WINTER WHEAT AND CHEAT RESPONSE TO FOLIAR NITROGEN APPLICATIONS

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Dedicated to my son Tommy

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ABSTRACT

Growing winter wheat (*Triticum aestivum L.*) cultivars in a weed-free environment is necessary for optimum grain yield. Cheat (*Bromus secalinus L.*) is an important grass weed in winter wheat in Oklahoma. Wheat grain yield losses can exceed 40% in fields heavily infested with cheat. A 2-year field experiment was initiated in the fall of 1995 and 1996 at the Efaw Experiment Station, to evaluate the influence of N rate and source of foliar fertilizer on the growth of winter wheat and cheat. Foliar solution fertilizers and other materials evaluated included urea-ammonium nitrate (UAN), molasses, 50% UAN and 50% molasses combination, ammonium hydroxide, and ammonium sulfate. Three wheat varieties ('Tonkawa', 'Longhorn' and 'Jagger') were also evaluated from 1995 to 1996. A logarithmic sprayer was used to apply solutions, whereby N rates were reduced by half every 3.0 m. Yield of wheat, grain protein and yield of cheat were determined after harvest. Cheat seeds were also collected for germination tests. Foliar N was applied after winter wheat had completed flowering, but 1 to 2 wks prior to cheat flowering. Both UAN and ammonium hydroxide solutions significantly desiccated immature cheat heads and reduced seed production. Cheat yield was also significantly reduced by UAN and ammonium hydroxide applications. Linear-plateau models indicated that foliar applied

UAN and ammonium hydroxide at a rate of 10 kg N ha^{-1} can result in cheat reduction (percent germination * cheat yield versus check) of 60%. Wheat grain yields were not reduced from foliar applied N following wheat flowering, while wheat grain protein increased significantly (1 to 3 % protein).

INTRODUCTION

Winter wheat (*Triticum aestivum L.*) is one of the most important crops in Oklahoma. The traditional wheat market classes in the USA are based primarily on milling and baking quality (Smith, 1991), and grain protein is the most important characteristic in determining baking quality. Nitrogen (N) is an essential element for plant growth and plays an important role in wheat production. Increasing the grain protein and yield of winter wheat depends on careful N management.

Growing winter wheat cultivars in a weed-free environment is necessary for optimum grain yield, because weeds are a yield-reducing factor. Cheat (*Bromus secalinus L.*) is an extremely important grass weed species in winter wheat in Oklahoma. Wheat grain yield losses can exceed 40% in fields heavily infested with cheat (Ratliff and Peeper, 1978).

Methods of application and sources of nitrogen (N) fertilizers are very important for both winter wheat and cheat growth and development. Soil fertility research programs have been successful in developing improved methods of nitrogen (N) fertilizer application in winter wheat. Bock and Hergert (1991), Johnston and Fowler (1991), Keeney (1982), and Keeney and Follett (1991) found that methods of fertilizer application can effect both crop yield and nitrogen uptake efficiency. The potential of using foliar fertilizer for plants has been recognized for many years. Numerous studies have shown that fertilizer N applications at flowering can increase grain protein. Grain protein increased significantly when the foliar nitrogen (N) was applied at or near wheat flowering (Finney, et al. 1957, Pushman, et al. 1976, Strong, 1982 and 1986, Morris, et al. 1985, and Smith, et al. 1989 and 1991). Also, Smith et al. (1991) reported that the foliar fertilizer N could be efficiently translocated to the head, subsequently increasing grain N concentration. However, foliar applied N after wheat flowering had no effect on grain yield. Conversely, Mahler et al. (1994) reported that winter wheat grain yield was greatest when N was applied in the fall and spring. In the same experiment, Mahler et al. (1994) also compared 15 different N placement-source-application timing treatments. They found that N source and placement did not significantly effect grain yield. Wuest and Cassman (1992) found that the amount of nitrogen (N) fertilizer applied at anthesis had the greatest influence on postanthesis nitrogen uptake, and also that grain protein level increased with late-season nitrogen (N) application, when applied at rates between 17 and 77 kg N ha^{-1}.

Sexsmith and Russell (1963) reported that preplant N fertilization in wild oats (*Avena fatua L.*) increased number of seed-bearing stems, plant height, straw weight, and seed yield. In other wild oat control work, Sexsmith and Pittman (1963) found that early spring N fertilizer application increased the germination of wild oat seed. They stated that in a wild oat control program, the use of nitrate fertilizer to induce germination of dormant seeds in the field should be considered. Nitrogen fertilizer might be used in fallow years to induce more wild oat seed to grow and thereby reduce the supply of available seed. The influence of fertilization on weed seed populations was also studied by Banks et al. (1976)

in a 47-year experiment. Results demonstrated that, for most weed species, plots receiving nitrogen (N), phosphorus (P), potassium (K) and lime contained the highest amount of weed seed, whereas plots with no fertilization produced the lowest amount of weed seed. In contrast, evening primrose (*Oenothera laciniata Hill)* produced fewer seeds with increased fertilizer treatment. Fawcett and Slife (1968) working with lambsquarters (*Chenopodium album L.*) found that ammonium nitrate had no significant effect on germination or dormancy.

Although the effects of preplant N fertilizer on the growth and composition of winter wheat and several weed species have been studied, foliar fertilizer applications have not been extensively evaluated for their effectiveness to increase winter wheat grain protein and simultaneously control weeds. Unlike some herbicides, foliar applied nitrogen (N) solutions leave no restrictive residues in the soil and can provide sufficient benefit to the crop.

Research by Donnelly et al. (1977) demonstrated that foliar N fertilizer applied before physiological maturity of grain sorghum (*Sorghum biocolor L.)* accelerated grain drying and reduced grain yield. The same authors found that foliar N fertilizer significantly decreased grain moisture. Our hypothesis was that foliar applied N fertilizer applied 1 or 2 wks before cheat flowering could desiccate immature cheat heads and reduce seed production.

The objectives of this research were to assess the effect of foliar N fertilizer on wheat grain yield and quality, and to determine the effect of N rate and source of foliar applied liquid N fertilizer on the reduction of cheat in winter wheat.

MATERIALS AND METHODS

One field experiment was established in fall of 1994 at the Efaw Experiment Station, Oklahoma State University to determine winter wheat and cheat response to foliar N fertilizer. Initial soil test characteristics and soil classification are reported in Table 1. A randomized complete block experimental design was used with two replications. In the 1994-95 crop season, two winter wheat varieties (Tonkawa and Longhorn), and three foliar applications (urea ammonium nitrate (UAN), 50% UAN-50% molasses, and molasses) were used in a complete factorial arrangement of treatments. In the 1995-96 crop season, winter wheat varieties (Tonkawa and Jagger) and three foliar applications (UAN, ammonium hydroxide (NH_4OH), and ammonium sulfate(($(NH_4)_2SO_4$)) were evaluated in a complete factorial arrangement of treatments. Main plot size was 2.6 m x 30 m, and subplots were 2.6 m x 3.0 m in both years.

In the fall of 1994, the entire experimental area was fertilized with 100.8 kg ha^{-1} of diammonium phosphate (18.1 kg ha^{-1} of carrier N), broadcast and incorporated in August. There were no preplant fertilizer treatments applied in the fall of 1995. The seeding date was October 15, 1994, and cheat was dribble applied (fertilizer box) to the entire area. The seeding rate for the cheat was 50.4 kg ha^{-1}, while the seeding rate for the wheat was 89.6 kg ha^{-1}. Foliar applications were applied to 'Tonkawa' treatments on May 11, and to 'Longhorn' treatments on May 16 which was after flowering had taken place in these wheat varieties, but prior to cheat flowering (Table 2). Foliar applications were made using a logarithmic sprayer that was calibrated at 177 L ha^{-1}. By constantly diluting the concentrate liquid fertilizer in a fixed volume canister traveling at a speed of 4.8 km hr^{-1}, concentrate rates were reduced by half every 3.0 m. The sprayer was equipped with 6-110O2 degree tip nozzles on 51 cm centers. In the 1994-95 crop year, three passes were made thus delivering a total volume of 531 L ha^{-1}. In 1995-96, two passes were used (354 L ha^{-1}). For all foliar applications, the surfactant 'X-77' (ORTHO, St. Paul, MN) was applied at a rate of 1 ml per liter of solution. Using the sprayer discussed, N rates ranged from 0.2 to 163.5 kg ha^{-1} for foliar N fertilizer solutions evaluated from 1994 to 1996. In the 1995-1996 growing season, the seeding rate for winter wheat was 78.4 kg ha^{-1}, and the seeding rate for cheat remained at 50.4 kg ha^{-1}. Foliar N fertilizer was applied on May 9, 1996 to both 'Tonkawa' and 'Jagger' plots. Foliar N application dates always took place once 20 random wheat heads from each variety were selected and examined under a microscope to assess complete wheat flowering, but prior to cheat flowering. Other activities for this experiment are reported in Tables 2 and 3.

During the 1994-95 crop year, cheat and wheat were hand harvested every 1.5 m (entire length of plot) in one replication. In the other replication, both cheat and wheat were harvested every 3.0 m using a self propelled combine whereby the blower was set to collect the cheat seed and all other fine materials in the bin. Results from hand harvested plots are not reported due to significant seed loss (shattering) imposed by this method. In the 1995-96 crop year, cheat and wheat were harvested every 1.5 m using a self propelled combine in both replications. Results from regression are reported on the means over replications. The harvested samples were cleaned with a small seed cleaner to separate cheat seed, wheat seed and other material. Yield of wheat and cheat were determined after cleaning. Total N analyses of wheat grain samples were accomplished using dry combustion (Schepers et al., 1989). Grain protein content was calculated by multiplying the percentage nitrogen by 5.7 (Martin del Molino, 1991). Cheat reduction was calculated as;

Cheat reduction (%) = 1 - CG (%) * CY / B

Where CG is the percentage of cheat germination, CY is the yield of cheat, B is the product of the highest percentage cheat germination and the yield of cheat where no foliar N was applied.

Cheat germination tests were determined as per the work of Copeland, 1978. One hundred seed from each treatment were placed in wet paper and refrigerated at 4 °C for 5 days, then replaced in the germination chamber (25 °C). A germination count was then completed after 7 days.

Wheat and cheat yield, cheat reduction and wheat grain protein were evaluated using two-segment linear-plateau models (Anderson and Nelson, 1975). Linear-plateau programs were adapted using the NLIN procedure (SAS, 1988). Equations for the linear-plateau models were $y = b_0 + b_1 [\min(X,A)]$ such that b_0 is the Y-intercept, b_1 is the slope of the line up to where X (N rate) = A (point where the combined residuals were at a minimum) (Mahler and McDole, 1987). Best estimates for b_0, b_1 and the point of intersection (joint for linear and plateau portions, defined here as the critical N rate) were obtained from the model which minimized combined residuals. Combinations of possible values of b_0, b_1 and the point of intersection were evaluated (holding the other two constant), that ultimately resulted in the highest coefficient of determination (Mahler and McDole, 1987).

RESULTS AND DISCUSSION

Wheat and cheat response to nitrogen (N) foliar fertilizers, 1994-95

With few exceptions molasses treatments evaluated in 1994-95 had little effect on wheat grain yield and cheat yield. Because of this, application of foliar molasses was not evaluated again in 1995-96. This treatment was initially included on the assumption that molasses might hinder cheat pollination via microbial decay due to having an easily oxidizable substrate. Due to the lack of any significant effects of molasses treatments for any of the dependent variables evaluated, no response data are reported. Foliar applied UAN had no affect on wheat grain yields (Figure 1). This was based on statistical analysis where no response could be observed on wheat grain yield by foliar N fertilizer applied post flowering. This finding agrees with results of previous studies, which showed no grain yield response to foliar applied N at or near anthesis (Smith, 1991 and Strong, 1982). These results also agree with the work of Mahler et al. (1994) who found that N source and placement did not significantly contribute to grain yield. However, wheat grain protein significantly increased from the foliar N applications (Figure 2). Linear-plateau models for foliar N rate versus wheat grain protein were all highly significant. Significant protein increases were observed at N rates ranging between 10.3 and 16.9 kg N ha^{-1} as is identified by the joint value from linear-plateau models. Increases in grain protein ranged from 1 to 3% as a result of applying foliar N when compared to plots that did not receive foliar N applications. These results agreed with research by Finney et al. (1957), Pushman et al. (1976), Strong (1982 and 1986), Morris et al. (1985), and Smith et al. (1989 and 1991) who found that grain protein significantly increased when foliar nitrogen (N) applications were made close to wheat flowering.

Linear-plateau models for foliar N rate versus cheat yield and cheat reduction were all highly significant (Figures 3 and 4). Three days after foliar N solutions were applied, serious damage in cheat flowers was observed. In addition, severe burn on the leaves of wheat and cheat could be observed in the field at the high N rates, when compared to plots that did not receive foliar N. Desiccation caused leaves to drop and hastened cheat physiological maturity. This in turn reduced harvestable cheat seed which confirmed our hypotheses that foliar applied N fertilizer 1 or 2 wks before cheat flowering could desiccate immature cheat heads and reduce seed set. Cheat yields decreased significantly at low N rates but this was variable over variety. Cheat reduction ranged from 47 to 64% when foliar UAN was applied at rates between 9 and 11 kg N ha^{-1} prior to cheat flowering for both varieties (Figure 4).

Wheat and cheat response to nitrogen (N) foliar fertilizers, 1995-96

In the 1995-96 crop year, results similar to 1994-95 were found, whereby wheat yields showed little response to applied foliar N and did not differ over N source (Figure 5). Linear-plateau models for foliar N rates versus wheat grain protein content were all highly significant for sources, excluding the ammonium sulfate application (Figures 6-8). Similar to results in 1994-95, N critical rates ranged between 15.3 and 25.6 kg N ha^{-1}. Wheat grain protein increased 4% as a result of applying foliar N.

