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YIELD AND PROTEIN RESPONSES TO NITROGEN FERTILIZER OF TWO WINTER WHEAT VARIETIES DIFFERING IN INHERENT PROTEIN CONTENT OF THEIR GRAIN

Virgil A. Johnson, et al

Nebraska University
Lincoln, Nebraska

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Yield and Protein Responses to Nitrogen Fertilizer of Two Winter Wheat Varieties Differing in Inherent Protein Content of Their Grain

V. A. Johnson, A. F. Dreier, and P. H. Grabouski

Yield and Protein Responses to Nitrogen Fertilizer of Two Winter Wheat Varieties Differing in Inherent Protein Content of Their Grain[1]

V. A. Johnson, A. F. Dreier, and P. H. Grabouski[2]

ABSTRACT

Genes that increase the grain protein potential of wheat (*Triticum aestivum* L.) are known. The interaction of such genes with factors of the production environment, particularly soil nitrogen availability, determines their probable value and contribution to higher protein content in wheat.

Two hard winter wheat varieties differing inherently in the protein content of their grain were grown in replicated plots at selected sites in Nebraska over a 3-year period. Nitrogen fertilizer was applied at five rates in the 1st year and at seven rates in the 2nd and 3rd years. Data were recorded for yield, test weight, and protein content of the grain.

Significant protein responses to nitrogen fertilizer occurred in all trials. Responses of both varieties were linear and positive. C.I.14016 maintained a protein advantage of 2 percentage points over 'Lancer' at all levels of fertilizer. The protein advantage of C.I.14016 over Lancer was independent of the relative yields of the two varieties. The feasibility of effectively increasing the grain protein content of wheat by breeding is indicated by the data.

Statistically significant yield responses to fertilizer were recorded in 6 of 10 trials. Yield responses of both varieties were nonlinear with the second-degree polynomial providing a good fit of the data. Less nitrogen fertilizer was required for maximum yield of Lancer, the lower protein variety, than for C.I.14016. Test weight responses of the varieties to fertilizer were negative and linear. The test weight of Lancer was higher than C.I.14016 at all fertilizer rates.

Additional index words: Test weight, Linear, Nonlinear, Regression coefficient, Genetic potential.

WHEAT (*Triticum aestivum* L.) is a major food crop. Much of the nutritional value of wheat is determined by its protein content. The soft wheat variety 'Atlas 66' has been effectively utilized by the Nebraska Agricultural Experiment Station as a genetic source of high grain protein to develop hard winter wheat varieties that possess high grain protein potential (7, 8). From this program 26 experimental high protein lines were released as elite germplasm by the Agricultural Research Service, USDA, and the Nebraska Agricultural Experiment Station in 1971 (6).

Published data provide evidence that high grain protein of the Atlas 66-derived lines results from more efficient and complete translocation of nitrogen from the plant to its grain (4). Differential nitrogen uptake by roots was not demonstrated to be a factor. The nitrate reductase system has been implicated in grain protein differences (1). The nitrate reductase research supports the Nebraska evidence for differential nitrogen translocation as the physiologic basis for high grain protein in wheat (1). Since differential nitrogen uptake does not appear to be involved, grain protein differences resulting from incorporation of genes from Atlas 66 into hard winter wheat varieties should have phenotypic expression in an array of environments and soil fertility levels. Evidence of the stability of expression in many environments was obtained from an International Winter Wheat Performance Nursery in which Atlas 66 and a derived hard winter line were evaluated (9).

The effect of nitrogen fertilizer in different production environments on the high protein trait from Atlas 66 was a major objective of this study. The relationship of grain yield to protein content under differing soil fertility levels also was investigated.

