Individual and Interactive Effects of Genetic Background and Environmental Conditions on Amount and Size Distribution of Polymeric Proteins in Wheat Grain

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Abstract: Bread-making quality of wheat flour is influenced by wheat storage proteins. The percentage of sodium dodecyl sulphate (SDS)-unextracted polymeric proteins in total polymeric proteins (% UPP), as one important factors determining bread-making quality, is largely influenced by the individual and interactive effect of genetical background and environmental conditions. Four spring wheat cultivars were grown in green house. Two of the cultivars have high molecular weight glutenin subunits 5+10 while the other two have 2+12. Four different nitrogen regimes and two different temperature levels (distinguished as low and high temperature) were used. The results highlighted the importance of interactive influence of cultivars, nitrogen regimes and temperature levels for creating differences in the amount of % UPP during grain maturation period (GMP) and at maturity. The shift to end up with either high or low % UPP at maturity happened early during GMP (around 12 days after anthesis). Influences of cultivars on % UPP was found early during the GMP while influences of temperature and nitrogen regimes were seen much later during the GMP. The results will help in understanding the relationship between quality parameters of wheat flour and how these are influenced by different environmental and genetic factors.

Keywords: environmental conditions; genetical background; grain maturation period; polymeric proteins

Wheat is an important staple food crop which is grown and used worldwide for different purposes. The bread-making quality of wheat flour is largely influenced by the grain storage proteins (Weegels *et al.* 1996). Gluten is the major storage protein in wheat grain, which is further classified into gliadins and glutenins, effecting bread-making quality (Wall 1979). Protein concentration, accumulation, composition and amount and size distribution of polymeric proteins (ASPP), which play a vital role in determining the bread-making quality of wheat, are influenced by number of factors (Finney & Barmore 1948). Among these factors the most crucial are the genetic background and the environmental conditions. Maturation time of the cultivars and specific protein composition i.e. high molecular weight glutenin subunits (HMW-GS) 5+10 and 2+12 are thought to be important regarding genetical background (Johansson *et al.* 2005). Among environmental conditions, nitrogen (N) and temperature (T) are the important factors (Weiser & Seilmeier 1998; Johansson *et al.* 2005).

The percentage of sodium dodecyl sulphate (SDS)-unextracted polymeric proteins in total polymeric proteins (% UPP) are known to determine the dough strength and thereby the baking quality of wheat (Marchylo *et al.* 1989). A number of studies have investigated the individual effects of genetic background and environmental conditions on % UPP (Stone & Nicolas 1996; Johansson *et al.* 2008). However, a very limited knowledge is available about the interactive effect of genetic background and environmental conditions on the % UPP. Therefore, the aim of the present study was to investigate the individual and interactive effect of genetic background and environmental conditions on % UPP in wheat grain. Furthermore, the aim was also to examine the effect of cultivar differences on the build-up of % UPP in wheat grain during grain maturation period (GMP).

MATERIAL AND METHODS

In this investigation, four spring wheat cultivars (Vinjet, Soljett, Springjet and Kronjet) were selected with variation in maturation time and specific protein composition. Two of the selected cultivars were early-maturing while the other two were late-maturing. Also, two cultivars showed the HMW-GS 2+12 and other two showed 5+10. Different N application time and T regimes were applied according to Malik *et al.* (2008). The T regimes selected were high (24/21°C) and low (17/14°C), corresponding to a Swedish warm and sunny summer and a normal summer during grain filling (Johansson 2002; Johansson *et al.* 2002; 2005). The plants were harvested at different occasions after anthesis according to Johansson *et al.* (2005). For the determination of % UPP and specific protein composition, size exclusion high performance liquid chromatography (SE-HPLC) and sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE) were used, respectively, according to Johansson *et al.* (2005). Microsoft Excel and SAS were used for statistical analysis. For the evaluation of data, spearman rank correlation, analysis of variance and standard deviation were used

RESULTS AND DICUSSION

The results showed that variation in cultivars, N regimes, T levels and their interactions were found to affect significantly the % UPP at maturity (Table 1). The results in our investigation were in accordance with previous studies where cultivar variation leads to differences in % UPP at maturity (Stone & Nicolas 1996). Specific protein composition (HMW-GS 5+10 and 2+12) is only determined by cultivar not by environment (Johansson *et al* 2005). In the current results, one of the cultivars (Springjet having HMW-GS 2+12) was having significantly higher levels of %UPP than the other cultivars at maturity (Figure 1a). This is not in accordance with the previous investigations which indicate that % UPP is higher in cultivars having HMW-GS 5+10 (Stone & Nicolas 1996). The cultivar Kronjet had significantly lower %UPP at maturity as compared to the other cultivars (Figure 1a). This difference was emerging 26 days after anthesis (DAA) and was present during the rest of the GMP (Figure 1). The interaction between cultivars and N regimes was also found to be highly significant for % UPP at maturity (Table 1).

