Food Science and Quality Management
ISSN 2224-6088 (Paper) ISSN 2225-0557 (Online)
Vol.58, 2016 

# Effect of Nitrogen Rate and Timing on Quality Parameters of Durum Wheat (Triticum turgidum L.var. durum) Varieties in the Highlands of Bale, Ethiopia

Girma Fana
Oromia Agricultural Research Institute, Sinana Agricultural Research Center, P.O.Box 208, Bale-Robe, Ethiopia

The research was financed by Oromia Agricultural Research Institute

**Abstract**
Ethiopia is among the major wheat producing countries in Africa. Durum wheat is known for its gluten strength which is used for quality pasta and macaroni making. The gluten complex plays the major role in determining the technological quality of wheat. Wheat gluten proteins have unique visco-elastic properties of three-dimensional structures formation. An experiment was conducted in 2007 and 2008 at three sites (Sinana, Selka and Robe) to determine the response of yield and quality parameters of durum wheat to nitrogen rate and timing. The treatments included 60 (30, 30), 60 (30, 30), 90 (30, 30, 30), 120 (30, 60, 30), 120 (30, 30, 60) and 180 (60, 60, 60) at planting, tillering and anthesis, respectively. It was found that there is significant difference between genotypes, locations, year and nitrogen rates and timing for sedimentation volume, vitreousness, dry gluten, wet gluten and gluten index except that there was no significant difference among genotypes for vitreousness and gluten index. Year x location interaction would not influence gluten contents but had significance for other parameters. The interaction of nitrogen by location and year was significant only for vitreousness. Most of the other cross other interactions were found not significant. The year effect was higher in 2007 for vitreousness, dry gluten and wet gluten whereas sedimentation volume and gluten index was higher in 2008. Rainfall during the growing months was higher in 2008 than in 2007 and this shows higher moisture related with lower gluten contents and vitreousness but with higher sedimentation volume and gluten index. The Robe site had higher vitreousness, dry gluten and wet gluten but lower sedimentation volume and gluten index. The Selka site had higher sedimentation volume but lower vitreousness, dry gluten, wet gluten and gluten index. The highest gluten index was obtained at Sinana on-station. Oda variety was found with higher gluten content and Bakalcha was with higher sedimentation volume. Increasing nitrogen levels was related with increasing gluten contents and vitreousness while gluten index decreased as nitrogen levels increase. Sedimentation volume decreased while vitreousness, dry gluten, wet gluten and gluten index increased with later application of N at anthesis than at mid tillering stage.
**Keywords:** gluten quality, end-use, environment, management, durum wheat

## 1. Introduction

Wheat (*Triticum aestivum* L.) is one of the most important agricultural food crops worldwide. Humans directly consume more than 60 % of this production. Wheat supplies about 20% of the energy and about 25% of the protein requirements of the world population. The crop is such a widely grown commodity because it can be used for a wide variety of food products (bread, cakes, etc.) and secondary products (starch, gluten etc.). Wheat quality can most simply be defined as the suitability of the grain for the intended processes and products. It may encompass several criteria such as milling performance, dough rheology, baking quality, nutritional value for humans and animals or storage properties, hence compositional requirements vary between different end-uses (Hogy and Fangmeier, 2008).

Wheat proteins are the best known cereal proteins, and the gluten complex plays the major role in determining the technological quality of wheat. Wheat gluten proteins have unique visco-elastic properties of three-dimensional structures formation. Gluten mainly consists of two major storage protein fractions, namely gliadin and glutenin (Ahmed et al., 2008). It is generally accepted that what makes wheat unique among the cereals is the visco-elasticity of the hydrated gluten proteins (Zhao et al., 2010). Gluten properties are largely responsible for the end-use quality of wheat in many food products. Understanding the factors affecting gluten properties is therefore of extreme importance (Wang et al., 2004). In durum wheat (Triticum turgidum L. var. durum), the capacity of semolina to form dough suitable for pasta production principally depends on the rheological properties of its gluten.