MATERIALS AND METHODS

Materials

Atlas 66 × 'Comanche,' C.I. 14016, and the commercially grown Nebraska variety 'Lancer,' C.I. 13547, were selected for study. C.I. 14016 was released as elite high-protein germplasm in 1971 (6). The two varieties are similar in date of heading and most agronomic traits, with Lancer the more productive on the average and resistant to stem rust, but susceptible to leaf rust. C.I. 14016 has exhibited good resistance to leaf rust but moderate susceptibility to stem rust in the field. Lancer produces grain with average protein content. The protein content of C.I. 14016 has been consistently higher than ordinary wheat varieties by 2 to 3 percentage points in Nebraska Experiment Station trials.

Experimental Procedure

The two varieties were grown in randomized plots comprised of four rows, 3 m long, spaced 25 cm apart and replicated five times at each test site. Nitrogen fertilizer in the form of ammonium nitrate was surface-applied in early spring at increments of 22.5 kg/ha from 0 to 90 kg/ha in 1968 and 0 to 135 kg/ha in 1969 and 1970. Blanket phosphorus applications were made at each site according to soil test indications. Rate of seeding was either 30 or 40 g per plot depending on the location of the test site in Nebraska. Lower seeding rates normally are used in western Nebraska than in central and eastern Nebraska where average annual precipitation is higher. The soil at each test site was analyzed for nitrate nitrogen content to a depth of 180 cm at seeding time in the fall. The two center rows of each plot were harvested for grain yield and protein determinations. Test weights were measured from replication composites of each variety and fertilizer treatment. All data were analyzed statistically. The Kjeldahl procedure was utilized for protein determinations. Protein is reported on a 14% moisture basis.

Test Sites

Test sites totaled four in 1968, three in 1969, and three in 1970. The cropping practices, soil nitrogen availability, and test conditions for each site are summarized in Table 1. Nitrate nitrogen in the soil profile (180 cm) ranged from extremely low (18 kg/ha) in Phelps County in 1970 to very high (902 kg/ha) in Logan County in 1968. Intense drought during the spring growing season occurred in Furnas County in 1969. Much above-normal precipitation occurred at the Jefferson County test site in 1970. A late spring freeze at the Dawes County site in 1968 caused heavy leaf damage and produced moderately heavy flower sterility. Straw growth was not excessive in any of these trials and differential lodging was not a factor.

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[2] Research Agronomist, PSRD, ARS, USDA; Professor and Assistant Professor of Agronomy, respectively, University of Nebraska.

EXPERIMENTAL RESULTS

Grain Yield

Preliminary examination of data from four test sites in 1968 indicated the need for nitrogen fertilizer rates above 90 kg/ha for full assessment of varietal responses to soil fertility level. Rates of 112.5 and 135 kg/ha were included in the 1969 and 1970 experiments. There were significant yield responses to fertilizer at three of four sites in 1968 (Table 2). At test site number 4 (Logan County) the soil nitrogen level at seeding time was very high. The experiment was subjected to severe drought after the wheat headed, and there was no measurable yield response to fertilizer treatments. In 1969 only one of three test sites produced significant yield responses to fertilizer, but in 1970 two of three sites showed significant responses in grain yield. In the latter year the failure of yield response occurred in Jefferson County, where both soil fertility and precipitation were high.

Mean responses of Lancer and C.I.14016 to nitrogen fertilizer treatments in grain yield, bushel weight, and grain protein content are summarized in Table 3. Mean values for 0 to 90 kg/ha of nitrogen over 10 experiments from 1968 through 1970 are shown separately from those for the 0- to 135-kg rates applied to six tests in 1969 and 1970.

Table 1. Cropping practice, available soil nitrogen, test conditions, and wheat performance at experimental sites in Nebraska, 1968-1970.