Table 1. Mean square values from ANOVA of four wheat cultivars at four nitrogen and two temperature regimes for percentage of SDS-unextractable polymeric protein in total un-extractable polymeric protein (% UPP) at maturity

Source	Df	% UPP
Cultivar (C)	3	0.07***
Temperature (T)	1	0.02***
Nitrogen (N)	3	0.07***
C × N	9	0.01***
C × T × N	9	0.01**
Error	59	0.00

*$P < 0.05$, **$P < 0.01$, ***$P < 0.0001$;
Df = degree of freedom

N and T were among the important environmental factors that affect % UPP in wheat grain (Johansson & Svensson 1999; Johansson *et al* 2005). For the cultivar Springjet, N application at spike formation (N regime C) resulted in the highest levels of % UPP at maturity compared to rest of the nitrogen regimes (Figure 1b). However, no significant differences in % UPP could be detected between the N regimes during the GMP before maturity (Figure 1b). The high temperature regime (24/21°C), for cultivar Springjet, resulted in higher amount of % UPP as compared to the low temperature regime (17/14°C) from 18 DAA and throughout to maturity (Figure 1c). These findings confirm previous results showing that high temperature lead to an increase in % UPP (Randall & Moss 1990).

By selecting the combination of treatments that resulted in the highest and the lowest % UPP at maturity, respectively, it was possible to differentiate that the start of the build-up of the % UPP,

