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The Accumulation and Distribution of Nitrogen

in Four Winter Wheat Cultivars

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Everett H Everson

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ACCUMULATION AND DISTRIBUTION OF NITROGEN
IN FOUR WINTER WHEAT CULTIVARS

By

Geoffrey M. Heinrich

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ABSTRACT

ACCUMULATION AND DISTRIBUTION OF NITROGEN
IN FOUR WINTER WHEAT CULTIVARS

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Different rates and sources of nitrogen were applied at different dates to two wheat cultivars. Nitrogen topdressings were split and applied to four cultivars. The cultivars studied varied in their nitrogen response patterns. The concentration of reduced nitrogen was determined in the above ground plant parts of the four cultivars over four growth stages and two nitrogen treatments to determine whether assimilation and/or partitioning systems for nitrogen were related to the response patterns.

The yield response patterns of cultivars to nitrogen varied considerably with location. There were no major effects due to date of application and no gains resulted from splitting the application over two dates.

Internal plant nitrogen levels showed no major differences in concentration or distribution of reduced nitrogen in plant parts, on a per culm basis. Nitrogen fertilizer increased the reduced nitrogen concentration in all plant parts, of all cultivars, at all growth stages.

ACKNOWLEDGEMENTS

I would like to express my appreciation to Dr. S. K. Ries for the use of his laboratory and equipment and for his advice in the analysis of plant nitrogen, and also to Dr. Violet Wert for her assistance.

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And lastly, I would like to thank my parents.

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INTRODUCTION

The increasing cost of nitrogen fertilizer and the possible harmful effects of excess nitrogen in ground water are making efficient use of nitrogen by crops a high priority.

Three winter wheat cultivars, Ionia, Yorkstar, and Tecumseh were found to have different yield response patterns to nitrogen fertilizer (17). Through understanding the genetic nature of these differences the characters of high responsiveness and efficient nitrogen utilization might be more effectively included in wheat breeding programs.

This study was initiated to: A) further examine the response patterns of wheat to nitrogen fertilization and the factors that affect them, and B) to determine whether restricted nitrogen assimilation or different nitrogen partitioning systems within the cultivars might be related to responsiveness.

LITERATURE REVIEW

The Importance of Nitrogen to Yields

G. W. Cooke in his book "The Control of Soil Fertility" (11), stated that in most agriculture, the nitrogen (N) supply controls the yield of crops that have enough water.

F. E. Allison, in "Advances in Agronomy" (2), attributed the large increases in the acre yields of crops, that have occurred in the U.S.A. in the last thirty years, mainly to the increase in application of commercial N. He stated that crops require greater amounts of N than other nutrients, and soils generally supply smaller quantities.

Varietal Differences in Response to Nitrogen

Varietal differences in yield response patterns under increasing increments of N have been well documented in small grains. Yamada (37) demonstrated responses in rice cultivars ranging from zero to 70% yield increases. Vose (35) in a review article in 1963 stated it was commonplace that differential responses to nutrition levels between cultivars occur and cites Lamb and Salter who concluded that wheat cultivars may respond differently to a given fertility level.

Morphological Response Characters

Investigations at the International Rice Research Institute (IRRI) in the Philippines showed that straw length was important because long strawed cultivars lodged at high nitrogen rates (7). Decard *et al.* (14)

in a study using paired, near-isogenic lines of durum wheat found that the semi-dwarf gene had no effect on yield. Apparently straw length affected yield only in relation to lodging.

The main morphological characters that govern yield increases in small grains are: 1) the number of heads per unit area; 2) the number of seeds per head, and ;3) the weight per seed (7, 25). Yamada (37) described five different yield responses to N in rice, in terms of yield components. One cultivar increased yields under high N rates solely through increasing panicle number per unit area, a second primarily through increases in the seed number per panicle and a third increased both panicle number and seed number per panicle, but to a lesser degree, and achieved yield levels between the first two cultivars. The fourth cultivar increased both panicle number and seeds per panicle as much as the first two cultivars and thus out-yielded both. The last cultivar showed no increase in panicle number or the number of seeds per panicle and achieved no yield increase through added N. This last cultivar had the greatest total and per-day dry matter accumulation rate.

In Yamada's study, increasing panicle number caused the greatest yield increase. A good example of the range that exists in tiller number between genotypes is work done by S. Yoshida (7) where rice cultivars ranged from thirty to one hundred and twenty-six tillers when the plants were widely spaced and heavily fertilized with N.

F. H. McNeal and D. J. Davis (25) showed differences in tillering between nine spring wheat cultivars. "Ceres" increased tiller number 7.5% and 31% between 0, 56 and 135 kg N/ha, while "Lee" showed the greatest increases of 46% and 105%. While increased culm number accounted for much of the yield increase in seven cultivars, more than half of the yield increase in "Ceres" and N2211 were due to a greater number of seeds per head. They found little variation in test weight.

Seed weight has not been shown to be a major factor but F. H. McNeal et al. (23), found that kernel weight and the grain/straw ratio decreased with added N.

The Balance of Morphological Characters with Carbohydrate Accumulation

Khalifa (20) found that early applications of N on wheat increased the leaf area index (LAI) near the time of ear emergence, and that this increased the leaf area duration (LAD) during grain development. This did not occur with applications made at ear emergence. He concluded that the response to early N applications was due to greater amounts of photosynthate produced during grain filling as a result of greater LAD.

Baba (4) found that the decrease in the starch content of the leaf sheath and stem, at high N levels, was greater in low-response rice cultivars than in high response types. From this, and the facts that (a) there were fewer infertile spikelets per head in high response cultivars, and; (b) the grain to straw ratio was reduced less in high response cultivars at high N levels, he concluded that starch accumulation and transport to the grain was reduced less in high response cultivars. He postulated that either: 1) higher N levels caused greater uptake of N during early growth and resulted in a rapid growth rate which consumed photosynthate and thus depleted carbohydrate reserves in low response cultivars; or 2) there was a greater LAI at high N levels. Low response cultivars, because of their leaf angle, had a greater mutual shading of leaves and therefore, less photosynthesis per unit leaf area. There was no reduction of the respiration rate per unit leaf area and therefore, the net accumulation of photosynthate was reduced, lowering the relative yield response. Work at IRRI (7) has shown smaller, more upright leaves to be an important factor in the responsiveness of rice cultivars. Furthermore, it has been found that roots obtained carbohydrates from the lower leaves of the plant (15). In cultivars where the light extinction coefficient was high there was reduced photosynthesis with unchanged respiration. The carbohydrate supply to the root was depleted, reducing the plant's nutrient uptake.

Thus, responsiveness to N has been found to be dependent upon the rate of N uptake, the LAI, LAD, leaf size and angle, and their interactive effects upon photosynthesis and respiration.

Internal Plant Nitrogen and Its Relationship to Yield

Plant nitrogenous constituents, apart from nitrate, contain N almost exclusively in the reduced form (22). The majority of plant N is contained in proteins to an extent such that multiplication of the plant RN content by the average nitrogen content of protein (100 g protein/ 16 g N) results in a fairly accurate measure of plant protein (5). Other important N containing compounds within the green plant material include free amino acids, nucleic acids, chlorophyll, ATP and NADP (5, 22). Nitrogen in the seed is almost exclusively in proteins (5).

There is considerable discussion in the literature about the role of plant nitrate levels, nitrate reductase (NR), nitrate reductase activity (NRA), the amount of reduced nitrogen (RN) in the plant and the relationship of these with grain yield and grain protein levels.

Nitrate reductase is the rate limiting enzyme in the assimilation of nitrate into usable organic form within the plant. It is induced by nitrate. However, Decard *et al*. (14), found all correlations between leaf nitrate and leaf NR to be near zero, thus showing that there were factors besides the levels of nitrate controlling the amount of NR in the plant.

Deckard (14) concluded that the total plant RN was largely dependent upon NRA and a number of researchers have found positive correlations between the NRA (prior to or at anthesis) and grain yield (1, 13, 16).

However, this also is not consistent; Rao _et al_. (29), in a study of two cultivars, found that while one cultivar had a 70% higher _in vitro_ NRA, there was little _in vivo_ difference in their capacities to reduce nitrate.

Researchers in rice have shown a high correlation between N in the top growth in the thirty days prior to flowering and grain yield. This effect seemed to be caused by increased photosynthetic activity (7).

