1.0	2.1	3.1
2	4	5	860	0-6	4.0	2.5	6.5
			860	6-12	1.7	2.5	4.2
			860	12-24	0.6	3.0	3.6
			860	24-36	0.6	3.9	4.5

B = block; C = cultivar, 1 = Stephens, 2 = OR 8313, 3 = Batum, 4 = Dusty; N = nitrogen fertilizer, 1 = 0 kg N/ha, 2 = 56 kg N/ha, 3 = 112 kg N/ha, 4 = 168 kg N/ha, 5 = 112 + 56 kg N/ha.

Appendix Table 27. Ending soil test results, 1989.

B	C	N	Sample ID #	Sample Depth	NO_3	NH_4	NO_3 + NH_4
				inch		PPM	
3	2	1	715	0-6	4.2	1.7	5.9
			715	6-12	1.9	1.6	3.5
			715	12-24	0.9	2.1	3.0
			715	24-36	0.6	4.2	4.8
			715	36-48	1.1	1.9	3.0
			715	48-60	2.1	1.4	3.5
3	2	2	762	0-6	4.2	2.4	6.6
			762	6-12	2.4	2.3	4.7
			762	12-24	0.7	3.7	4.4
			762	24-36	0.5	4.3	4.8
3	2	3	862	0-6	2.6	2.8	5.4
			862	6-12	1.3	2.3	3.6
			862	12-24	0.5	3.3	3.8
			862	24-36	0.5	3.2	3.7
3	2	4	763	0-6	8.4	2.4	10.8
			763	6-12	3.1	2.8	5.9
			763	12-24	0.8	3.6	4.4
			763	24-36	0.7	4.2	4.9
			763	36-48	1.2	2.9	4.1
			763	48-60	2.5	2.5	5.0
3	2	5	713	0-6	4.0	2.9	6.9
			713	6-12	2.2	2.2	4.4
			713	12-24	0.8	2.9	3.7
			713	24-36	0.6	4.0	4.6
3	1	1	764	0-6	4.2	2.4	6.6
			764	6-12	2.1	2.1	4.2
			764	12-24	0.8	2.4	3.2
			764	24-36	0.6	3.7	4.3
3	1	2	865	0-6	2.4	2.1	4.5
			865	6-12	1.2	1.8	3.0
			865	12-24	0.6	2.3	2.9
			865	24-36	0.5	4.3	4.8
3	1	3	714	0-6	4.5	2.1	6.6
			714	6-12	2.6	2.7	5.3
			714	12-24	3.8	3.7	7.5
			714	24-36	0.8	3.0	3.8

B = block; C = cultivar, 1 = Stephens, 2 = OR 8313, 3 = Batum, 4 = Dusty; N = nitrogen fertilizer, 1 = 0 kg N/ha, 2 = 56 kg N/ha, 3 = 112 kg N/ha, 4 = 168 kg N/ha, 5 = 112 + 56 kg N/ha.

Appendix Table 28. Ending soil test results, 1989.

B	C	N	Sample ID #	Sample Depth	NO_3	NH_4	NO_3 + NH_4
				inch	PPM		
3	1	4	812	0-6	3.6	2.9	6.5
			812	6-12	2.5	2.0	4.5
			812	12-24	0.8	3.3	4.1
			812	24-36	1.0	4.4	5.4
			812	36-48	1.7	3.0	4.7
			812	48-60	2.4	3.0	5.4
3	1	5	761	0-6	6.1	2.0	8.1
			761	6-12	3.0	1.8	4.8
			761	12-24	0.6	3.1	3.7
			761	24-36	0.5	3.3	3.8
3	3	1	815	0-6	4.1	2.3	6.4
			815	6-12	2.3	2.7	5.0
			815	12-24	1.0	3.7	4.7
			815	24-36	0.5	3.9	4.4
			815	36-48	0.8	2.4	3.2
			815	48-60	1.2	1.9	3.1
3	3	2	712	0-6	2.6	2.2	4.8
			712	6-12	1.9	2.3	4.2
			712	12-24	0.6	3.3	3.9
			712	24-36	0.5	4.2	4.7
3	3	3	861	0-6	3.3	3.0	6.3
			861	6-12	1.9	2.2	4.1
			861	12-24	0.6	4.6	5.2
			861	24-36	0.5	3.3	3.8
3	3	4	813	0-6	7.2	2.9	10.1
			813	6-12	2.4	2.9	5.3
			813	12-24	0.9	3.3	4.2
			813	24-36	0.8	3.7	4.5
3	3	5	864	0-6	11.1	1.7	12.8
			864	6-12	2.3	1.6	3.9
			864	12-24	0.7	2.6	3.3
			864	24-36	0.7	3.5	4.2
3	4	1	811	0-6	4.0	2.2	6.2
			811	6-12	1.6	1.9	3.5
			811	12-24	0.6	2.3	2.9
			811	24-36	0.5	4.5	5.0