Site no.	Year	County	Cropping practice	Soil profile nitrate N	Test conditions	Nonfertilized: Mean yield	Nonfertilized: Mean test weight	Nonfertilized: Mean protein content
				kg/ha		kg/ha	kg/hl	
1	1968	Box Butte	F*	35 h	Normal	2,013	[illegible]	9.5
2	1968	Cheyenne	F	35 l	Normal	1,962	[illegible]	11.5
3	1968	Thayer	C	92 m	Normal	3,152	80.1	11.0
4	1968	Logan	C	902 vh	Dry after heading	1,536	79.2	12.1
5	1969	Dawes	F	72 m	Late spring frost	2,003	[illegible]	13.8
6	1969	Furnas	F	110 m	Spring drought	2,023	75.2	13.0
7	1969	Fillmore	C	[illegible] l	Normal	2,591	76.2	12.5
8	1970	Deuel	F	80 m	Normal	2,345	80.9	10.8
9	1970	Phelps	F	68 vl	Normal	3,014	81.3	10.5
10	1970	Jefferson	C	265 h	Above-normal	1,168	73.6	14.3

* Mean of two varieties. F Fallow; C Continuous. vl very low; l low; m medium; vh very high; h high.

Table 2. Varietal yield and protein responses to ntrogen fertilizer at 10 experimental sites in Nebraska.

Site number	Availability of: Soil nitrogen	Availability of: Precipitation	Grain yield response: 10 tests (1968-70)	Grain yield response: 6 tests (1969-70)	Grain protein response: 10 tests (1968-70)	Grain protein response: 6 tests (1969-70)
1	Low	Normal		--	-	--
2	Low	Normal		--		--
3	Medium	Normal	*	--	**	--
4	V. high	Low	ns	-		*
5†	Medium	Normal	ns	ns	*	
6	Medium	Low	ns	ns	**	
7	Low	Normal		*	*	
8	Medium	Normal	*			
9	V. low	Normal	*			
10	High	High	ns	ns	*	*

* Significant at .05 level of probability. ** Significant at .01 level of probability.
† Late spring frost.

Lancer was generally more productive than C.I. 14016. The nonfertilized variety performance for six experiments was similar for the two varieties because C.I.14016 was much superior at one site where conditions were favorable and no yield response to nitrogen was obtained (Location 10). Maximum mean yield response of Lancer occurred at the 45 kg/ha rate of nitrogen; additional increments of nitrogen caused yield decreases.

C.I.14016 responded in yield to higher rates of nitrogen application than did Lancer. At least 67.5 kg/ha of nitrogen was required for optimum response of C.I.14016 and the higher rates did not decrease yields.

Yield responses of both varieties were nonlinear (Fig. 1). The second-degree polynomial provided a good fit of the data obtained. R^2 values for the regression of nitrogen on grain yield were .88 and .96 for Lancer and C.I.14016, respectively. R^2 values for corresponding linear regression were .33 and .80, respectively.

Relationships shown graphically in Fig. 1 to 4 are based on six sites at which rates of nitrogen application ranged from 0 to 135 kg/ha. Data from 10 experiments from 1968 to 1970 involving rates from only 0 to 90 kg/ha of nitrogen indicated a similar pattern of varietal response within the range of rates applied to that based on the 1969-1970 data. In the case of yield, however, the use of the lower range of application rates would have led to somewhat different inferences about varietal yield responses than those based on the entire range.

Test Weight

Lancer had higher test weight than C.I.14016 at all rates of N-fertilizer application. The effect of fertilizer on test weights of both varieties was pronounced.

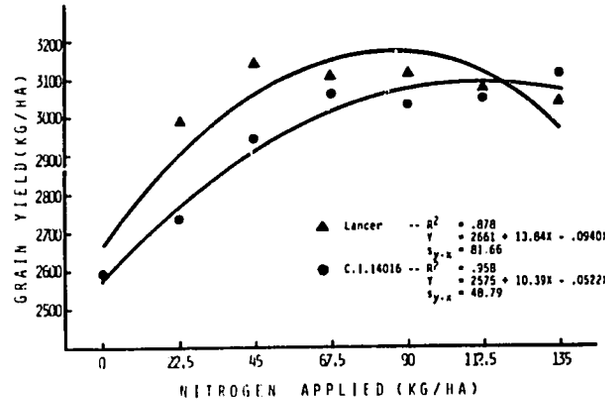

Fig. 1. Mean yield response of two winter wheat varieties to nitrogen fertilizer in six experiments in Nebraska, 1969-1970.