Abrol and Nair (1) stated that there is a linear relationship between N content or supply with; a) leaf expansion rate; b) total leaf area development; c) tiller numbers; d) the number of spikelets initiated per head, and; e) photosynthetic activity. These factors are important to crop yield and so available RN in the plant must be related to yield. However, all of these qualities can vary between cultivars. They can be affected by conditions such as soil moisture, light intensity and the level of other nutrients in the soil. Factors such as leaf size, leaf angle and LAI can alter the photosynthesis/respiration ratio, increasing or reducing the net accumulation rate. Thus it is clear that crop yield cannot be simply and directly correlated with the total RN content of the plant.

Nitrogen Uptake and Partitioning in Relationship to Yield

Ashley *et al.* (3) found that nitrate was reduced in both the roots and shoots of wheat seedlings and that the shoots had lower nitrate/RN ratios at all times. McNeal *et al.* (23) found that the levels of N in wheat roots were low throughout the plant's life. He concluded that there was rapid translocation of N from root to shoot. Huffaker and Rains (27) stated that nitrate uptake in wheat showed saturation kinetics, was closely coupled to metabolism with ATP or other high energy intermediates and a permease may have been involved in the transport system.

Using two wheat cultivars, Daigger *et al.* (12), found that while yield response to N varied between locations and years, plant N content was influenced only by the amount of applied N and the time of sampling.

Yamada (37) reported that low response cultivars of rice tended to take up more nutrients at low soil fertility levels than high response cultivars. He found that the optimum concentration of N in nutrient solution for Japonic cultivars caused "striking retardation" of root growth in Indica cultivars, which required a much lower concentration of N for optimum growth.

Chevalier and Schrader (8) showed that even among genotypes of maize with similar dry weight there were significant differences in nitrate uptake and suggested this was possibly related to differences in root dry weight. They showed that there were significant differences between inbred lines in the amount of dry matter produced per gram of nitrate absorbed.

N assimilation may be influenced by temperature. Peterson and Shrader (28) showed that RN in oat leaves was maximized by different day/night temperature regimes in different cultivars. They found that high day temperatures depressed RN accumulation in all cultivars, but this effect was more pronounced in some cultivars. The cultivar least affected had the greatest yield.

Thus, there are differences in N uptake and assimilation between cultivars. However, Rao et al. (29), concluded that cultivars differing in various production parameters do not necessarily absorb different amounts of soil N.

The Nitrogen Uptake Patterns

It has been postulated that different N uptake patterns affect a plant's growth habit (4) and thus, yield and grain protein.

McNeal et al. (23), found that leaf N in five wheat cultivars was maximized at flowering but the total N in top growth increased to maturity. Abrol and Nair (1) concluded from literature that wheat cultivars may or may not absorb N after anthesis depending on their genetic make-up.

Daigger et al. (12), noted that the rate of uptake of N was not a steady system. They found that accumulation of N and dry matter was rapid in the month prior to anthesis and that maximum plant N content occurred at anthesis. They reported net plant N losses, post anthesis, of 25 to 80 kg/ha, depending on the amount of N applied. With possible losses of this magnitude, it would be difficult to determine how much N was taken up after anthesis.

Nitrogen Partitioning

There are different partitioning systems and translocation patterns between grain genotypes (8, 26). However, there have been no reports to date of a specific partitioning pattern correlated to yield responsiveness.

The grain protein percent seems to be more related to the grain/straw ratio than with: 1) N in grain (kg/ha); 2) N in top growth or; 3) differences between cultivars in translocation of N.

Date of N Application

There is considerable disagreement in the literature over the best time to apply top dressings of N on winter wheat. Some farmers in Michigan apply top dressings in late fall when the ground is frozen, to ensure that N is available as soon as growth starts in the spring.

Stanford and Hunter (32) in Pennsylvania, Hunter *et al*. (19), and Clapp (10) in North Carolina, have all conducted experiments that showed no difference between fall and spring topdressings, or a slight yield advantage for fall applications. Clapp found that this did not hold true on sandy soils.

On the other hand, Welch *et al*. (36), in a three year study, found that spring topdressings increased yields over fall applications in most cases. Cooke (11) stated that almost all of the experiments done in Britain showed that for winter cereals, N given in the autumn was generally less effective than the same amount in spring.

Vitosh and Warncke (34) stated that: 1) spring applications of N in Michigan were usually more efficient than fall applications, especially on sandy soils and on poorly drained fine textured soils; 2) it was best to avoid topdressings on frozen soils with slopes greater than 3%, and; 3) March and April were the best months for N applications.

Losses of Applied Fertilizer

Nitrate, nitrite and ammonium constitute no more than 2% of the total soil N, but can be regarded agronomically as an important fraction since they are the major forms of N that are taken up by plants and from which soil N losses occur (9).

Allison (2) concluded that real losses of applied N were in the range of 5 to 25% of the fertilizer applied. He further stated that the largest losses of N were due to leaching of nitrate and nitrite in the fall and spring. As regards the quantification of leaching, he cited Wallace and Smith (1954) who found that when NO_3 was added to the surface of a 2 foot column of loam soil at field capacity, approximately 10 inches of water were needed to leach 50% of the added N from the soil, and 16 inches to remove 98%. He stated that the major form of gaseous loss of N was the denitrification of nitrate and nitrite.

These conclusions as to the major sources of soil N loss were generally supported by Cooke (11) but he described larger losses of applied N, ranging from 25 to 60%. He also described losses of applied N due to volatilization as high as 15%. He bases these conclusions on lysimeter studies which Allison questioned because they could not account for immobilized N.

When corn was grown on irrigated sandy soils, nitrate loss was correlated with water loss (r = .95) (31).

Twenty five to 80 kg N/ha may be lost from the crop between anthesis and maturity and that this may be affecting computation of crop recovery rates based on the N content of the crop at maturity (12). Volitalization losses of N from senescing leaves have been reported (18, 33). Soybeans were shown to lose 45 kg N/ha during a growing season in this manner (33).

Denitrification may occur rapidly under conditions of high soil moisture in the presence of rapidly decomposing organic matter. On acid soils (pH < 6.5) gaseous losses through the chemical dismutation of nitrite accounted for losses of up to two-thirds of the N in fertilizers releasing ammonium or ammonia. Volatilization losses of ammonium from surface applied ammonium salts were only likely on alkaline soils (9).

Splitting N Applications to Reduce Losses

Because losses of applied N can occur so rapidly, splitting the applications of N fertilizer should reduce the amount of N susceptible to loss at any one time.

G. W. Cooke (11) cited work done in Britain which showed that when nitrogen was applied at rates below 78 kg N/ha, in years when there was heavy winter precipitation, single applications in spring gave the best results. However, in years of normal or dry winters, when applied rates of N exceeded 112 kg N/ha equally split topdressings applied in fall and March or March and May, were superior to any single application. He also cited work by Devine and Holmes where split applications (betweel fall and spring) did not increase yields over spring applications, and may actually have increased the loss of applied N.

Work done by Boswell *et al*. (6), showed that split applications of ammonium sulfate on wheat were superior to fall applications, even when a nitrification inhibitor ("N-serve") was applied with the fall treatments. On a Cecil sandy loam, split applications were superior to fall applications without the nitrification inhibitor and equal in yield response when the N.I. was applied with the fall treatments.

In general, splitting the N application reduced loss of N from the soil and split applications were superior or equal to a well timed single application. However, spreading the applications out over a longer period of time increased the risk of N loss.

MATERIALS AND METHODS

The Fertilizer Experiments

The experiment on source, rate, date and cultivar and the split application experiment were conducted in the field at two locations, the Michigan State University farm at E. Lansing and the Carl Stuart farm near Saranac, Michigan. The study of the organic N content of different cultivars was conducted at E. Lansing.

All experiments at East Lansing were planted on October 4, 1977. The soil was primarily a Selfridge sand with a 2-6% slope. There was also a small area of Capac loam of 0-3% slope. The dates of the fertilizer applications and growth stages at the time of application were as follows: December 1977, winter dormant; April 10, 1978, growth initiation; May 5, 1978, growth initiation plus three weeks; May 27, 1978, fully tillered.

All experiments at Saranac were planted on October 6, 1977. The soil was predominantly a Matherton loam of 2-6% slope, the remainder being an Ionia loam of 2-6% slope. The dates of the fertilizer applications and growth stages at the time of application were as follows: December 1977, winter dormant; April 16, 1978, growth initiation; May 7, 1978, growth initiation plus three weeks; May 28, 1978, fully tillered.

