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AGRONOMIC AND QUALITY CHARACTERISTICS OF SPRING WHEAT LINES SELECTED FOR PROTEIN CONTENT AND PROTEIN YIELD[1]

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SUMMARY

High protein cultivars of spring wheat (*Triticum aestivum* L.) from eight foreign countries and the United States were used in crosses to provide progeny for a recurrent selection program. After two cycles of selection, 40 lines selected for protein yield and 16 lines selected for protein percentage were evaluated with parents in yield nurseries at Bozeman, Montana.

Lines selected for protein percentage had the highest protein percentages, protein yields similar to the parents, and grain yields lower than the parents. Lines selected for protein yield had protein percentages intermediate between those of the parents and lines selected for protein percentage, but they had the highest protein yields and grain yields. Protein percentage and grain yield were negatively correlated and protein yield and grain yield were positively correlated for both groups of lines. The data tend to suggest that protein yield may a better selection criterion than protein percentage for plant breeders to use in improving protein productivity, although additional testing of this hypothesis is proposed.

Milling and baking data showed transgressive improvement over the mean of the parents in many important quality aspects, indicating that good quality lines can be obtained from crosses involving poor to mediocre quality cultivars.

INTRODUCTION

Grain protein percentage of spring wheat produced in the northern Great Plains has been important to both producer and consumer. The consumer recognizes grain protein as an important item in the baking quality of bread and in the diets of man and animals, and the producer recognizes it as a potential bonus in the market place.

Maintaining and increasing grain protein percentages has been a long-time objective of hard red spring wheat breeders, and this has become more urgent in recent years as grain yield levels continue to increase. JOHNSON et al. (1963) and MIDDLETON et al. (1954) have observed winter wheat progeny with both high grain protein percentage and high grain yield, but finding this combination in recently developed, high yielding spring wheats has not been easy. SCHLEHUBER & TUCKER (1959) have suggested that the major factors responsible for grain protein percentage, in order of importance, are environment, soil, and cultivar.

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Cultivars selected from the World Wheat Collection by McNEAL et al. (1978) were incorporated into a recurrent selection program in an attempt to concentrate genes for protein percentage. This paper reports agronomic and quality data from the high protein lines after two cycles of intercrossing and testing.

MATERIALS AND METHODS

As reported by McNEAL et al. (1978), nine crosses were made in 1967 using U.S. cultivars and high protein genotypes from eight foreign countries. Two F_3 lines with the highest protein percentages from each of the nine crosses were then intercrossed in 1970 in all possible combinations to provide material for a second cycle of testing.

One hundred lines from each of 149 second-cycle crosses were tested in F_3 progeny rows in 1973 for grain protein percentage (%) and grain protein yield (g). F_4 lines with the highest protein percentages, together with those having the highest protein yields, were then evaluated in subsequent field trials for agronomic, protein, and quality characteristics. Forty lines from the protein yield group and 16 lines from the protein percentage group were selected by these tests and seed from them was saved for the agronomic and quality tests reported in this paper.

Eleven parents, the 16 lines from the protein percentage group, and the 40 lines from the protein yield group were planted in dryland and irrigated experiments at Bozeman, Montana in 1980. Each experiment was planted in a randomized block design using four replications of four-row plots with rows 30 cm apart and 3 m long.

The irrigated experiment was planted April 29 and the dryland experiment 3 days later on May 2. Because 20.6 cm of precipitation was received in May and June, the irrigated experiment was irrigated only once, receiving about 10.2 cm of water by sprinkler on July 12 at about flowering time.

Heading date was recorded when 50% of the heads in a plot had emerged from the leaf sheath. Plant heights were measured from ground level to the tip of the tallest heads. Grain yields were obtained by harvesting 2.4 m of each of the two center rows of each plot. Grain protein and flour protein percentages were determined by the Technicon InfraAlyzer 400 R instrument, and grain yields were multiplied by these percentages to obtain protein yield values.

We evaluated flour yield, test weight, farinograph peak, farinograph stability, mixing time, and loaf volume by using standard procedures as previously described by McNEAL et al. (1971).

All data were analyzed by the analysis of variance. Duncan's Multiple Range Test was used to test means for significant differences.

RESULTS AND DISCUSSION

The irrigated and dryland experiments grown in 1980 averaged 5213 and 4513 kg/ha, respectively, but there was no interaction between lines in the two tests so agronomic data from the two nurseries have been combined.

The combined data show that selecting for protein percentage and protein yield were each effective in improving protein percentage and protein yield of lines (Table 1). Parents averaged 14.9% protein compared to 16.2% for the protein percentage

Table 1. Agronomic data from parents, lines selected for protein percentage, and lines selected for protein yield, averaged across dryland and irrigated experiments grown in 1980.