B = block; C = cultivar, 1 = Stephens, 2 = OR 8313, 3 = Batum, 4 = Dusty; N = nitrogen fertilizer, 1 = 0 kg N/ha, 2 = 56 kg N/ha, 3 = 112 kg N/ha, 4 = 168 kg N/ha, 5 = 112 + 56 kg N/ha.

Appendix Table 29. Ending soil test results, 1989.

B	C	N	Sample ID #	Sample Depth	NO_3	NH_4	NO_3 + NH_4
				inch	PPM		
3	4	2	863	0-6	1.9	1.9	3.8
			863	6-12	1.2	2.0	3.2
			863	12-24	0.5	2.7	3.2
			863	24-36	0.5	3.5	4.0
3	4	3	765	0-6	3.7	2.1	5.8
			765	6-12	1.6	2.3	3.9
			765	12-24	0.6	3.2	3.8
			765	24-36	0.7	4.8	5.5
3	4	4	711	0-6	4.9	3.1	8.0
			711	6-12	2.0	2.6	4.6
			711	12-24	0.5	3.5	4.0
			711	24-36	0.5	4.6	5.1
3	4	5	814	0-6	9.1	2.4	11.5
			814	6-12	2.9	1.9	4.8
			814	12-24	0.8	2.1	2.9
			814	24-36	0.6	3.2	3.8

B = block; C = cultivar, 1 = Stephens, 2 = OR 8313, 3 = Batum, 4 = Dusty; N = nitrogen fertilizer, 1 = 0 kg N/ha, 2 = 56 kg N/ha, 3 = 112 kg N/ha, 4 = 168 kg N/ha, 5 = 112 + 56 kg N/ha.

Appendix Table 30. Nitrogen budget, 1989.

B	C	N	Sample #	Begin Total 3'	Fert N	N Uptake#	End Total 3'	N Available	Minlzd/ Lost N	Minlzd/ Lost N+30
				lb N/a						
1	1	1	508	71.6	0	61.5	42.4	29.2	32.3	62.3
1	1	2	812	71.6	50	106.8	45.2	76.4	30.4	60.4
1	1	3	814	71.6	100	174.8	56.4	115.2	59.6	89.6
1	1	4	801	71.6	150	242.6	44.8	176.8	65.8	95.8
1	1	5	826	71.6	150	180.4	61.6	160	20.4	50.4
1	2	1	645	71.6	0	78.6	51.2	20.4	58.2	88.2
1	2	2	783	71.6	50	180.9	45.8	75.8	105.1	135.1
1	2	3	799	71.6	100	128.5	57.4	114.2	14.3	44.3
1	2	4	828	71.6	150	231.4	43.2	178.4	53.0	83.0
1	2	5	813	71.6	150	168.7	66.4	155.2	13.5	43.5
1	3	1	782	71.6	0	85.3	45.6	26	59.3	89.3
1	3	2	798	71.6	50	146.9	46	75.6	71.3	101.3
1	3	3	800	71.6	100	176.3	54.6	117	59.3	89.3
1	3	4	827	71.6	150	238.1	47.6	174	64.1	94.1
1	3	5	797	71.6	150	153.9	61.4	160.2	-6.3	23.7
1	4	1	785	71.6	0	97.4	49.4	22.2	75.2	105.2
1	4	2	784	71.6	50	132.2	48.6	73	59.2	89.2
1	4	3	829	71.6	100	166.2	34.8	136.8	29.4	59.4
1	4	4	811	71.6	150	222.3	61.8	159.8	62.5	92.5
1	4	5	786	71.6	150	222.2	64	157.6	64.6	94.6
2	1	1	805	71.6	0	56.8	55.6	16	40.8	70.8
2	1	2	788	71.6	50	93.2	57	64.6	28.6	58.6
2	1	3	641	71.6	100	156.3	60.2	111.4	44.9	74.9
2	1	4	791	71.6	150	223.7	68.8	152.8	70.9	100.9
2	1	5	816	71.6	150	169.3	38.2	183.4	-14.1	15.9
2	2	1	830	71.6	0	92.0	46.6	25	67.0	97.0
2	2	2	831	71.6	50	171.3	64.2	57.4	113.9	143.9
2	2	3	789	71.6	100	268.5	56.8	114.8	153.7	183.7
2	2	4	818	71.6	150	253.1	46.8	174.8	78.3	108.3
2	2	5	802	71.6	150	160.4	36.4	185.2	-24.8	5.2
2	3	1	806	71.6	0	80.5	66.8	4.8	75.7	105.7
2	3	2	817	71.6	50	84.4	48.2	73.4	11.0	41.0
2	3	3	790	71.6	100	161.7	62.8	108.8	52.9	82.9
2	3	4	803	71.6	150	230.5	59.8	161.8	68.7	98.7
2	3	5	787	71.6	150	163.4	59.2	162.4	1.0	31.0
2	4	1	820	71.6	0	69.7	45	26.6	43.1	73.1
2	4	2	819	71.6	50	115.3	53.4	68.2	47.1	77.1
2	4	3	833	71.6	100	132.6	53	118.6	14.0	44.0
2	4	4	832	71.6	150	219.5	54.4	167.2	52.3	82.3
2	4	5	834	71.6	150	240.5	53.8	167.8	72.7	102.7