At both locations, the wheat was planted after soybeans which were plowed down in the last week of July, 1977. The seed was planted with a 4-row drill, at the rate of 60 g/plot (100 kg/ha). The soil was fertilized with 560 kg/ha 0-25-25, broadcast at time of planting. All plots were 1.22 x 5.49 m and cut back to 1.22 x 3.66 m for harvest. Each plot contained 4 rows of plants and received one treatment.

All fertilizer treatments were made by hand, except for the 0-25-25 at planting. At the time of the December applications, there was no snow cover at either location, but the ground was frozen and remained so until the spring thaw.

Weeds were controlled with 1 pt/a (1.45 l/ha) of 2, 4-D, applied at the fully tillered stage, before stem elongation. This treatment was very successful on the East Lansing field, but resulted in poor control at the Saranac location.

Nitrogen Source, Rate and Date Application on Wheat Cultivars

The effects of source, rate and date of application of N on two cultivars of wheat were examined in a split-split plot randomized block design at East Lansing and Saranac. Dates and cultivars were the first and second main plot factors respectively. A factorial arrangement of treatments was used with three blocks at each location.

Two cultivars of Michigan soft white winter wheat (Ionia and Tecumseh) were used because of their differing responses to nitrogen fertilizer.

Two types of fertilizer were used; ammonium nitrate (34-0-0) as a nitrogen source, and 19-19-19 as a complete fertilizer. The fertilizers were applied at four different rates (0, 45, 90 and 135 kg N/ha) and the applications were made at four separate growth stages (winter dormant, growth initiation, growth initiation plus three weeks, and fully tillered before stem elongation).

When all plots had reached full maturity the border rows of each plot were removed and the two center rows of plants were harvested with a "Hegge" combine. The grain from each plot was dried, recleaned, weighed, and test weight determined.

Split Application of Nitrogen on Wheat

The effect of applying N in two separate increments was studied in a split-application experiment using four cultivars of soft white winter wheat: Ionia, Yorkstar, Tecumseh and Frankenmuth. The experiment was conducted at East Lansing and Saranac as a split-split plot in a randomized complete block design. A factorial arrangement of treatments with three blocks was used.

Four rates of fertilizer were applied (0, 45, 90, 135 kg N/ha as NH_4NO_3) and there were three "time of application" treatments. These were:

1) Half the fertilizer at spring growth initiation and half at spring growth initiation plus three weeks.
2) Half at spring growth initiation and half at fully tillered.
3) Half at spring growth initiation plus three weeks and half at fully tillered.

Harvest and the post harvest treatment of the grain followed the same procedure as previously described.

Partitioning of Organic Nitrogen by the Wheat Plant

N uptake and distribution through the life cycle of the wheat plant was studied to determine whether there were differences in RN assimilation and partitioning between different response types.

The experiment was conducted in East Lansing as a split plot in a randomized complete block design with a factorial arrangement of treatments and three blocks. The whole plot factor (A) was the fertilizer and cultivar treatments and the split factor (B) was the plant parts within a plot.

Four rates of N were applied to the four cultivars (Ionia, Yorkstar, Tecumseh and Frankenmuth), but because of the generally low response to N (in 1978), only plants that received the two extremes (0 kg N/ha and 135 kg N/ha) were analyzed for organic nitrogen. The nitrogen application was split over two dates (67.5 kg N/ha at spring growth initiation and 67.5 kg N/ha at growth initiation plus three weeks). This was done to ensure high soil N levels during the early stages of growth as well as after the major portion of the spring run-off had occurred.

Whole-plant samples were harvested at growth initiation in the spring, at the fully tillered stage before stem elongation, at anthesis and maturity. The respective harvest dates were 4-14-78, 5-20-78, 6-13-78*, 7-22-78. Whole-plant samples were taken only from the center two rows of each plot, to avoid edge effects. The person harvesting the plants selected a uniform foot long section in one of the two center rows, more than 2' from either end. After measuring the section the plants were up-rooted and the soil on the roots removed. Each sample was placed in a pre-labelled paper bag and taken to a cold-storage room (42°F). These samples comprised the "bulk samples". Ten fairly uniform culms were selected out of each bulk sample, cut up with scissors into their major parts and the crowns washed free of soil. This was

*Tecumseh reached anthesis one week before the other cultivars and was harvested on 6-8-78.

all done on the day the samples were collected. The entire sample taken at growth initiation was partitioned, because the amount of plant material was so small.

At the growth initiation and fully tillered stages, the plants were partitioned into crowns, "stems" and leaves only. On the last two collection dates the plants were partitioned into crowns, stems, lower leaves, flag leaves and heads. The leaves were removed at the base of the blade, the leaf sheaths remaining on the stem. The grain was not separated from the rachis. The plant parts for each plot were placed separately in pre-labelled paper bags and dried at 70°C for four to five days. They were then stored.

After all the material had been harvested, cut into sections and dried, each plant part was weighed separately and ground in a Wiley-mill with a 40-mesh screen. This ground material was stored in labelled coin envelopes.

Two determinations were made of the organic N content of each plant part from each plot. The ground material was stirred for homogeneity and two identical samples were weighed out to one ten-thousandth of a gram. These weighed samples were put in test tubes, labelled, corked and stored until the analysis was done.

The sample sizes taken in the above process were as follows:

1) 20 mg samples were used in testing green leaf tissue because of its expected high protein content.
2) 30 mg samples were used in testing crown and dry leaf tissues.
3) 40 mg samples were used for stem-tissue analysis because of its low expected protein content.

The analysis for organic N was done using an automated micro-kjeldahl procedure performed on a Technicon Auto-analyser[1/]. The weighed samples were pre-digested by adding 4 ml of the standard digestion mixture and then boiling until clear. The samples were allowed to cool, diluted with 6 ml of distilled H_2O and stirred on an automatic stirrer. An aliquot of this liquid sample was then poured into an analyser cup. Forty such cups were prepared and placed on the analyser at one time. The machine measured only the RN content (Appendix 1). It gave the results as light adsorption peaks on a graph. The RN content was calculated from these peaks by the standard procedure. When all the organic nitrogen concentrations had been calculated, the values for the two determinations on each plant part were averaged to give one means value.

[1/] Description of procedure available from: Technicon Corporation, Tarrytown, NY.

RESULTS AND DISCUSSION

I. Nitrogen Source, Rate and Date of Application on Wheat Cultivars[1/]

Regardless of all other factors, nitrogen increased average yields. There was a strong response to N at Saranac, while at E. Lansing there were no yield increases from applied N above 45 kg/ha. Yields were higher in E. Lansing, but responses to N were lower. This might have been partially due to the higher disease and insect infestations and lower native N fertility at Saranac. In general, this year, yields of both cultivars were five to ten bu/a (350 to 650 kg/ha) lower than average (17). The mean yield of Tecumseh was lower than Ionia at both locations, but both cultivars showed similar response patterns. It appeared that there was a difference in the cultivars responses to date of N application. However, this was due to Tecumseh's low base yield in the blocks receiving fertilizer treatments in December (Fig. 1).

Both cultivars showed small, similar responses to N applications at all dates at both locations ranging from 45 kg/ha to 370 kg/ha in East Lansing and from 30 to 810 kg/ha at Saranac.

In general, the data supported the current recommendations for Michigan on N applications and suggests that there can be benefit from applying N even at the fully tillered stage if the soil was too wet for earlier applications.

[1/] Mean yields for each treatment at both locations are given in Appendix 2.

