IMPROVED NITROGEN RESPONSE AS AN OBJECTIVE IN WHEAT BREEDING

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ABSTRACT

Meeting the quality requirements of bread making industry and of wheat markets is becoming increasingly difficult because grain protein concentration is negatively correlated with grain yields and because limitation of nitrogen fertilizer use, for ecological and economical reasons, negatively affects grain protein concentration. To alleviate this problem, breeders should improve the ability to acquire Nitrogen, especially when available Nitrogen is limiting („N acquisition efficiency - NAE"), the ability to produce higher yield at a given Nitrogen availability („N use efficiency - NUE") and the ability to maintain higher N concentration at high grain yield levels („N storage efficiency - NSE"). This paper presents the criteria presently used in the breeding program at A.R.D.I. Fundulea – Romania for NAE, NUE and NSE, and reports some results of our search for genotypic differences among Romanian winter wheat cultivars. Results of testing 9 modern Romanian cultivars and the historical check Bezostaya 1, in 26 environments (location x years) were used to compute regression based parameters, describing the efficiency of N acquisition, use and storage. Results suggest that variation among modern Romanian cultivars in NAE, NUE and NSE is small, but usable in a breeding program. NUE correlated positively with grain yield and negatively with protein concentration and NAE when all cultivars were included, but correlations were not significant when only modern cultivars were taken into consideration. Nitrogen storage efficiency was not correlated with average grain yield or with Nitrogen acquisition or Nitrogen use efficiency. This suggests that combining these traits in one genotype should be possible.

Key words: wheat breeding, Nitrogen response, N storage efficiency

INTRODUCTION

Bread-making industry and wheat markets have definite grain protein concentration requirements, because grain protein concentration directly influences water absorption of the flour and loaf volume ((Finney et al., 1987). Meeting these requirements is becoming increasingly difficult because:

- grain protein concentration is negatively correlated with grain yields;
- limitation of nitrogen fertilizer use, for ecological and economical reasons, negatively affects grain protein concentration (Triboi et al., 1990).

Breeding for improved Nitrogen response might alleviate this problem (Fischer, 1981; Ortiz-Monasterio et al., 2001). Breeding should take into account the complex relationship between N availability, grain yield and N concentration in the grain.

Nitrogen response of wheat cultivars should be improved in three directions:

- improving the ability to acquire Nitrogen, especially when available Nitrogen is limiting („N acquisition efficiency");
- improving the ability to produce higher yield at a given Nitrogen availability („N use efficiency");
- improving the ability to maintain higher N concentration at high grain yield levels („N storage efficiency").

Breeders need simple parameters for each of these traits, easy to apply on a routine basis in breeding programs, for identification of genotypic differences in Nitrogen response and for use as selection criteria. This paper presents the criteria presently used in our breeding program at A.R.D.I. Fundulea, Romania for N acquisition, N use and N sto-rage efficiency, and reports some results of our search for genotypic differences among Romanian winter wheat cultivars.

MATERIAL AND METHODS

Wheat varieties and advanced lines from our breeding program are routinely tested in many locations, with and without supplementary nitrogen fertilizer, using a lattice design with 3 replications. Protein concentration is determined using a Perten infrared analyzer. Here we report results of testing 9 modern Romanian cultivars and the his-

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torical check Bezostaya 1, in 26 environments (location x years).

Genotypic responses to nitrogen were described by three parameters:

1. To characterize the ability to extract nitrogen, especially in low N conditions, we used the linear regression of N extracted by each cultivar on available N. The amount of N extracted with the grain yield, averaged on all tested cultivars was used as an estimation of N availability. The regression intercept was considered an estimation of the **nitrogen acquisition efficiency (NAE)**.

2. To characterize the ability to produce higher yields per unit of available nitrogen, we used the slope of regression of individual cultivar yields on available Nitrogen as an estimation of **nitrogen use efficiency (NUE)**.

3. To characterize the ability to produce grain of higher N concentration at the same yield level, deviations of individual cultivars from the all-cultivar regression of grain protein concentration on grain yield are often used. However, same average individual deviations from the all-cultivar regression of grain protein concentration on grain yield can result from different cultivar responses of protein concentration to yield variation. Therefore the ability of each cultivar to accumulate nitrogen in the grain, i.e. of the level of „coupling" between C and N accumulation, is better described by the regression of grain protein concentration on grain yield for the particular cultivar. We used the slope of this regression as an estimation of **Nitrogen storage efficiency (NSE)**.

We believe that these parameters offer a better way to characterize the complex processes of plant responses to Nitrogen.

RESULTS AND DISCUSSION

The historical check Bezostaya 1 had lowest yield, highest protein concentration, best NAE, lowest NUE and average to low NSE (Table 1). Smaller, but interesting differences were found among the modern Romanian cultivars, for all parameters.