Table 3. Average yield, bushel weight, and protein content of Lancer and C.I. 14016 at seven rates of nitrogen application.

Nitrogen rate, kg/ha	Grain yield, kg/ha: Lancer 10 tests	Lancer 6 tests	C.I.14016 10 tests	C.I.14016 6 tests	Test weight, kg/hl: Lancer 10 tests	Lancer 6 tests	C.I.14016 10 tests	C.I.14016 6 tests	Protein content, %: Lancer 10 tests	Lancer 6 tests	C.I.14016 10 tests	C.I.14016 6 tests	Protein hectare, kg: Lancer 10 tests	Lancer 6 tests	C.I.14016 10 tests	C.I.14016 6 tests
0	2,731	2,589	2,529	2,578	[illegible]	79.1	78.4	[illegible]	9.[illegible]	10.5	11.5	12.5	267	275	295	325
22.5	3,031	2,968	2,747	2,747	79.1	79.3	77.9	78.1	10.3	11.2	12.2	13.3	310	327	334	361
45	3,127	3,141	2,845	2,905	79.6	79.0	77.1	77.[illegible]	11.3	11.8	13.2	14.0	349	360	372	402
67.5	3,057	3,107	2,966	3,090	[illegible]	79.1	76.8	76.9	12.1	12.6	14.1	14.9	370	380	410	441
90	3,100	3,111	2,979	3,033	[illegible]	78.3	75.[illegible]	75.[illegible]	13.5	14.[illegible]	14.8	15.[illegible]	391	401	433	456
112.5	-	3,074	--	3,049	--	77.[illegible]	-	75.[illegible]	-	13.6	-	15.[illegible]	--	407	--	470
135	--	3,020		3,107		77.[illegible]	--	75.0	--	14.0	-	16.1	-	417	-	498
LSD .05	118	111	105	114	1.1	2.1	1.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12	16	12	16

Mean weights for each rate of application (Table 3) reveal that both varieties were adversely affected. Lancer was less affected than C.I.14016. Its test weight was reduced from 79.1 kg/hl with no nitrogen application to 77.7 kg/hl at the 135-kg rate. The test weight of C.I.14016 was reduced from 78.4 kg/hl (0 nitrogen) to 75.9 kg/hl at the 135-kg rate, a reduction of 2.5 kg/hl compared to only 1.4 kg/hl for Lancer.

The response in test weight of Lancer to N-fertilizer application probably was linear within the range of applications utilized in this study (Fig. 2). However, observed values for the varieties, particularly C.I. 14016, at the high rates (90 kg and above) suggest a reduction or disappearance of the negative response evident at lower rates. Also, Lancer differed from C.I.14016 in that there was no significant reduction of its test weight in the 0 to 67.5-kg rates of application in contrast to a pronounced one for C.I.14016. For Lancer, expansion of the quadratic equation provided the highest correlation ($R^2 = .92$), whereas for the linear regression the R^2 value is only .74. The difference between the two was not statistically significant, however. Observed bushel weight values for C.I.14016 provided equally good fits to linear ($R^2 = .92$) and quadratic regressions ($R^2 = .95$).

Grain Protein

There were significant grain protein responses to nitrogen fertilizer treatments at every test site over the 3-year period of experimentation (Table 2). The protein responses of Lancer and C.I.14016 are summarized in Table 3. The protein content of C.I.14016 was significantly higher than that of Lancer at every level of fertility. However, both varieties responded similarly. Increases of nitrogen application in 22.5-kg increments produced highly consistent and predictable increases in the protein content of the grain of both varieties. The protein content of Lancer increased from 10.8 to 14.0% when fertilizer was applied up to 135 kg/ha. This was an average 0.46 percentage point of protein increase for each 22.5-kg increment of nitrogen application. The response of C.I.14016 was greater. Its protein content increased from 12.5 to 16.3% or an average increase of 0.54 percentage points for each 22.5-kg nitrogen increment. The difference in the regression of protein on fertilizer nitrogen was highly significant statistically for the two varieties (Fig. 3).