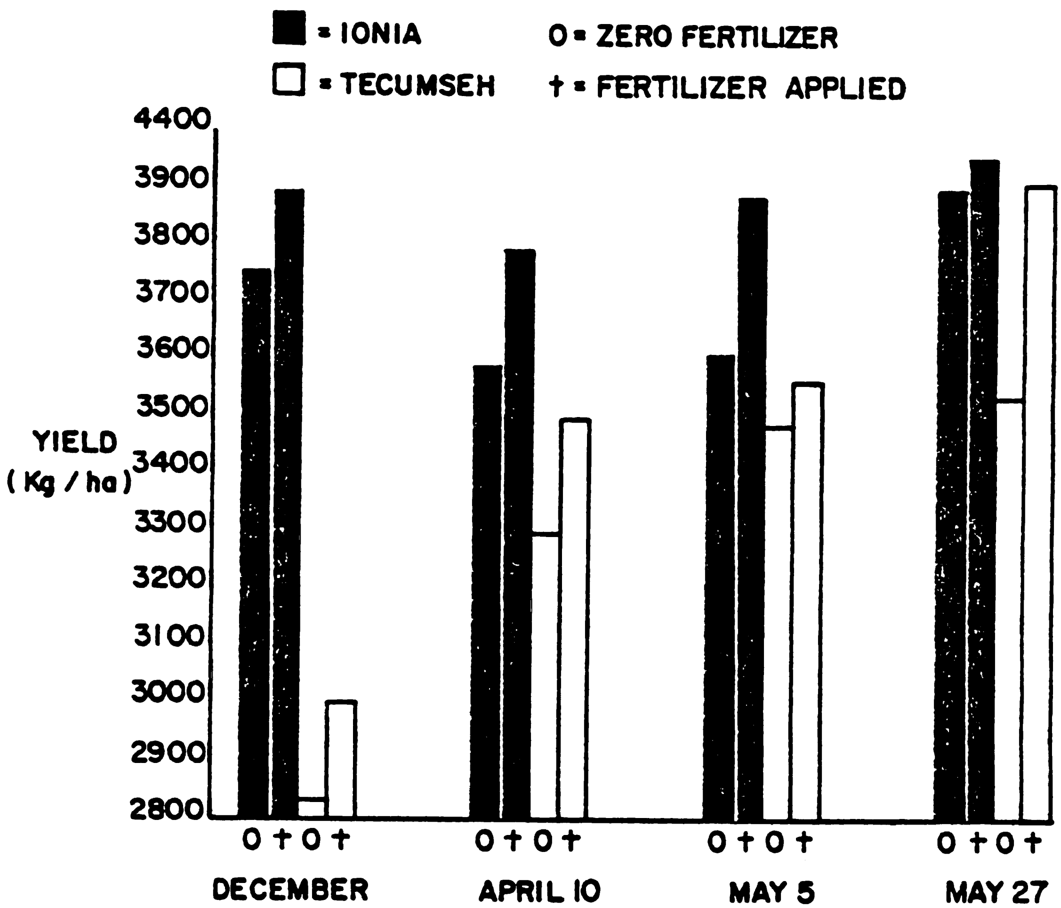

Figure 1. The mean yield response of two wheat cultivars (Ionia and Tecumseh) to nitrogen applied on four different dates in East Lansing. Columns designated with a + represent mean yields averaged over 45, 90 and 135 kg/ha and over two sources (34-0-0 and 19-19-19) L.S.D. .05 for the date x cultivar interaction = 331 kg/ha.

There was a difference in yield in relation to source of N at Saranac. The consistently higher yields of plots that received N from the complete fertilizer (19-19-19) over plots that received the same amount of N from NH_4NO_3 indicated this was not due to chance. Ionia showed it's usual low response pattern when topdressed with N alone, but had a high response pattern under complete fertilizer topdressings (Figure 2a. and 2b.). At Saranac, the yield of Tecumseh was also higher under complete fertilizer (Figure 3a. and 3b.).

Soil tests at Saranac showed 83 kg/ha of phosphorous and 165 kg/ha of potassium and at E. Lansing 83 kg/ha of phosphorous and 340 kg/ha of potassium. With 560 kg/ha of 0-25-25 plowed down at planting, P and K should not have been limiting factors.

This data suggests that higher P and K levels could be of benefit to Ionia. Moreover, the increased yields with 19-19-19 in both cultivars, indicate that with the new varieties in use today, and the higher levels of N being used on wheat, higher levels of P and K may be of benefit, or banding of fertilizer may be necessary.

Split-Application of Nitrogen on Wheat Cultivars[1/]

In this experiment each N application was split over 2 dates. Three combinations of such splits were compared. The different date treatments had no effect on response so only the effects of the total rate of N (45, 90, 135 kg/ha) applied in this fashion are considered in Figures 4a. and 4b.

All cultivars showed a significant response to applied N at Saranac (Figure 4b.). In E. Lansing, (Figure 4a.) increasing rates of applied N caused yield increases in Ionia and Frankenmuth only.

[1/] Mean yields for both locations are shown in Appendix 3.

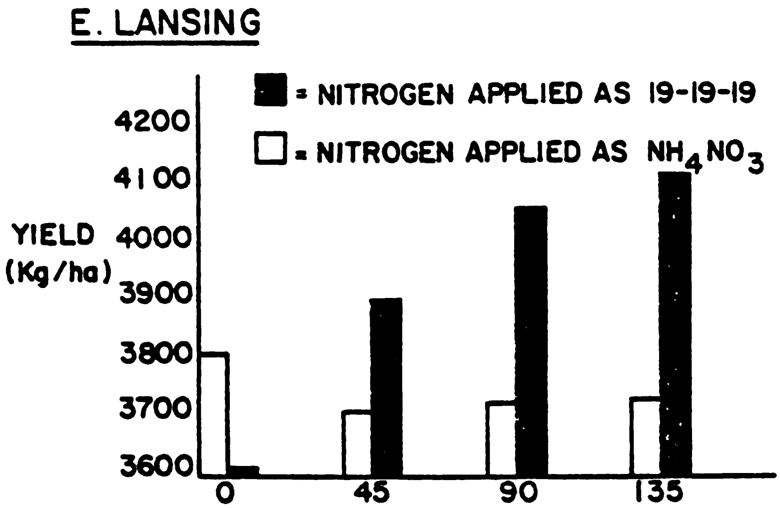

Figure 2a

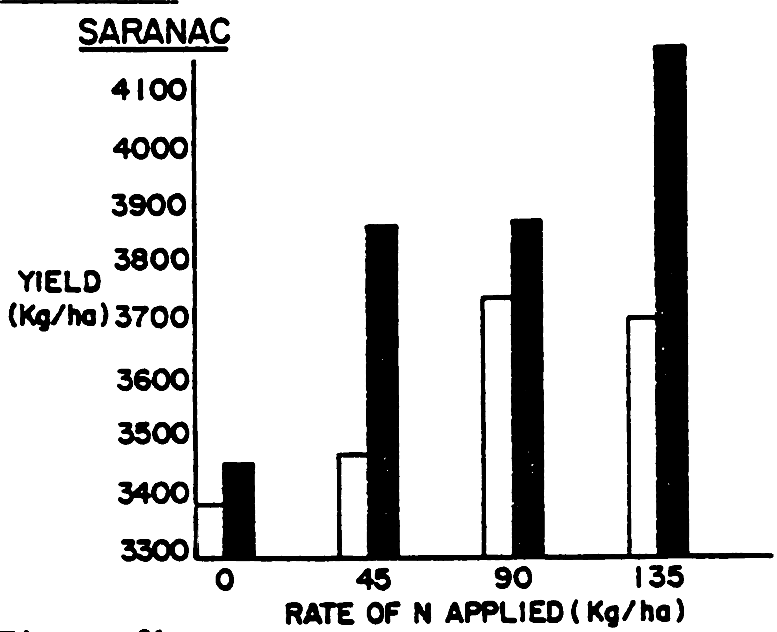

Figure 2b

Figures 2a and 2b. The mean yields of the wheat cultivar Ionia in response to rates of nitrogen applied as NH_4NO_3 and 19-19-19 at two locations. Results are averaged over dates of application. The difference between sources at Saranac is significant at the .05 level.