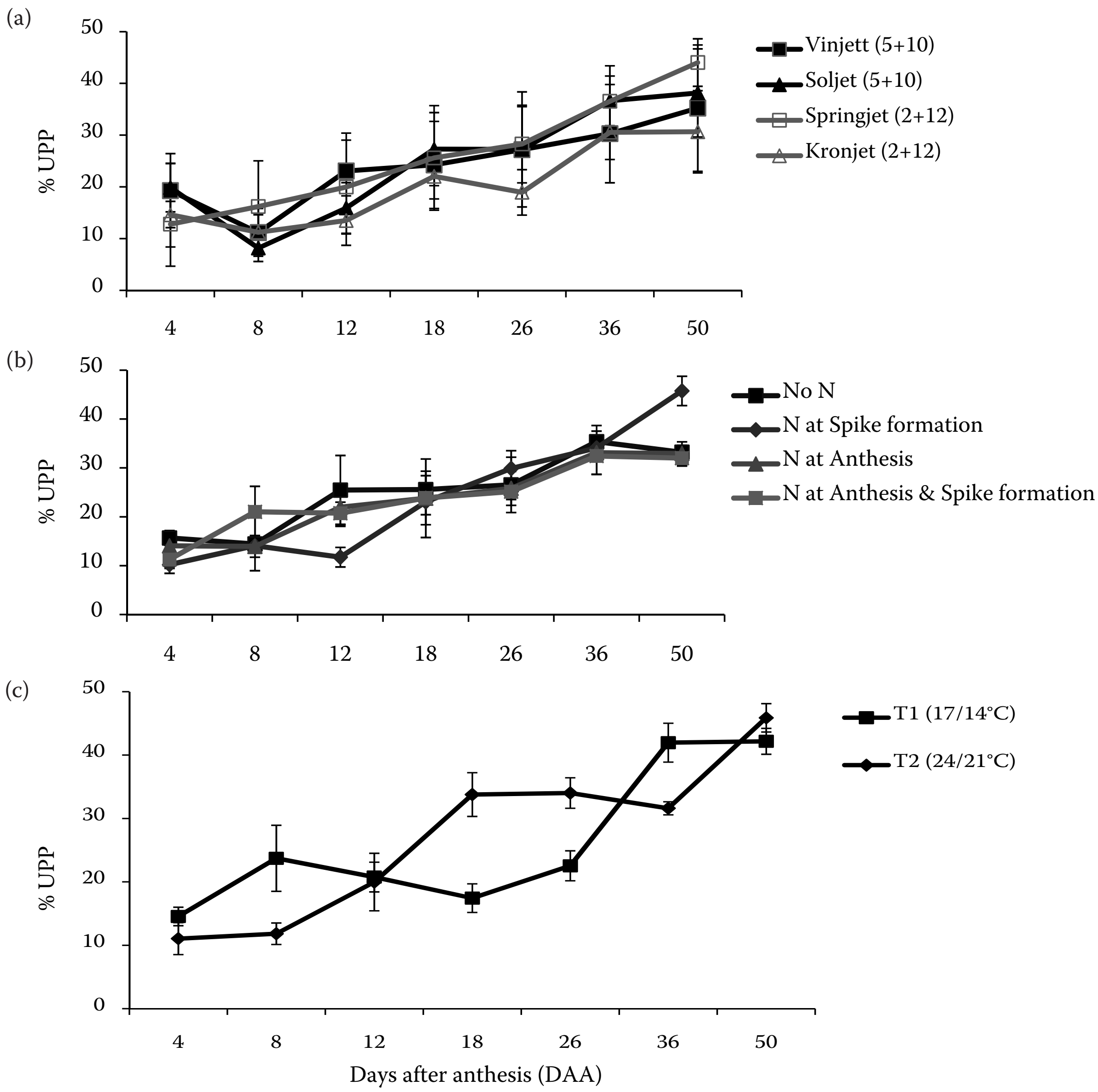

Figure 1. Build-up of percentage of SDS-unextractable polymeric protein in total un-extractable polymeric protein (% UPP) during grain maturation period (a) for four wheat cultivars (b) for wheat cultivar Springjet at different nitrogen regimes (c) for wheat cultivar Springjet at different temperature levels

resulting in high versus low values, was at 12 DAA (compare Figures 2a and 2b). For the selected combinations of treatments, that resulted in high % UPP at maturity, the increase was steady from 12 DAA (Figure 2a) while for the combination of treatments resulting in low % UPP, no increase in % UPP could be seen during the whole GMP (Figure 2b). During the first half of GMP (before 12 DAA) there is no clear variation in the build-up of ASPP, which is a predetermined process, and polymerisation process. However, from 12 DAA the variation in the build-up of ASPP and the polymerisation process starts and continued through out the GMP up till maturity.

Hence, it was concluded that % UPP, as one of the determinants of dough strength influencing bread-making quality, is affected by interactive effects of combinations of nitrogen application and temperature regime, and cultivar. Although, individual environmental and genetic factors were also found to have an impact on % UPP. By choice of the right factors (cultivars, N regimes and T levels) it will be possible to obtain the most optimal % UPP in desired end-use wheat products (e.g. bread). The variation in build-up of polymeric proteins that results in differences in % UPP at maturity starts at 12 DAA and continues throughout the rest of the GMP.

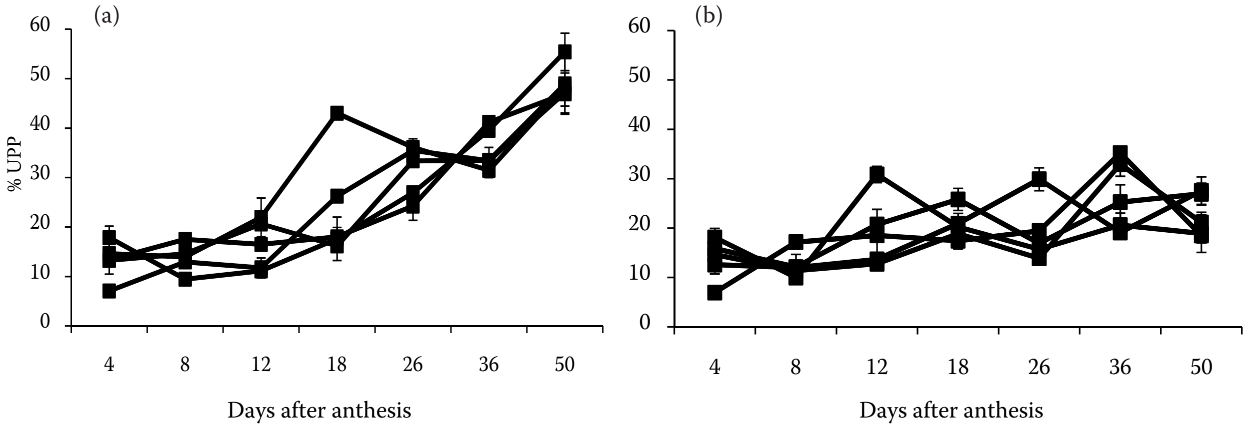

Figure 2. Build-up of percentage of SDS-unextractable polymeric protein in total un-extractable polymeric protein (% UPP) during grain maturation period (a) for selected combinations of treatments (cultivars, nitrogen regimes and temperature levels) resulting in high % UPP (b) selected combinations of treatments (cultivars, nitrogen regimes and temperature levels) resulting in low % UPP

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