Responses of Barley and Wheat Cultivars to Applications of Fish-Solubles and Ammonium Nitrate

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INTRODUCTION

Recent regulations established by the EPA controlling the amount of effluent which can be discharged into coastal waters has led the fish industry to convert these waste products into fish-solubles (FS) and to seek economic uses for this product. One usage which has been proposed is as fertilizer for agricultural crops. Experiments on house plants, tomatoes (Lycopersicon esculentum), lettuce (Lactuca sativa), radish (Rhaphanus sativus), peas (Pisum sativum), mushrooms (Agaricus spp.), soybeans (Glycine max), and corn (Zea mays L.) have shown favorable responses to FS (2). FS applied on winter barley (Hordeum vulgare) as a spring topdressing showed a significant response, but yield was considerably below that obtained from an equivalent amount of N from NH_4NO_3 (30). The lack of a substantial response to a spring application led to this experiment using a fall application of FS.

The objectives of this experiment were: 1) to compare the response of four cultivars each of barley and wheat (Triticum aestivum) to a fall application of FS and a spring application of NH_4NO_3; 2) to estimate the ability of FS to supply the N needs of barley and wheat, and to see if FS is as effective as NH_4NO_3 in this respect; 3) to obtain data on grain yield and the components of yield, and determine the relationships of these components to yield.

Others (32) have reported that samples of 10 best heads from a barley plot can be used to estimate relative plot yields, based on kernel weight and total grain weight from the heads. Such samples were taken from the plots in this experiment to see if they would be of value in estimating treatment yields and to see how components of yield estimated from the 10 heads related to the same components estimated from a 61 cm section taken from the border row of the plots.

REVIEW OF LITERATURE

Condensed fish-solubles (FS) is produced from 'menhaden stickwater' which has been concentrated approximately seven times through vacuum evaporation. Stickwater has previously been considered effluent and disposed of into the ocean by the fish industry. In the early 1950's, production of fish meal increased and the by-product (stickwater) gained recognition for its nutritional value. Analysis has revealed this material as being a rich source of choline, niacin, pantothenic acid, riboflaven, biotin, and vitamin B12. For many years FS has been used as a nutritional source in farm animal feeds. FS is composed of approximately 50% dry matter in a complex of protein, fat, minerals, and vitamins. The exact composition will vary considerably with the species and age of fish, season and location of the catch, handling techniques, and the type of plant equipment used during processing (26).

The protein fraction of the FS is composed of a series of 16 amino acids which account for most of the 5.3% total nitrogen content. Mineral elements and their percentages or proportion of the total weight of FS are as follows: phosphorus (P) 1.5%, potash (K) 2.2%, calcium 0.06%, magnesium 0.11%, sodium and chlorine 1.14%, iron 573 ppm, aluminum 194 ppm, copper 44.3 ppm, zinc 18.1 ppm, manganese 5.22 ppm, and lesser amounts of barium, strontium, boron, chromium, lithium, nickel, rubidium, and silicone. Each gallon weighs 4.4 kg with a pH of 4.7 and 0.23 kg nitrogen, 0.06 kg phosphorus, and 0.10 kg potash (26).

The use of fish and fish by-products as fertilizer is an ancient practice which has long been associated with the American Indian. Recently, evidence has been discovered which shows the true origin of this practice to be uncertain (8). Interest in fish by-products as a source of plant nutrients has resulted in a few recent experiments. Information is available demonstrating a favorable response to FS with tomatoes, mushrooms, and vegetation along highway embankments (3). Various ornamental house plants, lettuce, radish, and peas have also exhibited favorable responses to FS (2). All plants expressed vigorous growth, dark and sometimes glossy foliage, and in the annuals, delayed fruiting and senescence. Growth responses by corn and soybeans are favorable, with a significant yield response for soybeans. One unfavorable characteristic is the inhibition of growth at high concentrations on sweet corn and tomatoes (2). FS are of complex composition, and comparison with chemical fertilizers cannot be accurately made until further information is made available (1).

To date, only one experiment using FS on winter barley has been conducted. An application of FS was made as a topdressing to barley in the spring of 1980 at the Eastern Virginia Research Station, Warsaw (29). The experiment was confounded by conditions which generally reduced yields, such as the lack of sufficient rainfall and a severe outbreak of barley yellow dwarf virus. The control yielded only about 8.8 q/ha and the plot receiving a spring topdressing of 56 kg N/ha from ammonium nitrate yielded 21.6 q/ha. That yield was significantly higher than those plots which received 14, 28, and 56 kg N/ha from FS. Those yields were 10.2, 11.7, and 13.1 q/ha, respectively. From these results, conclusions were that rainfall was insufficient or time was not available for the FS to mineralize and supply nutrients to the barley.

The major effects of the FS will probably be observed as a response to nitrogen, given enough time and suitable climatic conditions. Barley's response may be similar to the manner in which it responds to organic or inorganic N sources. Previous experiments testing the effects of various treatments of cattle and swine manure slurries on barley have demonstrated at research stations in Great Britain that slurry N is almost as effective as inorganic N (23). Slurry consisted of 2 to 3 day old floor scrapings from a shed which housed cows. Slurry composition ranged from 4.2 to 5.1 kg N/t. In this particular experiment with spring barley, winter or spring applications out-yielded fall applications. With a low slurry application (0 or 37.5 t/ha), an additional application of inorganic N was beneficial. However, when 112.5 t/ha was applied, any further N applications reduced yields. The largest grain yield, 48.7 q/ha, was obtained with a rate of 75 t slurry/ha applied at the end of February, without any additional fertilizer. Research has shown large applications of slurry are necessary because only about 50% of the total N becomes available to the plant during the growing season.

Slurry treatments in one of the years increased the proportion of large kernels, possibly leading to a higher 1000 kernel weight (Mkw), but inorganic N had no effect on this component. The second year, no effects were observed. Weight/unit volume (test weight) was increased by both inorganic N and slurry, though the effects of slurry treatments were greater (23).

Another similar experiment conducted at Alberta, Canada used 2 to 3 year-old barnyard (cattle) manure, which was applied and incorporated into the soil prior to planting spring barley each year of a six year experiment (17). The rates of manure, 134 and 150 t/ha, were compared with applications of 112 and 146 kg N/ha from a commercial fertilizer. The results revealed that plots which received the fertilizer treatment out-yielded those receiving the manure four out of the six years. In one of the years, the fertilizer plus manure treatments yielded significantly less than the fertilizer treatments. The probability exists that the N content of the two year old manure was substantially lower than the fresh manure, and that decomposition of this material may have tied up part of the inorganic N. This in part would explain lower yields with heavy applications when compared to the inorganic N.

A study was conducted at Blacksburg, Va. using NH_4NO_3 and four winter barley cultivars, a fall application of 56 kg N/ha, and three levels, 0, 28, and 56 kg N/ha applied in the spring (29). The highest mean yield was obtained with the addition of 28 kg N/ha, although some cultivars did increase further in yield at the 56 kg/ha level. Time of heading was delayed and lodging increased when the

N rates increased. Generally, the difference between the 28 and 56 kg N/ha treatments was small, suggesting an optimum split-application rate of 84 kg N/ha for winter barley.

Several researchers have experimented with rates of N applications on spring barley cultivars in an effort to determine an optimum rate. An experiment conducted at an experiment station in Great Britain showed a linear increase in yield up to 50 kg N/ha, and only a slight change with increases up to 100 kg N/ha, after which yields expressed a linear decline (22). A linear, but small, decrease was recorded for the Mkw with increasing rates of N. The difference between the 0 and 150 kg N/ha treatments revealed an average decline of 10% in kernel weight. High yielding cultivars were discovered to have moderate to large Mkw.

A Canadian research station experiment determined mean yields of two cultivars to be greatest at 60 to 90 kg N/ha application rates, with significantly lower yields at both 30 and 120 kg N/ha. Increasing rates of N increased the number of kernels/spike, but decreased kernel weight. Cultivars in this experiment expressed different responses to N and references were made to similar conclusions obtained in previous experiments (7). Another Canadian study at the University of Manitoba compared ammonium nitrate and urea, with the ammonium nitrate treatments giving the best yields. With an increase in N up to 100 kg/ha, yields increased to 36 q/ha. Above 100 kg N/ha, yields rose only slightly and declined with applications of 120 kg N or more (30).

Timing studies of N applications on spring barley, conducted by Gately in Ireland, demonstrated that applying N at planting increased yields (13). Mean yields of 29.6, 35.3, and 38.8 q/ha, were obtained with 0, 39, and 78 kg N/ha, respectively. A slight mean increase over the control of 0.7 and 1.0 g in Mkw was detected with an increase in N from 39 to 78 kg/ha.

An experiment conducted in South-east Scotland used applications of 35 kg N/ha at the beginning of tillering, at the end of tillering, and at awn emergence (16). In the first year of the four year experiment, early top-dressing generally reduced yields, with the later applications giving positive responses, though none of the effects were significant. For the second year, early applications gave a substantial increase in yield (40.2 q/ha), 6.2 q/ha larger than the control. That year, the later applications had a progressively reduced effect. Over the last two years, all treatments gave small increases in yield of 2.7 q/ha for any of the 35 kg N/ha top-dressings, with no significant differences between dates. An increase in lodging and plant height was also obtained with the higher rates of N. Early applications gave greater height increases than late applications. Seedbed applications of all the N appeared to be the best practice. If a top-dressing is made, recommendations were to apply the N early.

In an experiment using irrigated plots of spring barley conducted at Yuma, Arizona, high N applications resulted in high yields (25). Nitrogen rates were 67 kg/ha applied in the fall, and 269 kg/ha applied at one or more of three times in the following combinations: all at planting, all at internode elongation, all at pollination, or split applications between two or three of these times. Yield for the higher rate was 25% better than the low rate. Single applications made at different growth stages revealed significant yield increases over the control. Single applications at planting produced yields nearly twice those from the topdressing at pollination. The best yields were achieved when treatments were split between all three growth stages or when split between planting and pollination.

Kernels/spike appeared to be quite sensitive to both the rate and time of N applications. High rates and early applications produced the greatest number of kernels/spike. Late N applications had little effect on kernel weight, but they were increased substantially with the early applications. Maximum kernel weights were produced with a 134 kg N/ha seedbed application and an additional 67 kg/ha at elongation and 67 kg/ha at pollination. If N was not applied at planting, low kernel weights resulted regardless of the N applied later in the season (25).

In conjunction with the previous experiment, another was implemented at the same site to evaluate seedbed applications to rates of N of 0, 67, 134, and 269 kg/ha (27). The results showed an increase in yield with an increase in N, but the 134 and 269 kg/ha treatments were not significantly different from the 67 kg treatment. Yields increased through an increase of kernels/spike. Kernel weight increased, test weights decreased, and the barley headed earlier with high rates of N. An experiment conducted at Montana State University gave results which showed kernel weight increased and test weight decreased with increasing N applications. Also, the spring barley headed earlier and plants grew taller with more N (21).

From available information, conclusions can be drawn pertaining to barley's response to N. Spring barley responded well to high rates of fresh manure. A majority of the data suggest N applications of 60 to 100 kg/ha would be the proper amount to achieve optimum yields under dryland conditions. Winter barley gave the best yields with a fall application of 56 and a spring application of 28 kg N/ha. Spring barley has responded well to a single seed bed application, expressing only slight yield increases with topdressings. Where there is an adequate supply of water, spring barley will respond to high rates and split applications of N.

These studies also indicate that with increasing rates of N, Mkw may decline, although results are conflicting. Kernels/spike appear to increase with ascending rates of N, and test weights decline. One explanation for reduced kernels/ spike is that with low N treatments, 60% fewer spikelet positions are formed , resulting in a reduced number of kernels/spikelet without reducing the average kernel weights. Therefore, conditions which reduce kernels/spike do not affect ultimate kernel size (10).

There have been no published experiments regarding the effects of FS on yield and yield components of winter wheat. Extensive research has been conducted with winter wheat regarding its response to applications of nitrogenous fertilizers. Most of these experiments pertain to the rate and time of application, such as one by Sanford and Hunter in Pennsylvania (28), comparing rates of 0, 34, 67, 100, 135, and 168 kg/ha at five locations as fall and spring applications. Nitrogen increased yields at all locations at rates up to 135 kg N/ha, with higher rates depressing yields. At one of the five locations, yield was significantly affected by time of application, being highest with fall applications. None of the locations displayed higher yields when all the N was applied in the spring. In this experiment, with references to others, the authors point out the importance of cultivar differences such as yielding ability, length and stiffness of straw, and susceptibility to lodging in gaining maximum responses to N fertilization.

Three sources of N; ammonium sulfate, ammonium nitrate, and calcium nitrate; and three times of application were tested over a three year period at a research station in Great Britain (12). The rate was 67 kg N/ha and the three times were all in the fall, 1/3 fall and 2/3 spring, and all in the spring. Also, one treatment was no N and another was 89 kg N/ha as ammonium sulfate applied in the spring. Grain yields increased with all spring N treatments, with all ten experiments showing a mean increase of slightly more than 1 q/ha obtained from the 67 kg/ha rate. Yields from spring applications were significantly higher than those from the fall applied N. The split applications gave lower yields than the spring only applications. The difference between response to spring and fall applications were related to rainfall.