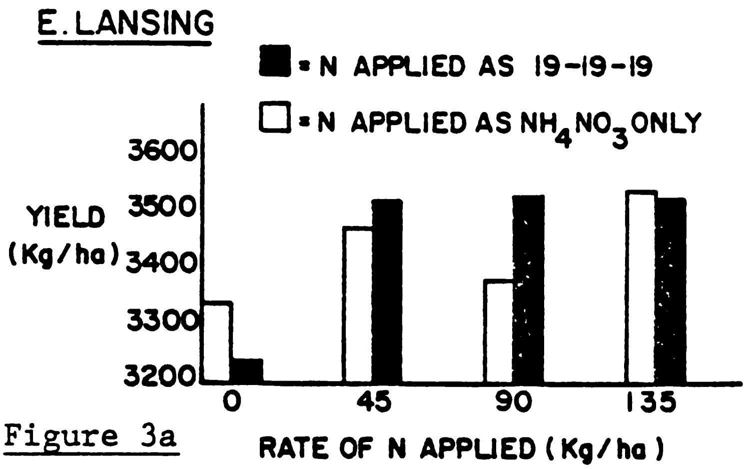

Figure 3a

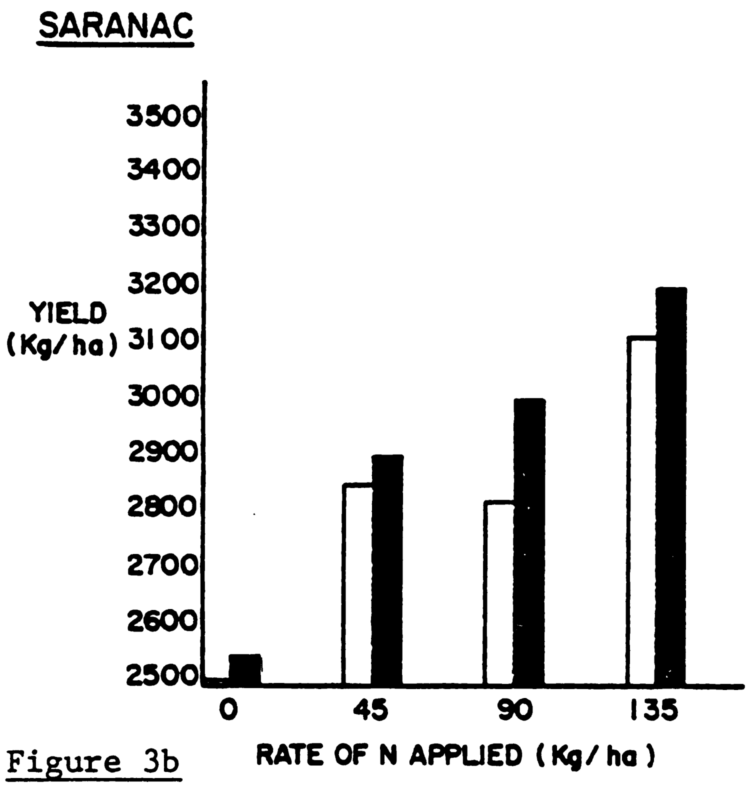

Figure 3b

Figures 3a and 3b. The mean yields of the wheat cultivar Tecumseh in response to rates of nitrogen applied as NH_4NO_3 and 19-19-19 at two locations. Results are averaged over dates of application. The differences between sources at Saranac is significant at the .05 level

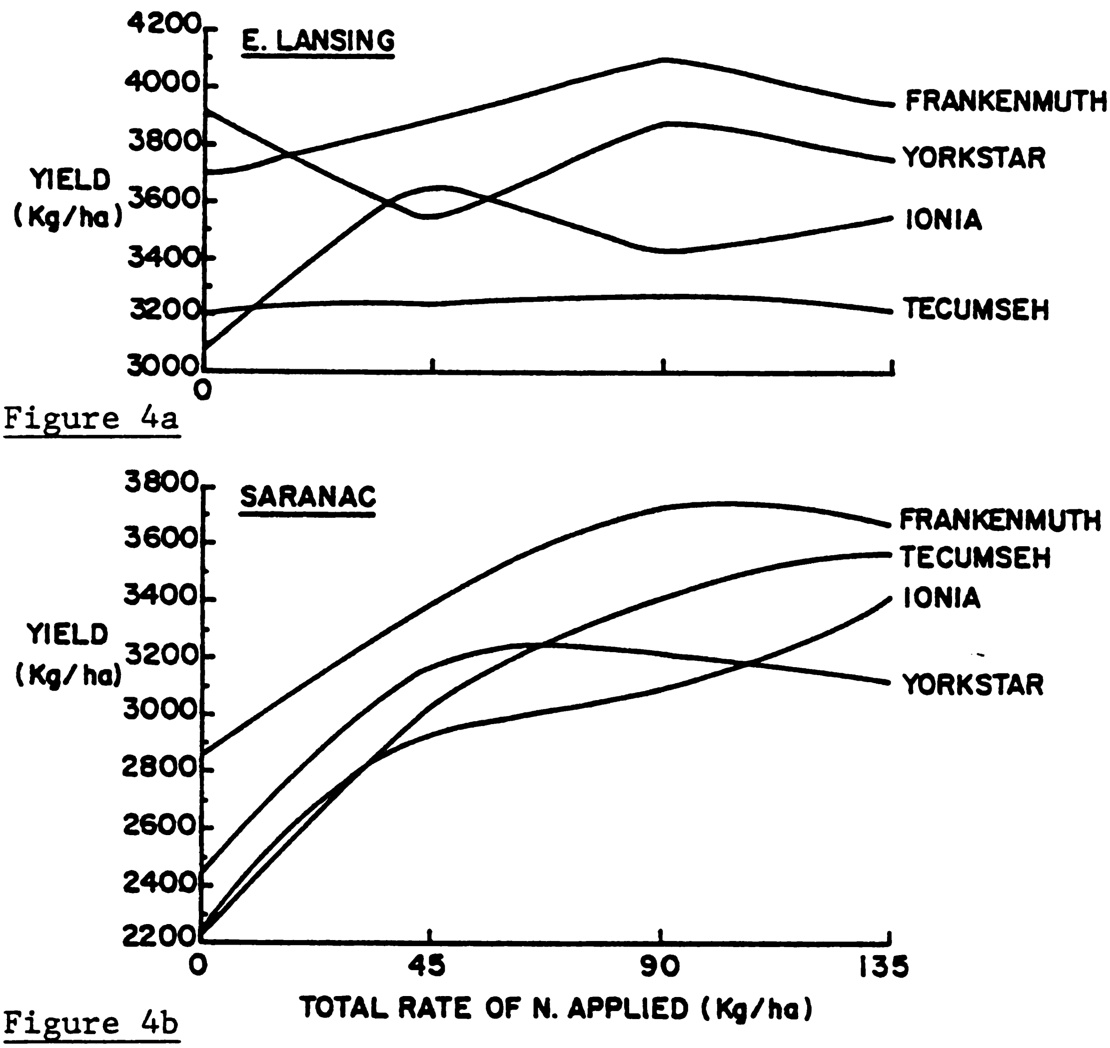

Figure 4a

Figure 4b

Figures 4a and 4b. The yields of four wheat cultivars in response to three rates of applied nitrogen at the East Lansing and Saranac locations. At East Lansing the L.S.D. .05 = 313 kg/ha for comparisons between cultivars at the same or different rates of applied nitrogen. The data is averaged over three dates of application and the curves are hand drawn.

At Saranac (Figure 4b.) there were no differences in response between cultivars and yield responses were much more pronounced. The yield of all varieties increased with additional increments of nitrogen except for Yorkstar. Yorkstar increased with 45 kg/ha of nitrogen, plateaued and declined slightly with higher increments of N. The overall yield of Yorkstar at Saranac was reduced because of a lack of resistance to leaf rust and Hessian fly. The other cultivars were resistant.

Mean yields from the split applications never reached those of applications made on a single date. The yield of plots that received half their total N after the fully tillered stage were no different from those receiving the same application entirely before the fully tillered stage had been reached. This was true for all cultivars.

Summary

1) Ionia, generally considered a low response cultivar, showed a response to N equal to Tecumseh and greater than Yorkstar (both high response cultivars) at Saranac under split applications. Tecumseh showed no response to N in E. Lansing but increased yields with increasing increments of N at Saranac under split applications. This shows the important effect that environment may have on response patterns.
2) At both locations Ionia showed a greater response when N was provided in a complete fertilizer (19-19-19).
3) Tecumseh's greatest yield response to N in E. Lansing occurred when the application was made after the fully tillered stage. Ionia responded equally to N applied at or before this stage.

4) In general the data supported fertilizer recommendations of the Michigan State Cooperative Extension Service.

Partitioning of Organic Nitrogen by the Wheat Plant

The Concentration of Reduced Nitrogen in Plant Parts at Different Growth Stages[1/] [2/]

At growth initiation, there were no differences between cultivars in the concentration of reduced nitrogen (RN) in any plant parts. In all cultivars, the leaves contained higher concentrations than the crown sections, and the "stem" sections tended to be intermediate.

At the fully tillered stage applying N increased the RN concentration in all plant parts of all cultivars. Frankenmuth had an RN concentration in the leaves that was higher than Ionia. Ionia was not different from Yorkstar or Tecumseh.

At anthesis, plants with added fertilizer continued to have greater RN concentrations in all plant parts except the heads. There were no differences between cultivars.

At maturity, with added fertilizer, plants had higher RN concentrations in all parts except the crowns which showed small, nonsignificant increases. Ionia had lower concentrations than other cultivars in the lower leaves and flag leaves and Yorkstar had higher concentrations. Tecumseh had a higher concentration in the head than other cultivars, but had similar concentrations in all other plant parts. Concentrations of RN in the stems tended to be lower than in the crowns, and showed no differences between cultivars.

