Partitioning of Nitrogen among monomeric protein fractions during grain development in wheat is not influenced by Nitrogen nutrition and post-anthesis temperature

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Abstract

Nitrogen nutrition and post-anthesis temperature-induced changes in the kinetics of accumulation monomeric protein fractions (albumins-globulins, amphiphils, gliadins and glutenins) were examined for winter wheat (*Triticum aestivum* L.). Crops were grown in controlled environment tunnels, where five post-anthesis temperatures (average temperature ranging from 13?C to 25?C) were applied during grain filling, and in the field, where nine levels of nitrogen fertiliser were applied. When expressed in thermal time, the kinetics of accumulation of the fractional proteins were not significantly affected by post-anthesis temperature; whereas, nitrogen fertilisation significantly increased the rate and duration of accumulation of storage proteins. Structural and metabolic proteins accumulated during the early stage of grain development, and their rate of accumulation was significantly decreased at *ca*. 250?Cday after anthesis, when the storage proteins started to accumulate significantly. Single allometric relationships for the different environmental conditions exist for the partitioning of nitrogen within the structural and storage proteins. From these results we concluded that: (1) the process of nitrogen allocation are not significantly affected by post-anthesis temperature and nitrogen nutrition, (2) at maturity, the variations of fractional proteins composition are mainly due to differences in the quantity of total nitrogen accumulated during the grain filling period. The relationships between the quantity of each fractional proteins and the total nitrogen content can be used to model environmental as well as genetic effects on the dynamic accumulation of fractional proteins into the grain.

Key Words

Protein composition, grain development, flour quality, gluten.

Introduction

Proteins are the most important components of wheat grains governing end-use quality parameters [1]. Although grain protein composition depends primarily on genotype, it is significantly affected by environmental factors and their interactions [2, 3]. In wheat, grain proteins can be separated on the base of their solubility as albumins-globulins, amphiphils, gliadins and glutenins. The first two fractions are metabolic and structural proteins, whereas the last two are storage proteins.

The accumulation of fractional proteins during grain development is highly asynchronous. Thus conditions that shorten the grain filling, such as high temperature or nitrogen shortage, affect the balance of protein fractions [4]. Few studies have examined separately the effects of environmental factors and their interactions on the accumulation of protein fractions during grain filling. In the present study, the effect of N nutrition and post-anthesis temperature on the kinetics of accumulation of fractional proteins have been studied in separate experiments in controlled environment tunnels and in the field.

Methods

Experimental treatments

To analyse the effect of post-anthesis temperature and drought, crops of wheat were grown outside under natural light in 2 m^2 containers. From 5 days after anthesis to grain maturity four air temperatures relative

to outside air temperature were applied under the controlled environment tunnels: -5?C; 0?C; +5?C; +5?C until 300?Cday, base 0?C, after anthesis then +10?C until harvest maturity; and +10?C until 300?Cday after anthesis then +5?C until harvest maturity.

The effect of N availability at anthesis in relation to the level of N nutrition before anthesis was studied in a field experiment. Three levels of N supply before anthesis were applied. Low N treatments (treatments L) were established on plots that had not received N since 1948; moderate N nutrition treatments (M) received 50 KgN?ha^{-1} at the beginning of tillering; and high N nutrition treatments (H) were on plots where leaves of sugar beet from a previous cultivation and a cut of alfalfa had been buried. At anthesis, each plot was split into three sub-plots to which 0 KgN?ha^{-1} (L0, M0, and H0), 30 KgN?ha^{-1} (L1, M1, and H1) or 150 KgN?ha^{-1} (L2, M2, and H2) were applied.

Plant sampling, protein extraction and N content determination

Plants were sampled from anthesis to grain maturity at approximately 75?Cdays intervals (base 0?C). Grains were frozen in liquid N, freeze-dried, and stored at 4?C before analysis. Grains were ground to wholemeal flour and the monomeric protein fractions albumins-globulins, amphiphils, gliadins, and glutenins were sequentially extracted [5]. Total N content for the wholemeal flour and for the different monomeric protein fractions were determined on lyophilised samples by the Kjeldhal method.

Results

When expressed in thermal time, the kinetics of accumulation of the fractional proteins were not significantly affected by post-anthesis temperature (data not shown), whereas nitrogen fertilisation significantly increased the rate and duration of accumulation of storage proteins (Fig. 1). Accumulation of storage proteins (i.e. gliadins and glutenins) were more sensitive to nitrogen nutrition than that of structural protein (i.e. albumins-globulins and amphiphils). Structural and metabolic proteins accumulated during the early stage of grain development, and their rate of accumulation was significantly decreased at *ca*. 250?Cday after anthesis, when the storage proteins started to accumulate significantly.