The grain protein responses of Lancer and C.I.14016 to nitrogen fertilizer were clearly linear within the range of applications utilized in this study. The highest application rate, 135 kg/ha, was insufficient to indicate any changes in the protein responses of these two varieties. R^2 values based on linear regression were .99 for Lancer and .98 for C.I. 14016.

Interactions

Significance levels of analysis of variance mean square values appear in Table 4. Highly significant differences for yield, protein, and test weight were associated with test sites, varieties, and fertilizer treatments. Similarly, there were highly significant interactions of test sites with varieties and fertilizer treatments for grain yield and protein content. Variety × fertilizer interaction was significant for yield only. Lancer was significantly higher in yield at seven locations; and C.I.14016, at 2; and there were no variety yield differences at one location.

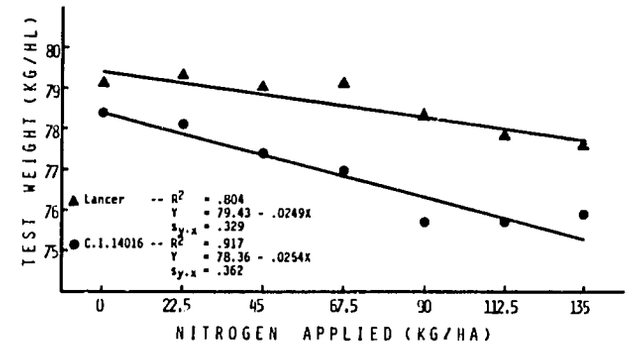

Fig. 2. Mean effect of nitrogen fertilizer on the test weight of two winter wheat varieties grown in six experiments in Nebraska, 1969-1970.

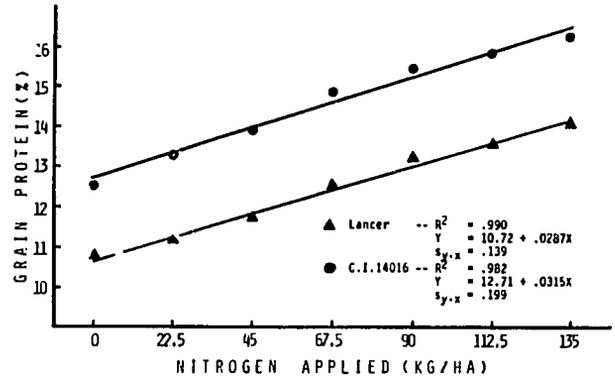

Fig. 3. Mean protein response of two winter wheat varieties to nitrogen fertilizer in six experiments in Nebraska 1969-1970.

Table 4. Combined analysis of variance mean square significances for 10 experiments, 1969-1970 and 6 experiments, 1969-1970.

Source	Degrees of freedom		Grain yield		Test weight		Protein content		Protein hectare	
	10 tests	6 tests	10 tests	6 tests	10 tests	6 tests	10 tests	6 tests	10 tests	6 tests
Total	490	419	--	--	--	--	--	--	--	--
Locations (L)	9	5	*	*		*	**	*	**	**
Reps (L)	40	24	*	*	--	--	*	--	*	**
Varieties (V)	1	1			*			*	--	**
LV	9	5		**	--	--		**	*	--
Fertilizer (F)	4	3		--			*	--	*	**
LF	36	30		*	--	--		*	--	--
VF	4	3		*	ns	ns	ns	ns	ns	--
LVF	36	30	ns	ns	--	--	ns	ns	ns	*
Error	360	312	--	--	--	--	--	--	--	--

* Significant at .05 level. ** Significant at .01 level.

Protein vs Grain Yield

Since C.I.14016 was less productive than Lancer on the average, except at very high levels of nitrogen application, its protein advantage over Lancer could merely reflect a productivity difference. If so, the protein advantage would be an artifact from a genetic point of view. To test this, protein differences from each fertility level at each test site were categorized according to the relative grain yields of Lancer and C.I.14016.