Two levels of fall applied N, 22 and 44 kg/ha, and spring applied levels of 0, 33, 67, and 100 kg/ha were studied using three cultivars in an experiment conducted in Canada (19). No significant difference was found between the two fall rates. Yields increased with increasing rates of spring N, up to 100 kg/ha in one year and 67 kg/ha in the other two years. The results suggest the low application, 22 kg N/ha, would be sufficient in the fall with a need for a spring top-dressing of at least 67 kg N/ha.

In another experiment conducted in Great Britain, the responses of conventional and semi-dwarf cultivars were compared with 17 kg N/ha applied to the seedbed and top-dressed with rates of 0, 60, or 180 kg N/ha on April 23 (6). The semi-dwarf cultivars consistently gave a higher yield response to the 60 kg/ha top-dressing of N. This increase was caused by an increase in the number of spikes/square meter.

Eight spring applications of N, ranging from 0 to 210 kg/ha in 30 kg increments, were applied to wheat in a two year experiment conducted in Great Britain (24). Fungicides were also applied to control powdery mildew (Erysiphe graminis f. sp. tritici) and yellow rust (Puccinia striiformis). All varieties produced maximum yields with 150-180 kg N/ha. Interactions between cultivars and N were few and small compared to the main effects. Yields increased with increasing rates of N, with the number of spikes/square meter increasing with rates up to 90 kg/ha. Cultivars differed in kernels/spike, dry weight/kernel, and in the response of these components to N. Dry weight/kernel had a tendency to decline with increasing N rates. Grains/spike increased up to between 90 and 120 kg N/ha, after which they began to decline. Grain/spike were increased through increases in both the number of spikelets/spike and the number of kernels/spikelet.

Splitting applications was the subject of a three-year experiment conducted in Great Britain which utilized two levels of N, 67 and 135 kg/ha, the first year and 58 and 112 kg/ha the last two years (33). All possible combinations of fall N (applied immediately after planting), early spring (first or second week of March), and late spring (late April or early May), were applied to a total of 16 experiments. When compared to the control, significant increases in yield were consistently present for the low and high levels at most locations. At the higher level, split dressings (1/2 fall and 1/2 May or 1/2 March and 1/2 May), produced greatest yields. The 1/2 March - 1/2 May treatments gave the most consistent results, with the highest yields for the last two years of the experiment. Single May applications resulted in the lowest yields and there was no advantage to splitting the N among all three dates. Yields for the fall only application were lower than for one spring application.

An experiment by Hucklesby et al. conducted in Illinois compared rates and time of spring N applications on three wheat cultivars (18). On April 2, 23, and May 9, 56 and 112 kg N/ha were applied; 224 kg N/ha was applied only on April

23. Grain yield increased with all N treatments for all varieties. Only one cultivar displayed an increase in yield with the highest rate of N. The other varieties expressed maximum yields when 112 kg N/ha was applied on May 9. This experiment demonstrated that cultivar and time of N applications are critical factors in determining final yields.

A split-application study by Clapp in North Carolina used one cultivar and N rates of 56, 112, 168, and 224 kg/ha applied at planting or part at planting (56 kg/ha) and topdressed with the rest in February (9). On the clay-loam soil at one of the test sites, fall only and split-applications both resulted in high yields. The soil at the other location was a sandy loam and significant yield increases were obtained with February applications when compared to the applications made at planting for rates of 168 kg N/ha or less. On the clay loam soil, there was no significant difference in test weight between fall and February applications of N. However, when a majority of N was applied in February, a trend toward lower test weights was noted. The test weights declined as the rate of N increased. On the sandy loam, they measured similar test weight responses with the February applications. Increasing N from 112 to 224 kg/ha decreased test weight, regardless of when the N was applied. Kernel weight declined with increases in N from 46 to 184 kg/ha. This reduction in seed weight probably contributed to the lower test weights.

Two researchers working in Great Britain showed that increasing N rates gave no increase in the number of spikes/ square meter, but kernels/spike were increased, as was kernel weight/spike (20). Weight/kernel declined when rates of N increased from 0 to 180 kg/ha. Another experiment conducted in Great Britain showed late spring applications of 35 kg N/ha slightly increased Mkw, while early applications caused a slight decline in kernel weight. Applications of 35 kg N/ha at both early and late spring resulted in a definite decrease on Mkw (5).

The total dry weight of wheat is a function of the size of the photosynthetic system. However, grain yield is dependent on the proportion of the total dry weight that is found in the economically useful part. An increase in dry weight will not necessarily lead to an increase in yield if the storage capacity of the spike is limiting. Kernel size is only one of the components governing the storage capacity of the spike. Evidence points to the fact that assimilate supply, as well as the kernel's capacity to accumulate dry matter, ultimately controls final kernel size (20).

Cultivars respond differently to N applications and the components of yield seem to show different responses in different experiments. The majority of the available information indicates that kernel weights decline with increases in N and with early applications. Late spring top-dressing can result in higher Mkw. Test weights often decrease and kernels/spike often increase with moderate increases in N. The number of spikes/unit area seems to increase or sometimes remains unchanged.

In summary, these experiments indicate a need for high rates of N if all is applied in the fall to most soils in order to obtain high yields. High yields can be obtained with fall applications of approximately 30 kg N/ha and additional spring applications of up to 100 kg/ha. Studies suggest the necessity to split spring top-dressings to insure the highest yields, especially on lighter soils. With extremely high rates of N, it seems advisable to apply a fungicide to prevent crop damage due to the outbreak of diseases. Soil type, cultivar, and winter rainfall play an important role in yield responses to N.

MATERIALS AND METHODS

The fish-solubles experiment was established at the Eastern Virginia Research Station, Warsaw, on a Kempsville loam soil (Typic Hapludult; fine-sandy, silicious, thermic), using a split-split plot design with three replications. The whole plots were amounts of spring nitrogen (0 and 56 kg/ha) applied in the form of ammonium nitrate; the sub plots were amounts of fall nitrogen (0, 28, and 56 kg/ha) applied as FS; the sub-sub plots were cultivars of barley ('Barsoy', 'Surry', 'Henry', and 'Maury') or wheat ('McNair 1003', 'Coker 747', 'Tyler' and 'Wheeler'). Prior to planting, all plots received an application of 8-24-24 commercial fertilizer applied at the rate of 392 kg/ha. This fertilizer was applied with a fertilizer distributor and was disked into the soil several days prior to planting. A whole-plot was 6.1 m wide by 16.45 m long; a sub-plot, which contained four varieties, was bordered on two sides with a constant cultivar, using Henry barley or Tyler wheat. There was no border on the other two sides since tiers of plots were separated by 0.91 m alleyways. The wheat and barley whole-plots were interspersed within the experimental area for convenience in applying the whole-plot treatments; however each crop constituted a separate experiment and the data were summarized and analyzed on this basis.

On Nov. 8, 1980, the varieties were planted with push-type cone planters into 3-row plots, at a rate of 20 gm per row, with rows 6.1 m long and spaced 30.5 cm apart. Two days later, the FS were sprayed on the soil surface, using a push-type plot sprayer which sprayed a width of 3.05 m. It was necessary to make two trips across each sub-plot to cover the entire width. The FS material was diluted at a rate of one part FS to two parts water and was screened as it was poured into the tank to remove particles which would clog the spray nozzles. Spraying required several passes across each sub-plot in order to apply the amount of FS needed to provide 28 or 56 kg/ha of nitrogen. The several trips should have resulted in a uniform application of the materials.

The spring application of ammonium nitrate was applied on March 2, 1981. In order to obtain uniform distribution, the amount of ammonium nitrate needed for each sub-plot was weighed and broadcast on the surface by hand. This assured that each sub-plot received the proper amount of nitrogen. On March 9, soil samples were taken from the plots where ammonium nitrate was not applied to estimate the amount of nitrogen still available from the FS application. In order to obtain a representative sample, a soil probe was used to take ten borings (approximately 15 cm deep) from each subplot. Soil from the ten borings was thoroughly mixed, and analyses of the samples for nitrogen in the forms of NH_4 and NO_3 were carried out in the laboratory. Twenty grams were taken from each soil sample, mixed with 200 ml of 2N KCl, and shaken for one hour. These mixtures were filtered through a Buchner funnel and the extracts stored in test tubes. Within the funnel was placed a piece of moistened filter paper to prevent soil particles from contaminating the extracts. Contaminated samples were refiltered until the liquid appeared clear. Nitrate determination involved an initial reduction of NO_3 to NO_2, using a granulated copper-coated cadmium column described in the Manual of Methods for Chemical Analysis of Water and Waste (31). For a period of 1.5 minutes, each sample was run through the column with the assistance of a Cole-Palmer peristatic pump. Between samples, the column was rinsed for 30 seconds using 1 ml NH_4Cl-EDTA wash solution. Samples consisted of 13 drops collected during the last 20 seconds of the 1.5 minute cycle. A buffered color reagent was added to the samples and nitrate concentrations were determined colorimetrically with the aid of a Hitachi flow-through spectrophotometer at the 450 nm wavelength (32).

The 2N KCl extract was also used for ammonium determination. To the extract, 0.2 ml of 12.5N NaOH was added and NH_4 determined with an HNU ammonia electrode. The electrode was attached to a 901 Orion microprocessor ionalyzer which had been calibrated to a standard of 1 ppm NH_4 (15). Ammonium readings were taken directly from the digital readout on the microprocessor.

Tissue samples were collected on April 28 by harvesting 36 flag leaves (9 from each cultivar) within each sub-plot while the varieties were in the late boot to early bloom stage. The nine leaves per cultivar were collected at random from the entire length of the border rows in the sub-sub plots. These samples were analyzed by the Soil Testing and Plant Analysis Laboratory of Virginia Polytechnic Institute and State University. The results of the tissue analyses were recorded as percent nitrogen, phosphorus, potassium, calcium, and magnesium; as parts per million of zinc, manganese, copper, and iron.

In early spring, Paraquat herbicide was used to mark a row length of 5 m and the ends of the plots were mowed as needed to keep down regrowth. The plots were checked for heading at two-day intervals, and date headed was recorded when approximately one-third of the heads had emerged from the flag-leaf sheath. The date was expressed as days after

March 31. Prior to harvesting, plant height in cm was recorded, measuring the distance from the ground to the tip of the spikes. The percent of lodged plants was estimated visually on the day of harvest and expressed as a percentage.

On June 16, the center rows of the three row barley cultivar plots were harvested, using a modified Jari mower. The bundles were then threshed in a Vogel nursery thresher, and the grain samples collected in paper bags and stored. The wheat was harvested in the same manner six days later. Following harvest of the center rows, a '61 cm section' sample and a 'ten best head' sample were taken from the border rows of each plot. The 61 cm section samples were used to estimate number of spikes/61 cm and kernels/spike, and the ten best head samples were used to evaluate the usefulness of such samples in estimating yield and other traits. A measuring tool was fashioned to expedite taking the 61 cm section samples and to ensure consistency from plot to plot. This wooden tool was 61 cm in length with metal spikes placed at each end. Both barley and wheat samples were taken from one of the border rows, near the center of the row. A location representative of that row was selected.

The tool was inserted into the row at ground level and plants not belonging to that section were carefully separated. The sample was gathered in one hand and cut with a hand sickle. These samples were placed in paper bags and stored. The ten best head samples were taken from both border rows by visually selecting the better looking spikes and storing them in a small paper bag.

Approximately two weeks following threshing, the grain from the center rows was weighed. The three replicated samples of the same treatment were composited and a test weight was determined, using a Borner bushel-test-weight apparatus.

The heads in the 61 cm section samples were counted and the excess straw was clipped, leaving only the spikes. Threshing these spikes, as well as those of the ten head samples, was accomplished using a Wintersteiger head thresher. An air-blast seed cleaner was used to separate foreign materials from the kernels. Procedures followed for obtaining the data from the 61 cm sections and the ten head samples were as follows:

1) All the samples were weighed, with the weights for the center rows and 61 cm samples recorded to the nearest gram and that for the ten best heads to the nearest 0.1 gm.

2) A Count-a-pac seed counter was used to count 1000 kernels from the 61 cm section samples. The weights of these were recorded to the nearest 0.1 gm.

3) The Count-a-pac seed counter was used to count the total number of kernels in the ten best head samples.

4) From the 61 cm section data, an estimate of kernels/spike was determined by dividing the 1000 kernel weight into the total weight of the sample to estimate total kernel number, which was divided by the number of spikes.

5) From the ten best head data, estimates of 1000 kernel weight and of kernels/spike were made.

Data analyses were performed, using a SAS program for analyses of variance, estimating significance of the F values, and determining correlations (14).

RESULTS AND DISCUSSION

Although the barley and wheat plots were interspersed throughout the experimental area, data from the two crops were analyzed separately. Therefore, the results and discussion for each crop will be presented separately, followed by a general comparison of similarities and differences of responses to the fall applications of FS and spring applications of NH_4NO_3.