Group	Number of entries	Days Jan. 1 to heading	Plant height (cm)	Grain protein[1]		Test weight (kg/hl)	Grain yield (g/plot)
				content (%)	yield (g/plot)		
Parents	11	191.8 a*	116.3 b	14.9 c	104 b	67.4 b	704 b
Protein (%)	16	191.0 b	120.9 a	16.2 a	107 b	68.6 a	664 c
Protein (g)	40	189.9 c	116.3 b	15.4 b	114 a	68.8 a	744 a

* Values in each column followed by the same letters are not significantly different at P = 0.05.
[1] Adjusted to 14% moisture basis.

lines and 15.4% for the protein yield lines. Parents also averaged 104 g of protein compared to 107 g and 114 g for the protein percentage and protein yield lines, respectively. The significant increases in protein over the parents by selecting for protein yield are also reflected in a significant grain yield increase of 40 g/plot over the parents. Selecting for protein percentage, on the other hand, provided lines with increased protein percentages, but with no significant increase over the parents in protein yield and a significant reduction in grain yield of 40 g/plot.

Observation of the range in protein values by groups (Table 2) suggests that lines

Table 2. Range in protein data from parents, lines selected for protein percentage and lines selected for protein yield.

Group	Range in grain protein	
	content (%)	yield (g/plot)
Parents	13.9–16.1	86–124
Protein (%)	15.2–17.5	88–113
Protein (g)	13.4–16.8	96–134

in the protein yield group, because of their skewness toward higher protein yields, with acceptable protein percentages, probably offer more opportunity for improving grain protein than do lines from the protein percentage group. This tends to suggest, as proposed by BHATIA (1975), that protein yield may be a better selection criterion than protein percentage for plant breeders to use in improving protein productivity. However, since selection intensity in the current study was not identical for protein percentage and protein yield, additional testing should probably be done before finalizing such an interpretation.

Heading dates and plant heights showed some significant differences, but these seem unimportant in relation to grain protein (Table 1). Test weights of the two selection groups were similar, but significantly better than the parents.

Table 3. Correlation coefficients from lines selected for protein percentage and lines selected for protein yield.

Items correlated	Protein percentage lines (N = 16)	Protein yield lines (N = 40)
Protein (%) vs Grain yield (g/plot)	−0.26	−0.52**
Protein (%) vs Protein yield (g/plot)	0.28	−0.01
Protein (g/plot) vs Grain yield (g/plot)	0.85**	0.85**

** Values significant at P = 0.01.

Table 4. Flour and farinograph data from parents, lines selected for protein percentage, and lines selected for protein yield, averaged across dryland and irrigated experiments grown in 1980.

Group	Number of entries	Flour		Farinograph			
		yield (%)	ash (%)	absorption (%)	peak (min.)	stability (min.)	valorimeter
Parents	11	66.8 b*	.444 ab	63.5 c	7.5 b	13.0 b	72 a
Protein (%)	16	70.0 a	.449 a	66.3 a	8.7 a	17.2 a	76 a
Protein (g)	40	69.5 a	.431 bc	65.4 b	8.5 a	15.5 b	75 a

* Values in each column followed by the same letters are not significantly different at P = 0.05.

Table 5. Baking data from parents, lines selected for protein percentage, and lines selected for protein yield, averaged across dryland and irrigated experiments grown in 1980.

Group	Number of entries	Flour[1] protein (%)	Absorption (%)	Mixing time (min)	Loaf volume (cm^3)	Grain and texture (score)
Parents	11	14.1 c*	63.7 b	1.8 b	855 b	2.2 b
Protein (%)	16	15.6 a	65.7 a	2.0 ab	940 a	3.7 a
Protein (g)	40	14.6 b	65.2 a	2.1 a	938 a	3.6 a

[1] Adjusted to 14% moisture basis.
* Values in each column followed by the same letters are not significantly different at P = 0.05.

Correlation coefficients using average values show that protein percentage is negatively correlated with grain yield, as has been previously reported by GRANT & MCCALLA (1949), MALLOCH & NEWTON (1934), and SCHLEHUBER & TUCKER (1959); that protein percentage and protein yield show little relationship; and that positive r values between protein yield and grain yield are highly significant (Table 3). The relationship between protein yield and grain yield is expected since grain yield was used in calculating protein yield. Protein content was also used in calculating protein yield and yet these two values appear to be nearly unrelated. TAKEDA & FREY (1979) also found no relation between protein yield and protein percentage in their work with an interspecific oat cross.

Milling and baking data from the protein percentage and protein yield lines show significant differences for flour ash, farinograph absorption, farinograph stability and flour protein (Tables 4 and 5). Farinograph absorption and stability are both related in some degree to flour protein percentage.

The most interesting information from the milling and baking data concerns the comparison of parents with lines. With few exceptions, the lines show a significant improvement over the parental means (Tables 4 and 5). Baking characteristics might be expected to improve with higher levels of grain protein, but even flour yield was improved although it is known to be unrelated to grain protein percentage.

The tendency for transgressive improvement in quality of the protein lines suggests a complementary or additive effect of genes from parents which were of poor or mediocre quality. Such transgressive segregation is already known to occur for disease resistance, where higher levels of resistance to stripe rust (*Puccinia striiformis* WEST) has been observed in selections than in either parent in many wheat crosses (HENRIKSEN & POPE, 1971; KRUPINSKY & SHARP, 1979).

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