Linear-plateau models for foliar N rates versus cheat yield were all highly significant excluding the ammonium sulfate foliar treatment (Figures 9 and 10). Cheat yields were decreased by 130 to 400 kg ha^{-1} with foliar N rates between 16 and 21 kg ha^{-1} when compared with plots that did not receive foliar N applications (Figures 9-11). Cheat reduction was variable in 1995-96 depending on N source (Figures 12-14). A 64% cheat reduction was achieved when ammonium hydroxide was applied at 5.7 kg N ha^{-1} (Figure 13). Critical N rates from linear-plateau models were not entirely consistent for the two varieties (Figure 13). However, excellent cheat reduction was achieved at low N rates in both varieties. Rates of 0.8 to 5.7 kg N ha^{-1}, using ammonium hydroxide, provided 64% to 70% cheat reduction. Foliar applied ammonium sulfate solution at a rate of 7.7 kg N ha^{-1} achieved 71.6% cheat reduction (Figure 14). Increased foliar N fertilizer (10-15 kg ha^{-1}) prior cheat flowering generally decreased cheat yield and increased cheat reduction.

CONCLUSIONS

Winter wheat grain protein increased when foliar N fertilizer was applied after wheat flowering. Grain protein was maximized in the 1994-95 crop year at foliar N rates between 10 and 17 kg ha^{-1} with a corresponding increase of 1 to 3% when compared to plots not receiving foliar applications. In the 1995-96 growing season, linear-plateau models also indicated that wheat grain protein increased 4% with foliar N rates between 15 and 25 kg ha^{-1} when compared with plots not receiving foliar N following wheat flowering. Wheat yields were not affected by applied foliar N after wheat flowering in either year.

Cheat yield and cheat reduction showed a significant response to foliar N applications. Cheat yield and cheat significantly decreased with increased foliar applied N fertilizer prior to cheat flowering. Sixty four percent reduction in cheat was achieved with UAN applied at a rate of 10.9 kg N ha^{-1}. Ammonium hydroxide applied at a rate of 0.8 to 5.7 kg N ha^{-1} resulted in 64% to 70% cheat reduction. Linear-plateau models suggest that 7.7 kg ha^{-1} was the critical N rate necessary for a 72% cheat reduction using ammonium sulfate foliar solution.

The response of wheat and cheat to foliar N application in this study indicates that foliar application of nitrogen (N) fertilizer can be used to effectively increase winter wheat protein, and to decrease cheat yield.

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Table 1. Soil chemical characteristics and classification, Efaw experimental station

Classification	Depth	pH	Total N	Organic C	NH4-N	NO3-N	P	K
			----------mg kg^{-1}----------		--------mg kg^{-1}---------		---------mg kg^{-1}---------	
Kirkland silt loam, fine, mixed, thermic Udertic	0-15cm	5.4	944	105	7.9	6.4	41.7	171

Table 2. Treatment and field activities, Efaw experiment station, 1995

Replication	N rate range (kg ha^{-1})	Treatment	Winter wheat variety	Foliar N application date	Harvest method
1	0.2-163.5	UAN	Tonkawa	5/11/95	Manual
1	0 - 0	Molasses	Tonkawa	5/11/95	Manual
1	0.1-81.7	50% (UAN + Molasses)	Tonkawa	5/11/95	Manual
1	0.2-163.5	UAN	Tonkawa	5/16/95	Manual
1	0 - 0	Molasses	Tonkawa	5/16/95	Manual
1	0.1-81.7	50% (UAN + Molasses)	Tonkawa	5/16/95	Manual
2	0.3-143.6	UAN	Longhorn	5/11/95	Combine
2	0 - 0	Molasses	Longhorn	5/11/95	Combine
2	0.1-71.8	50% (UAN + Molasses)	Longhorn	5/11/95	Combine
2	0.3-143.6	UAN	Longhorn	5/16/95	Combine
2	0 - 0	Molasses	Longhorn	5/16/95	Combine
2	0.1-71.8	50% (UAN + Molasses)	Longhorn	5/16/95	Combine

*: Log sprayer used to apply solutions whereby N rates were cut in half every 3.0 m.

Manual harvest: harvest every 1.5 m.

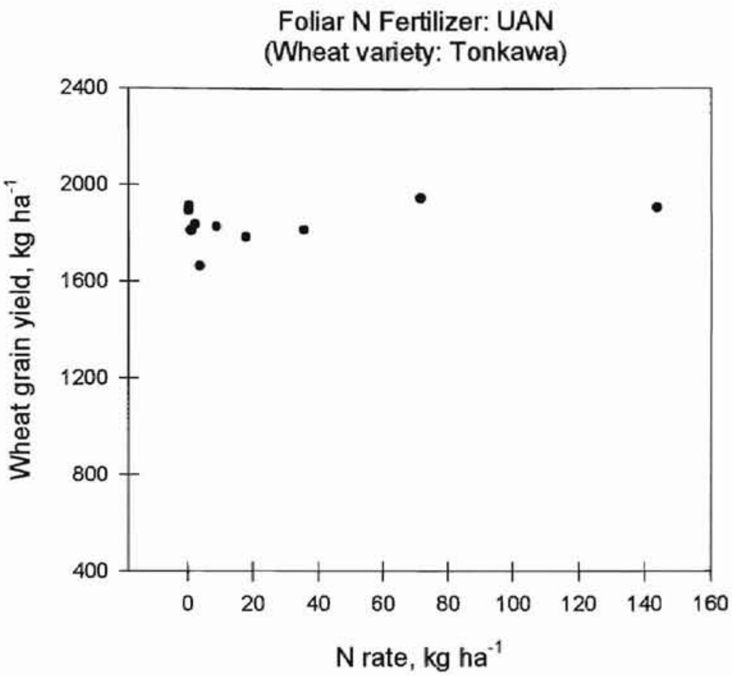
Combine harvest: harvest every 3.0 m.

Table 3. Treatment and field activities, Efaw experiment station, 1996

N rate range (kg ha^{-1})	Treatment	Winter wheat variety	Foliar N application date	Harvest method
0.2-109.4	UAN	Tonkawa	5/9/95	Combine
0.1- 63.6	Ammonium Hydroxide	Tonkawa	5/9/95	Combine
0.1- 80.3	Ammonium Sulfate	Tonkawa	5/9/95	Combine
0.2-109.4	UAN	Jagger	5/9/95	Combine
0.1- 63.6	Ammonium Hydroxide	Jagger	5/9/95	Combine
0.1- 80.3	Ammonium Sulfate	Jagger	5/9/95	Combine

*: Log sprayer used to apply solutions whereby N rates were cut in half every 3.0 m.

Combine harvest: harvest every 3.0 m.



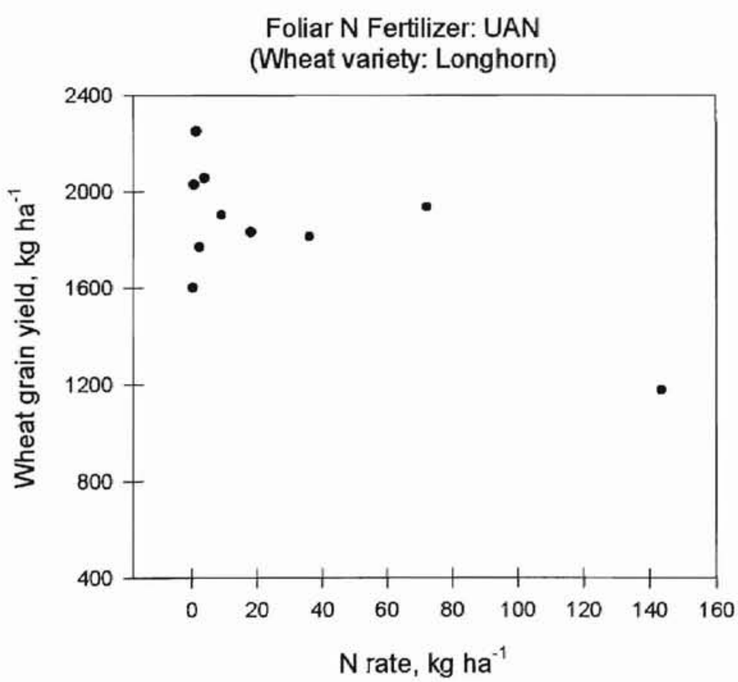


Figure 1. Winter wheat yield response to foliar N application, 1995 (UAN)

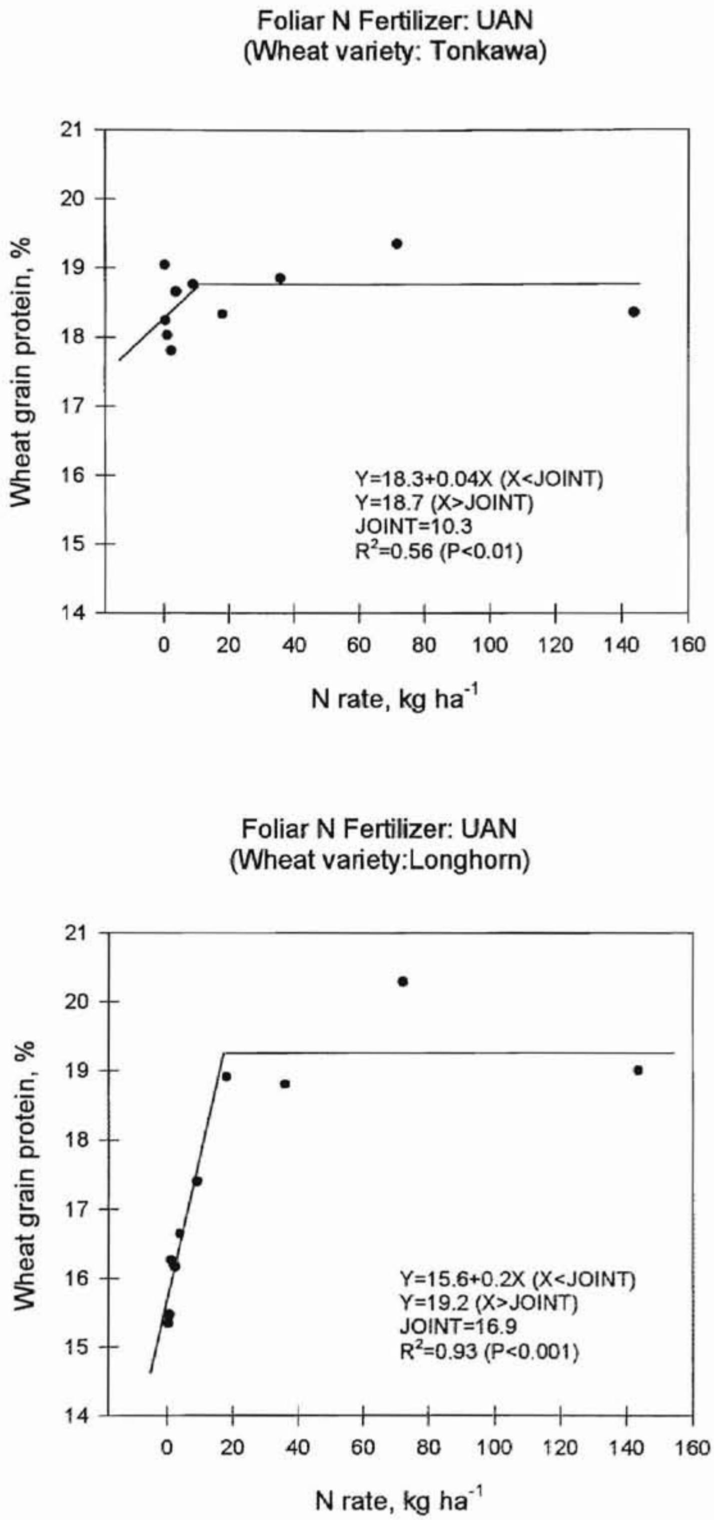
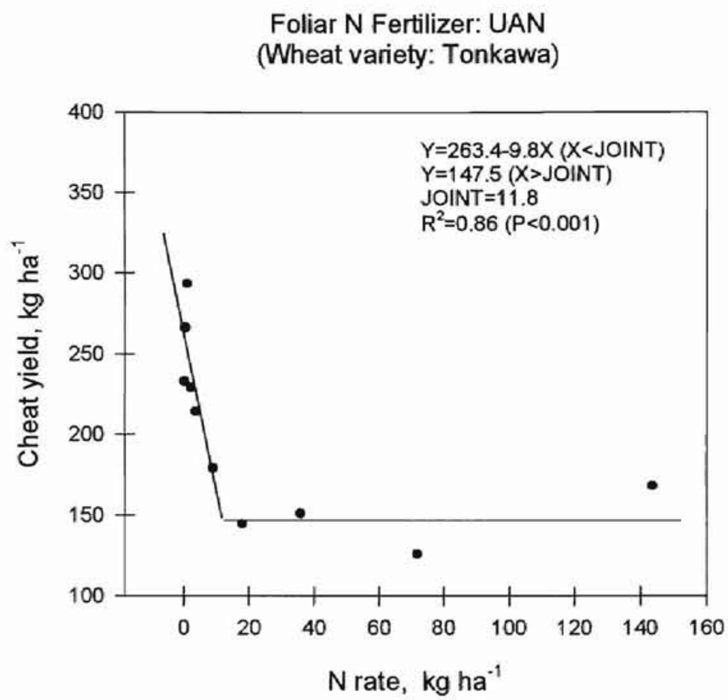


Figure 2. Winter wheat grain protein response to foliar N application (UAN, 1995)