[1/] Throughout this study, only productive tillers were considered at anthesis and maturity.

[2/] Mean values for each plant part of each treatment are given in Appendix 4.

Weight of Plant Parts Per Shoot[1/]

At growth initiation, the leaves comprised just less than half of the total dry weight and the "stem" sections were only slightly heavier than the crowns. There were no differences between cultivars.

At the fully tillered stage, Tecumseh had less leaf dry matter than the other cultivars. There were no other differences between cultivars. Leaf dry matter still out-weighed "stem" and crown dry matter.

At anthesis, Ionia had heavier stems than all other cultivars. Tecumseh had less leaf, stem and head dry weight. There were no other differences between plant parts across cultivars.

At maturity, Tecumseh had smaller heads than the other cultivars (approximately 2/3 the size of the others) and less stem dry matter than Ionia. There were no other differences between plant parts across cultivars.

Added nitrogen did not cause any increases in the weight of any plant parts at any growth stage. This was further reflected in total dry weight per culm since there was no response to applied N in any cultivar on a whole shoot basis. Tecumseh had less dry weight than all other cultivars at the fully tillered stage, anthesis and maturity. Figure 5 shows the total dry matter accumulated per culm at different growth stages. The differences between Tecumseh and the others at anthesis is largely due to a smaller stem. At maturity the difference is mostly in head weight.

[1/] Mean values for each plant part of each treatment are given in Appendix 5.

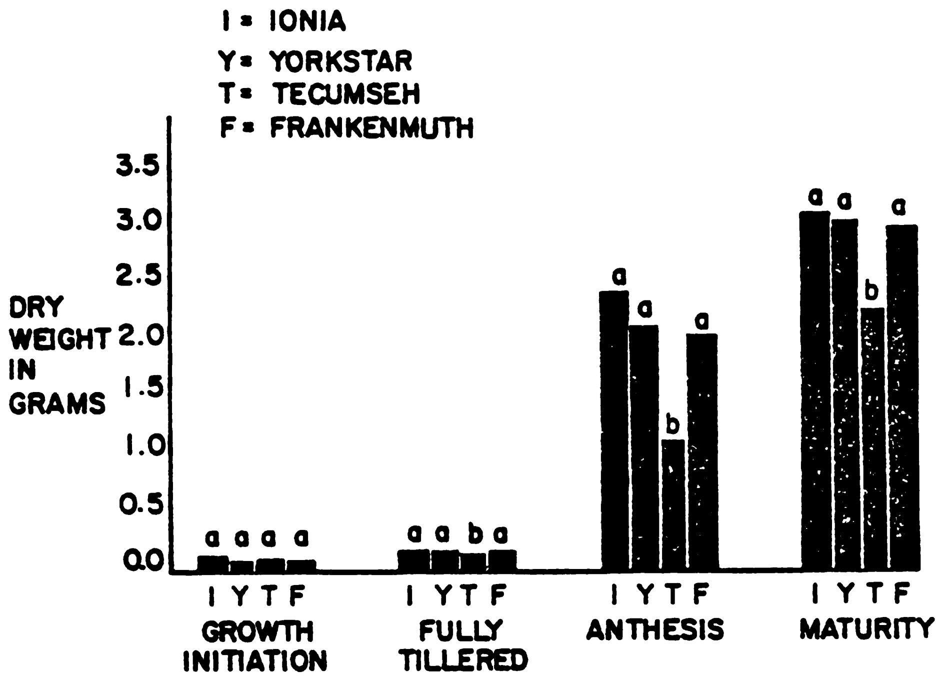

Figure 5. The total dry weight per culm of four wheat cultivars at four growth stages. Within a growth stage, columns topped with the same letter are not significantly different at the .01 level.

Total Accumulation of RN Per Plant Part

At growth initiation, there were no differences between cultivars. The total RN in the leaves was greater than in the crown section. The "stem" sections tended to contain an intermediate amount.

At the fully tillered stage, there were no differences between Ionia, Yorkstar and Frankenmuth. The distribution of total plant RN followed the same pattern as at growth initiation. Tecumseh contained similar amounts of RN as the other cultivars in the crown and "stem" sections, but had less total RN in the leaves because of the dry matter difference. Applied N showed a tendency to increase the total RN in all plant parts, but the increases were nonsignificant.

At anthesis, Ionia, Yorkstar and Frankenmuth contained similar quantities in all plant parts except that Ionia had more in the stem than Frankenmuth. Tecumseh, being shorter than the other cultivars, contained less RN in all plant parts except in the crowns. Added N increased the total RN accumulated in the stems and leaves of all cultivars but not in the crown or heads.

At maturity, Tecumseh contained an average of 6 to 8 mg of RN less than the other cultivars, but there were no significant differences between plant parts across cultivars. Applied N tended to increase RN in all plant parts, but only the heads showed significant increases.

Total RN Accumulation Within Culms

Figure 6. shows the RN accumulation per culm of the four cultivars, averaged across N application rates.

At anthesis Ionia contained more RN than Frankenmuth largely because of the greater amount contained in the stem.

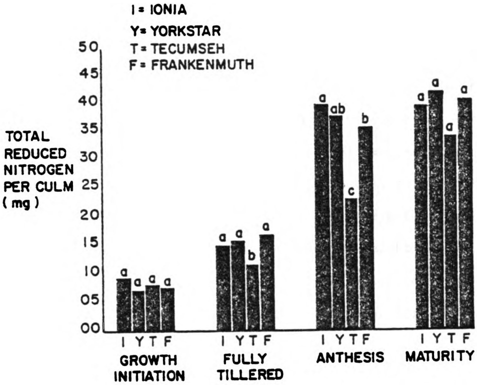

Figure 6. The reduced nitrogen content per culm (averaged over rates of applied nitrogen) of four wheat cultivars at four growth stages. Within a growth stage, columns topped by the same letter are not significantly different at the .01 level.

Tecumseh accumulated more RN than other cultivars between anthesis and maturity. Yorkstar, Frankenmuth and Ionia accumulated most of their total RN between the fully tillered stage and anthesis. Yorkstar and Frankenmuth both showed small net gains between anthesis and maturity. Ionia showed no net gain in this period but it is unlikely that the small differences between these three cultivars would have any significant effect on yield.

Discussion

There were no differences between cultivars in response to N fertilizer in terms of concentration and total accumulated RN. Figures 7a and 7b show that there were no major differences in the way the cultivars partitioned RN within culms at any growth stage.

Neither increased accumulation of RN per culm, nor increased concentration of RN caused any increase in the dry weight of plant parts on a per culm basis. At maturity, the head dry weight of Ionia and Frankenmuth decreased slightly with applied N, while Yorkstar and Tecumseh increased 7.6% and 4% respectively. These differences were not statistically significant.

These data show no major differences in the amount of RN accumulated per culm, nor in the way the RN is partitioned within culms that can account for the differing yield responses between cultivars. Furthermore, since increased total RN and %RN did not increase head weight per culm, these data suggest that the differing yield responses may be due to differing relative increases in head number per unit area.

One years' data collected by Mark Winslow at Michigan State University, showed significant differences between these cultivars in the number of heads produced per plot in response to applied N. Counts