Table 1 shows significant yield responses by barley to both the FS and NH_4NO_3 applications, with no significant interaction between them. Between the 0 and 28 kg N/ha from FS at both levels of N from NH_4NO_3, little difference was evident, the major difference being between the two lower levels and the 56 kg N/ha level. Where NH_4NO_3 was not applied, the 56 kg N/ha from FS yielded over 8 q/ha higher than the other two FS levels. However, when NH_4NO_3 was applied, the difference decreased to less than 1.6 q/ha. A yield difference of 1.8 q/ha was noted when the 56 kg N/ha treatment from FS was compared to the same amount of N from NH_4NO_3, with the higher yield being from the NH_4NO_3 application. The highest rate of FS combined with the addition of

Table 1 . Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on yield (q/ha) of four barley cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	Yield (q/ha) for indicated levels of N (kg/ha) from FS: 0	28	56	Avg.
0	Barsoy	35.0	32.7	39.9	35.9
	Surry	34.4	36.8	51.3	40.8
	Henry	39.7	38.7	46.3	41.5
	Maury	39.8	46.3	50.0	45.3
	Avg.	37.2	38.6	46.9	40.9
56	Barsoy	41.9	41.1	48.4	43.7
	Surry	52.4	49.8	53.4	51.8
	Henry	50.7	54.0	50.5	51.7
	Maury	49.7	50.8	52.7	51.1
	Avg.	48.7	49.0	51.3	49.6
Avg.	Barsoy	38.4	36.9	44.1	39.8
	Surry	43.4	43.3	52.4	46.4
	Henry	45.2	46.3	48.4	46.6
	Maury	44.8	48.5	51.3	48.2
	Avg.	42.9	43.8	49.1	45.2

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	322270.7	211.58**
Reps.	2	3557.2	3.50
Error A	2	1523.2	-----
Fish-solubles (FS)	2	62106.3	7.17*
FS x SN	2	20338.5	2.35
Error B	8	8659.0	-----
Cultivars (Cul)	3	58638.4	13.39**
Cul x SN	3	6113.3	1.39
Cul x FS	6	5309.4	1.21
Cul x SN x FS	6	6396.6	1.46
Error C	36	4380.9	-----
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

NH_4NO_3 increased yield by 4.4 q/ha over the highest FS treatment without NH_4NO_3. That combination of treatments also resulted in the highest yield.

There were highly significant differences among cultivars, with no significant interactions with the FS or NH_4NO_3 treatments. Maury had the highest yield, followed closely by Henry and Surry, with Barsoy being considerably lower than the others. Although interactions were not significant, the differences in yield responses among the cultivars appeared to be influenced by the FS and NH_4NO_3 treatments. For example, at the 0 and 28 kg N/ha levels from the FS only treatments, Surry yielded considerably less than Maury. However, at the 56 kg level without NH_4NO_3 and at all levels of FS when NH_4NO_3 was applied, Surry yielded as well as Maury. Barsoy and Surry were similar in yield on the plots receiving no nitrogen, but Surry was superior to Barsoy in all treatments when FS and/or NH_4NO_3 were applied.

Sections 61 cm in length were harvested from the border rows of each barley cultivar to estimate the number of spikes/61 cm, grain yield, thousand kernel weight (Mkw), and the number of kernels/spike. The results and analyses are summarized in Tables 2, 3, 4, and 5. Data for spikes/61 cm section (Table 2) showed only small effects from the N treatments or cultivars on this trait. However, the NH_4NO_3

Table 2 . Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on the number of spikes per 61 cm section four barley cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	No. of spikes for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	Barsoy	73.3	64.0	78.0	71.8
	Surry	70.7	80.0	71.3	74.0
	Henry	63.3	66.0	60.0	63.1
	Maury	73.0	64.0	70.0	69.0
	Avg.	70.1	68.5	69.8	69.5
56	Barsoy	71.7	74.7	65.7	70.7
	Surry	77.3	70.7	78.3	75.4
	Henry	66.7	69.7	75.3	70.6
	Maury	76.3	74.3	81.0	77.2
	Avg.	73.0	72.3	75.1	73.5
Avg.	Barsoy	72.5	69.3	71.8	71.2
	Surry	74.0	75.3	74.8	74.7
	Henry	65.0	67.8	67.7	66.8
	Maury	74.7	69.2	75.5	73.1
	Avg.	71.5	70.4	72.5	71.5

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	228.00	7.94
Reps.	2	11.26	0.31
Error A	2	36.29	----
Fish-solubles (FS)	2	26.00	0.26
FS x SN	2	8.29	0.09
Error B	8	97.26	----
Cultivars (Cul)	3	208.98	2.51
Cul x SN	3	93.52	1.12
Cul x FS	6	26.86	0.32
Cul x SN x FS	6	139.42	1.67
Error C	36	83.36	----
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 3 . Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on the grain yield (g) from the 61 cm sections of four barley cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	Yield/61 cm (g) for indicated levels of N (kg/ha) from FS			
		0	28	56	Avg.
0	Barsoy	74.0	74.0	86.0	78.0
	Surry	77.3	90.3	89.0	88.2
	Henry	72.0	89.7	83.7	81.8
	Maury	76.3	80.0	94.7	83.7
	Avg.	74.9	85.5	88.3	82.9
56	Barsoy	91.0	91.7	86.3	89.7
	Surry	100.0	98.0	100.7	99.6
	Henry	85.3	100.0	103.0	96.1
	Maury	100.3	98.3	105.7	101.4
	Avg.	94.2	97.0	98.9	96.7
Avg.	Barsoy	82.5	82.8	86.2	83.8
	Surry	88.7	98.2	94.8	93.9
	Henry	78.7	94.8	93.3	88.9
	Maury	88.3	89.2	100.2	92.6
	Avg.	84.5	91.2	93.6	89.8

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	3416.89	365.55**
Reps.	2	704.84	75.41*
Error A	2	9.34	----
Fish-solubles (FS)	2	532.60	2.09
FS x SN	2	136.02	0.53
Error B	8	254.28	----
Cultivars (Cul)	3	363.87	2.13
Cul x SN	3	40.11	0.23
Cul x FS	6	123.97	0.73
Cul x SN x FS	6	100.79	0.59
Error C	36	170.94	---
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 4 . Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on the Mkw (g) from the 61 cm section of four barley cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	Mkw (g) for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	Barsoy	36.9	36.8	37.1	36.9
	Surry	35.4	36.5	35.7	35.9
	Henry	37.2	38.6	39.4	38.4
	Maury	34.5	35.8	36.9	35.8
	Avg.	36.0	37.0	37.3	36.8
56	Barsoy	37.5	36.8	37.3	37.2
	Surry	35.4	36.4	36.6	36.1
	Henry	39.4	40.0	40.3	39.9
	Maury	36.3	35.7	36.2	36.1
	Avg.	37.2	37.3	37.6	37.4
Avg.	Barsoy	37.2	36.8	37.2	37.1
	Surry	35.4	36.5	36.2	36.0
	Henry	38.4	39.4	39.9	39.2
	Maury	35.4	35.8	36.6	35.9
	Avg.	36.6	37.1	37.5	37.1

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	6.18	1.23
Reps.	2	10.60	2.00
Error A	2	5.04	----
Fish-solubles (FS)	2	4.38	3.02
FS x SN	2	1.44	0.99
Error B	8	1.45	----
Cultivars (Cul)	3	41.42	21.17**
Cul x SN	3	1.72	0.88
Cul x FS	6	1.17	0.60
Cul x SN x FS	6	0.84	0.43
Error C	36	1.96	----
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 5 . Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on the estimate of kernels/spike from the 61 cm section of four barley cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	Kernels/spike for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	Barsoy	26.9	31.5	30.0	29.5
	Surry	31.0	33.7	35.3	33.3
	Henry	30.9	35.2	35.4	33.8
	Maury	30.4	34.3	36.5	33.7
	Avg.	29.8	33.7	34.3	32.6
56	Barsoy	34.0	33.3	35.3	34.2
	Surry	36.6	38.1	34.7	36.4
	Henry	32.2	35.8	34.0	34.0
	Maury	36.2	37.1	37.2	36.8
	Avg.	34.4	36.0	35.3	35.4
Avg.	Barsoy	30.5	32.4	32.7	31.8
	Surry	33.8	35.9	35.0	34.9
	Henry	31.5	35.5	34.7	33.9
	Maury	33.3	35.7	37.5	35.3
	Avg.	32.3	34.9	34.8	34.0

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	137.78	33.57*
Reps.	2	34.98	8.52
Error A	2	4.11	---
Fish-solubles (FS)	2	53.66	2.89
FS x SN	2	24.26	1.31
Error B	8	18.59	---
Cultivars (Cul)	3	42.42	5.52**
Cul x SN	3	16.13	2.10
Cul x FS	6	2.86	0.37
Cul x SN x FS	6	5.48	0.71
Error C	36	7.69	---
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

application did increase the number of spikes/61 cm, (significant at p=.10). When averaged over all N levels, Henry had slightly fewer spikes/61 cm than the other cultivars with the differences being significant at the 10% level.

Table 3 contains the data on the grain yield from the 61 cm sections. These yields are similar to those obtained from the 5 m center rows, having a highly significant correlation, r=.35**, as shown in Table 23. However, the 61 cm sections had a higher coefficient of varation than the 5 m rows (14.5% vs 9.5%) and this may explain why the same factors did not express significance in the analyses of variance. Highly significant differences were expressed between the 0 and 56 kg N/ha from NH_4NO_3, with a mean increase of 13.8 g from the top-dressing. Applications of FS had a tendency to increase the grain yield, and cultivars expressed different responses, though neither was significant.

Cultivars were significantly different for Mkw (Table 4) and kernels/spike (Table 5), and the spring application of NH_4NO_3 caused a significant increase in kernels/spike. Henry had the highest Mkw (39.2 g) and Maury the largest estimate of kernels/spike (35.3). Maury and Barsoy had the lowest Mkw (35.9 g) and kernels/spike (31.8), respectively. Spring nitrogen applications had little effect on Mkw, but between the 0 and 56 kg N/ha levels of NH_4NO_3, the top-dressing produced approximately three more kernels/spike than the 0 level. On plots where NH_4NO_3 was not applied, FS tended to cause a slight increase in kernels/spike.

Tables 6, 7, and 8 contain data relating to grain weight, kernels/spike, and Mkw, respectively, from the ten head samples. For all three traits, cultivars displayed significant differences and a significant FSxSN interaction was noted for both grain weight (Table 6) and kernels/spike (Table 7). Maury had the highest grain weight (22.7 g) and the most kernels/spike (59.6), and Barsoy was the lowest in both instances (20.5 g and 52.1). Henry had the highest Mkw (40.2 g) and Surry the lowest (38.0 g), (Table 8). Where NH_4NO_3 was not applied, the application of FS increased grain weight, but the FS in combination with the NH_4NO_3 caused a slight decline; thus, the interaction. For kernels/spike, the interaction appears to have resulted from a decrease in kernels/spike with the application of FS when NH_4NO_3 was applied, with very little or no change when NH_4NO_3 was not applied.

The grain weight from the ten heads of the cultivars ranked them the same as yield from the 5 m row, (Table 1). When compared with the 61 cm sections (Table 3), Maury and Barsoy were ranked the same, but Surry and Henry were switched. The correlation between yield based on the ten heads and yield based on the entire row was r=.28*, (Table

Table 6 . Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on the grain weight (g) from the ten heads of four barley cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	Grain wt.(g) for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	Barsoy	19.7	19.8	21.5	20.3
	Surry	20.4	21.3	21.2	21.0
	Henry	22.2	21.0	21.7	21.6
	Maury	22.3	23.9	23.2	23.1
	Avg.	21.1	21.5	21.9	21.5
56	Barsoy	20.9	21.3	19.6	20.6
	Surry	22.3	20.9	20.7	21.3
	Henry	21.8	21.1	20.8	21.2
	Maury	22.7	21.2	22.9	22.3
	Avg.	21.9	21.1	21.0	21.3
Avg.	Barsoy	20.3	20.6	20.5	20.5
	Surry	21.4	21.1	20.9	21.2
	Henry	22.0	21.0	21.2	21.4
	Maury	22.5	22.5	23.1	22.7
	Avg.	21.5	21.3	21.4	21.4

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	0.55	0.25
Reps.	2	1.60	0.72
Error A	2	2.24	----
Fish-solubles (FS)	2	0.28	0.53
FS x SN	2	4.46	8.30*
Error B	8	0.54	---
Cultivars (Cul)	3	15.74	13.29**
Cul x SN	3	1.31	1.12
Cul x FS	6	0.69	0.58
Cul x SN x FS	6	2.65	2.23
Error C	36	1.18	----
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 7 . Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on the estimate of kernels/spike from the ten heads of four barley cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	Kernels/spike for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	Barsoy	51.4	49.9	53.5	51.6
	Surry	55.2	55.7	56.2	55.7
	Henry	54.7	53.2	53.5	53.5
	Maury	59.8	61.2	60.1	60.4
	Avg.	55.3	54.8	55.8	55.3
56	Barsoy	53.8	53.3	50.8	52.7
	Surry	57.8	54.7	54.1	55.5
	Henry	54.7	53.2	51.4	53.1
	Maury	59.7	56.8	59.7	58.7
	Avg.	56.5	54.5	54.0	55.0
Avg.	Barsoy	52.6	51.6	52.2	52.1
	Surry	56.5	55.2	55.2	55.6
	Henry	54.7	52.7	52.5	53.3
	Maury	59.8	59.0	59.9	59.6
	Avg.	55.9	54.6	54.9	55.1