B = block; C = cultivar, 1 = Stephens, 2 = OR 8313, 3 = Batum, 4 = Dusty; N = nitrogen fertilizer, 1 = 0 kg N/ha, 2 = 56 kg N/ha, 3 = 112 kg N/ha, 4 = 168 kg N/ha, 5 = 112 + 56 kg N/ha.

Appendix Table 31. Nitrogen budget, 1989.

B	C	N	Sample #	Begin Total 3'	Fert N	N Uptake#	End Total 3'	N Available	Minlzd/ Lost N	Minlzd/ Lost N+30
				lb N/a						
3	1	1	809	71.6	0	59.7	51.6	20	39.7	69.7
3	1	2	839	71.6	50	126.0	45.8	75.8	50.2	80.2
3	1	3	795	71.6	100	158.9	69	102.6	56.3	86.3
3	1	4	822	71.6	150	199.9	60	161.6	38.3	68.3
3	1	5	509	71.6	150	228.4	55.8	165.8	62.6	92.6
3	2	1	796	71.6	0	76.8	50	21.6	55.2	85.2
3	2	2	807	71.6	50	125.1	59.4	62.2	62.9	92.9
3	2	3	836	71.6	100	196.0	48	123.6	72.4	102.4
3	2	4	808	71.6	150	174.3	70.6	151	23.3	53.3
3	2	5	794	71.6	150	202.9	55.8	165.8	37.1	67.1
3	3	1	825	71.6	0	78.4	59.2	12.4	66.0	96.0
3	3	2	793	71.6	50	116.7	52.4	69.2	47.5	77.5
3	3	3	835	71.6	100	219.2	56.8	114.8	104.4	134.4
3	3	4	823	71.6	150	171.8	65.6	156	15.8	45.8
3	3	5	838	71.6	150	224.0	63.4	158.2	65.8	95.8
3	4	1	821	71.6	0	104.9	51	20.6	84.3	114.3
3	4	2	837	71.6	50	123.6	42.8	78.8	44.8	74.8
3	4	3	810	71.6	100	178.1	56.6	115	63.1	93.1
3	4	4	792	71.6	150	156.7	61.6	160	-3.3	26.7
3	4	5	824	71.6	150	135.2	59.4	162.2	-27.0	3.0

B = block; C = cultivar, 1 = Stephens, 2 = OR 8313, 3 = Batum, 4 = Dusty; N = nitrogen fertilizer, 1 = 0 kg N/ha, 2 = 56 kg N/ha, 3 = 112 kg N/ha, 4 = 168 kg N/ha, 5 = 112 + 56 kg N/ha.