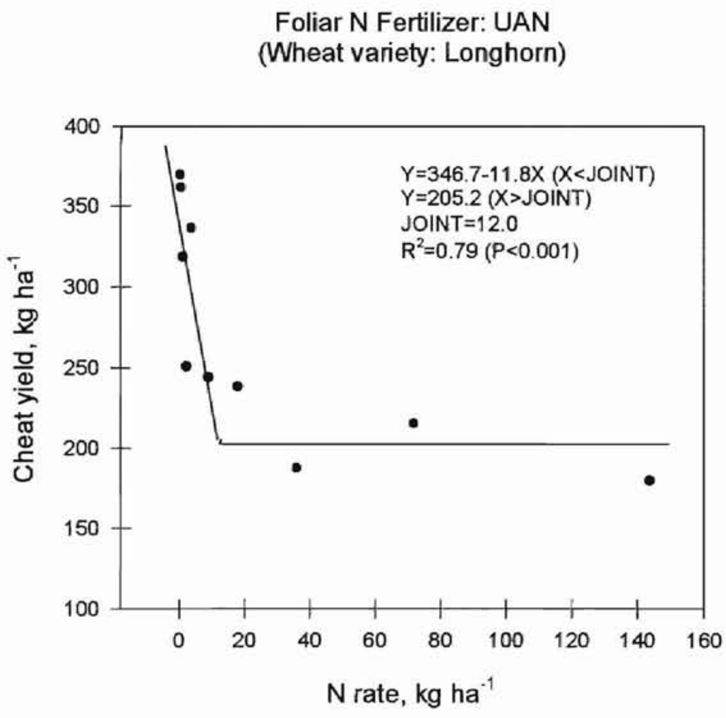
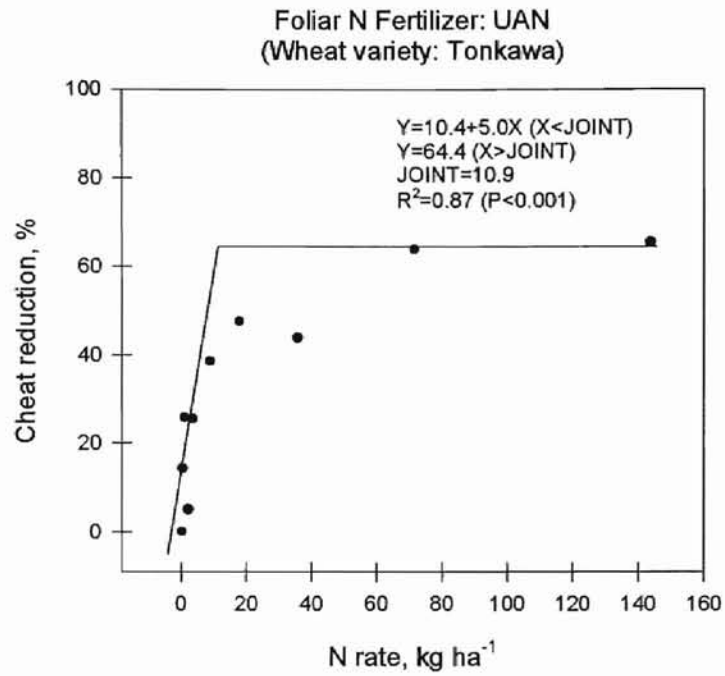


Figure 3. Cheat yield response to foliar N application, 1995 (UAN)



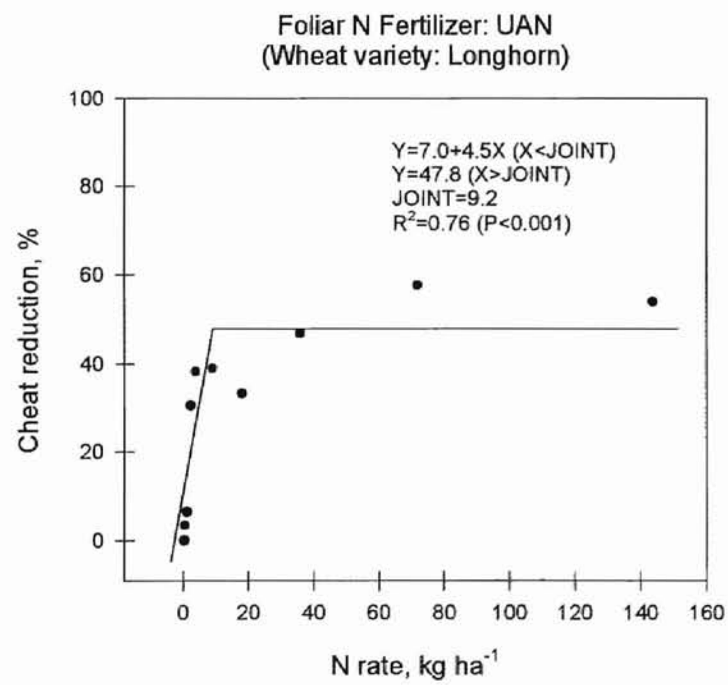
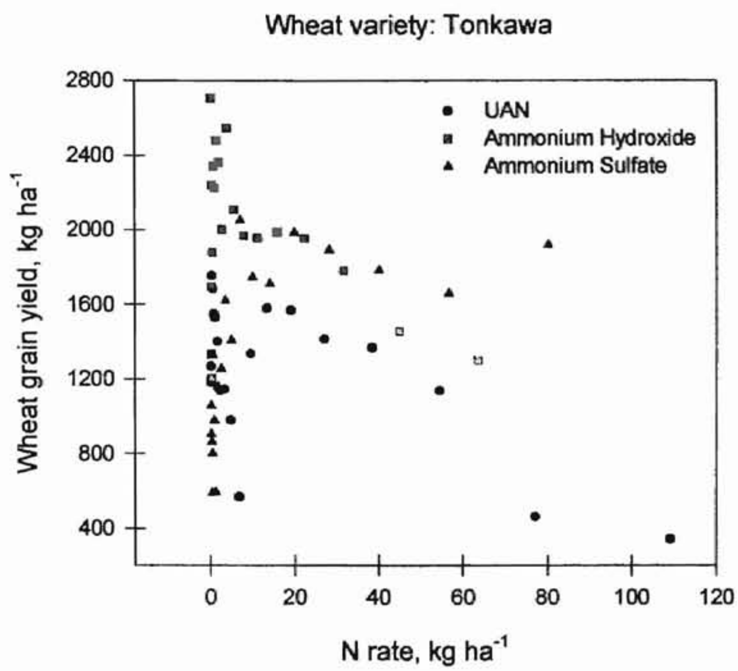


Figure 4. Cheat reduction response to foliar N application, 1995 (UAN)



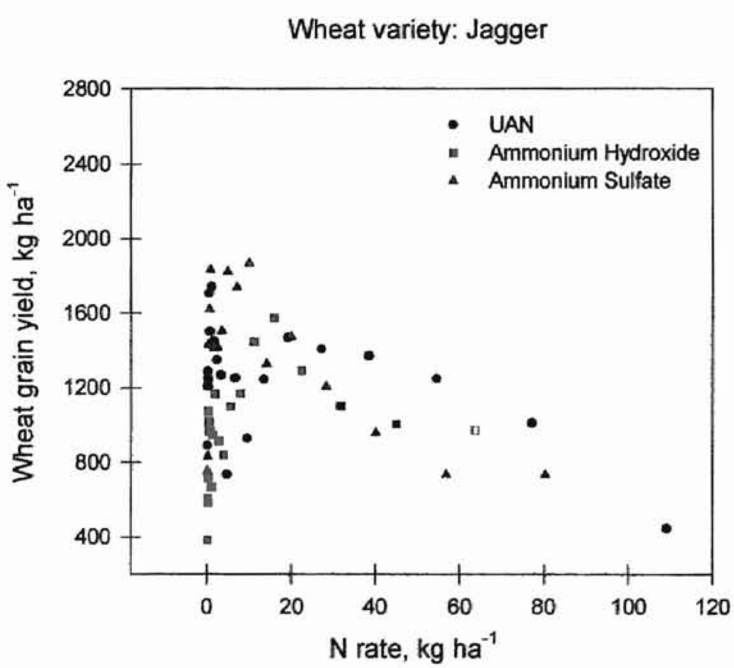
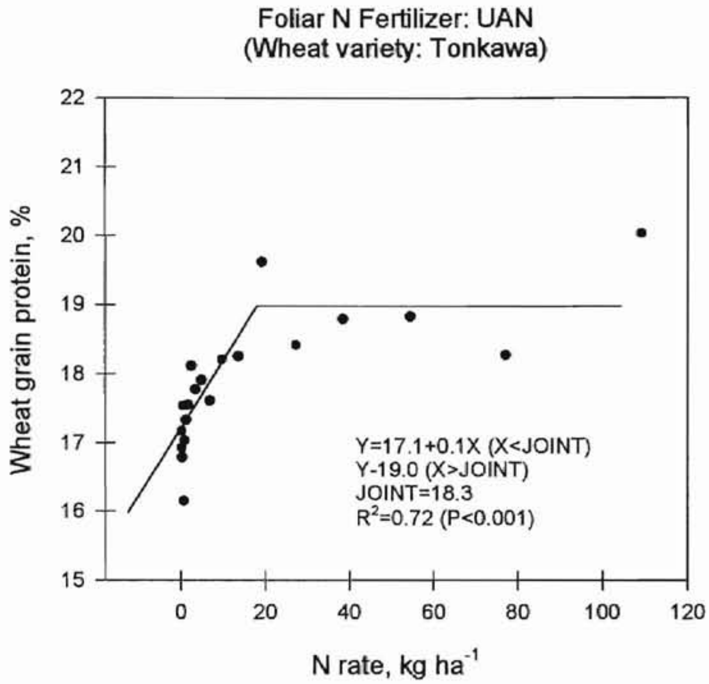


Figure 5. Winter Wheat grain yield response to foliar N applications, 1996 (UAN, Ammonium hydroxide and Ammonium sulfate)



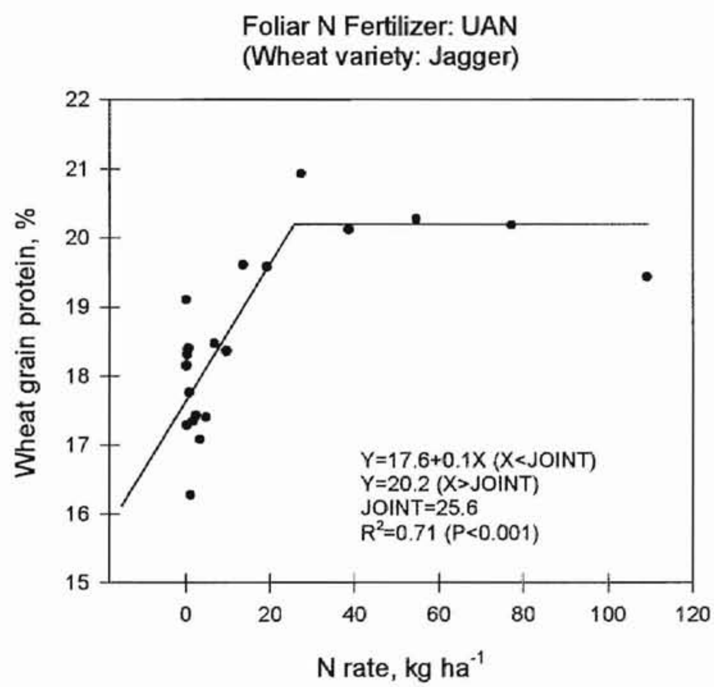
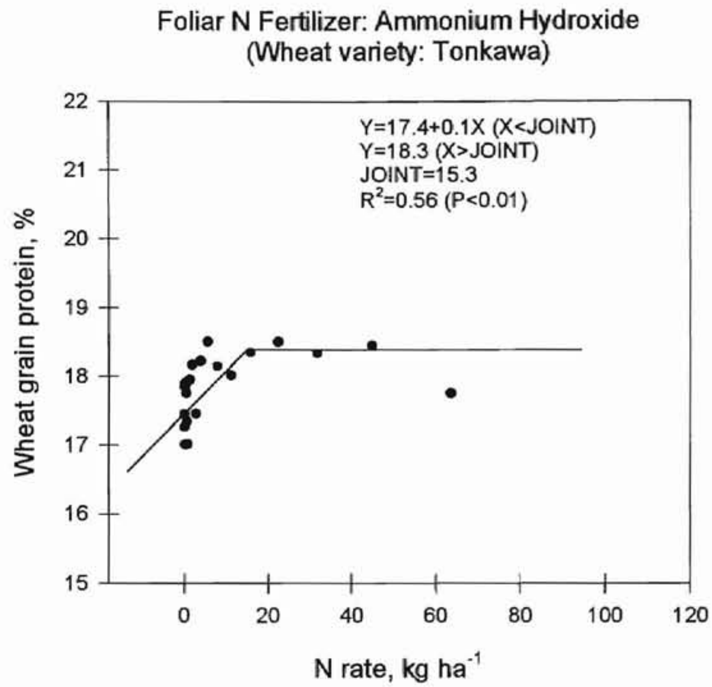


Figure 6. Winter wheat grain protein response to foliar N application, 1996 (UAN)



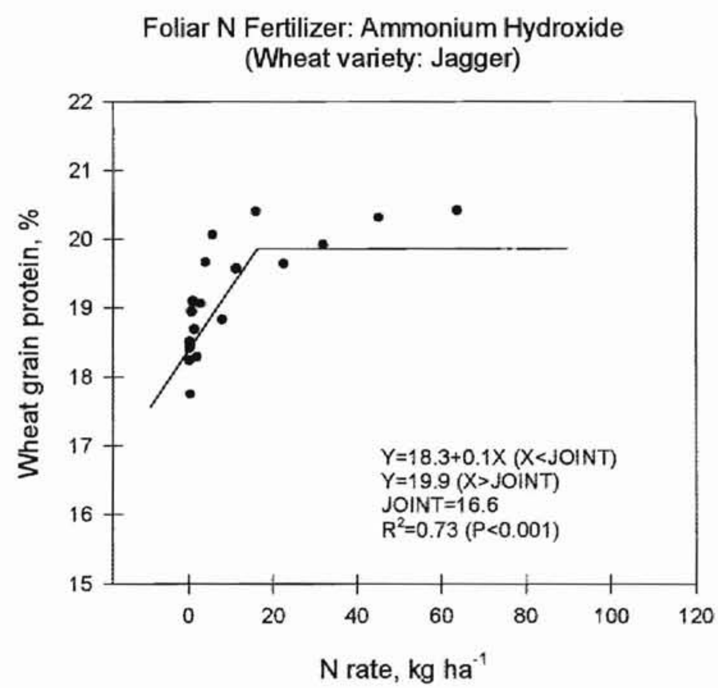


Figure 7. Winter wheat grain protein response to foliar N application, 1996 (Ammonium hydroxide)