The grouping included (i) C.I.14016 less productive than Lancer, (ii) C.I.14016 more productive than Lancer, and (iii) the two varieties no different in produc-

tivity. An arbitrary criterion for difference in productivity was set at 70 kg/hl (1 bu/acre). The results are summarized in Table 5. It is evident that no relationship between grain yield and grain protein content existed under the conditions of this study. The protein advantages of C.I.14016 over Lancer was independent of the relative yields of the two varieties.

Increasing rates of nitrogen progressively increased protein yields of both varieties (Fig. 4). Higher nitrogen rates raised grain protein. High nitrogen applications caused yield depression of Lancer but not C.I.14016. Therefore, protein yields of Lancer showed a tendency to level off after 90 kg/ha of nitrogen fertilizer, while those of C.I.14016 continued to rise. The data indicate a potential for even higher protein production by C.I.14016 with added nitrogen in excess of 135 kg/ha.

DISCUSSION

Protein responses of Lancer and C.I.14016 to nitrogen fertilizer were highly similar in each year of this 3-year study. This was so even though the test sites were different each year and the tests were subjected to an array of environmental conditions that ranged from severe drought to excessive moisture. Also, soil profile nitrogen levels ranged from only 18 kg/ha to as much as 902 kg/ha. There was highly consistent response to nitrogen fertilizer and a consistent varietal relationship for grain protein content that persisted throughout the entire range of nitrogen applications and in all production environments sampled. Relationships evident from 10 test sites over a 3-year period in which nitrogen application rates ranged to 90 kg/ha were the same as those based on six tests in 2 years in which additional nitrogen treatments included 112.5 and 135 kg/ha rates.

Nonfertilized wheat in western Nebraska, northwestern Kansas, and eastern Colorado often is low in protein content. The low protein problem of this area has been fully recognized only in the last decade. The protein content of hard red winter wheat should be 13% or higher for maximum value for bread-making purposes. Little of the wheat produced in the low-protein problem area since 1960 has had much protein.

Profitable use of nitrogen fertilizer on wheat requires a favorable yield response to the nitrogen or a price premium for protein. In the existing wheat marketing systems of the United States the farmer who markets higher protein wheat than his neighbor seldom receives a premium for the additional protein. Under dryland production conditions, significant increases in yield from nitrogen applications above 67.5 kg/ha seldom occur in the High Plains. The average protein content of Lancer wheat at the 67.5 kg/ha level of nitrogen fertilization in this study was only 12.1%. An average protein level for Lancer of 14.0% was achieved by application of 135 kg nitrogen/ha, but this was associated with a decrease in yield from 3,141 kg/ha at the 45-kg nitrogen level to only 3,020 kg/ha at the high rate of nitrogen.

In contrast to the response of Lancer, the yield of C.I.14016 at the 67.5-kg nitrogen level was 3,060 kg/ha and its average grain protein content was 14.9%. Interestingly, C.I.14016 continued to show favorable yield and protein responses with higher rates of nitrogen up to 135 kg/ha.

Table 5. Effect of relative grain yield on protein content of Lancer and C.I.14016.

N-fertilizer treatment	Mean protein advantage of C.I.14016 over Lancer when C.I.14016 yielded:		
	Less than Lancer	Equal to Lancer	More than Lancer
kg/ha	Percentage points difference		
0	1.6 (1)	- -	1.5 (3)
22.5	1.9 (8)	- -	2.1 (2)
45	1.9 (6)	- -	1.9 (2)
67.5	2.1 (1)	- -	1.7 (3)
90	1.9 (5)	1.7 (1)	2.3 (2)
112.5	2.4 (2)	2.4 (2)	1.9 (2)
135	2.0 (2)	2.1 (1)	2.3 (3)
$\bar{x}$	1.9 (39)	2.0 (6)	1.9 (17)

Number of individual values comprising the mean protein value.