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	1.47	0.39
Reps.	2	4.11	0.51
Error A	2	4.86	----
Fish-solubles (FS)	2	10.55	3.44
FS x SN	2	13.73	5.21*
Error B	8	3.38	---
Cultivars (Cul)	3	193.13	42.24**
Cul x SN	3	5.41	1.25
Cul x FS	6	1.67	0.39
Cul x SN x FS	6	7.70	1.60
Error C	36	4.20	----
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 8 . Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on the estimate of Mkw (g) from the ten heads of four barley cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	Mkw (g) for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	Barsoy	38.3	39.7	40.2	39.4
	Surry	37.0	38.3	37.7	37.7
	Henry	40.6	40.2	40.5	40.4
	Maury	37.2	39.1	38.6	38.3
	Avg.	38.3	39.3	39.2	38.9
56	Barsoy	38.8	40.0	38.5	39.1
	Surry	38.6	38.3	38.2	38.4
	Henry	39.9	39.6	40.4	40.0
	Maury	38.1	37.3	38.4	37.9
	Avg.	38.8	38.8	38.9	38.8
Avg.	Barsoy	38.6	39.8	39.3	39.2
	Surry	37.8	38.3	37.9	38.0
	Henry	40.2	39.9	40.4	40.2
	Maury	37.6	38.2	38.5	38.1
	Avg.	38.5	39.1	39.1	38.9

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	0.22	0.12
Reps.	2	2.19	1.17
Error A	2	1.86	----
Fish-solubles (FS)	2	2.05	3.67
FS x SN	2	2.15	3.85
Error B	8	0.56	---
Cultivars (Cul)	3	19.05	14.65**
Cul x SN	3	1.23	0.95
Cul x FS	6	0.78	0.61
Cul x SN x FS	6	1.35	1.04
Error C	36	1.30	----
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

23). The estimates of kernels/spike based on the ten heads were considerably higher than those based on the 61 cm section. Cultivars were ranked the same in both estimates; however, the correlation between the two was not significant. Estimates of Mkw based on the ten heads and on the 61 cm sections were highly correlated (r=.53**), indicating that the kernels/spike and grain weight from ten heads could be used to provide a valid estimate of yield and components of yield. Both estimates of Mkw ranked Henry first and Barsoy second, but Surry and Maury were switched in order. However, the latter two cultivars were extremely similar based on both estimates.

Days to heading, height, and % lodging data are presented in Tables 9, 10, and 11, respectively. Cultivars expressed significant differences for all three traits. Barsoy was the shortest (77 cm) and the first to head (25), while Maury was the tallest (93 cm) and the last to head (36). That relationship was responsible for the highly significant correlation between height and heading date (r=.76**, Table 23). Surry lodged the most and Maury and Henry lodged the least. Nitrogen from NH_4NO_3 and FS caused significant responses for days to heading and height. Both the FS and NH_4NO_3 applications slightly decreased days to heading and caused an increase in plant height. The significant FSxSN interaction

Table 9 . Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on the heading date (days after March 31) of four barley cultivars.

		Days after 3/31 for indicated levels of N (kg/ha) from FS			
Kg/ha of N from NH_4NO_3	Cultivar	0	28	56	Avg.
0	Barsoy	26	25	24	25
	Surry	32	31	31	31
	Henry	35	34	34	34
	Maury	37	36	35	36
	Avg.	33	32	31	32
56	Barsoy	26	25	24	25
	Surry	31	30	30	30
	Henry	35	33	34	34
	Maury	36	35	35	35
	Avg.	32	31	31	31
Avg.	Barsoy	26	25	24	25
	Surry	32	30	30	31
	Henry	35	34	34	34
	Maury	36	36	35	36
	Avg.	32	31	31	31

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	9.39	96.57*
Reps.	2	0.68	7.00
Error A	2	0.10	----
Fish-solubles (FS)	2	11.76	41.32**
FS x SN	2	0.68	2.39
Error B	8	0.28	---
Cultivars (Cul)	3	398.72	1324.98**
Cul x SN	3	0.65	2.15
Cul x FS	6	0.26	0.88
Cul x SN x FS	6	0.32	1.09
Error C	36	0.30	----
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 10 . Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on the height (cm) of four barley cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	Height (cm) for indicated levels of N (kg/ha) from FS: 0	28	56	Avg.
0	Barsoy	73	74	77	75
	Surry	84	81	89	85
	Henry	86	86	90	87
	Maury	87	89	95	90
	Avg.	82	84	88	85
56	Barsoy	77	81	79	79
	Surry	88	91	91	90
	Henry	91	95	94	93
	Maury	93	97	96	95
	Avg.	87	91	90	89
Avg.	Barsoy	75	77	78	77
	Surry	86	86	90	87
	Henry	88	89	92	90
	Maury	90	92	95	93
	Avg.	85	88	89	87

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	78.13	38.27*
Reps.	2	0.43	0.21
Error A	2	2.04	----
Fish-solubles (FS)	2	14.34	9.39**
FS x SN	2	8.79	5.75*
Error B	8	1.52	---
Cultivars (Cul)	3	136.98	229.36**
Cul x SN	3	0.53	0.89
Cul x FS	6	0.76	1.26
Cul x SN x FS	6	0.20	0.33
Error C	36	0.60	----
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 11. Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on lodging (%) of four barley cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	Lodging (%) for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	Barsoy	0	3	2	2
	Surry	12	8	5	8
	Henry	2	8	2	4
	Maury	1	2	2	2
	Avg.	4	5	3	4
56	Barsoy	3	5	15	8
	Surry	7	13	25	14
	Henry	2	5	8	5
	Maury	3	3	13	7
	Avg.	3	7	15	8
Avg.	Barsoy	2	4	9	5
	Surry	8	11	15	9
	Henry	3	7	5	4
	Maury	2	2	8	4
	Avg.	3	6	9	6

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	396.68	4.14
Reps.	2	881.56	9.21
Error A	2	95.72	---
Fish-solubles (FS)	2	182.39	2.46
FS x SN	2	281.56	3.80
Error B	8	74.01	---
Cultivars (Cul)	3	235.09	4.89**
Cul x SN	3	27.50	0.57
Cul x FS	6	16.30	0.34
Cul x SN x FS	6	28.98	0.60
Error C	36	48.10	---
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

for height was due to the FS response when no NH_4NO_3 was applied, with FS rates in the absence of NH_4NO_3 causing larger increases in height than when NH_4NO_3 was applied. There was a trend toward increased lodging as the N levels increased, and particularly at the highest level. Lodging in general was minimal and occurred late.

Test weight differences (Table 12), were significant for all main effects, except FS, and for all interactions. Applications of NH_4NO_3 increased test weights at all levels of FS. Since data for this trait was not available by replications, the FSxSN interaction was used to test FS and SN, and the CulxFSxSN interaction was used to test Cul, CulxSN, and CulxFS. Barsoy had the highest test weight (65.5), followed by Henry (63.3), with Maury being the lowest (62.6). The differences among cultivars were greater when NH_4NO_3 was applied than with the FS only treatments.

Flag leaves were sampled when the barley cultivars were in the late-boot to early-bloom stage, taking nine leaves from each cultivar. Leaves from the four cultivars within a FS plot were composited and analyzed for mineral content. The results of the analyses are presented in Tables 13 through 21.

Content of nitrogen (Table 13), potassium (Table 15), zinc (Table 18), and copper (Table 20), was not significant-

Table 12. Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on test weight (kg/hl) of four barley cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	Test wt. (kg.hl) for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	Barsoy	64.4	64.3	64.4	64.4
	Surry	62.1	62.6	63.3	62.7
	Henry	62.6	62.7	64.0	63.1
	Maury	62.6	62.0	61.8	62.1
	Avg.	62.9	62.9	63.4	63.1
56	Barsoy	66.9	66.7	66.6	66.7
	Surry	62.7	63.0	62.7	62.8
	Henry	62.6	63.6	63.9	63.4
	Maury	63.5	62.5	62.9	63.1
	Avg.	63.9	64.0	64.0	64.0
Avg	Barsoy	65.6	65.5	65.5	65.6
	Surry	62.4	62.8	63.0	62.8
	Henry	62.6	63.2	64.0	63.3
	Maury	63.0	62.2	62.4	62.6
	Avg.	63.4	63.4	63.7	63.5

Analysis of Variance

Source	Degrees of freedom	Mean square	F Value
Spring N (SN)	1	2.94	48.00**
Fish-solubles (FS)	2	0.12	1.97
Error A	2	0.06	---
Cultivars (Cul)	3	6.94	119.79**
Cul x SN	3	0.93	16.06**
Cul x FS	3	0.26	4.55*
Error B	6	0.06	---
Total	23		

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 13 . Average effects of applications of fish-solubles and spring applications of NH_4NO_3 on nitrogen (%) in the flag leaves of barley.

Kg/ha of N from NH_4NO_3	% N for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	4.58	4.63	4.67	4.63
56	4.70	4.73	4.79	4.74
Avg.	4.64	4.68	4.74	4.68

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Reps.	2	0.0260	6.90
Spring NH_4NO_3 (SN)	1	0.0570	15.16
Error A	2	0.0040	---
Fish-solubles (FS)	2	0.0140	2.08
FS x SN	2	0.0002	0.03
Error B	8	0.0060	---
Total	17	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 14 . Average effects of applications of fish-solubles and spring applications of NH_4NO_3 on phosphorus (%) in the flag leaves of barley.

Kg/ha of N from NH_4NO_3	% P for indicated levels of N (kg/ha) from FS			
	0	28	56	Avg.
0	0.40	0.40	0.37	0.39
56	0.40	0.38	0.41	0.40
Avg.	0.40	0.39	0.39	0.39

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Reps.	2	0.00020	3.31
Spring NH_4NO_3 (SN)	1	0.00010	1.92
Error A	2	0.00007	---
Fish-solubles (FS)	2	0.00030	2.23
FS x SN	2	0.00120	10.14**
Error B	8	0.00010	---
Total	17	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 15 . Average effects of applications of fish-solubles and spring applications of NH_4NO_3 on potassium (%) in the flag leaves of barley.

Kg/ha of N from NH_4NO_3	% K for indicated levels of N (kg/ha) from FS: 0	28	56	Avg.
0	2.62	2.54	2.59	2.58
56	2.56	2.54	2.67	2.59
Avg.	2.59	2.54	2.63	2.59

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Reps.	2	0.02330	14.83
Spring NH_4NO_3 (SN)	1	0.00009	0.06
Error A	2	0.00160	---
Fish-solubles (FS)	2	0.01220	3.41
FS x SN	2	0.00900	2.50
Error B	8	0.00360	---
Total	17	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 16 . Average effects of applications of fish-solubles and spring applications of NH_4NO_3 on calcium (%) in the flag leaves of barely.

Kg/ha of N from NH_4NO_3	% Ca for indicated levels of N (kg/ha) from FS			
	0	28	56	Avg.
0	0.56	0.59	0.65	0.60
56	0.59	0.63	0.64	0.62
Avg.	0.57	0.61	0.64	0.61

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Reps.	2	0.0024	1.16
Spring NH_4NO_3 (SN)	1	0.0018	0.87
Error A	2	0.0021	---
Fish-solubles (FS)	2	0.0077	4.98*
FS x SN	2	0.0010	0.66
Error B	8	0.0016	---
Total	17	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 17 . Average effects of applications of fish-solubles and spring applications of NH_4NO_3 on magnesium (%) in the flag leaves of barley.

Kg/ha of N from NH_4NO_3	% Mg for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	0.18	0.19	0.21	0.19
56	0.21	0.23	0.23	0.22
Avg.	0.20	0.21	0.22	0.21

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Reps.	2	0.00050	1.47
Spring NH_4NO_3 (SN)	1	0.00405	11.57
Error A	2	0.00035	---
Fish-solubles (FS)	2	0.00070	19.54**
FS x SN	2	0.00002	0.46
Error B	8	0.00004	---
Total	17	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 18 . Average effects of applications of fish-solubles and spring applications of NH_4NO_3 on zinc (ppm) in the flag leaves of barley.

Kg/ha of N from NH_4NO_3	Ppm Zn for indicated levels of N (kg/ha) from FS			
	0	28	56	Avg.
0	33	35	34	34
56	40	38	39	39
Avg.	39	37	37	37

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Reps.	2	27.44	5.83
Spring NH_4NO_3 (SN)	1	107.56	15.24
Error A	2	7.06	---
Fish-solubles (FS)	2	0.17	0.03
FS x SN	2	6.06	1.02
Error B	8	5.94	---
Total	17	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 19 . Average effects of applications of fish-solubles and spring applications of NH_4NO_3 on manganese (ppm) in the flag leaves of barley.

Kg/ha of N from NH_4NO_3	Ppm Mn for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	45	49	54	49
56	55	65	60	60
Avg.	50	57	57	55

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Reps.	2	9.72	0.45
Spring NH_4NO_3 (SN)	1	480.50	22.35*
Error A	2	21.50	---
Fish-solubles (FS)	2	96.06	10.26**
FS x SN	2	41.16	4.40
Error B	8	9.36	---
Total	17	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 20 . Average effects of applications of fish-solubles and spring applications of NH_4NO_3 on copper (ppm) in the flag leaves of barley.

Kg/ha of N from NH_4NO_3	Ppm Cu for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	5	5	6	5
56	7	6	6	6
Avg.	6	5	6	6

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Reps.	2	5.56	3.57
Spring NH_4NO_3 (SN)	1	3.56	2.29
Error A	2	1.56	---
Fish-solubles (FS)	2	0.89	1.23
FS x SN	2	0.89	1.23
Error B	8	0.72	---
Total	17	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 21 . Average effects of applications of fish-solubles and spring applications of NH_4NO_3 on iron (ppm) in the flag leaves of barley.