Stability of quality parameters is becoming an important requirement for the milling and pasta industries because of potentially high annual variation in both grain yield and quality (Rharrabti *et al*., 2003). An increase in grain nitrogen concentration would normally be expected to result in increases in the proportion of vitreous grains, sedimentation volumes, gluten concentration and dough strength. The relationship between nitrogen concentration and protein quality criteria may, however, vary depending on weather conditions (Troccoli *et al*., 2000). Vitreousness is the natural translucent colouring that gives the wheat kernels a hard, glossy appearance, and is usually related to protein content (Shahin et al., 2005).Two important determinants of flour quality are the amount of protein, which is strongly influenced by environment, and the protein composition, which is determined by genetics and environment. Gluten polymers from wheat are among the largest and most complex protein networks in nature. The differences in bread-making quality between flour of different wheat varieties also parallel differences in a gluten protein fraction called glutenin macro-polymer (GMP). GMP is the glutenin fraction which is insoluble in various solvents, Sodium Dodecyle Sulphate (SDS) or acetic acid (Herpen *et al*., 2008). The SDS sedimentation test basically measures the sedimentation volume of an acidified suspension of wheat flour. The higher the sedimentation volume, the better the baking quality (Oelofse et al., 2010). Low-molecular-weight glutenin subunits (LMW-GS) are among the major components of wheat storage proteins, collectively known as Prolamins because of their high content of the amino acids proline and glutamine. Prolamins are used as nutrients by the embryo, during the early phase of germination and seedling growth, before photosynthesis is established (D'Ovidio and Masci, 2004). Gluten rheology is by essence more directly related to prolamin structure, composition, and interactions than dough rheology (Lefebvre *et al*., 2003). Nitrogen, S and temperature also influence the proportions of the different protein types in flour (DuPont *et al*., 2007). The amount of HMW-GS and LMW-GS is genetically determined and their amounts are only slightly increased by (late) N application. HMW-GS content was greatly dependent on environmental factors, such as site, season and nitrogen. Nitrogen application was also reported to increase HMW-GS content by 56–101% (Yue *et al*., 2007). Gluten index decreased as N fertilizer rates rose (Garrido-Lestache *et al*., 2007). Baking performance of durum wheat improves as gluten becomes stronger, but loaf volumes of the best performing durum wheat cultivars were substantially lower than for bread wheat. Very strong gluten durum wheat has tenacious gluten, which imparts inextensible dough and associated dough handling problems, and lower loaf volume due to reduced oven response (Saperstein et al., 2007).

## 2. Materials and Methods

The experiment was conducted at two locations of Southeast Ethiopian highlands for two years (2007 and 2008) during the main cropping season (June-January). The major soils of the area are cambisols and vertisols with clay to sandy loam structure and a pH of 7.5 (1: 2.5 soil:water ratio). Most of the soils are poor in total nitrogen, medium in available phosphorus and high in potassium. The highland of Bale is characterized by bimodal rainfall pattern receiving peak amounts in April and September. Days are hotter in February and nights are cooler in December. The average temperature is 9.5 $^{0}$C, maximum mean temperature of 21 $^{0}$C and the average total annual rainfall of the experimental years is 960 mm.

The trail was laid out in Split Plot design with varieties (Oda and Bakalcha) as main plot factor and N rate as sub-plot factor. The N rates included 0 and 30 kg N/ha applied at planting and the split application rates included 60 (30p, 30a), 60 (30p, 30t), 90 (30p, 30t, 30a), 120 (30p, 60t, 30a), 120 (30p, 30t, 60a) and 180 (60p, 60t, 60a) where p= application at planting, t= at mid-tillering and a= at anthesis stages of the crop growth. Urea was used in the study as sources of nitrogen. Data were subjected to Analysis of Variance with General Linear Model of SAS and means were separated by Fisher's least significant difference (LSD) test.