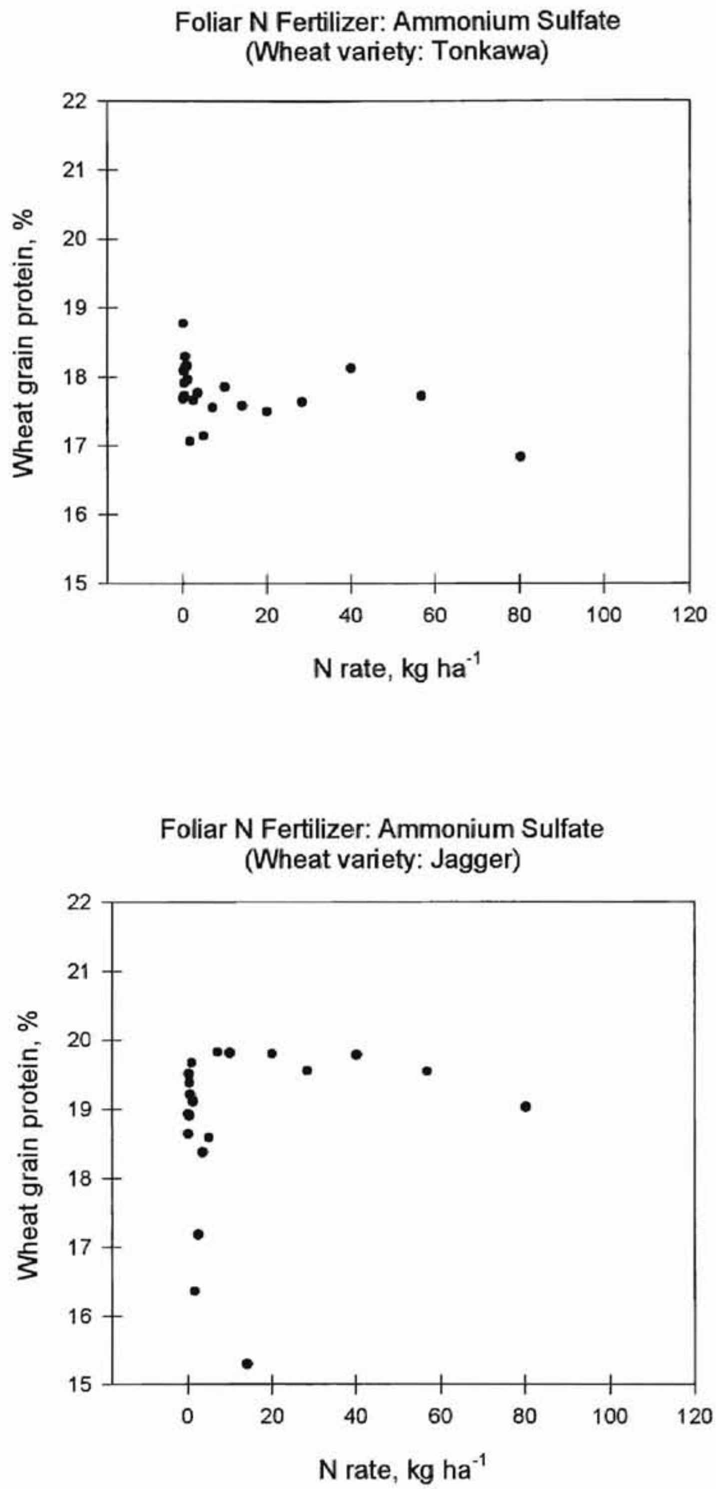
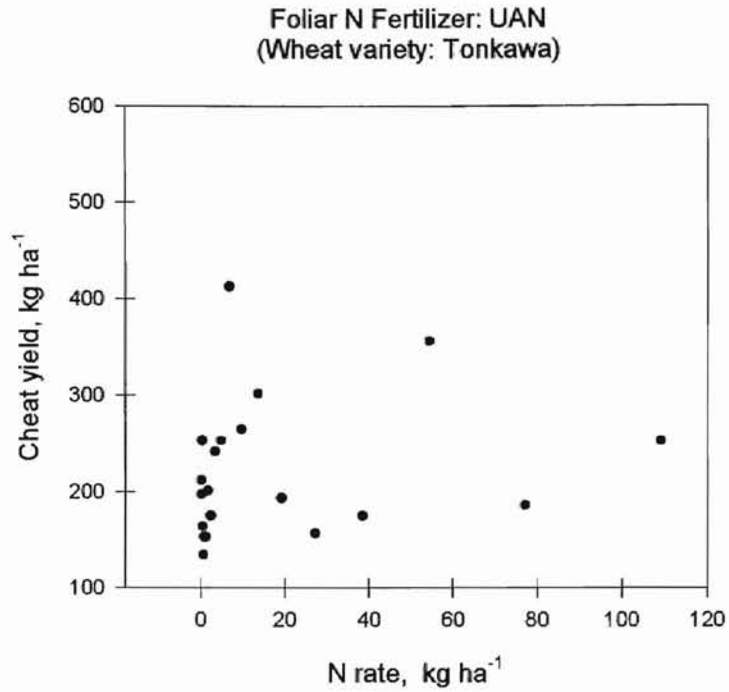


Figure 8. Winter wheat grain protein response to foliar N application, 1996 (Ammonium sulfate)



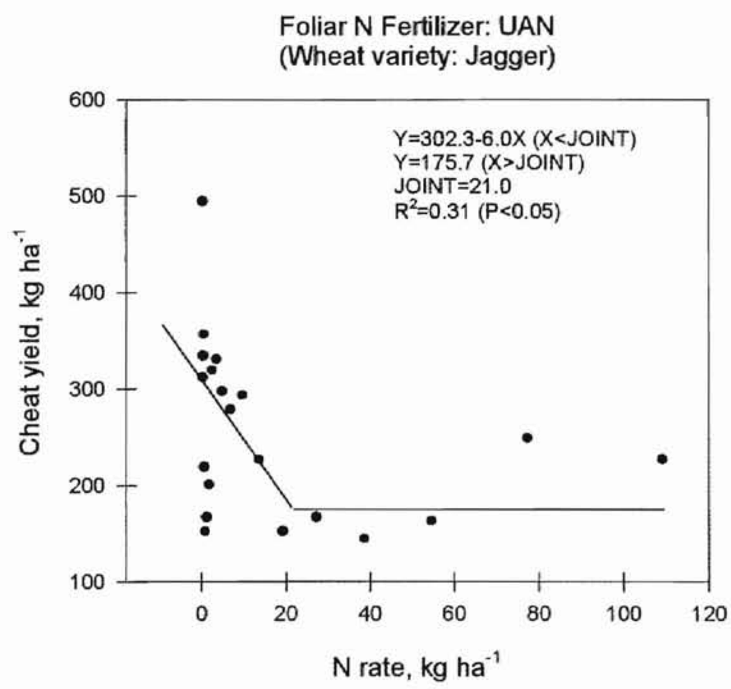
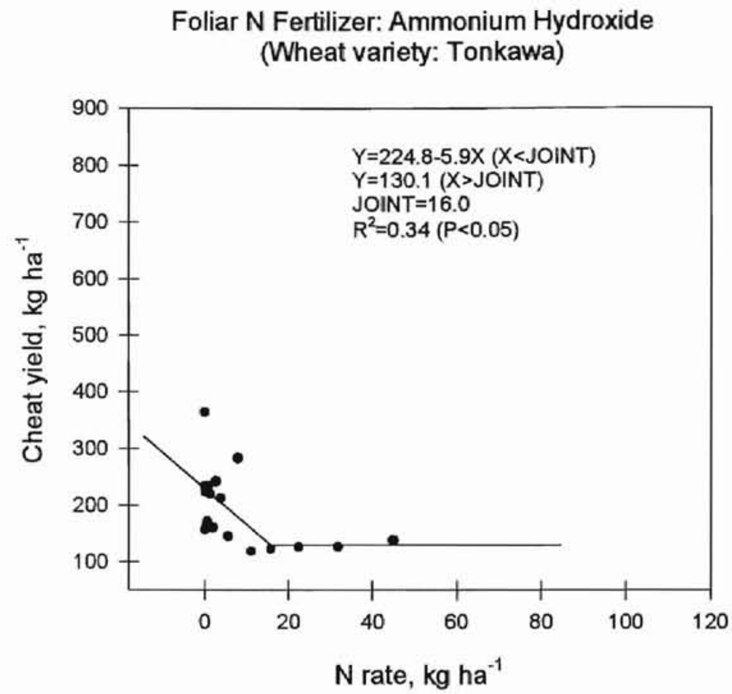


Figure 9. Cheat yield response to foliar N application, 1996 (UAN)



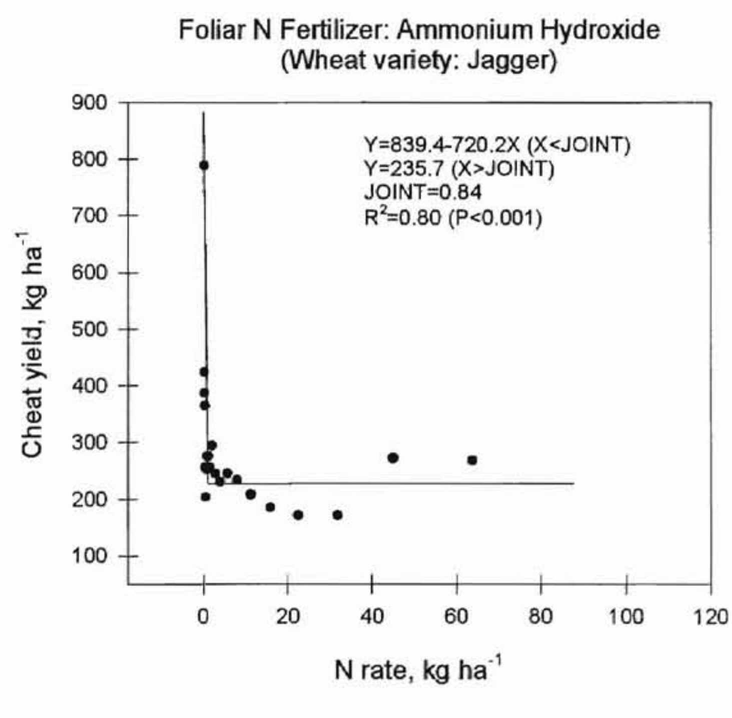
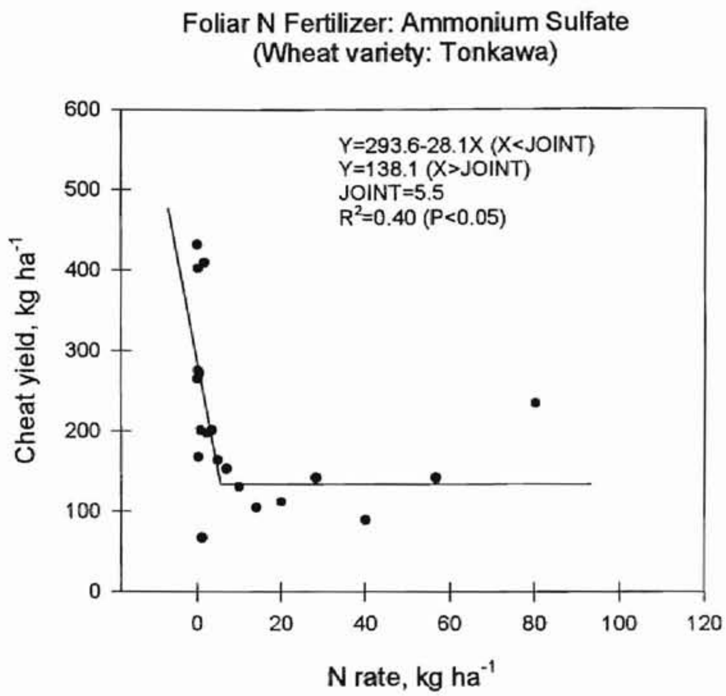


Figure 10. Cheat yield response to foliar N application, 1996 (Ammonium hydroxide)



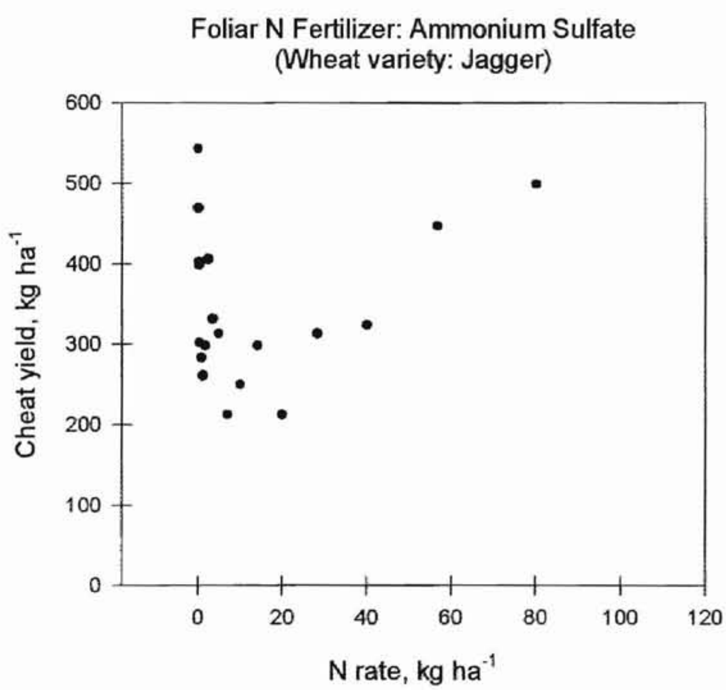
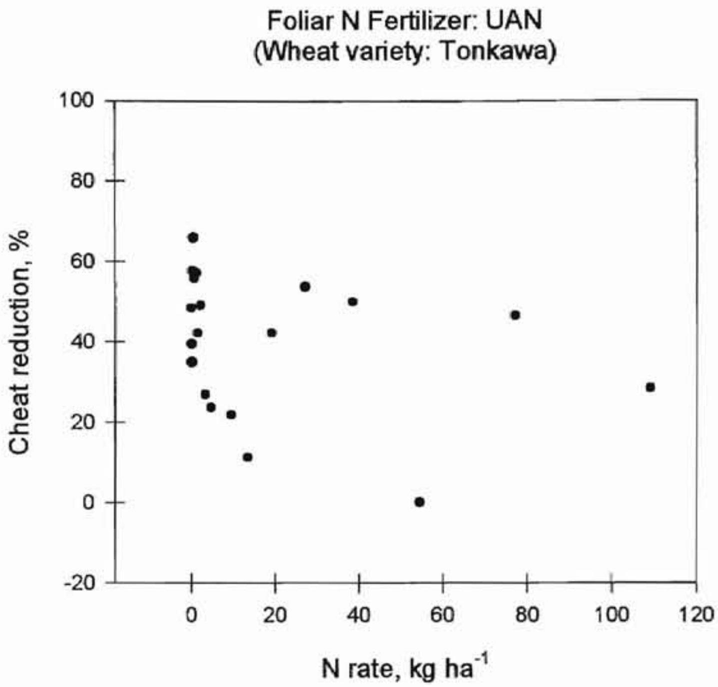