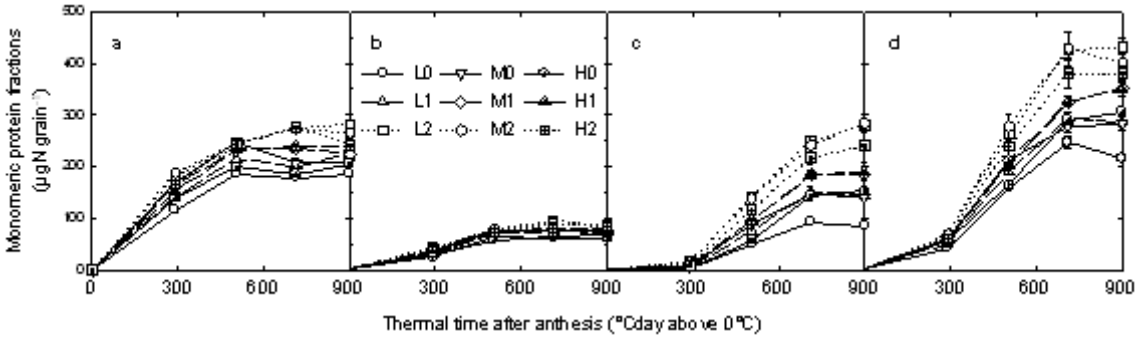

Figure 1. Relationships between the quantity of albumins-globulins (a), amphiphils (b), gliadins (c), and glutenins (d) versus the thermal time after anthesis for grains of wheat grown in the field with different rates and timing of N fertilisation. Treatments are denoted as outlined in Methods. Data are means ??1?SE for n = 3.

Single allometric relationships for the different environmental conditions exist for the partitioning of nitrogen within the structural and storage proteins (Fig. 2).

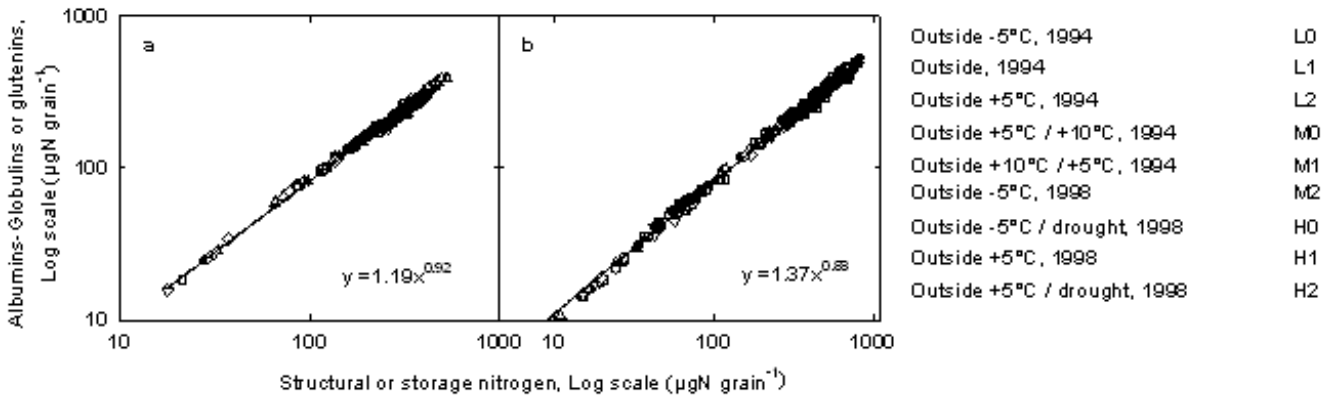

Figure 2. Relationships between the quantities of albumins-globulins and of structural nitrogen (a), and between the quantities of glutenins and storage nitrogen (b) for grains of wheat grown in controlled environment tunnels and in the field.

Conclusion

For the cultivar studied, the partitioning of nitrogen between the monomeric protein fractions was modified neither by post-anthesis temperature or drought nor by the rate or timing of N nutrition. Thus the fractional protein composition depended mostly on the total quantity of N per grain. Structural proteins (albumins-globulins and amphiphils) accumulated in the grain first and their accumulation is most likely sink driven, whereas the storage proteins (gliadins and glutenins) accumulated mainly during the filling period and their accumulation is most likely supply limited. The next step in the study of the environmental determination of grain protein fractions will be to transcribe these results and hypotheses into a simulation model. This will allow us to analyse the effect of varied environmental conditions, but also to frame hypotheses of the effect of the genotypic variability of N remobilisation on fractional protein accumulation and synthesis of storage proteins.

References

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