Kg/ha of N from NH_4NO_3	Ppm Fe for indicated levels of N (kg/ha) from FS			
	0	28	56	Avg.
0	409	288	923	540
56	597	695	355	549
Avg.	503	492	639	545

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Reps.	2	1013937.7	27.50*
Spring NH_4NO_3 (SN)	1	800.0	0.02
Error A	2	36877.2	----
Fish-solubles (FS)	2	42276.2	0.22
FS x SN	2	396002.7	2.02
Error B	8	195818.9	---
Total	17	----	---

*, ** Significant at the .05 and .01 probability levels, respectively.

ly affected by FS or NH_4NO_3 applications. However, the %N was increased with the spring top-dressing of NH_4NO_3, (significant at p=.06). The N treatments had little effect on % phosphorus (Table 14), but there was a significant FSxSN interaction, the cause of which is unclear. The FS applications caused a significant increase in % calcium, increasing from .57% at the 0 level to .64% when 56 kg N/ha from FS was applied (Table 16). Magnesium (Table 17) increased significantly from the application of FS and increased with NH_4NO_3 at all levels of FS, though the response to NH_4NO_3 was not statistically significant. There was an increase in ppm zinc, (significant at p=.08), with the application of NH_4NO_3 at all levels of FS. Manganese (Table 19), increased significantly with both the FS and NH_4NO_3 applications. Replications gave the only significant effect for the levels of iron (Table 21), suggesting the results were variable and unreliable.

In comparison to the tissue samples taken from the first FS experiment in 1980 (29), the mineral contents from this experiment appear much larger than those of the previous year. The % nitrogen for the 0 level was nearly double, with the SN treatments being greater by a full percentage point. Comparisons for the 28 and 56 kg N/ha from FS treatments showed the estimates of N to be nearly two percentage points larger for both treatments. Potassium is the only mineral which was in greater quantity in the previous year's experiment; the readings were between .5 and 1% larger for each treatment. Values for calcium an magnesium were nearly equivalent. These data provide evidence substantiating the fact that the spring application of FS was unable to supply the necessary nutrients to the barley.

Table 22 contains the data on the soil samples taken in the spring following the fall applications of FS. The data show that concentrations of NH_4 and NO_3 ions increased with the FS applications. The responses were very nearly significant at .05, indicating that the FS were decomposing and becoming available for plant uptake. The lack of significance probably relates to the small number of degrees of freedom for error. Hoyt and Rice in Canada reported that mineral nitrogen (NH_4 plus NO_3) was increased by both fertilizer and manure, but the increases were moderate considering the large amounts supplied in the fertilizer and manure (17).

Correlations between measurements reported in Tables 1 through 12 were determined and are presented in table 23. Some of the correlations were previously referred to in the text and therefore, they will only be mentioned briefly. Heading date and height were significantly and negatively

Table 22 . Average effects of fall applications of fish-solubles on NH_4+ and NO_3- ion concentrations in soil samples taken from the barley plots the following spring.

Nitrogen ion	Ppm of NH_4+ and NO_3- ions for indicated levels of N (kg/ha) from FS			
	0	28	56	Avg.
NH_4+	0.081	0.106	0.146	0.111
NO_3-	5.42	10.62	13.80	9.94

Analysis of Variance

Source	Degrees of freedom	Mean square	F value
		NH_4+ ion	
Reps.	2	0.0005	1.00
Fish-solubles	2	0.0030	6.00
Error	4	0.0005	---
Total	8	---	---
		NO_3- ion	
Reps.	2	5.41	0.63
Fish-solubles	2	53.72	6.26
Error	4	8.58	---
Total	8		---

Table 23. Barley correlation coefficients.

				Ten head samples			61 cm sections			
	Test wt.	Height	Heading date	Mkw	Kern/ spike	Grain wt.	Kern/ spike	Mkw	Grain yield	No. of spikes
Yield	-0.14	0.72**	0.30*	-0.06	0.32**	0.28*	0.46**	0.06	0.35**	0.04
61 cm sections: No. of spikes	-0.21	0.06	-0.07	-0.09	0.15	0.09	-0.03	-0.21	0.66**	---
61 cm sections: Grain yield	-0.22	0.37**	0.09	0.06	0.13	0.16	0.67**	0.23	---	
61 cm sections: Mkw	0.23	0.06	0.01	0.53**	-0.36**	-0.06	0.16	---		
61 cm sections: Kern/ spike	-0.18	0.47**	0.21	-0.04	0.20	0.18	---			
Ten head samples: Grain weight	-0.30	0.43**	0.52**	0.29*	0.85**	---				
Ten head samples: Kern/ spike	-0.38	0.50**	0.57**	-0.26*	---					
Ten head samples: Mkw	0.16	-0.11	-0.08	---						
Heading date	-0.76**	0.76**	---							
Height	-0.46*	---								

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

correlated with test weight. Barsoy, which was the shortest and the earliest cultivar, had the highest test weight, while Maury, the latest and tallest cultivar, had the lowest test weight. Height was positively correlated with plot yield, grain yield, and kernels/spike from the 61 cm sections, and with grain weight and kernels/spike from the ten heads. These relationships are caused by the shortest cultivar, Barsoy, having the lowest yield, fewest kernels/spike (in both estimates), and the lowest grain weight, and by the tallest cultivar, Maury, having the highest yield, the most kernels/spike (in both estimates), and the highest grain weight.

Thousand kernel weight estimated from the ten heads was positively correlated with Mkw from the 61 cm sections and with grain weight for the ten heads, and negatively correlated with the estimate of kernels/spike based on the ten head samples. This indicates that, in the ten head samples, grain weight increased as Mkw increased, but Mkw decreased as kernels/spike increased. Kernels/spike from the ten head samples was positively correlated with plot yield and grain weight, but was negatively correlated with Mkw based on the 61 cm sections. The cultivar with the fewest kernels/spike, Barsoy, also had the lowest grain weight, and the second highest Mkw, and Maury, with the most kernels/spike, had the highest grain weight and lowest Mkw. Kernels/spike (61 cm section) was positively correlated with plot yield and with grain yield of the 61 cm sections, the reason for which has already been discussed. Grain yield (61 cm section) was positively correlated with plot yield and with number of spikes/61 cm. Barsoy had the lowest grain yield and also had the second lowest number of spikes/61 cm.

Examination of the components of yield which were influenced by the FS and NH_4NO_3 applications shows both kernels/spike (Table 5) and Mkw (Table 4) increased through the application of these materials. Spikes/61 cm section, though not affected by FS, did show a tendency to increase with the application of NH_4NO_3. There were no significant interactions between cultivars and FS or NH_4NO_3 for the components of yield.

Yield and components of yield from ten head samples were investigated by Walcutt and Ramage at the University of Arizona (32). They reported such samples gave a reasonable estimate of yield and could also be used to estimate Mkw. They compared data collected from yield plots with the ten best spikes selected from the same plots prior to harvest. Their plot yield showed a high linear correlation with spike yield (grain weight), r=.59**. Plot yield also showed a high correlation with seed weight (Mkw) of the spikes, r=.64**. Seed weight (Mkw) for the spikes and Mkw from the plots were almost completely linearly correlated, r=.97**. They concluded that such high correlations indicated that seed weight and spike yield could be used as indicators of yield potential.

Most of the correlations between the same traits in this experiment were positive, although the r values were smaller than those obtained by Walcutt and Ramage (32). Only one correlation did not agree with theirs; plot yield and Mkw were poorly correlated (r=-.06). Kernels/spike and grain weight gave good correlations with plot yield. Mkw (ten heads) provided a good estimate of Mkw (61 cm section), but a good estimate of kernels/spike was not provided. Ten head samples probably could be used to distinguish large differences in yield and kernels/spike, but would be less useful as these differences between cultivars or treatments narrow.

Table 24 presents the wheat yield data, with the statistical analysis showing a significant response to FS. The major difference was between the 0 and 28 kg N/ha levels with little difference in yields between the 28 and 56 kg levels. The application of NH_4NO_3 did produce a yield response, significant at the 10% level, with no interaction between FS and NH_4NO_3. Applying 56 kg N/ha from FS produced a yield approximately 5 q/ha less than the yield obtained

Table 24 . Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on yield (q/ha) of four wheat cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	Yield (q/ha) for indicated levels of N (kg/ha) from FS			
		0	28	56	Avg.
0	McNair 1003	32.5	37.9	41.5	37.3
	Coker 747	35.5	38.1	35.7	36.4
	Tyler	39.4	45.8	40.2	41.8
	Wheeler	41.0	40.6	39.8	40.5
	Avg.	37.1	40.6	39.3	39.0
56	McNair 1003	44.7	44.2	44.3	44.3
	Coker 747	43.1	40.8	44.9	42.9
	Tyler	47.4	49.3	52.2	49.7
	Wheeler	41.8	47.7	46.9	45.4
	Avg.	44.2	45.5	47.1	45.6
Avg.	McNair 1003	38.6	41.0	42.9	40.8
	Coker 747	39.2	39.5	40.3	39.7
	Tyler	43.4	47.6	46.2	45.7
	Wheeler	41.4	44.1	43.3	42.9
	Avg.	40.6	43.1	43.2	42.3

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	183517.0	16.23
Reps.	2	22546.4	1.99
Error A	2	11303.8	---
Fish-solubles (FS)	2	11490.6	8.40*
FS x SN	2	3363.3	2.45
Error B	8	1367.9	---
Cultivars (Cul)	3	29837.1	15.41**
Cul x SN	3	1588.4	0.82
Cul x FS	6	1635.0	0.84
Cul x SN x FS	6	6613.4	3.42**
Error C	36	1935.9	
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

from the 56 kg N/ha application from NH_4NO_3. The applications of 56 kg N/ha from FS plus the 56 kg from NH_4NO_3 produced a yield almost 8 q/ha greater than the 56 kg N/ha from FS only treatment. There was also a highly significant difference among cultivars, with Tyler yielding the best (45.7 q/ha) and Coker 747 the poorest (39.7 q/ha). The only significant interaction was CulxFSxSN, indicating that cultivars did not rank the same in yield at all levels of FS and NH_4NO_3. McNair 1003 tended to perform poorly at levels of 0 and 28 kg N/ha from FS alone and at the 56 kg N/ha FS plus NH_4NO_3 level, but ranked high at the intermediate levels. Coker 747 maintained its relative rank (3 or 4) at all levels. Tyler ranked high (1 or 2) at all levels and Wheeler tended to be inconsistant in rank, going from 1 to 4 for various N levels.

The data compiled from the 61 cm sections are given in Tables 25 (spikes/61 cm), 26 (grain yield), 27 (Mkw), and 28 (kernels/spike). Cultivars differed significantly for all traits. Coker 747 had the most spikes/61 cm (127.2) and the lowest grain yield (76.8 g), the lowest Mkw (31.7 g), and the lowest estimate of kernels/spike (19.1). McNair 1003 had the fewest spikes/61 cm (91.3), Wheeler had the highest grain yield (92.7 g) and the highest Mkw (41.0 g), while Tyler had the highest estimate of kernels/spike (24.8). The

Table 25 . Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on the number of spikes per 61 cm section of four wheat cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	No. of spikes for indicated levels of N (kg/ha) from FS: 0	28	56	Avg.
0	McNair 1003	76.7	81.7	76.0	78.1
	Coker 747	120.3	115.0	116.0	117.1
	Tyler	88.7	95.0	84.0	89.2
	Wheeler	85.0	94.7	99.0	92.9
	Avg.	92.7	96.6	93.8	94.3
56	McNair 1003	89.7	113.7	110.3	104.6
	Coker 747	128.0	137.0	146.7	137.2
	Tyler	114.3	112.3	102.3	109.7
	Wheeler	113.0	104.3	115.7	111.0
	Avg.	111.2	116.8	118.8	115.6
Avg.	McNair 1003	83.2	97.7	93.2	91.3
	Coker 747	124.2	126.0	131.3	127.2
	Tyler	101.5	103.7	93.2	99.4
	Wheeler	99.0	99.5	107.3	101.9
	Avg.	102.0	106.7	106.2	105.0

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	8149.39	25.72*
Reps.	2	1102.26	3.48
Error A	2	316.84	---
Fish-solubles (FS)	2	164.76	0.66
FS x SN	2	66.52	0.26
Error B	8	251.28	---
Cultivars (Cul)	3	4310.02	32.01**
Cul x SN	3	58.17	0.43
Cul x FS	6	188.12	1.40
Cul x SN x FS	6	166.90	1.24
Error C	36	134.63	---
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 26 . Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on the grain yield (g) from the 61 cm sections of four wheat cultivars

Kg/ha of N from NH_4NO_3	Cultivar	Yield/61cm (g) for indicated levels of N (kg/ha) from FS: 0	28	56	Avg.
0	McNair 1003	63.7	80.3	73.7	72.6
	Coker 747	79.3	68.7	71.0	73.0
	Tyler	69.7	82.3	78.0	76.7
	Wheeler	79.7	91.0	92.7	87.8
	Avg.	73.1	80.6	78.8	77.5
56	McNair 1003	79.3	93.0	91.7	88.0
	Coker 747	83.3	75.3	83.0	80.6
	Tyler	101.7	103.0	91.7	98.8
	Wheeler	99.3	94.7	99.0	97.7
	Avg.	90.9	91.5	91.3	91.3
Avg.	McNair 1003	71.5	86.7	82.7	80.3
	Coker 747	81.3	72.0	77.0	76.8
	Tyler	85.7	92.7	84.8	87.7
	Wheeler	89.5	92.8	95.8	92.7
	Avg.	82.0	86.0	85.1	84.4