Figure 11. Cheat yield response to foliar N application, 1996 (Ammonium sulfate)



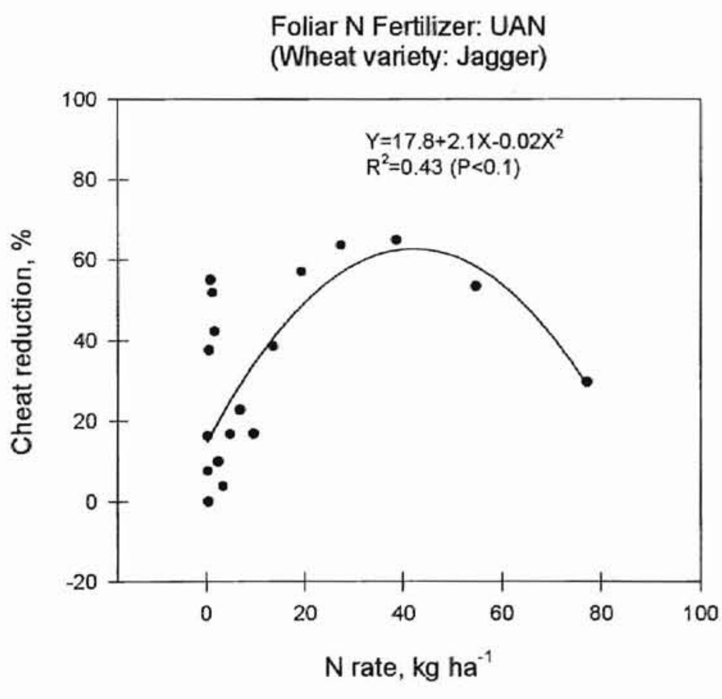


Figure 12. Cheat reduction response to foliar N application, 1996 (UAN)

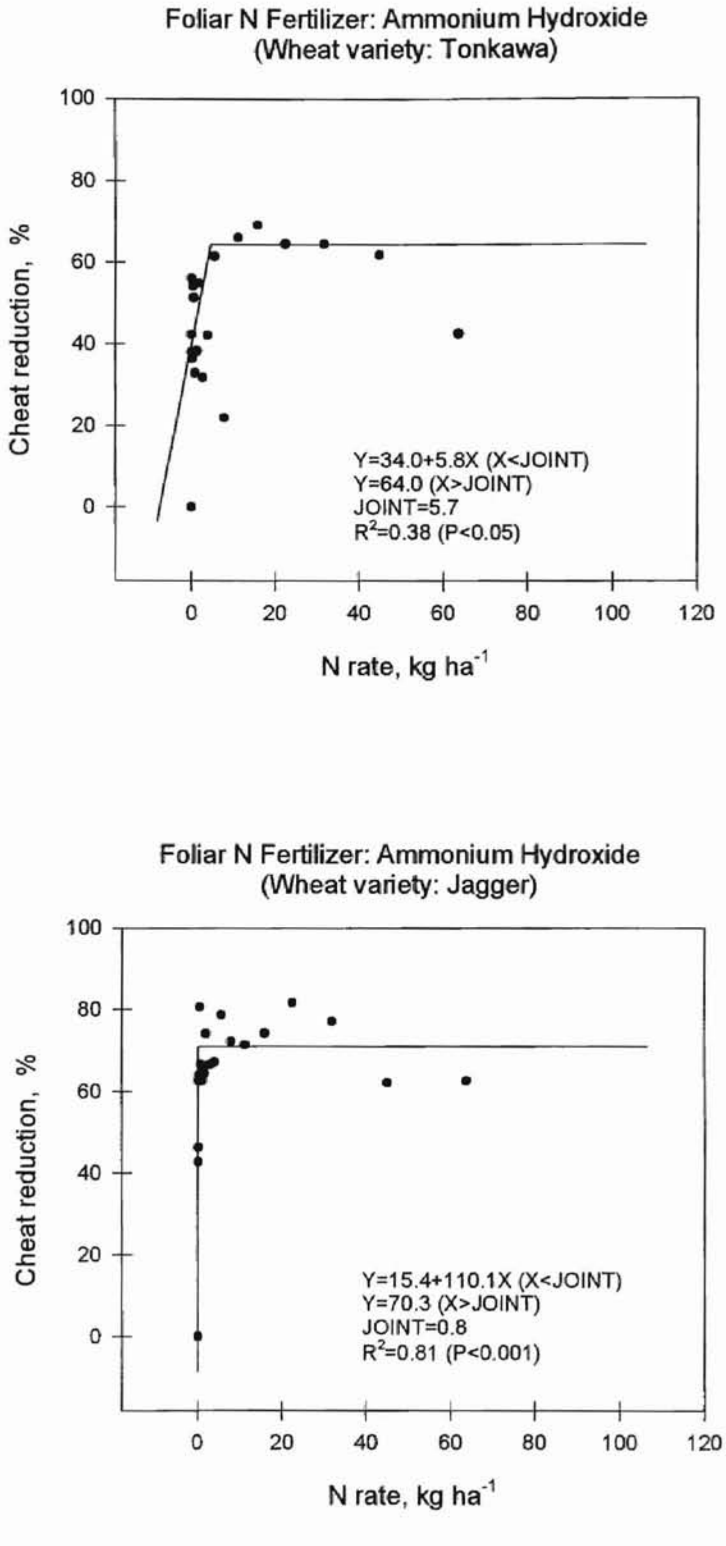
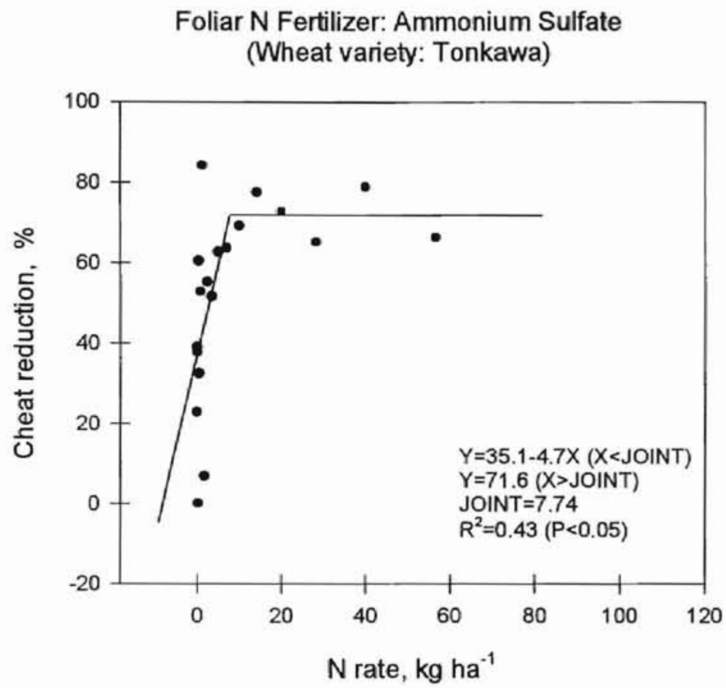


Figure 13. Cheat reduction response to foliar N application, 1996 (Ammonium hydroxide)



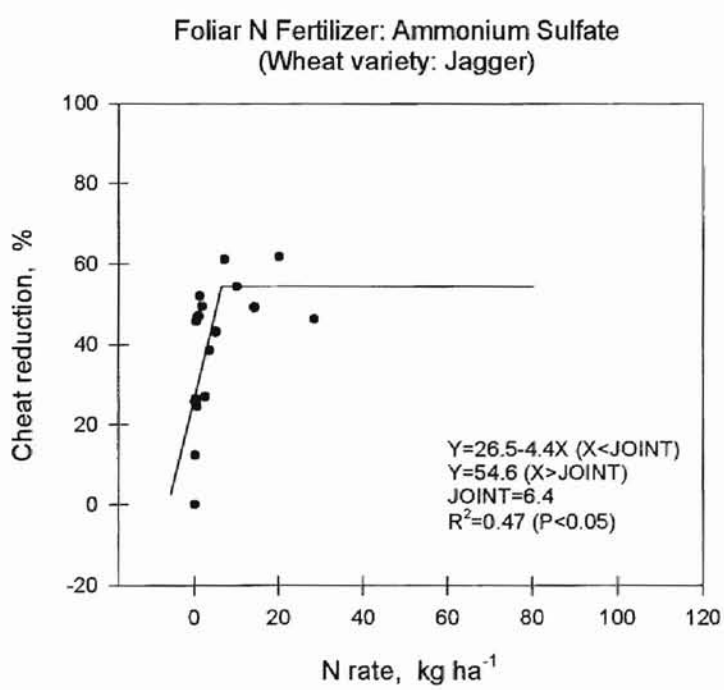
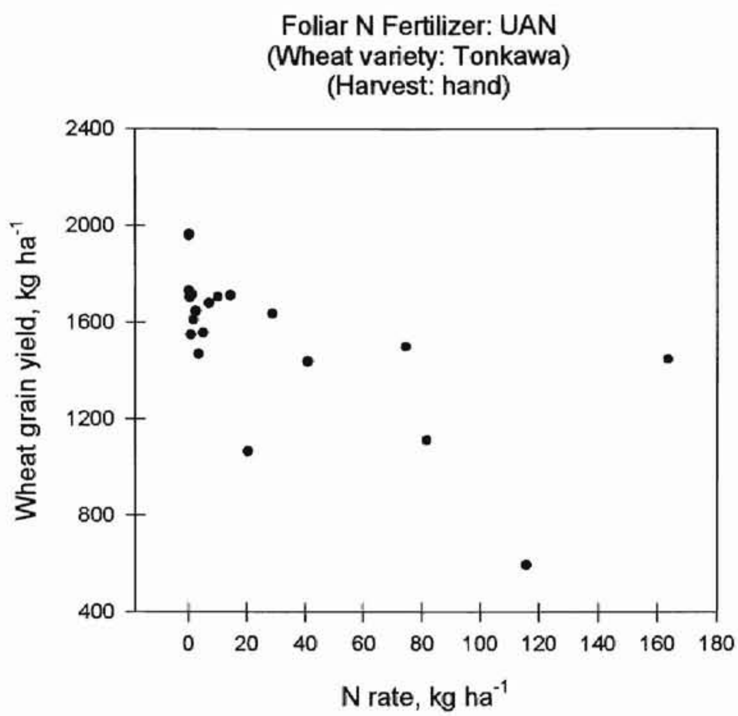


Figure 14. Cheat reduction response to foliar N application, 1996 (Ammonium sulfate)

APPENDICES



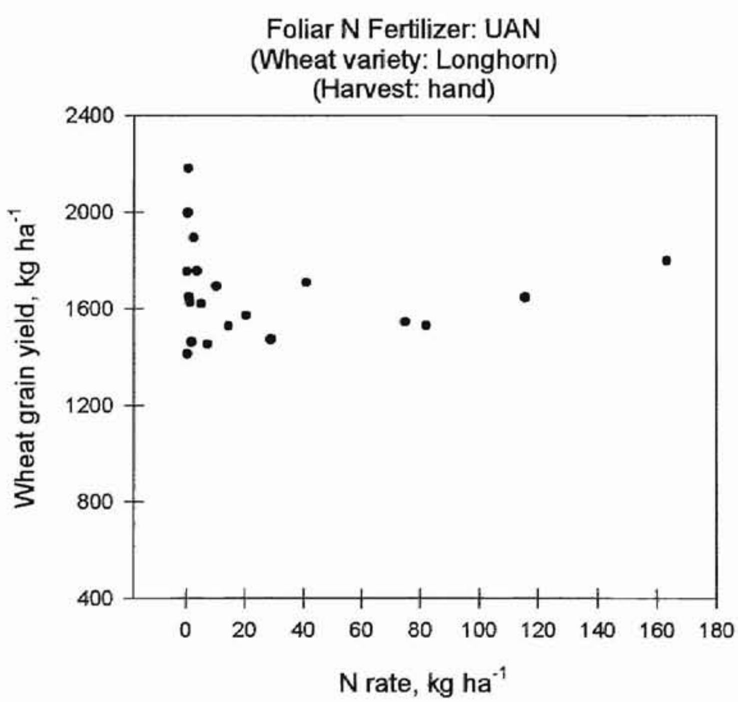


Figure 1. Winter wheat yield response to foliar N application, 1995 (UAN)