Table 1. Parameters describing Nitrogen response of 10 winter wheat cultivars

Cultivar	Average yield (kg ha^{-1})	Average grain protein concentration (%)	NAE*	NUE*	NSE* (with N fertilizer)	NSE* (no N fertilizer)
Gruia	5507	12.8	0.88	47.0	-0.48	-0.32
Glosa	5430	12.8	-4.84	49.2	-0.47	-0.38
Dor	5449	12.8	-3.55	49.3	-0.57	-0.38
Boema	5255	13.0	-0.57	44.5	-0.64	-0.35
Crina	5175	13.2	-3.20	47.0	-0.69	-0.47
Fundulea 4	5203	12.8	-2.37	48.6	-0.71	-0.54
Faur	5242	13.3	7.96	44.2	-0.64	-0.36
Delabrad	5094	13.3	-0.20	43.4	-0.55	-0.36
Flamura 85	5079	13.3	-8.86	48.1	-0.49	-0.37
Bezostaya 1	4459	13.6	14.77	31.8	-0.59	-0.53

*) as defined in Material and Methods.

With the exception of the older check Bezostaya 1, differences in NAE were generally small. However, slightly better NAE's were found in cultivars Faur and Gruia, while Flamura 85 had the lowest NAE. The better NAE of the cultivar Gruia is particularly interesting since this cultivar had the highest average yield and has relatively shorter straw.

Figures 1 and 2 present, for some selected cultivars, the regression lines of N extracted by each cultivar on available N, estimated by the amount of N extracted with the grain yield averaged on all tested cultivars. Obviously the historical check Bezostaya 1 had a higher intercept of the regression line, indicating a tendency to use more nitrogen the other cultivars at low N availability, a feature that might be related with the taller plant and later maturity (Figure 1).

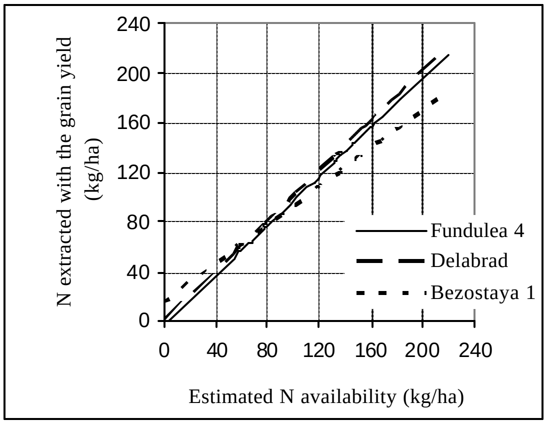

Figure 1. Nitrogen acquisition efficiency in cultivars Fundulea 4, Delabrad and Bezostaya 1

On the other hand, the modern semidwarf cultivar Faur, also showed a higher intercept of the regression line (Figure 2). In this case plant height cannot be an explanation.

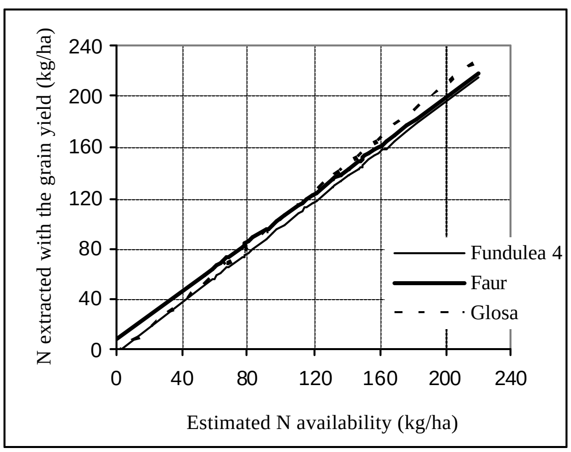

Figure 2. Nitrogen acquisition efficiency in cultivars Fundulea 4, Faur and Glosa

Differences in NUE were more interesting. Cultivars Dor, Glosa and Fundulea 4 had the best NUE, while Bezostaya 1 and Delabrad had the lowest NUE. Generally, best NUE's were found among the highest yielding cultivars, while cultivars with lower average yield had relatively lower NUE, but the association was not perfect. For example, Boema and Gruia had lower NUE than expected from their average yield.

Figures 3 and 4 present the regression lines of grain yield on available N, for several of the tested cultivars. The older cultivar Bezostaya 1, clearly contrasted with all modern cultivars, having the smallest regression slope (Figure 3).

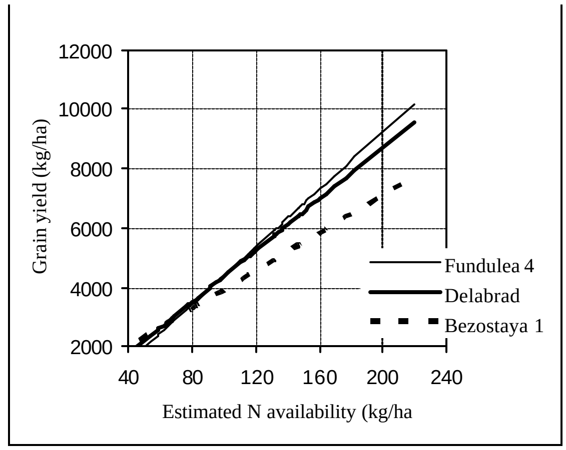

Figure 3. Nitrogen use efficiency in cultivars Fundulea 4, Delabrad and Bezostaya 1