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	3403.12	13.78
Reps.	2	1003.62	4.07
Error A	2	246.88	---
Fish-solubles (FS)	2	107.04	0.72
FS x SN	2	78.79	0.53
Error B	8	148.17	---
Cultivars (Cul)	3	932.31	8.80**
Cul x SN	3	189.09	1.78
Cul x FS	6	188.62	1.78
Cul x SN x FS	6	65.14	0.61
Error C	36	105.97	---
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 27. Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on the Mkw (g) from the 61 cm section of four wheat cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	Mkw(g) for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	McNair 1003	38.5	39.5	39.8	39.3
	Coker 747	33.8	32.3	33.0	33.0
	Tyler	35.4	36.1	36.5	36.0
	Wheeler	41.5	42.1	41.0	41.5
	Avg.	37.3	37.5	37.6	37.5
56	McNair 1003	37.8	36.7	36.0	36.8
	Coker 747	31.6	29.5	30.1	30.4
	Tyler	34.8	35.6	35.1	35.2
	Wheeler	40.0	41.4	40.0	40.5
	Avg.	36.1	35.8	35.3	35.7
Avg.	McNair 1003	38.2	38.1	37.9	38.1
	Coker 747	32.7	30.9	31.6	31.7
	Tyler	35.1	35.8	35.8	35.6
	Wheeler	40.7	41.7	40.5	41.0
	Avg.	36.7	36.6	36.4	36.6

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	54.43	17.71*
Reps.	2	8.67	2.82
Error A	2	3.07	---
Fish-solubles (FS)	2	0.37	0.25
FS x SN	2	1.54	1.04
Error B	8	1.48	---
Cultivars (Cul)	3	277.96	267.29**
Cul x SN	3	3.84	3.69*
Cul x FS	6	2.77	2.66*
Cul x SN x FS	6	1.02	0.98
Error C	36	27.48	---
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 28. Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on the estimate of kernels/spike from the 61 cm section of four wheat cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	Kernels/spike for indicated levels of N (kg/ha) from FS: 0	28	56	Avg.
0	McNair 1003	21.7	24.9	24.3	23.6
	Coker 747	19.5	18.5	18.5	18.8
	Tyler	22.2	24.1	25.5	23.9
	Wheeler	22.8	22.7	22.6	22.7
	Avg.	21.5	22.6	22.7	22.3
56	McNair 1003	23.4	22.5	23.0	23.0
	Coker 747	20.6	18.7	18.8	19.4
	Tyler	25.6	25.8	25.8	25.7
	Wheeler	21.9	22.0	21.4	21.8
	Avg.	22.9	22.2	22.2	22.5
Avg.	McNair 1003	22.6	23.4	23.7	23.3
	Coker 747	20.1	18.6	18.6	19.1
	Tyler	23.9	24.9	25.6	24.8
	Wheeler	22.3	22.4	22.0	22.2
	Avg.	22.2	22.4	22.5	22.4

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	0.64	0.19
Reps.	2	0.16	0.05
Error A	2	3.38	---
Fish-solubles (FS)	2	0.42	0.08
FS x SN	2	6.12	1.18
Error B	8	5.17	---
Cultivars (Cul)	3	105.44	36.82**
Cul x SN	3	6.85	2.39
Cul x FS	6	3.74	1.39
Cul x SN x FS	6	1.69	0.59
Error C	36	2.86	----
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

FS application did not significantly affect the number of spikes/61 cm, Mkw, kernels/spike, or grain yield. However, when NH_4NO_3 was not applied, the 28 and 56 kg N/ha from FS treatments increased grain yield by 5 to 7 g. Applying NH_4NO_3 did not effect kernels/spike, but it increased grain yield at all levels of FS, although not significantly. Ammonium nitrate had a highly significant effect on the number of spikes/61 cm, causing an increase of 21 spikes/61 cm. Thousand kernel weight decreased significantly (1.8 g) with the addition of NH_4NO_3, with the decrease occuring at all levels of FS.

Significant interactions occured only for Mkw, where CulxSN and CulxFS were significant. The CulxSN interaction was due to McNair 1003 and Coker 747 showing a greater decline with the application of NH_4NO_3 than did Tyler or Wheeler. For the CulxFS interaction, the cultivars ranked the same at all levels of FS, but Coker 747 appeared to decrease in Mkw more than the others with applications of FS.

Tables 29 (grain weight), 30 (kernels/spike), and 31 (Mkw) contain data from the ten head samples. Cultivars responded significantly different for all three traits. Coker 747 had the lowest grain weight (10.7 g), lowest estimate of kernels/spike (31.9), and the lowest Mkw (33.5 g). McNair 1003 produced the highest grain weight (14.8 g), and

Table 29. Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on the grain weight (g) from the ten heads of four wheat cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	Grain wt. (g) for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	McNair 1003	14.9	14.7	15.3	14.9
	Coker 747	10.7	10.7	11.4	10.9
	Tyler	13.9	13.8	13.0	13.6
	Wheeler	14.8	13.9	14.5	14.4
	Avg.	13.6	13.3	13.5	13.5
56	McNair 1003	14.3	14.8	14.9	14.7
	Coker 747	10.1	10.5	10.8	10.5
	Tyler	13.6	13.0	13.6	13.4
	Wheeler	14.0	12.8	13.7	13.5
	Avg.	13.0	12.8	13.3	13.0
Avg.	McNair 1003	14.6	14.8	15.1	14.8
	Coker 747	10.4	10.6	11.1	10.7
	Tyler	13.8	13.4	13.3	13.5
	Wheeler	14.4	13.3	14.1	13.9
	Avg.	13.3	13.0	13.4	13.2

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	3.47	1.42
Reps.	2	1.24	0.51
Error A	2	2.44	---
Fish-solubles (FS)	2	0.94	1.70
FS x SN	2	0.12	0.23
Error B	8	0.55	---
Cultivars (Cul)	3	57.27	59.53**
Cul x SN	3	0.40	0.42
Cul x FS	6	0.73	0.75
Cul x SN x FS	6	0.32	0.33
Error C	36	0.96	---
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 30. Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on the estimate of kernels/spike from the ten heads of four wheat cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	Kernels/spike for indicated levels of N (kg/ha) from FS			
		0	28	56	Avg.
0	McNair 1003	38.6	37.7	38.5	38.3
	Coker 747	31.7	31.5	32.8	32.0
	Tyler	37.4	37.5	34.6	36.5
	Wheeler	34.5	32.3	33.6	33.5
	Avg.	35.5	34.8	34.9	35.1
56	McNair 1003	37.3	38.9	37.9	37.9
	Coker 747	31.1	31.2	32.9	31.7
	Tyler	37.2	36.1	37.6	37.0
	Wheeler	33.3	30.0	32.3	31.9
	Avg.	34.7	34.0	35.2	34.6
Avg.	McNair 1003	37.9	38.4	38.2	38.1
	Coker 747	31.4	31.4	32.9	31.9
	Tyler	37.3	36.8	36.1	36.7
	Wheeler	33.9	31.2	32.9	32.7
	Avg.	35.1	34.4	35.0	34.9

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	3.17	0.25
Reps.	2	1.54	0.12
Error A	2	12.52	---
Fish-solubles (FS)	2	3.52	2.11
FS x SN	2	2.34	1.40
Error B	8	1.67	---
Cultivars (Cul)	3	168.08	37.67**
Cul x SN	3	3.31	0.74
Cul x FS	6	4.80	1.08
Cul x SN x FS	6	2.87	0.64
Error C	36	4.46	---
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 31. Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on the estimate of Mkw (g) from the ten heads of four wheat cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	Mkw (g) for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	McNair 1003	38.7	39.0	39.7	39.1
	Coker 747	33.7	33.8	34.6	34.0
	Tyler	37.2	36.8	37.5	37.2
	Wheeler	42.8	42.9	43.2	43.0
	Avg.	38.1	38.1	38.7	38.3
56	McNair 1003	38.3	38.2	39.4	38.6
	Coker 747	32.7	33.5	32.9	33.0
	Tyler	36.5	36.1	36.3	36.3
	Wheeler	42.2	42.7	42.5	42.4
	Avg.	37.0	37.6	37.8	37.6
Avg.	McNair 1003	38.5	38.6	39.5	38.9
	Coker 747	33.2	33.6	33.7	33.5
	Tyler	36.9	36.4	36.9	36.7
	Wheeler	42.5	42.8	42.8	42.7
	Avg.	37.6	37.9	38.2	37.9

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	9.17	16.75
Reps.	2	4.84	8.83
Error A	2	0.55	---
Fish-solubles (FS)	2	1.56	0.78
FS x SN	2	0.36	0.18
Error B	8	2.00	----
Cultivars (Cul)	3	267.41	144.92**
Cul x SN	3	0.24	0.13
Cul x FS	6	0.48	0.26
Cul x SN x FS	6	0.24	0.13
Error C	36	1.85	----
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

highest estimate of kernels/spike (38.1), and Wheeler had the highest Mkw (42.7 g). No other effects or interactions were significant.

The correlation between grain weight from the ten heads and plot yield (Table 45) was r=.08, obviously not significant. Kernels/spike for both the 61 cm sections and the ten heads ranked the cultivars similarly, except that Tyler and McNair 1003 switched ranks. However, these two were similar in number of kernels/spike in both estimates, and the correlation between the estimates was r=.56**. The kernels/spike estimate based on the ten best heads (34.9) was considerably higher than the estimate from the 61 cm sections, (22.4). The correlation between the Mkw of both estimates was very high (r=.89**). As in the estimates based on the 61 cm sections, NH_4NO_3 also decreased Mkw at all levels of FS, with differences being nearly significant at .05. The cultivars ranked the same for Mkw in both estimates.

Tables 32 and 33 contain the heading and height data. For both traits, cultivars responded differently. McNair 1003 and Coker 747 were the earliest and Tyler was the latest and the tallest, while Coker 747 was the shortest. There was a significant CulxSN interaction, possibly due to McNair 1003 heading later with the spring nitrogen application, while the other cultivars did not change. FS had a

Table 32 . Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on the heading date (days after March 31) of four wheat cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	Days after 3/31 for indicated levels of N (kg/ha) from FS: 0	28	56	Avg.
0	McNair 1003	34	34	34	34
	Coker 747	34	34	34	34
	Tyler	37	37	38	37
	Wheeler	35	35	35	35
	Avg.	35	35	35	35
56	McNair 1003	35	34	35	35
	Coker 747	35	34	34	34
	Tyler	38	37	37	37
	Wheeler	35	35	36	35
	Avg.	36	35	36	35
Avg.	McNair 1003	35	34	34	34
	Coker 747	34	34	34	34
	Tyler	38	37	38	38
	Wheeler	35	35	36	35
	Avg.	35	35	35	35

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	1.68	3.37
Reps.	2	1.43	2.78
Error A	2	0.52	---
Fish-solubles (FS)	2	1.39	1.43
FS x SN	2	0.39	0.40
Error B	8	0.97	---
Cultivars (Cul)	3	37.42	161.66**
Cul x SN	3	0.79	3.42*
Cul x FS	6	0.18	0.80
Cul x SN x FS	6	0.11	0.48
Error C	36	0.23	
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 33 . Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on the height (cm) of four wheat cultivars.

Kg/ha of N from NH_4NO_3	Cultivar	Height (cm) for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	McNair 1003	86	90	88	88
	Coker 747	87	86	85	86
	Tyler	97	99	100	99
	Wheeler	92	93	92	93
	Avg.	91	92	91	91
56	McNair 1003	90	94	95	93
	Coker 747	89	93	91	91
	Tyler	102	106	104	104
	Wheeler	96	97	97	96
	Avg.	94	97	97	96
Avg.	McNair 1003	88	92	91	90
	Coker 747	88	89	88	88
	Tyler	100	102	102	101
	Wheeler	94	95	94	94
	Avg.	92	95	94	94

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Spring NH_4NO_3 (SN)	1	64.22	18.72*
Reps.	2	7.34	2.14
Error A	2	3.43	---
Fish-solubles (FS)	2	4.39	2.09
FS x SN	2	1.39	0.66
Error B	8	2.10	---
Cultivars (Cul)	3	91.63	230.14**
Cul x SN	3	0.44	1.12
Cul x FS	6	0.68	1.72
Cul x SN x FS	6	0.72	1.81
Error C	36	0.40	
Total	71	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

slight, but nonsignificant effect on height. Ammonium nitrate caused increases in height at all levels of FS, averaging 5 cm taller where NH_4NO_3 was applied.

Applications of FS tended to increase test weight (Table 34), while NH_4NO_3 applications tended to decrease it very slighty, though neither was significant. The major difference in test weight was among cultivars, with Wheeler and Coker 747 being highest and McNair 1003 the lowest. There was a significant CulxSN interaction due to Tyler and Wheeler only decreasing slightly with the application of NH_4NO_3, while McNair 1003 and Coker 747 expressed a greater decline.