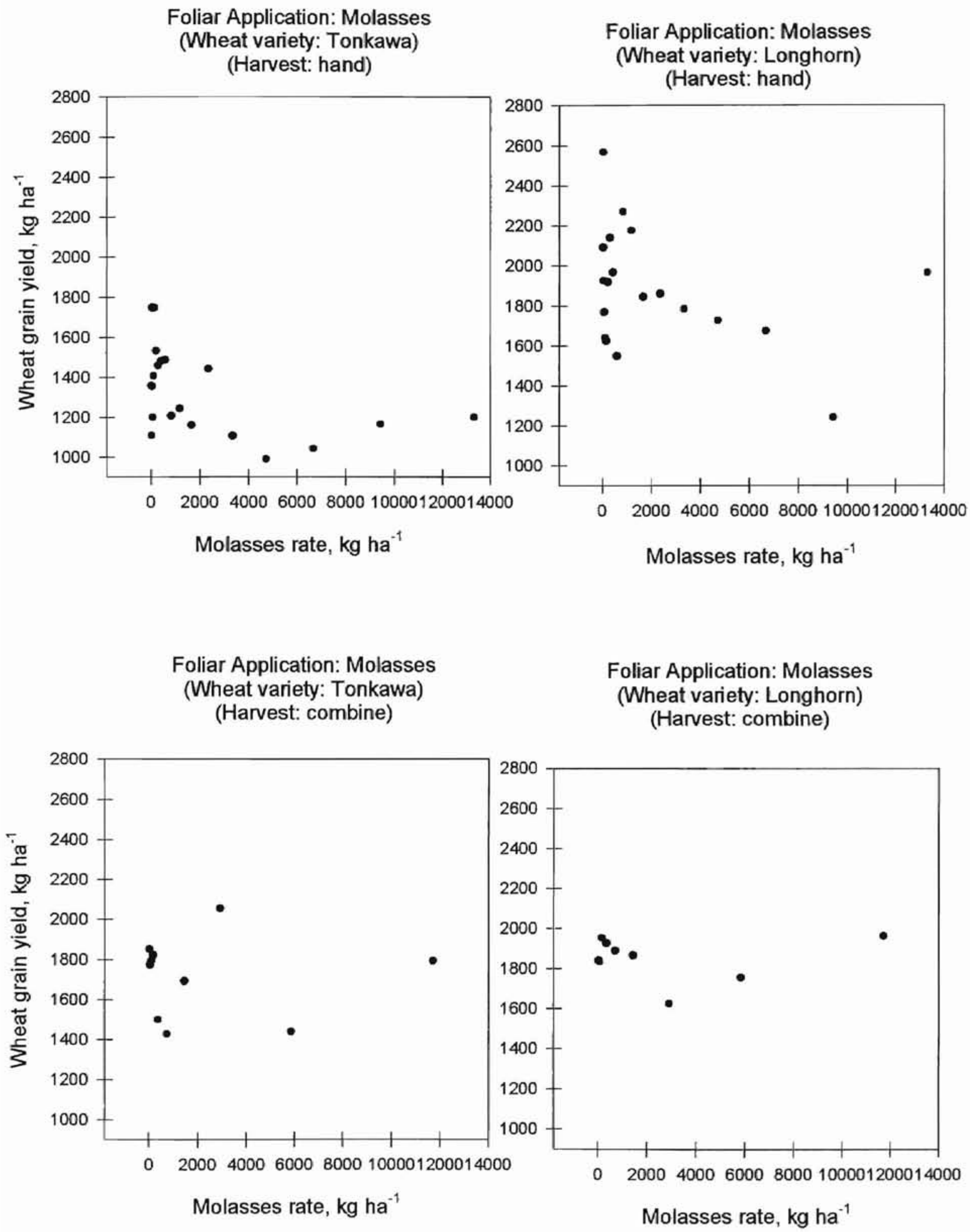


Figure 2. Winter wheat yield response to foliar N application, 1995 (Molasses)

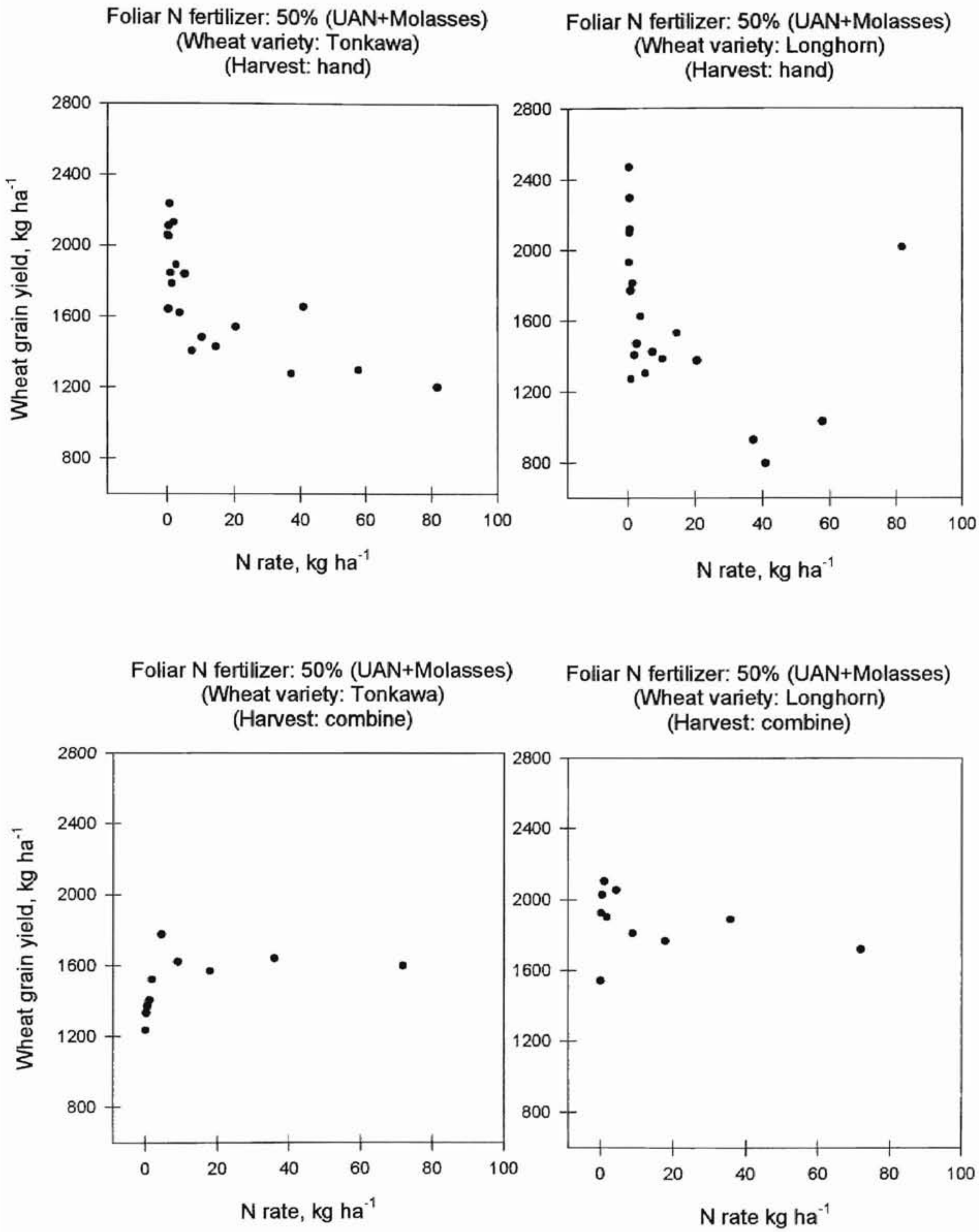
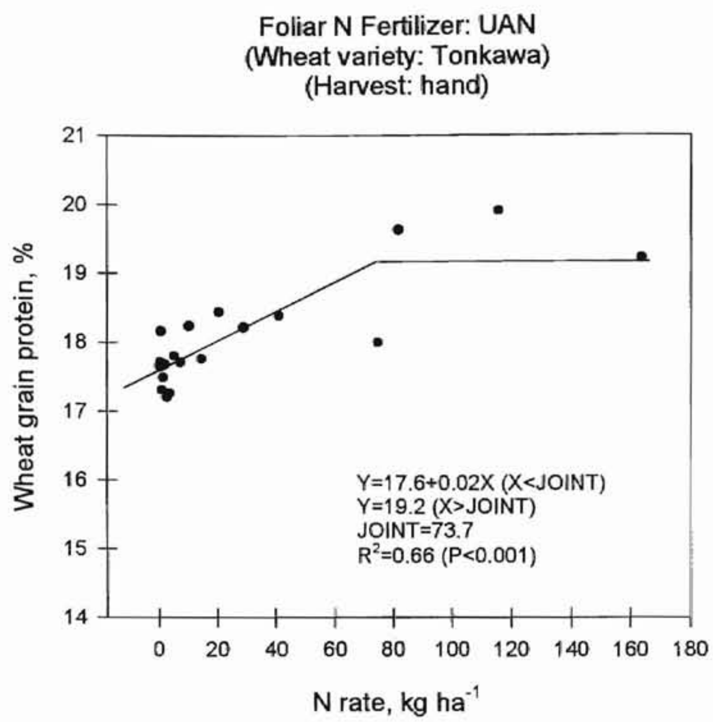


Figure 3. Winter wheat yield response to foliar N application, 1995 (50% (UAN+Molasses))



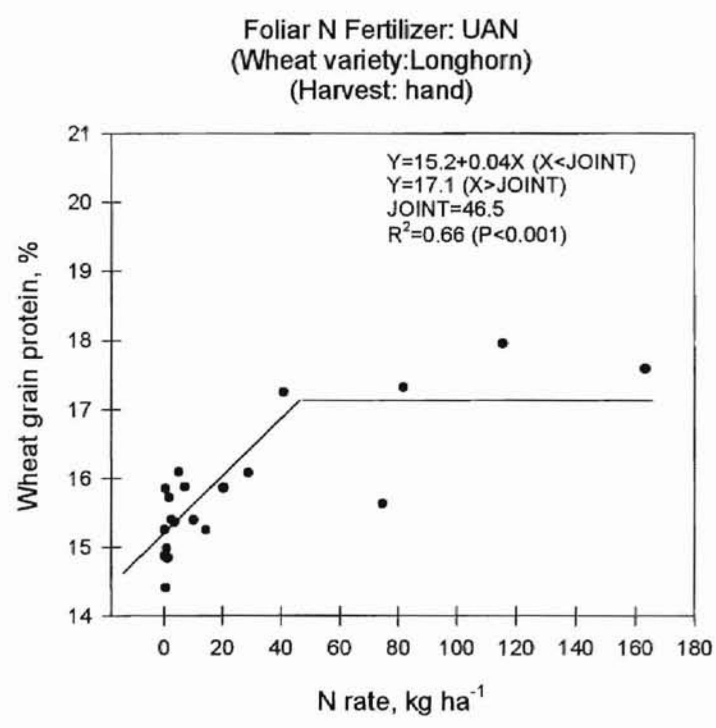


Figure 4. Winter wheat grain protein response to foliar N application, 1995 (UAN)

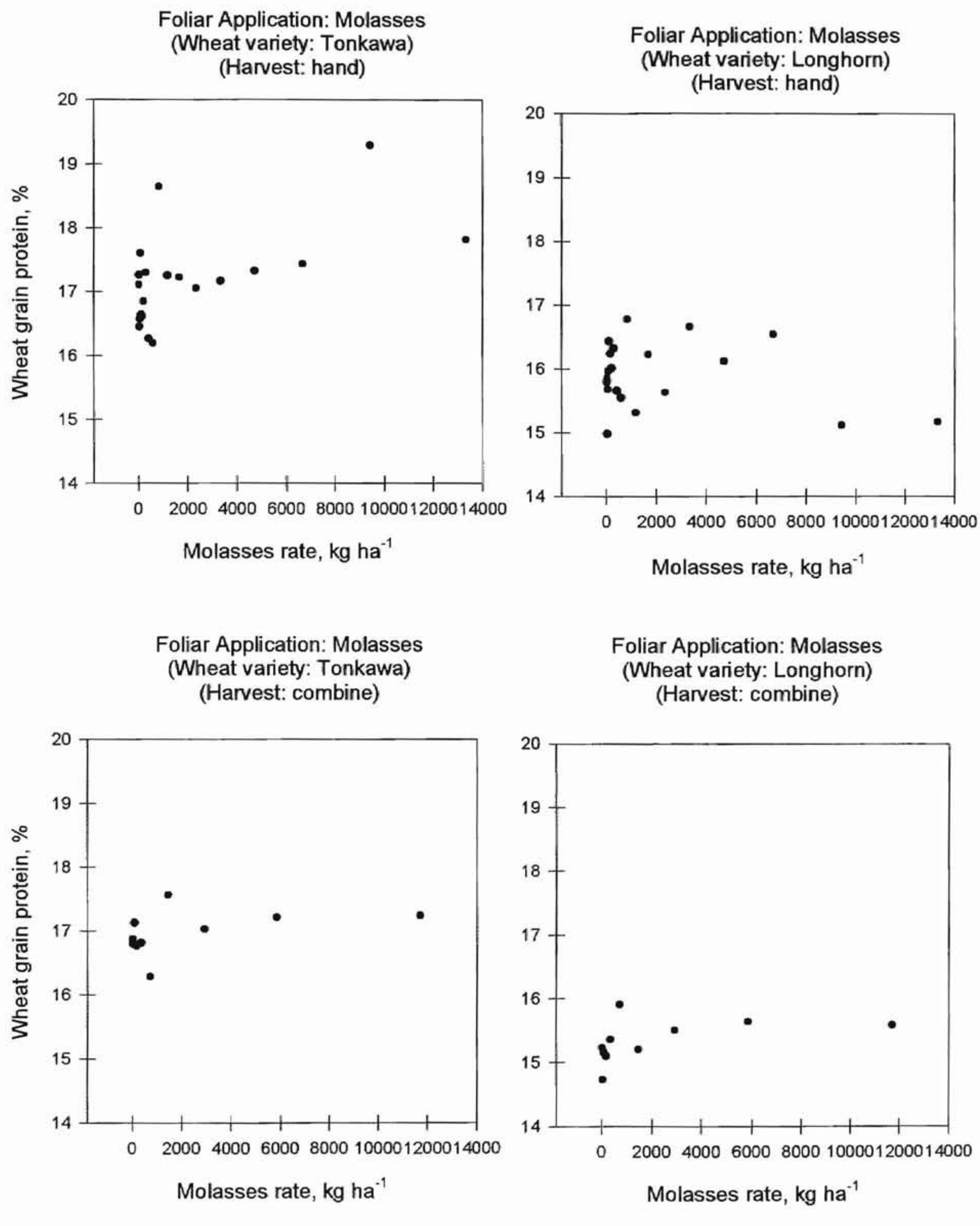


Figure 5. Winter wheat protein response to foliar N application, 1995 (Molasses)