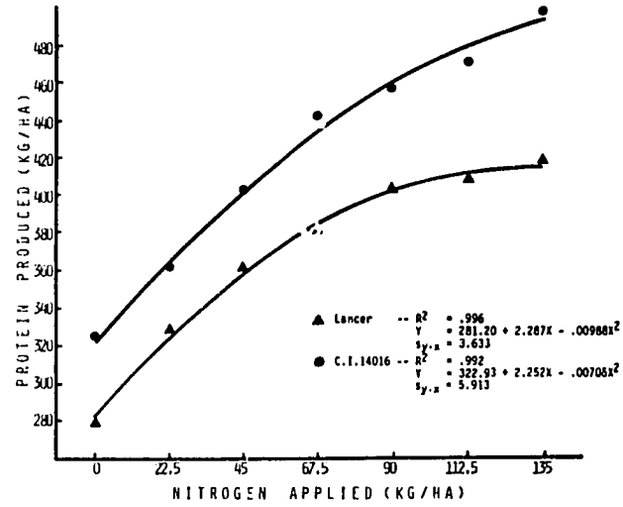

Fig. 4. Mean protein production of two winter wheat varieties under different levels of nitrogen fertilizers in six experiments in Nebraska, 1969-1970.

These data point to the need for development of winter wheat varieties with genetic potential for high grain protein. With such varieties the wheat producer could be assured of profitable maintenance of acceptable levels of protein in the wheat he produces.

C.I.14016 was not a productive on the average as Lancer under the conditions of this study. Thus, the high protein of C.I.14016 was partially offset by its lower productivity. Despite this, Fig. 4 provides good evidence that C.I.14016 was a more efficient producer of protein per unit area than was Lancer. It is significant that a relationship between grain yield and grain protein content could not be detected. We conclude that under the conditions of this study, the high protein content of C.I.14016 compared to Lancer was not associated with its lower grain yield. C.I.14016 was not higher in protein content than Lancer because it was less productive.

The development of varieties superior in grain protein and grain yield has been suggested by several other investigators (2, 3). Performance data from Nebraska high protein selections from the second cycle of breeding provide evidence of the feasibility of simultaneous improvement of both yield and protein by breeding (5).

LITERATURE CITED

1. Croy, L. I., and R. H. Hageman. 1970. Relationship of nitrate reductase activity to grain protein production in wheat. Crop Sci. 10:280-285.

2. Duffield, R. D., L. I. Croy, and E. L. Smith. 1972. Inheritance of nitrate reductase activity, grain protein and straw protein in a hard red winter wheat cross Agron. J. 64:249-251.
3. Hucklesby, D. P., C. M. Brown, J. E. Howell, and R. H. Hageman. 1971. Late spring applications of nitrogen for efficient utilization and enhanced production of grain and grain protein of wheat. Agron. J. 63:274-276.
4. Johnson, V. A., P. J. Mattern, and J. W. Schmidt. 1967. Nitrogen relations during spring growth in varieties of *Triticum aestivum* L. differing in grain protein content. Crop Sci. 7: 664-667.
5. ———, ———, and ———. 1972. Genetic studies of wheat protein. Seed Proteins — Synthesis, Properties and Processing. Avi Publishing Co., Inc., Westport, Conn. (In Press)
6. ———, J. W. Schmidt, and P. J. Mattern. 1971. Registration of high protein wheat germplasm. Crop Sci. 11:141-142.
7. ———, P. J. Mattern, D. A. Whited, and J. W. Schmidt. 1969. Breeding for high protein content and quality in wheat. Proc. IAEA/FAO Panel on New Approaches to Breeding for Plant Improvement, Rostanga, Sweden. p. 29-40.
8. ———, J. W. Schmidt, P. J. Mattern, and A. Haunold. 1963. Agronomic and quality characteristics of high protein F_2-derived families from a soft red winter-hard red winter wheat cross. Crop Sci. 3:7-10.
9. Stroike, J. E., V. A. Johnson, J. W. Schmidt, and P. J. Mattern. 1971. Results of the First International Winter Wheat Performance Nursery. Nebr. Res. Bull. 245. 84 p.