Tissue samples were collected from the wheat plots in the same manner as for barley and the summaries of the data can be found on Tables 35 through 43. Calcium (Table 38), manganese (Table 41), and iron (Table 43) were not significantly affected by FS or NH_4NO_3. Significant increases with the application of NH_4NO_3 were found for levels of nitrogen (Table 35), phosphorus (Table 36), potassium (Table 37), manganese (Table 39), and zinc (Table 40). Copper (Table 42) showed a significant SNxFS interaction, the cause of which was unclear. Though calcium did not increase significantly with applications of NH_4NO_3, there was a .05% increase. Manganese also increased (4 ppm) and iron declined (268 ppm) with the NH_4NO_3 application.

Table 34. Effect of fall applications of fish-solubles and spring applications of NH_4NO_3 on test weight (kg/hl) of four wheat cultivars.

Kg/ha of N from NH_4NO_3	Variety	Test wt. (kg/ha) for indicated levels of fish-solubles (kg/ha) 0	28	56	Avg.
0	McNair 1003	68.0	68.8	68.8	68.5
	Coker 747	75.1	75.2	75.6	75.3
	Tyler	71.8	72.4	72.4	72.2
	Wheeler	74.6	75.2	74.9	74.9
	Avg	72.4	72.9	72.9	72.7
56	McNair 1003	67.9	66.2	67.8	67.3
	Coker 747	74.7	74.3	75.2	74.8
	Tyler	72.1	72.0	72.5	72.2
	Wheeler	75.2	75.8	75.6	75.5
	Avg.	72.5	72.1	72.8	72.5
Avg	McNair 1003	68.0	67.5	68.3	67.9
	Coker 747	74.9	74.8	75.4	75.0
	Tyler	72.0	72.2	72.4	72.2
	Wheeler	74.9	75.5	75.2	75.2
	Avg	72.4	72.5	72.9	72.6

Analysis of Variance

Source	Degrees of freedom	Mean square	F value
Spring N (SN)	1	0.282	0.93
Fish-solubles	2	0.245	0.81
Error A	2	0.302	---
Cultivars (Cul)	3	42.072	532.56**
Cul x SN	3	0.593	7.51*
Cul x FS	6	0.086	1.09
Error B	6	0.079	---
Total	23	---	---

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

Table 35 . Average effects of applications of fish-solubles and spring applications of NH_4NO_3 on nitrogen (%) in the flag leaves of wheat.

Kg/ha of N from NH_4NO_3	% N for indicated levels of N (kg/ha) from FS			
	0	28	56	Avg.
0	4.20	4.22	4.18	4.20
56	4.48	4.55	4.55	4.52
Avg.	4.34	4.38	4.36	4.36

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Reps.	2	0.078	3.44
Spring NH_4NO_3 (SN)	1	0.470	20.89*
Error A	2	0.022	---
Fish-solubles (FS)	2	0.003	0.44
FS x SN	2	0.002	0.40
Error B	8	0.006	---
Total	17	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 36 . Average effects of applications of fish-solubles and spring applications of NH_4NO_3 on phosphorus (%) in the flag leaves of wheat.

Kg/ha of N from NH_4NO_3	% P for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	0.32	0.32	0.32	0.32
56	0.34	0.34	0.33	0.34
Avg.	0.33	0.33	0.33	0.33

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Reps.	2	0.00001	1.00
Spring NH_4NO_3 (SN)	1	0.00140	256.00**
Error A	2	0.00001	---
Fish-solubles (FS)	2	0.00004	0.82
FS x SN	2	0.00004	0.82
Error B	8	0.00005	---
Total	17	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 37 . Average effects of applications of fish-solubles and spring applications of NH_4NO_3 on potassium (%) in the flag leaves of wheat.

Kg/ha of N from NH_4NO_3	% K for indicated levels of N (kg/ha) from FS			
	0	28	56	Avg.
0	2.68	2.70	2.67	2.68
56	2.82	2.83	2.74	2.80
Avg.	2.75	2.77	2.70	2.74

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Reps.	2	0.001	0.86
Spring NH_4NO_3 (SN)	1	0.058	46.24*
Error A	2	0.001	---
Fish-solubles (FS)	2	0.006	1.09
FS x SN	2	0.002	0.27
Error B	8	0.006	---
Total	17	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 38 . Average effects of applications of fish-solubles and spring applications of NH_4NO_3 on calcium (%) in the flag leaves of wheat.

Kg/ha of N from NH_4NO_3	% Ca for indicated levels of N (kg/ha) from FS			
	0	28	56	Avg.
0	0.37	0.37	0.36	0.37
56	0.41	0.41	0.44	0.42
Avg.	0.39	0.38	0.40	0.40

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Reps.	2	0.00250	2.33
Spring NH_4NO_3 (SN)	1	0.01280	12.00
Error A	2	0.00110	---
Fish-solubles (FS)	2	0.00009	0.20
FS x SN	2	0.00080	1.80
Error B	8	0.00040	---
Total	17	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 39 . Average effects of applications of fish-solubles and spring applications of NH_4NO_3 on magnesium (%) in the flag leaves of wheat.

Kg/ha of N from NH_4NO_3	% Mg for indicated levels of N (kg/ha) from FS			
	0	28	56	Avg.
0	0.14	0.14	0.15	0.14
56	0.16	0.17	0.17	0.17
Avg.	0.15	0.16	0.16	0.16

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Reps.	2	0.00016	7.00
Spring NH_4NO_3 (SN)	1	0.00220	100.00**
Error A	2	0.00002	---
Fish-solubles (FS)	2	0.00007	2.36
FS x SN	2	0.00004	1.27
Error B	8	0.00003	---
Total	17	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 40 . Average effects of applications of fish-solubles and spring applications of NH_4NO_3 on zinc (ppm) in the flag leaves of wheat.

Kg/ha of N from NH_4NO_3	Ppm Zn for indicated levels of N (kg/ha) from FS			
	0	28	56	Avg.
0	18	20	19	19
56	22	22	22	22
Avg.	20	21	21	21

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Reps.	2	1.39	8.33
Spring NH_4NO_3 (SN)	1	50.00	300.00**
Error A	2	0.17	---
Fish-solubles (FS)	2	2.72	2.00
FS x SN	2	1.50	1.10
Error B	8	1.36	---
Total	17	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 41. Average effects of applications of fish-solubles and spring applications of NH_4NO_3 on manganese (ppm) in the flag leaves of wheat.

Kg/ha of N from NH_4NO_3	Ppm Mn for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	58	59	58	58
56	63	60	63	62
Avg.	60	60	60	60

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Reps.	2	31.06	1.27
Spring NH_4NO_3 (SN)	1	72.00	2.94
Error A	2	24.50	---
Fish-solubles (FS)	2	1.06	0.10
FS x SN	2	8.17	0.78
Error B	8	10.53	---
Total	17	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 42 . Average effects of applications of fish-solubles and spring applications of NH_4NO_3 on copper (ppm) in the flag leaves of wheat.

Kg/ha of N from NH_4NO_3	Ppm Cu for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	3	4	3	3
56	3	3	3	3
Avg.	3	4	3	3

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Reps.	2	0.50	9.00
Spring NH_4NO_3 (SN)	1	0.22	4.00
Error A	2	0.06	---
Fish-solubles (FS)	2	0.17	1.50
FS x SN	2	0.72	6.50*
Error B	8	0.11	---
Total	17	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

Table 43. Average effects of applications of fish-solubles and spring applications of NH_4NO_3 on iron (ppm) in the flag leaves of wheat.

Kg/ha of N from NH_4NO_3	Ppm Fe for indicated levels of N (kg/ha) from FS 0	28	56	Avg.
0	897	1250	436	861
56	760	433	584	593
Avg.	829	842	510	727

Analysis of variance

Source	Degrees of freedom	Mean square	F value
Reps.	2	105750.5	0.88
Spring NH_4NO_3 (SN)	1	324012.5	2.69
Error A	2	120405.5	---
Fish-solubles (FS)	2	211172.2	1.61
FS x SN	2	368230.2	2.81
Error B	8	130913.9	---
Total	17	---	---

*, ** Significant at the .05 and .01 probability levels, respectively.

The increase in the levels of mineral elements in the flag leaves due to the application of spring nitrogen can be explained by the manner in which nutrients are absorbed by the plant. Plant nutrients reach the roots by root extension, mass flow, and diffusion. Corn plants will grow to less than 3% of the available soil nutrients, and mass flow could supply the root with most of the plant's needs for calcium, magnesium, and nitrogen. Usually, most of the phosphorus and potassium must reach the root by diffusion. The application of ammonium nitrate with the addition of rainfall increases the nitrogen in the soil solution. This nitrogen is transported to the root by mass flow, and upon absorption, leads to an increase in canopy density. With the increased surface area comes an acceleration in the rate of evapo-transpiration which draws more water and nutrients through the roots. The increased absorption by the root depletes the nutrients surrounding the root and establishes a concentration gradient. Minerals such as phosphorus and potassium will diffuse across the gradient to the root where they become positionally available for uptake (15).

As in the barley plots, fall applications of FS did increase NH_4 and NO_3 ions in the soil samples taken in the spring (Table 44). They were nearly significant at .05; again the lack of significance is due to the low degrees of freedom.

Table 44 . Average effects of fall applications of fish-solubles on NH_4+ and NO_3- ion concentrations in soil samples taken from the wheat plots the following spring.

Nitrogen ion	Ppm of NH_4+ and NO_3- ions for indicated levels of N (kg/ha) from FS			
	0	28	56	Avg.
NH_4+	0.111	0.119	0.137	0.122
NO_3-	4.55	8.45	10.30	7.78

Analysis of Variance

Source	Degrees of freedom	Mean square	F value
	NH_4+ ion		
Reps.	2	0.0007	1.08
Fish-solubles	2	0.0010	1.54
Error	4	0.0006	---
Total	8	---	---
	NO_3- ion		
Reps.	2	3.86	0.40
Fish-solubles	2	9.87	1.02
Error	4	9.65	---
Total	8		---

Table 45. Wheat correlation coefficients.

Group		Test wt.	Height	Heading date	Ten head samples: Mkw	Ten head samples: Kern/spike	Ten head samples: Grain wt.	61 cm sections: Kern/spike	61 cm sections: Mkw	61 cm sections: Grain yield	61 cm sections: No. of spikes
	Yield	0.30	0.67**	0.34**	0.07	0.07	0.08	0.39**	0.01	0.55**	0.22
61 cm sections	No. of spikes	0.37	0.01	-0.19	-0.47**	-0.39**	-0.58**	-0.48**	-0.56**	0.46**	---
61 cm sections	Grain yield	0.12	0.46**	0.17	0.27*	0.04	0.19	0.38**	0.26*	---	
61 cm sections	Mkw	-0.17	0.08	0.01	0.89**	0.15	0.67**	0.41**	---		
61 cm sections	Kern/spike	-0.27	0.54**	0.49**	0.36**	0.56**	0.62**	---			
Ten head samples	Grain weight	-0.57**	0.14	0.12	0.72**	0.76**	---				
Ten head samples	Kern/spike	-0.76**	0.13	0.20	0.10	---					
Ten head samples	Mkw	0.02	0.11	0.01	---						
	Heading date	-0.04	0.74**	---							
	Height	0.03	---								

*,** Significant at the .05 and .01 probability levels, respectively.

Correlation coefficients among components of the wheat data are given in Table 45, and show a significant negative correlation for test weight with grain weight and kernels/spike (ten heads). Coker 747, with fewest kernels/spike and the lowest grain weight, had the highest test weight. Correlated with height was plot yield, grain yield, kernels/spike (61 cm sections), and heading date. Tyler was the tallest cultivar with the second highest grain yield, the most kernels/spike, and it was the last to head, while Coker 747, the shortest cultivar, had the lowest grain yield, fewest kernels/spike and it was one of the first to head.

Heading date correlated positively with yield and kernels/spike (61 cm sections). Tyler, the latest, gave the highest yield, and Coker 747, the earliest, was lowest in yield with the fewest kernels/spike. The Mkw from the ten heads was negatively correlated with spikes/61 cm, and positively correlated with grain yield, Mkw, and kernels/spike from the 61 cm sections, and with grain weight from the ten heads. Coker 747 had the most spikes/61 cm, and had the lowest values for Mkw, grain yield, kernels/spike, and grain weight. McNair 1003 had the fewest spikes/61 cm, a high Mkw, and the most kernels/spike. Wheeler had the highest Mkw, grain yield, and a high grain weight.

Kernels/spike (ten heads) correlated negatively with spikes/61 cm, and positively with kernels/spike from the 61 cm sections and grain weight from the ten heads. Coker 747 had the fewest kernels/spike (both estimates), the highest number of spikes/61 cm, and the lowest grain weight. Grain weight from the ten head samples was also negatively correlated with the number of spikes/61 cm section, and positively with Mkw and kernels/spike, both based on the 61 cm sections. Coker 747 had the lowest grain weight, the most spikes/61 cm, and the lowest values for Mkw and kernels/spike, while McNair 1003 had the highest grain weight, the fewest spikes/61 cm, the highest Mkw, and the second highest number of kernels/spike.