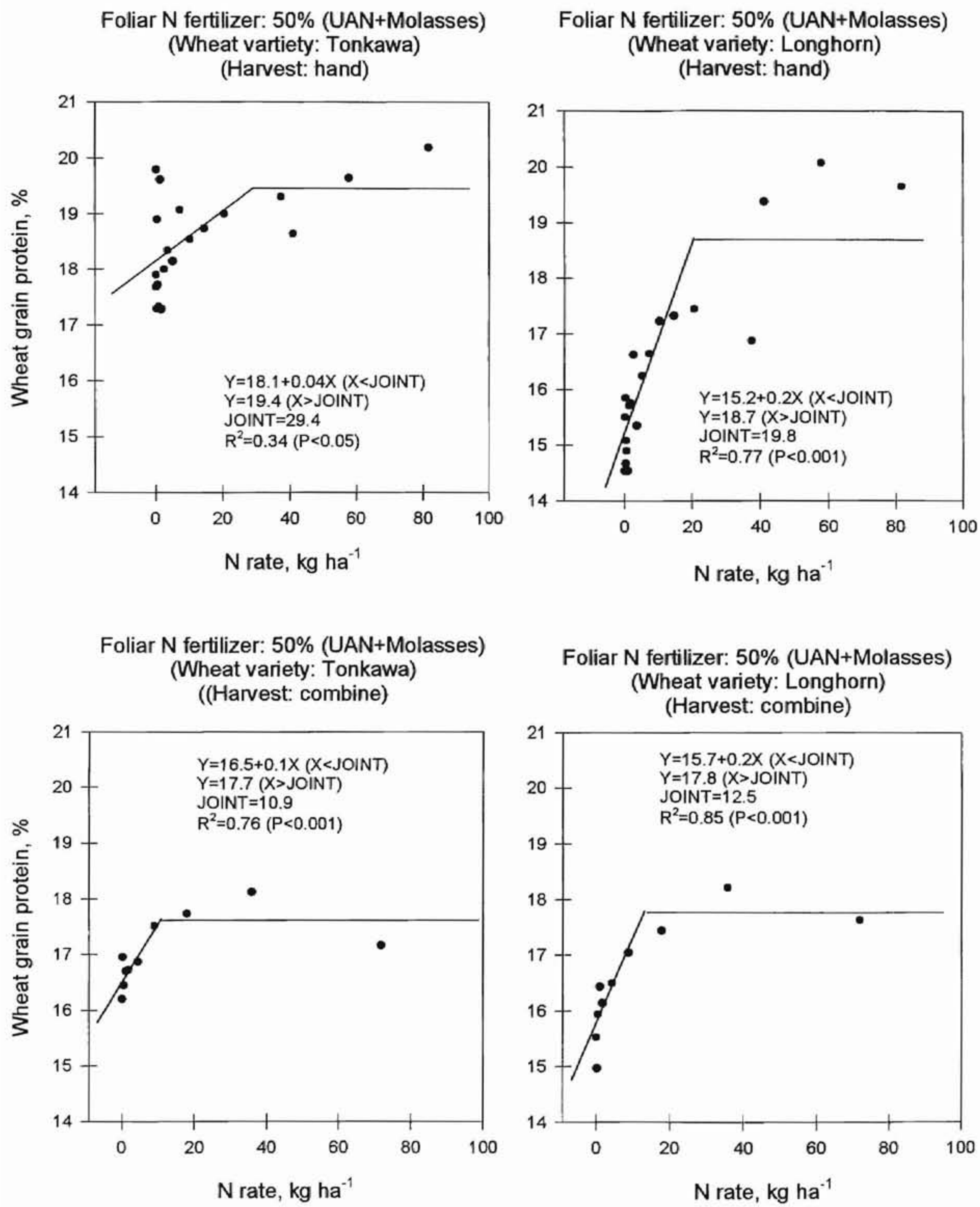


Figure 6. Winter wheat grain protein response to foliar N application, 1995 (50% (UAN+Molasses))

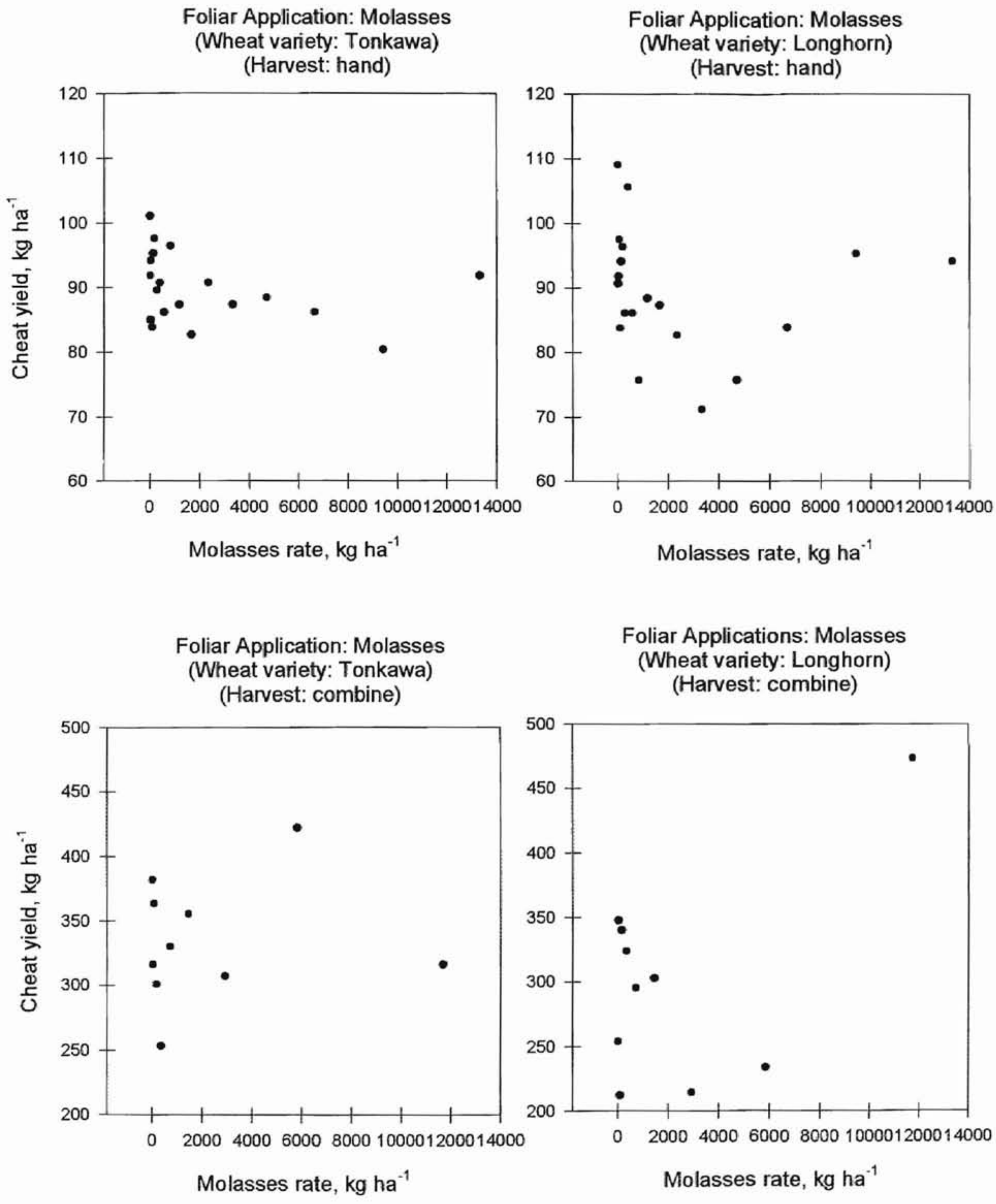


Figure 8. Cheat yield response to foliar N application, 1995 (Molasses)

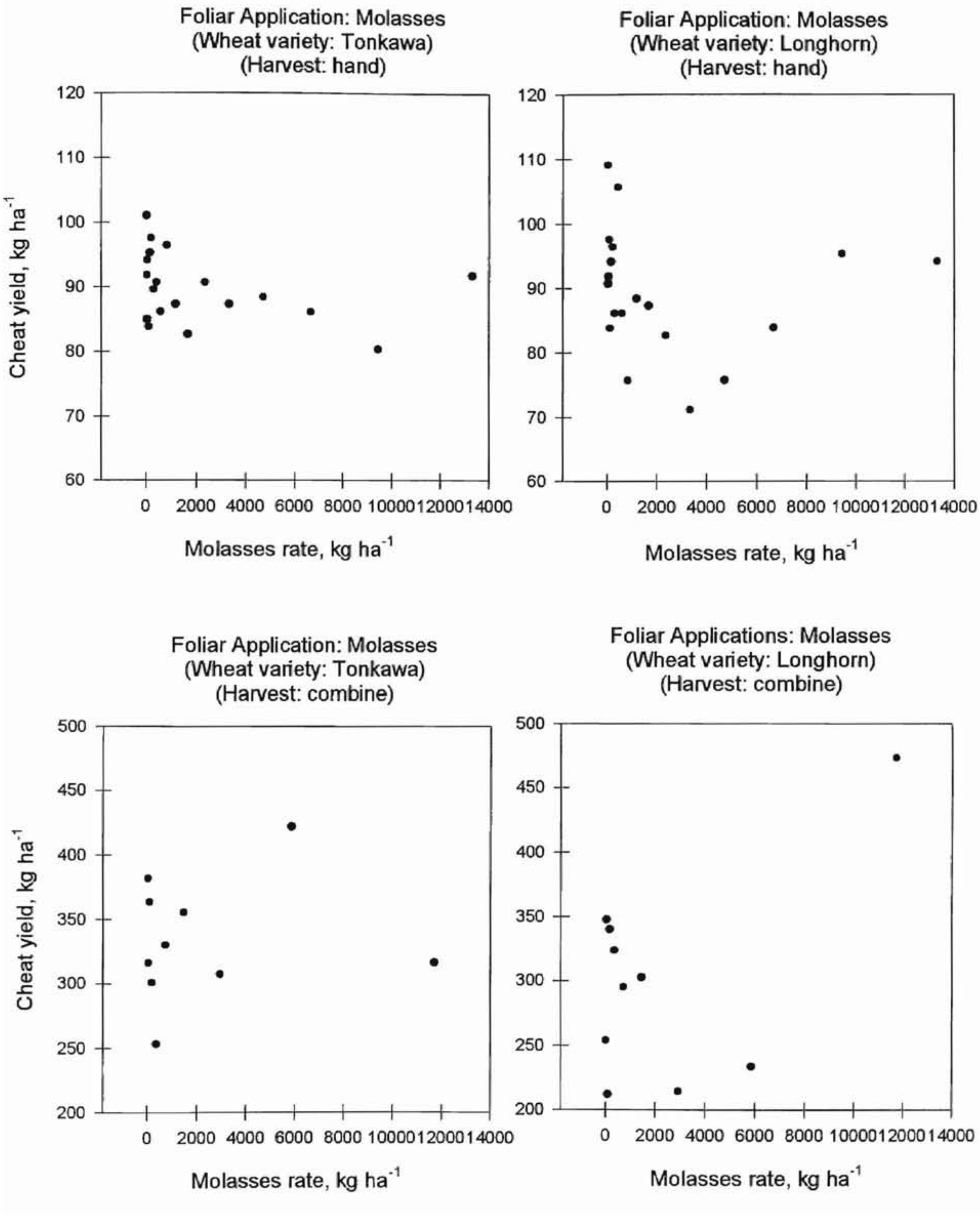


Figure 8. Cheat yield response to foliar N application, 1995 (Molasses)