## 3. Result and Discussion

Analysis of Variance indicates that most of the cross over interactions are not significant. The main effects of year, location, genotype and nitrogen have significant effect on quality parameters of durum wheat (Table 1). The interaction of year by location was observed significant for sedimentation volume, vitreousness and gluten index and that of year by genotype was significant for sedimentation volume and dry gluten. Year by nitrogen was not significant for all except for vitreousness. The interaction of nitrogen and genotype with location were not significant for all parameters except for that of location by nitrogen on vitreousness. Genotype and nitrogen rates also did not interact for all parameters. The three way interactions of year x location x genotype and year x location x nitrogen were also observed non-significant for all except vitreousness. The interactions of Year x location x N was in contrast with the findings of Garrido-Lestache et al. (2005) where they reported significant interaction for gluten index.

The overall analysis showed that vitreousness as well as dry and wet gluten contents are higher in 2008 than in 2007 whereas sedimentation volume and gluten index are higher in 2007 (Table 2). This shows that years with higher rainfall will Vitreousness, dry gluten and wet gluten are higher at Robe site. Sedimentation volume is higher at Selka and gluten index is higher at Sinana on-station. Sedimentation volume is higher for the variety Bakalcha while dry and wet gluten contents are higher for the variety Oda. Variety did not however influence vitreousness and gluten index. Increasing nitrogen rate decreased gluten index in agreement with the report by other authors where it was shown that gluten index decreased with increasing N rates (Garrido Lestache et al., 2005). Sedimentation volume and vitreousness were not consistent with increasing N rates, however they had a general increasing trend. Both dry and wet gluten contents progressively increased with increasing nitrogen rates. Timing and splitting of N fertilizer had also significant effect on the quality parameters. Sedimentation volume decreased while vitreousness, dry gluten, wet gluten and gluten index increased with later application of N at anthesis than at mid tillering stage. Other authors have also witnessed that vitreousness tends to increase with later applications of N, particularly at stem elongation (Garrido Lestache et al., 2005).

## 4. Conclusion

Durum wheat has strong gluten which is required by the industries to make different end-use products such as pasta and macaroni. The different quality parameters are of concern since they are influenced by the growing environment, fertilizer management and their interactions. Gluten content and vitreousness decreased in high rainfall years whereas sedimentation volume and gluten index increased with rain fall. Varieties also showed significant responses to gluten contents and sedimentation volume but not to vitreousness and gluten index. Increasing nitrogen rate was also associated with decrease in gluten index and inconsistent decrease in sedimentation volume. However, gluten content and vitreousness increased with increasing nitrogen rates. Higher nitrogen at later stages was related with decreasing sedimentation volume and gluten contents but increasing vitreousness and gluten index. Late application of nitrogen may hence contribute to amino acid quantity than to quality. Therefore, it seems wise to increase nitrogen earlier in growth stage of the plant (at tillering) to have required gluten quality.

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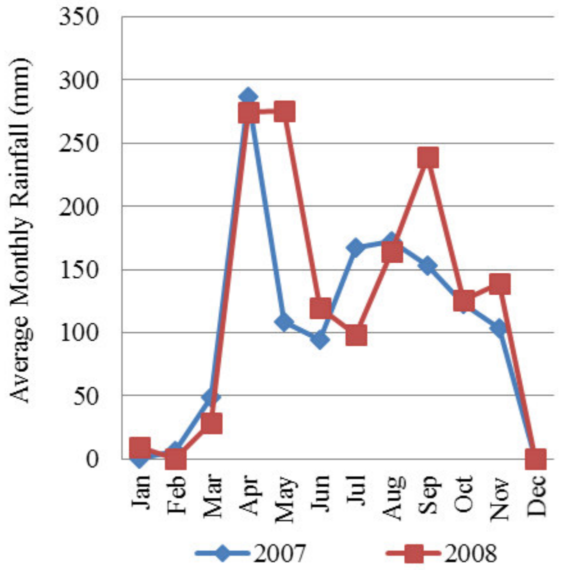