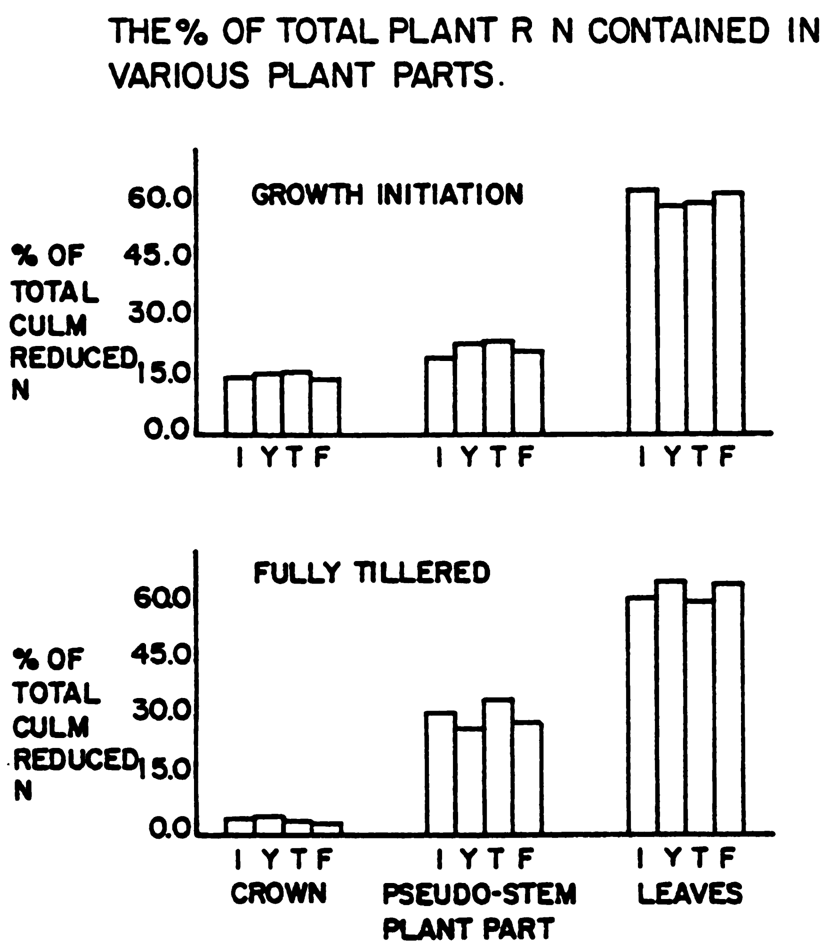

Figure 7a. The percent of total plant reduced nitrogen contained in the plant parts of four wheat cultivars at two growth stages.
I=Ionia, Y=Yorkstar, T=Tecumseh, F=Frankenmuth.

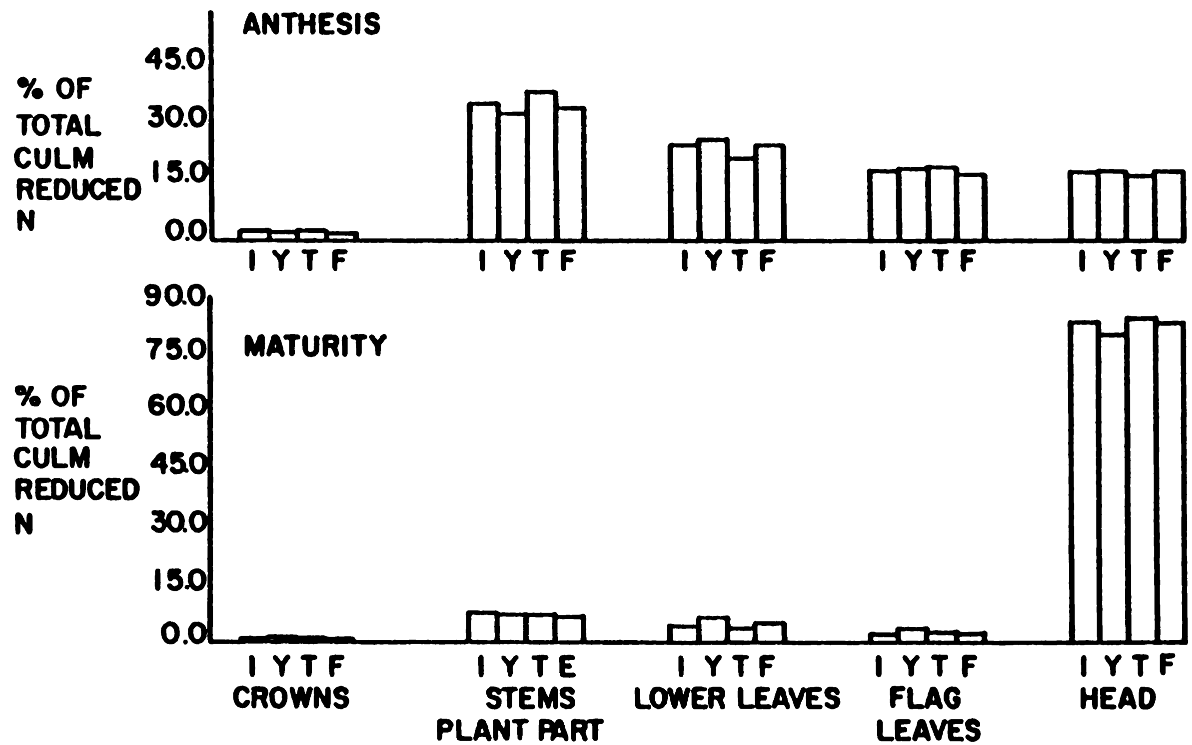

Figure 7b. The percent of total plant reduced nitrogen contained in the plant parts of four wheat cultivars at two growth stages.
I=Ionia, Y=Yorkstar, T=Tecumseh, F=Frankenmuth

taken at anthesis on the number of tillers initiated versus the number that matured suggested that this was another possible source of differences between cultivars.

Notes on Protein Content Per Head, on a Per Culm Basis

Tecumseh had a higher grain protein concentration than the other cultivars. At maturity, Tecumseh's concentration of RN in vegetative plant parts was similar to all other cultivars. Tecumseh also had a similar distribution of its total plant RN (Figure 7b.). Thus the high grain protein level of Tecumseh was not due to greater remobilization of previously assimilated RN.

Ionia, Yorkstar and Frankenmuth virtually attained their maximum RN content by anthesis whereas Tecumseh assimilated 38% of its maximum RN content between anthesis and maturity. Ries et al. (33) showed that protein content per seed was greatest in the lower ten spikelets of a head, and in the first two seeds per spikelet. Unpublished data collected by Mark Winslow of Michigan State University showed Tecumseh to have the fewest spikelets per head and the fewest seeds per spikelet of the four cultivars used. Thus Tecumseh's higher grain protein content appeared to be due to a different head morphology rather than a different uptake or remobilization system.

SUMMARY AND CONCLUSION

Yield responses to N fertilizer varied between cultivars and locations. Yields were five to ten bu/a (350-650 hg/ha) lower than usual this year and where yields were lowest, all cultivars increased yields equally with increasing increments of N. Splitting N applications over time and/or varying the date of application had no effect on yields.

At Saranac, yields were increased when 19-19-19 was used as a topdressing rather than 34-0-0. The specific cause was not determined.

All cultivars had similar concentrations of RN in all plant parts at all growth stages, except that Tecumseh had a higher RN concentration in the head at maturity. All cultivars showed a similar capacity to increase RN concentrations in all plant parts on a per culm basis when fertilized with N. Though uptake of N was increased, there was no increase in the dry weight of leaves, stems or heads per tiller. The distribution of the total RN contained per tiller was similar for all cultivars. Ionia, Yorkstar and Frankenmuth assimilated most of their RN prior to anthesis while Tecumseh assimilated 38% of its maximum total RN after anthesis.

It was concluded that:

1) Yield response patterns to nitrogen, for the four cultivars used, were heavily dependent upon the environment and were affected differently by the same environment.

2) With today's higher N rates, increased applications of P and K fertilizer may be of benefit on some cultivars.

3) The generally low yield response pattern of Ionia was not due to restricted N assimilation.

4) The different yield response patterns of these cultivars were not due to differences in the partitioning of N.

5) Increased head weight was not a major response mechanism in these cultivars.

6) Tecumseh's high grain protein level was not due to greater relative assimilation of RN, nor to greater translocation of RN from the vegetative plant parts to the grain. It may be related to the fact that Tecumseh has fewer spikelets/head and fewer seeds/spikelet.

APPENDICES

Appendix 1

An experiment was carried out to test whether the Technicon Auto Analyser measured total nitrogen or only organic nitrogen.

The experiment was conducted in a completely randomized design with three replications and anayzed using the analysis of variance method. Two types of plant tissues were used. These were the "stems" at the fully tillered stage and the heads at maturity. These materials were collected, dried, ground and stored as described in the Materials and Methods of the organic nitrogen study. From each type of tissue one gram samples were prepared containing 0%, 0.25%, 0.5% and 1.0% added nitrate by weight. These samples were thoroughly homogenized and then analyzed for nitrogen on the Technicon Auto Analyser by the procedure described in the Materials and Methods of the organic nitrogen study.

The average N content was 22.96 mg/gm dr. wt. in the heads and 37.23 mg/gm dr. wt. in the stems. These results were consistent and showed no significant differences between treatments within a plant tissue type. No trends were apparent either.

It was concluded that when nitrate levels were within the range generally found in plants the Technicon Auto Analyser measured only RN.