Kernels/spike based on the 61 cm sections correlated positively with yield, grain yield, and Mkw (61 cm sections), and negatively with the number of spikes/61 cm. Here again Coker 747 had the fewest kernels/spike, the lowest grain yield, and the lowest Mkw. Tyler had the most kernels/spike, second highest grain yield, and second highest Mkw. The negative correlation was caused by the same relationship with kernels/spike as that of the ten head samples.

A negative correlation between Mkw (61 cm sections) and spikes/61 cm was caused by the same relationship previously described. Thousand kernel weight also correlated positively with grain yield due to Coker 747 having a low Mkw and a low grain yield, while Wheeler had the highest Mkw and the highest grain yield. Grain yield correlated positively with plot yield and with spikes/61 cm. Coker 747 had the lowest grain yield and the lowest plot yield, and Wheeler had the highest grain yield and the second highest plot yield. The correlation with spikes/ 61 cm may be due to Wheeler having the highest grain yield and the second highest number of spikes/61 cm, while McNair 1003 had the second lowest grain yield with the fewest spikes/ 61 cm section.

Wheat responded in yield to applications of FS and NH_4NO_3, although only the FS response was significant. However, 56 kg N/ha from FS, fall applied, produced a yield which was considerably less than that from an equivalent amount of N from NH_4NO_3, spring applied. The yield of wheat increased with the increasing levels of N up to the highest level, indicating that rates may not have been sufficiently high to determine the level for maximum response. Tyler was the highest yielding cultivar, and Coker 747 was the lowest. Applications of NH_4NO_3 significantly increased spikes/61 cm, with FS causing only slight and nonsignificant increases.

A significant decrease in Mkw was caused by NH_4NO_3, with the FS having little effect. Neither FS nor NH_4NO_3 had a significant effect of kernels/spike, although each caused a slight increase. Within all of these components of yield, cultivars differed significantly, with Coker 747 having the most spikes/61 cm, Wheeler the highest Mkw, and Tyler the most kernels/spike. McNair 1003 had the fewest spikes/61 cm, and Coker 747 was lowest in Mkw and kernels/spike.

The ten best head samples appeared useful in estimating kernels/spike and Mkw. Grain weight from these spikes was not correlated with plot yield or grain yield/ 61 cm section.

The NH_4NO_3 application caused a significant increase in nitrogen, phosphorus, potassium, magnesium, and zinc in the flag leaves of wheat, while the FS had no significant effect on the concentration of the minerals measured. Results from the soil sample analyses showed that nitrogen in the forms of NH_4 and NO_3 was becoming available from the FS for plant uptake.

Summaries of yield and the yield components can be found on Table 46, with both barley and wheat expressing yield responses to the FS only applications. However, the barley responded to all application levels, while wheat yields increased from the 0 to 28 kg N/ha, with little change between the 28 and 56 kg levels. Barley responded significantly to the NH_4NO_3 and wheat yield increases were nearly significant. Barley and wheat gave their highest yields with the combined 56 kg N/ha treatments from both FS and NH_4NO_3. The

Table 46. Summary of the effects of fish-solubles and spring applications of NH_4NO_3 on yield and components of yield of four barley and wheat cultivars.

Kg/ha of N from NH_4NO_3	Cultivars	Response of indicated traits at indicated levels of N (kg/ha) from FS															
		Yield (q/ha)				Spikes/61 cm				Kernels/spike				Mkw (g)			
		0	28	56	Avg.	0	28	56	Avg.	0	28	56	Avg.	0	28	56	Avg.
									Barley								
0	Barsoy	35.0	32.7	39.9	35.9	73	64	78	72	27	32	30	30	37	37	37	37
	Surry	34.4	36.8	51.3	40.8	71	80	71	74	31	34	35	33	35	36	36	36
	Henry	39.7	38.7	46.3	41.5	63	66	60	63	31	35	35	34	37	39	39	38
	Maury	39.8	46.3	50.0	45.3	73	64	70	69	30	34	36	34	34	36	37	36
	Avg.	32.7	38.6	46.9	40.9	70	68	70	69	30	34	34	33	36	37	37	37
56	Barsoy	41.9	41.1	48.4	43.7	72	75	66	71	34	33	35	34	38	37	37	37
	Surry	52.4	49.8	53.5	51.8	77	71	78	75	37	38	35	36	35	36	37	36
	Henry	50.7	54.0	50.5	51.7	67	70	75	71	32	36	34	34	39	40	40	40
	Maury	49.7	50.8	52.7	51.1	76	74	81	77	36	37	37	37	36	36	36	36
	Avg.	48.7	49.0	51.3	49.6	73	72	75	74	34	36	35	35	37	37	38	37
									Wheat								
0	McNair 1003	32.5	37.9	41.5	37.3	77	82	76	78	22	25	24	24	38	40	40	39
	Coker 747	35.5	38.1	37.5	36.4	120	115	116	117	20	18	18	19	34	32	33	33
	Tyler	39.4	45.8	40.2	41.8	89	95	84	89	22	24	26	24	35	36	36	36
	Wheeler	41.0	40.6	39.8	40.5	85	95	99	93	23	23	23	23	42	42	41	42
	Avg.	37.1	40.6	39.3	39.0	93	97	94	94	22	23	23	22	37	38	38	38
56	McNair 1003	44.7	44.2	44.3	44.3	90	114	110	105	23	23	23	23	38	37	36	37
	Coker 747	43.1	40.8	44.9	42.9	128	137	147	137	21	19	19	19	32	30	30	30
	Tyler	47.4	49.3	52.2	49.7	114	112	102	110	26	26	26	26	35	36	35	35
	Wheeler	41.8	47.7	46.9	45.4	113	104	116	111	22	22	21	22	40	41	40	40
	Avg.	44.2	45.5	47.1	45.6	111	117	119	116	23	22	22	23	36	36	35	36

Values for spikes/61 cm, kernels/spike, and Mkw have been rounded to the nearest whole number.

number of spikes/61 cm section was not affected by FS on either crop, but NH_4NO_3 did increase the number of spikes, though only the wheat response was significant. The Mkw remained unchanged for barley, while wheat showed a significant decline with the application of NH_4NO_3. FS caused only a slight increase in Mkw for both crops. The application of NH_4NO_3 caused a significant increase in kernels/spike for barley, while only slightly increasing the number in wheat. The FS alone application showed a tendency to increase kernels/spike in both barley and wheat, but neither response was significant.

All yield component estimates from the ten head samples expressed significant differences for cultivars, with no other main effects being significant. The only noted trend was a slight decline in all measured components with the NH_4NO_3 applications. Apparently, the nitrogen applications did not produce measurable effects on the components of yield as measured by the ten best heads.

Nitrogen applications from both FS and NH_4NO_3 caused barley to head earlier, with no clear effect on wheat. Spring top-dressing with NH_4NO_3 led to taller plants. Barley expressed a small percentage of lodging, which increased as the rates of nitrogen increased, whereas wheat did not lodge. The application of NH_4NO_3 significantly increased the test weight of all barley cultivars, while only one wheat cultivar increased, with two decreasing, and one cultivar remaining unchanged.

Mineral elements present in the flag leaves of both crops showed an increase in all mineral elements with the application of NH_4NO_3. However, most of the increases were significant for wheat only. Generally, barley had higher endogenous levels of all minerals, with potassium being the only element found in greater quantities in wheat leaves. The soil test for NO_3 and NH_4 gave similar results for the plots of both crops.

The ten head samples from both crops appeared to be useful for predicting Mkw and kernels/spike. They were not useful in estimating yield effects from the nitrogen treatments, but did appear to be somewhat useful in ranking cultivars for yield, especially in barley.

SUMMARY

An experiment was conducted at the Eastern Virginia Reaearch Station, Warsaw, comparing the effects of fall applications of N from fish-solubles FS and spring applications of N from NH_4NO_3 on yield and yield components of four cultivars each of barley and wheat. Tissue samples, (flag leaves), collected from the two crops in the late-boot to early-bloom stage showed that FS caused a significant increase in the content of calcium, magnesium, and manganese in barley, with no significant effect on wheat. The NH_4NO_3 significantly increased the content of manganese in barley, and all the analyzed minerals in wheat, except for calcium, manganese, copper, and iron.

Nitrogen from FS and NH_4NO_3 caused significant increases in barley yield, with no interaction between the two sources. Averaged over the two levels of N from NH_4NO_3, 56 kg N/ha from FS increased yield by 6.2 q/ha compared with no FS. When averaged across the three levels of N from FS, the application of 56 kg N/ha from NH_4NO_3 increased yield by 8.7 q/ha. The application of 56 kg N/ha from both FS and NH_4NO_3 increased barley yield by 16.9 q/ha over the check plot. In

comparing equivalent amounts of N from FS and NH_4NO_3, 56 kg N/ha from NH_4NO_3 (spring applied) yielded 1.8 q/ha more than the equivalent amount of N from FS (fall applied). There were significant differences in yield among the four barley cultivars, with Barsoy being the lowest (39.8 q/ha) and Maury the highest (48.2 q/ha). There was no significant interaction between cultivars and the N rates or sources.

The FS applications did not have a significant effect on any of the components of yield in barley. However, the application of NH_4NO_3 increased kernels/spike with slight increases from FS applications, and while effects on Mkw were extremely small, they did tend to increase with both sources of N. Cultivars differed significantly in Mkw (Maury and Surry lowest and Henry the highest) and kernels/spike (Barsoy the lowest and Maury the highest). There was no interaction for these traits between cultivars and N levels or sources.

The ten best barley head samples appeared to have some usefulness in estimating cultivar yield and Mkw.

Applications of N from both FS and NH_4NO_3 increased wheat yields, although the increases from NH_4NO_3 were not statistically significant. When averaged over the two levels of NH_4NO_3, the application of 56 kg N/ha from FS increased yield by 2.6 q/ha. The application of 56 kg N/ha from

NH_4NO_3 increased yield by 6.6 q/ha when averaged across the three levels of FS. There was no interaction between the FS and NH_4NO_3 levels of N, with the highest combined levels yielding 8.5 q/ha more than the check plot. Where 56 kg N/ha from FS (fall applied) was compared to an equivalent amount of NH_4NO_3 (spring applied), the NH_4NO_3 produced a 5.2 q/ha higher yield. Cultivars expressed significant differences in yield; Coker 747 yielded the least (39.6 q/ha) and Tyler gave the highest yield (45.7 q/ha). While there was no significant interaction between cultivars and N from FS or NH_4NO_3, there was a significant CulxFSxSN interaction, indicating that cultivars did not respond the same to the combined nitrogen levels.

Applications of N from FS caused significant increases in spikes/61 cm, but did not affect Mkw or kernels/spike. The spring application of NH_4NO_3 caused significant increases in spikes/61 cm, a very slight nonsignificant decrease in kernels/spike, and a decrease in Mkw. Cultivars differed significantly in all three components of yield, with Coker 747 being highest in spikes/61 cm and lowest in kernels/spike and Mkw. McNair 1003 was lowest in spikes/61 cm, Tyler had the most kernels/spike, and Wheeler was highest in Mkw.

The ten best wheat head samples were useful for estimating kernels/spike and Mkw, but were ineffective in estimating yield.

In summary, FS are a useful source of N for production of barley and wheat, but a fall N application of FS does not appear to be as effective as a spring N application from NH_4NO_3 in increasing yield. The highest yields were obtained through the combination of FS (fall applied) and NH_4NO_3 (spring applied). A preliminary experiment with barley showed that spring applications of FS, while increasing yield, were not nearly as effective as a similar amount of N from NH_4NO_3. Therefore, it was believed the fall application would be more effective, giving a longer period of time for the organic N from FS to mineralize and become available to the plant. The FS appeared to more nearly fulfill the N needs of barley than wheat, as shown by differences in yield between 56 kg N/ha from FS compared to NH_4NO_3 (a 1.8 q/ha difference in barley vs. a 5.2 q/ha difference in wheat). The N applications from FS and NH_4NO_3 had similar effects on the components of yield in barley and wheat, except that in wheat the application of NH_4NO_3 decreased Mkw, while appearing not to affect Mkw in barley.

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RESPONSES OF BARLEY AND WHEAT CULTIVARS TO APPLICATIONS OF FISH-SOLUBLES AND AMMONIUM NITRATE

by

Gordon W. Snyder, Jr.

(Abstract)

An experiment was conducted at the Eastern Virginia Research Station, Warsaw, comparing the effects of fall applications of nitrogen (N), (0, 28, 56 kg/ha) from fish-solubles (FS) and spring applications of N (0, 56 kg/ha) from NH_4NO_3 on yield and components of yield of four cultivars each of barley (Hordeum vulgare) and wheat (Triticum aestivum). Both barley and wheat expressed significant yield responses to FS. The NH_4NO_3 application increased yields in both crops, although the increase in wheat was not statistically significant. Interactions between the barley cultivars and N source or rates were nonexistant; however cultivar yield and thousand kernel weight (Mkw) did express interactions with the nitrogen levels and sources in wheat. Cultivars of both crops displayed significant differences for almost every analyzed trait.

Both crops responded similarly in the effect of N rates and sources on components of yield, with the greatest response being an increase in spikes/61 cm as the N rates increase. In barley, the increasing rates of N caused a slight increase in kernels/spike, while there was very little effect in wheat. In wheat, the spring application of NH_4NO_3 decreased Mkw, but there was no such effect in barley.

Samples of the ten best heads taken from the plots provided useful estimates of kernels/spike in wheat, Mkw in both crops, and of cultivar yield in barley.