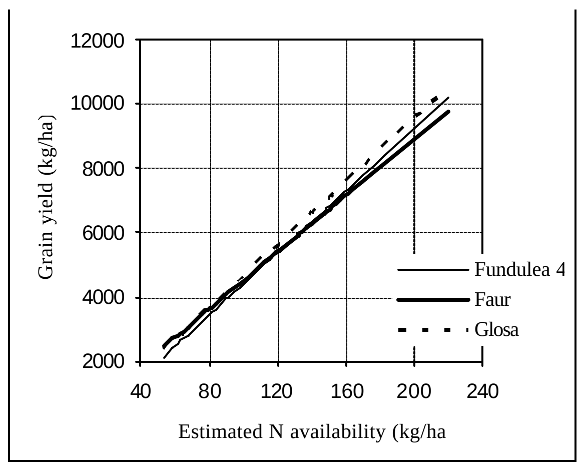

Figure 4. Nitrogen use efficiency in cultivars Fundulea 4, Faur and Glosa

Glosa and Gruia, had the best NSE (smallest slope) in fertilized trials, while Gruia and Boema were the best in non-fertilized trials. Fundulea 4 had the most rapid decline in protein concentration at higher yields, while Delabrad and Glosa showed a relatively smaller reduction of protein concentration at high grain yields (Figures 5 and 6).

At this stage it is difficult to speculate about the mechanisms, which could cause such differences in N storage efficiency. Higher root activity during grain filling, or differences in leaf senescence, might produce differences in the usual „coupling" of N and C metabolism. Physiological studies are under way, in order to find possible explanations.

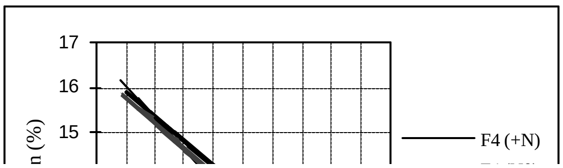

Figure 5. Nitrogen storage efficiency in cultivars Fundulea 4, Delabrad and Bezostaya 1

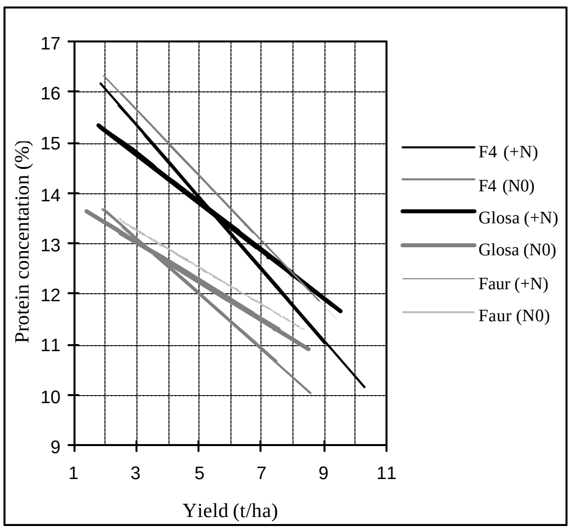

Figure 6. Nitrogen storage efficiency in cultivars Fundulea 4, Faur and Glosa

As expected, average grain yield was negatively correlated with average protein concentration in the grain (Table 2).

Table 2. Correlations among parameters describing nitrogen response (including the historical check, above the diagonal/including only modern cultivars, below the diagonal)

	Average yield	Average grain protein concentration	NAE	NUE	NSE (with N fertilizer)	NSE (without N fertilizer)
Average yield	1.00	**-0.85**	-0.62	**0.88**	0.21	0.61
Average grain protein concentration	**-0.80**	1.00	0.56	**-0.77**	-0.11	-0.24
NAE	0.14	0.17	1.00	**-0.87**	-0.23	-0.30
NUE	0.42	-0.64	-0.66	1.00	0.12	0.38
NSE (with N fertilizer)	0.37	-0.12	-0.32	0.22	1.00	0.59
NSE (without N fertilizer)	0.32	0.16	0.23	-0.38	**0.69**	1.00

Bolded coefficients are significant at P< 0.05 level

NUE correlated positively with grain yield and negatively with protein concentration and NAE when all cultivars were included, but correlations were not significant when only modern cultivars were taken into consideration.

CONCLUSIONS

Regression based parameters for Nitrogen acquisition and Nitrogen storage efficiency, alongside with the usual Nitrogen use efficiency, are useful for a more complete characterization of Nitrogen response of wheat cultivars.

Results from yield trials under a wide range of environmental conditions, with and without supplementary N fertilization, suggest that variation among modern Romanian cultivars in Nitrogen acquisition, Nitrogen use and Nitrogen storage efficiency is small, but usable in a breeding program.

Nitrogen storage efficiency was not correlated with average grain yield or with Nitrogen acquisition or Nitrogen use efficiency. This suggests that combining these traits in one genotype should be possible.

Search for new sources of larger genetic variation for these traits should be a high priority in wheat breeding programs.

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