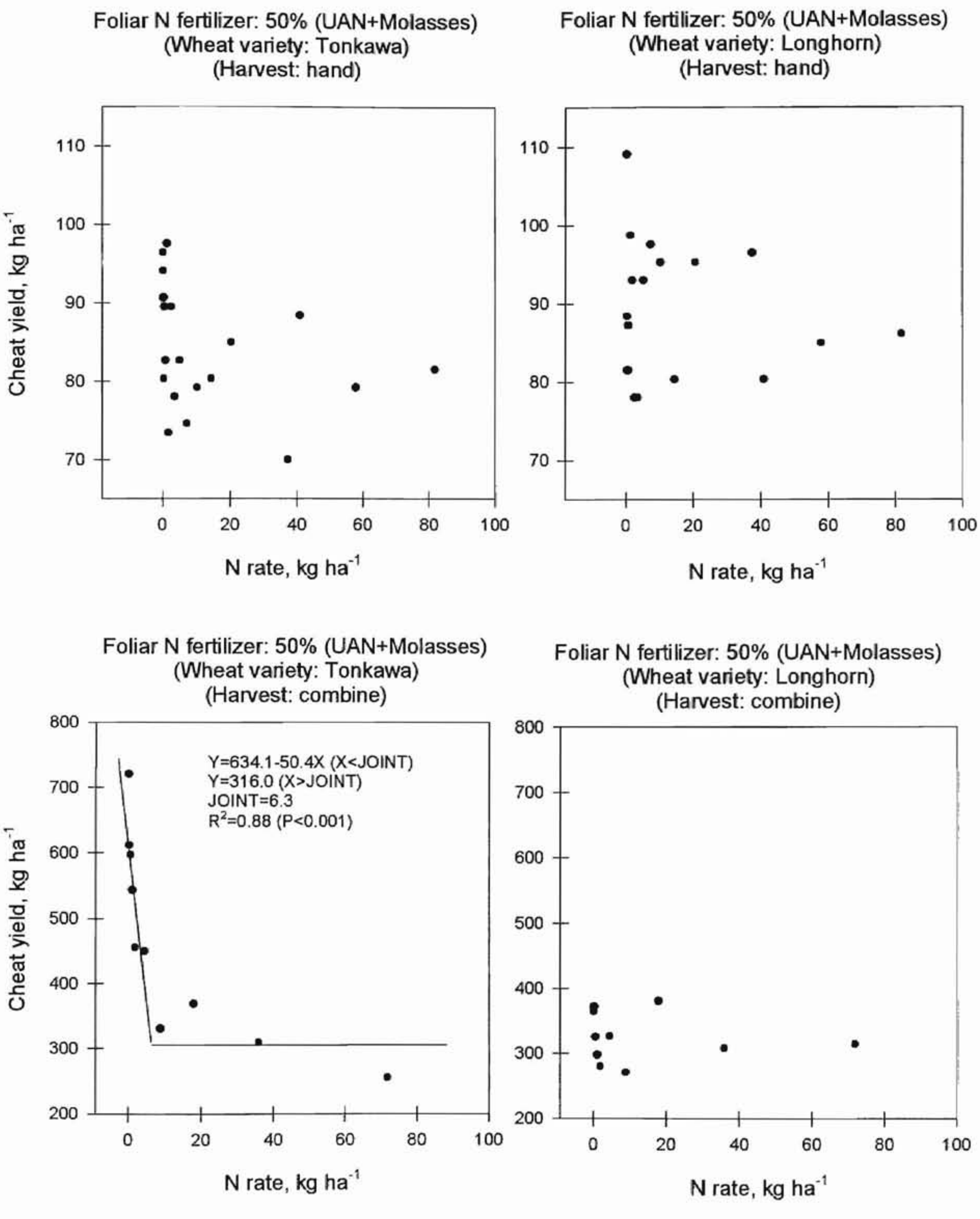


Figure 9. Cheat yield response to foliar N application (50% (UAN+Molasses), 1995)

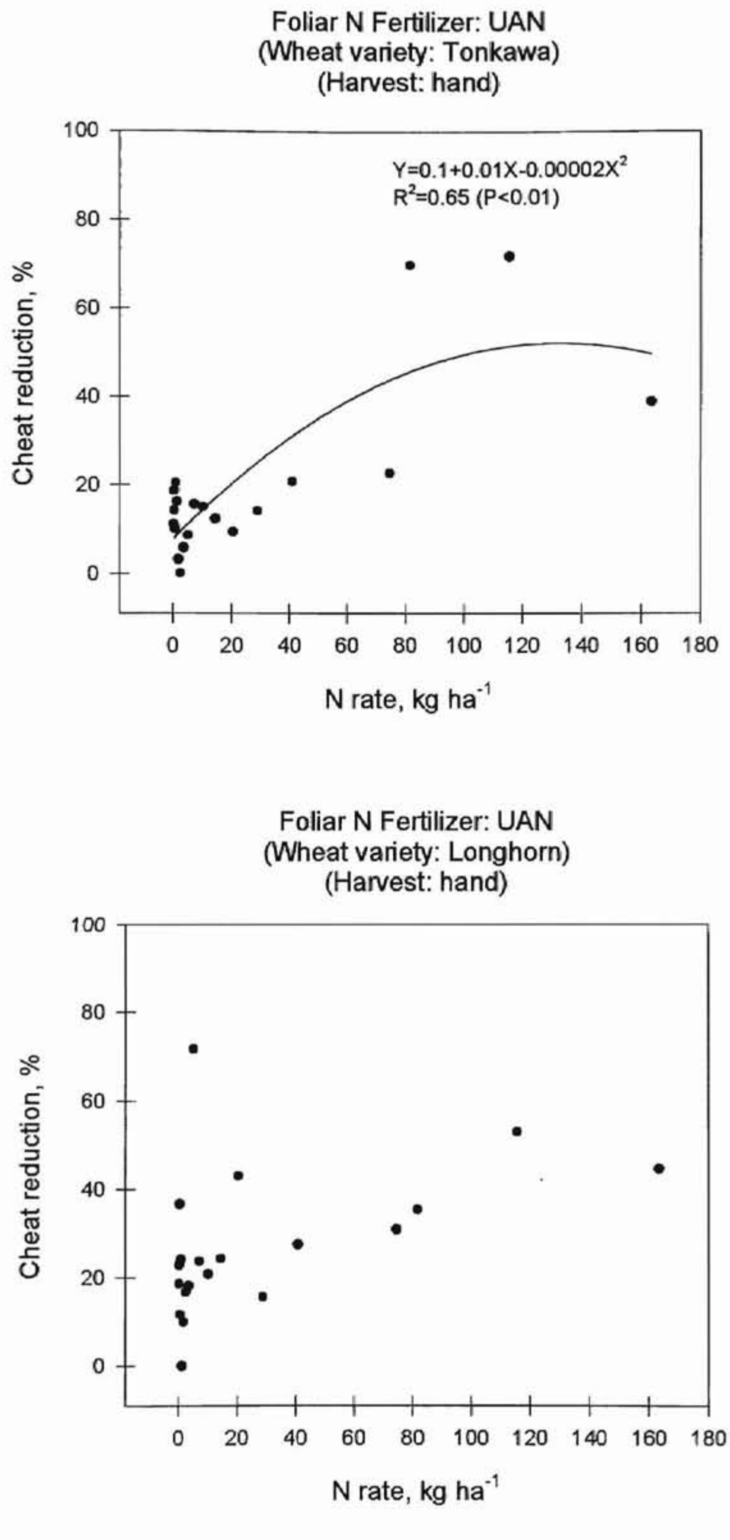


Figure 10. Cheat reduction response to foliar N application,1995 (UAN)

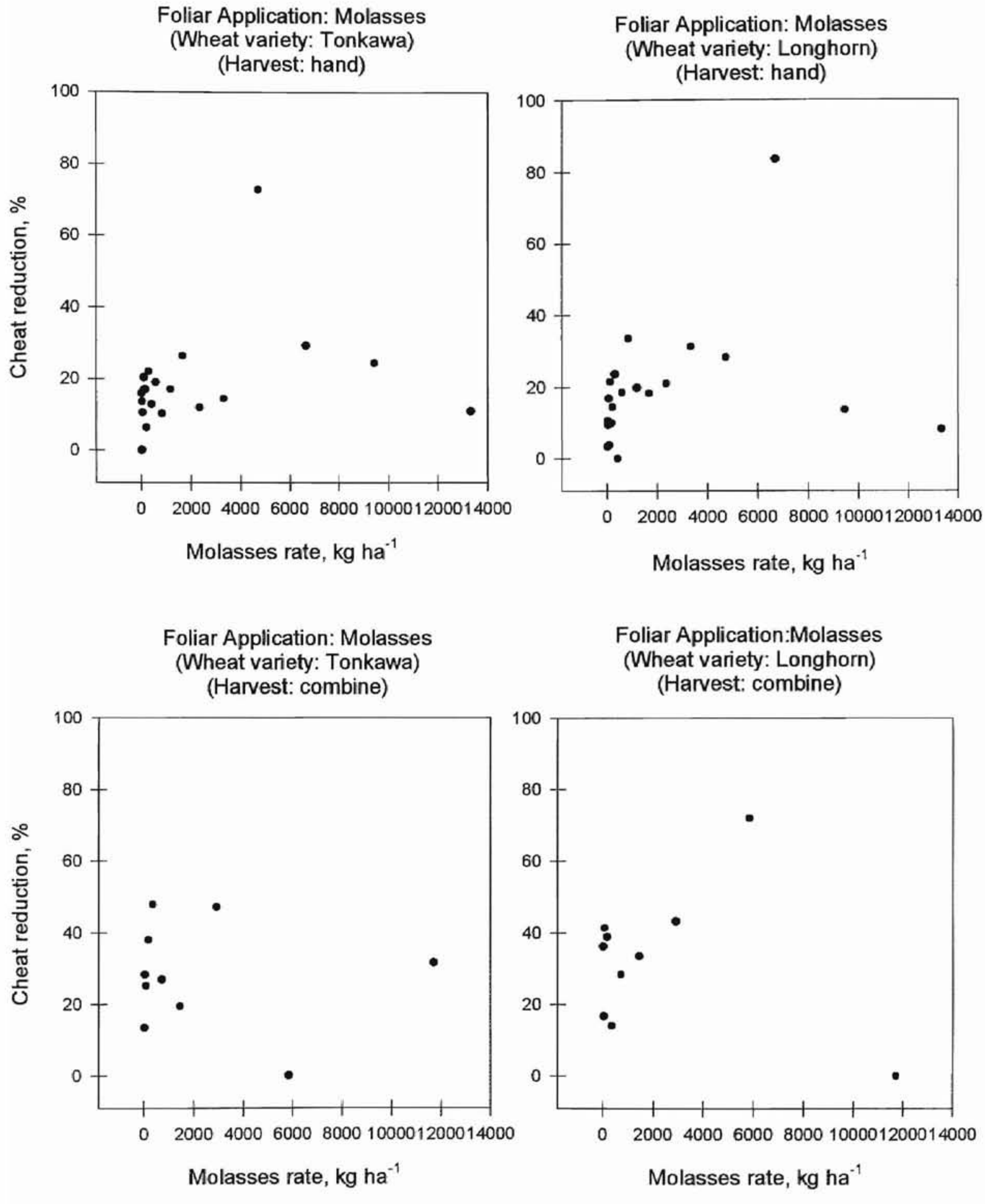


Figure 11. Cheat reduction response to foliar N application, 1995 (Molasses)

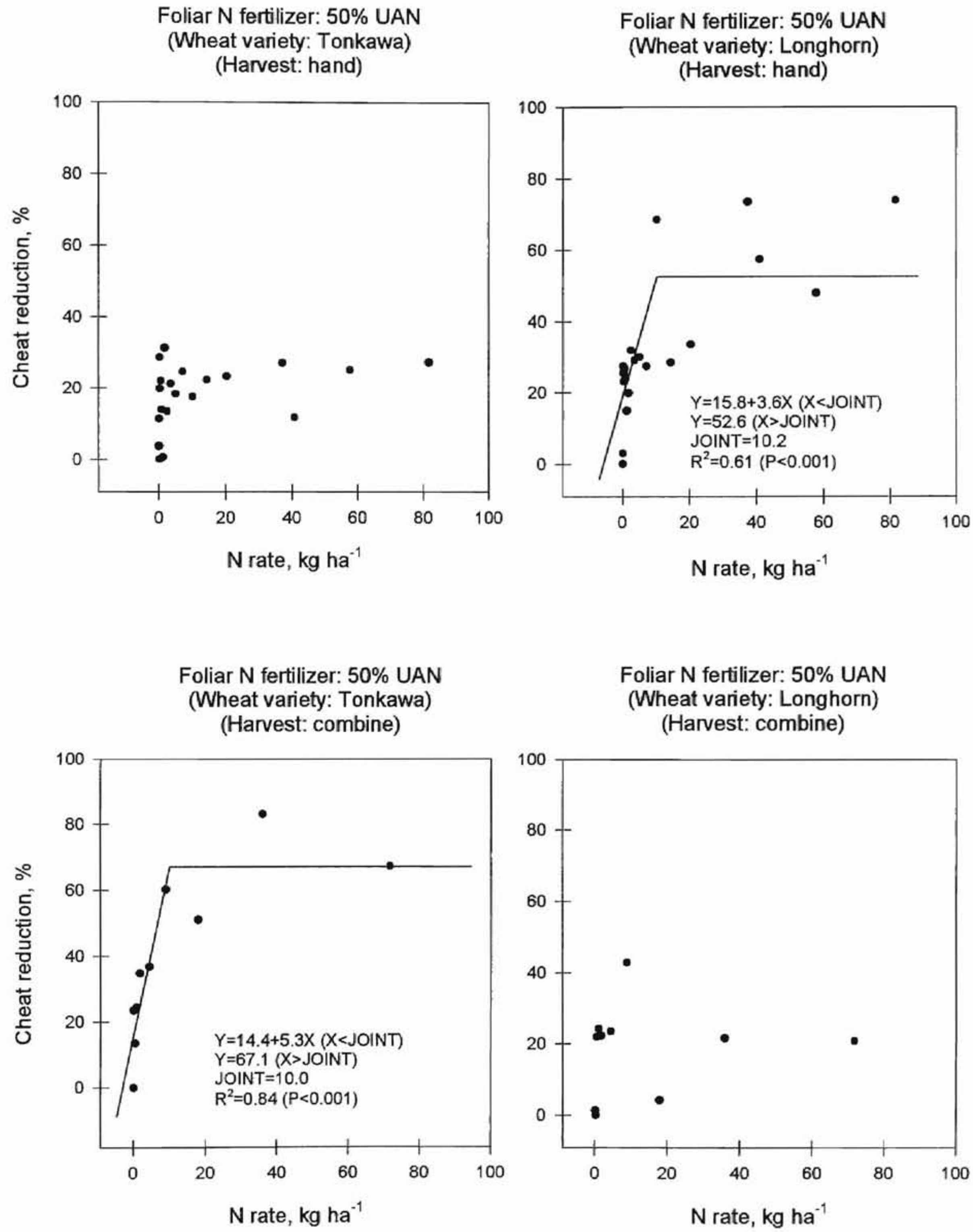


Figure 12. Cheat reduction response to foliar N application, 1995 (50% (UAN+Molasses))

VITA

Jing Chen

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Master of Science

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