Appendix 2

FERTILIZER DATA

1. <u>The Rate, Date, Source and Cultivar Experiment</u>

A) At East Lansing

	Ionia				Tecumseh			
NH_4NO_3	Date of Application*				Date of Application*			
Rate of N applied (kg/ha)	1	2	3	4	1	2	3	4
0	3929.8	3870.5	3527.7	3936.2	3081.4	3504.0	3396.9	3379.9
45	3749.6	3800.3	3588.9	3706.1	2919.5	3416.1	3507.4	4055.1
90	3541.2	3484.4	3927.4	3976.4	2682.7	3479.7	3514.5	3880.2
135	3400.1	3767.5	3705.4	4075.1	3184.7	3537.2	3539.5	3902.8
19-19-19								
N applied (kg/ha)								
0	3578.2	3312.6	3690.6	3875.2	2592.7	3089.4	3582.3	3694.7
45	4099.4	3802.4	4119.0	3620.3	3402.9	3412.0	3352.0	3922.1
90	4067.0	3953.3	4184.2	4053.8	2986.6	3642.6	3797.7	3702.3
135	4504.9	3955.8	3788.3	4273.9	3150.2	3559.5	3402.6	4008.1

*<u>Date of Application</u> 1 = December, 1977 2 = mid April, 1978 3 = early May, 1978 4 = late May, 1978

B) At Saranac

	Ionia				Tecumseh			
NH_4NO_3	Date of Application*				Date of Application*			
Rate of N applied (kg/ha)	1	2	3	4	1	2	3	4
0	2630.4	3802.5	3662.8	3487.5	2606.0	2487.7	2344.6	2567.4
45	2849.6	4008.6	3788.7	3282.9	2172.2	2876.4	2682.2	3716.1
90	3055.4	4372.6	3873.9	3742.7	2619.0	3638.7	2354.7	2724.2
135	3421.0	3502.3	2997.3	3944.8	2450.7	3530.0	3410.3	3112.0
19-19-19								
Rate of N applied (kg/ha)								
0	3502.5	4053.6	3157.2	3157.0	2466.2	2628.0	2506.7	2603.3
45	3620.6	4178.0	3940.7	3588.1	2252.8	3191.6	2916.5	3287.5
90	2989.8	4378.5	3967.1	4215.1	2628.9	3378.5	2852.6	3174.1
135	3913.1	4853.5	3990.0	4041.7	3280.6	3648.4	3009.1	2896.0

*<u>Date of Application</u> 1 = December, 1977 2 = mid April, 1978 3 = early May, 1978 4 = late May, 1978

Appendix 3

SPLIT APPLICATION EXPERIMENT

A) At East Lansing

Date of N Application*	Rate of Applied N (kg/ha)	Cultivar			
		Ionia	Yorkstar	Tecumseh	Frankenmuth
		Yield (kg/ha)			
1	0	3035.5	3642.8	3553.8	3846.1
	45	3790.2	3540.6	2996.2	3881.1
	90	3196.3	3790.7	3297.9	4449.7
	135	3521.3	3536.8	2866.9	4039.3
2	0	3066.0	4202.3	3121.3	3618.3
	45	3410.5	3842.1	3381.6	3945.0
	90	3594.7	3860.8	3332.7	4043.7
	135	3856.5	3914.7	3577.1	3959.6
3	0	3110.7	3902.8	2942.4	3623.0
	45	3745.5	3249.4	3325.6	3826.7
	90	3498.3	3969.6	3161.1	3854.8
	135	3295.0	3792.7	3201.4	3862.4

*Date 1 = mid April, 1978 2 = early May, 1978 3 = late May, 1978

B) At Saranac

Date of N Application*	Rate of Applied N (kg/ha)	Cultivar			
		Ionia	Yorkstar	Tecumseh	Frankenmuth
		Yield (kg/ha)			
1	0	2032.5	2596.2	2237.7	2858.6
	45	2874.7	3294.9	3041.0	3302.8
	90	2870.8	3344.9	3560.0	3832.9
	135	3233.6	3051.4	3805.1	3447.8
2	0	2329.6	2280.9	2306.5	2885.0
	45	3065.5	3122.9	3067.7	3393.2
	90	3090.6	3199.9	3418.1	3874.8
	135	3364.7	3286.5	3414.8	3620.2
3	0	2389.8	2440.6	2169.0	2818.7
	45	2877.7	3126.7	3006.7	3466.9
	90	3314.8	3062.8	3228.0	3497.6
	135	3674.9	3008.2	3496.9	3957.5

*Date 1 = mid April, 1978 2 = early May, 1978 3 = late May, 1978

Appendix 4

The RN concentration in Plant Parts of four Winter Wheat Cultivars at four growth Stages, over two levels of N fertility.

Growth Stage and Plant Part	Fertilizer Rate: 0 kg N/ha Cultivar* I	Y	T	F	Fertilizer Rate: 135 kg N/ha Cultivar* I	Y	T	F
	% RN				% RN			
Growth Initiation:								
crown	3.95	4.06	4.25	4.04	4.02	4.06	4.44	3.84
"stem"	4.04	4.42	4.13	4.38	4.00	4.34	4.15	4.33
leaves	4.30	4.34	4.42	4.65	4.32	4.62	4.63	4.54
				Fertilizer applied here				
Fully Tillered:								
crown	2.41	2.12	2.16	2.33	3.04	3.03	2.61	2.92
"stem"	3.36	2.96	2.73	3.29	3.75	4.01	3.69	3.80
leaves	4.60	5.06	4.66	5.27	5.31	5.54	5.50	5.56
Anthesis:								
crown	1.30	1.00	1.00	1.00	1.73	1.60	1.40	1.60
lower leaves	3.59	3.24	3.30	3.26	3.77	3.63	3.54	3.84
flag leaves	4.79	4.52	4.69	4.47	4.97	4.89	5.25	5.20
head	2.01	1.77	1.78	1.86	1.94	1.87	1.91	2.00
stems	0.98	0.95	1.04	0.88	1.13	1.22	1.41	1.20
Maturity:								
crown	0.47	0.40	0.48	0.39	0.50	0.53	0.45	0.51
lower leaves	0.83	1.38	1.05	1.07	1.62	1.90	1.68	1.96
flag leaves	0.95	1.35	1.08	1.13	1.32	1.80	1.67	1.65
head	1.62	1.74	2.09	1.76	2.24	2.08	2.47	1.93
stems	0.26	0.33	0.31	0.29	0.35	0.43	0.41	0.37

* I = Ionia Y = Yorkstar T = Tecumseh F = Frankenmuth

Appendix 5

Dry Weight of Plant Parts of four Winter Wheat Cultivars at four growth Stages and two levels of N fertility.

Growth Stage and Plant Part	Fertilizer Rate							
	0 kg N/ha Cultivar*				0 kg N/ha Cultivar*			
	I	Y	T	F	I	Y	T	F
	Dry Wt. (g)				Dry Wt. (g)			
Growth Initiation**:								
crown	0.039	0.033	0.029	0.025	0.034	0.026	0.029	0.038
stems	0.040	0.038	0.046	0.032	0.049	0.038	0.041	0.041
leaves	0.150	0.127	0.089	0.105	0.147	0.079	0.150	0.124
				Fertilizer applied here				
Fully Tillered:								
crown	0.021	0.023	0.019	0.032	0.030	0.377	0.176	0.026
stems	0.129	0.138	0.136	0.141	0.144	0.140	0.126	0.147
leaves	0.188	0.184	0.143	0.202	0.194	0.224	0.135	0.217
Anthesis:								
crown	0.065	0.063	0.053	0.056	0.054	0.063	0.048	0.055
lower leaves	0.262	0.265	0.143	0.225	0.307	0.339	0.151	0.296
flag leaf	0.142	0.131	0.076	0.106	0.159	0.172	0.098	0.155
head	0.354	0.282	0.233	0.345	0.368	0.403	0.231	0.367
stems	1.371	1.201	0.754	1.304	1.416	1.263	0.758	1.233
Maturity:								
crown	0.142	0.161	0.086	0.096	0.079	0.082	0.121	0.131
lower leaves	0.137	0.154	0.089	0.159	0.138	0.176	0.096	0.144
flag leaves	0.067	0.085	0.052	0.071	0.082	0.093	0.077	0.069
head	1.748	1.711	1.240	1.899	1.711	1.842	1.291	1.839
stems	1.106	0.888	0.803	0.853	1.082	0.937	0.737	0.884

* I = Ionia Y = Yorkstar T = Tecumseh F = Frankenmuth

** The weights for growth initiation are representative of the proportional weights of the plant parts but cannot be used for comparisons with other growth stages.

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