Figure 1: Average rainfall during the crop season

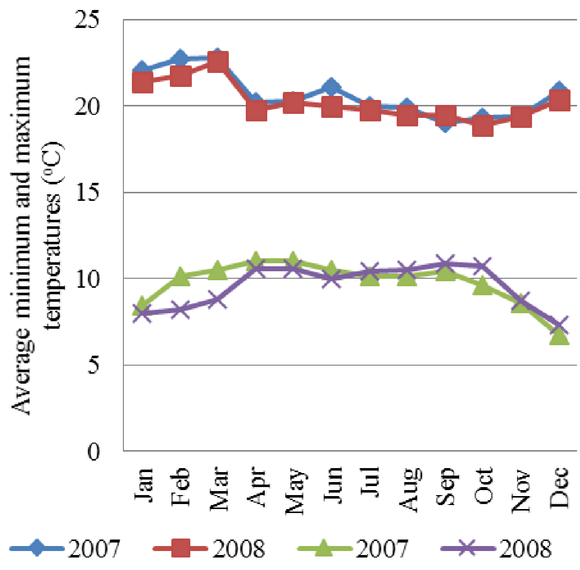


Figure 2: Maximum and minimum temperature

Table 1: Significance of Interactions among year (Y), Location (L), nitrogen rate (N), and genotype (G) on gluten quality parameters of durum wheat

| Source of variation | SV | V | DG | WG | GI |
|---|---|---|---|---|---|
| Yr | ** | ** | ** | ** | ** |
| Loc | ** | ** | ** | ** | ** |
| G | ** | ns | * | * | ns |
| N | ** | ** | ** | ** | ** |
| Yr. Loc | *** | ** | ns | ns | *** |
| Yr. N | ns | * | ns | ns | ns |
| Yr. G | ** | ns | * | ns | ns |
| Loc. N | ns | ** | ns | ns | ns |
| Loc. G | ns | ns | ns | ns | ns |
| G.N | ns | ns | ns | ns | ns |
| Loc. G.N | ns | ns | ns | ns | ns |
| Yr. G.N | ns | ns | ns | ns | ns |
| Yr.Loc.N | ns | * | ns | ns | ns |
| Yr.Loc.G | ns | ** | ns | ns | ns |
| Yr.Loc.G.N | ns | ns | ns | * | ns |

*= significance level at $P \leq 0.05$, **= significance level at $P \leq 0.01$, ***= significance level at $P \leq 0.001$, ns= non-significant at all significance levels, Y= year, L= location, N= nitrogen, G= genotype, SV= sedimentation volume, V= vitreousness, DG= dry gluten, WG= wet gluten, GI= gluten index

Table 2: Response of quality parameters to year, location, variety and nitrogen rates

| **Source of variation** | | **SV** | **V** | **DG** | **WG** | **GI** |
|---|---|---|---|---|---|---|
| **Year** | 2007 | 26.62b | 88.58a | 10.26a | 27.34a | 37.16b |
| | 2008 | 27.81a | 82.49b | 8.69b | 22.63b | 52.53a |
| | LSD | 1.163 | 1.683 | 0.74 | 1.13 | 3.374 |
| **Location** | Sinana OS | 27.35ab | 85.35b | 8.86b | 22.31c | 56.26a |
| | Selka | 27.98a | 81.32c | 9.17b | 23.95b | 36.41c |
| | Robe | 26.33b | 89.94a | 10.40a | 28.68a | 41.86b |
| | LSD | 1.425 | 2.061 | 0.90 | 1.38 | 4.133 |
| **Variety** | Oda | 25.80b | 86.09 | 10.26a | 27.34a | 45.09 |
| | Bakalcha | 28.64a | 84.97 | 8.69b | 22.63b | 44.59 |
| | LSD | 1.163 | ns | 0.74 | 1.13 | ns |
| **N (kg ha$^{-1}$)** | 0-0-0 | 28.14a | 80.52c | 8.45c | 21.54d | 50.51a |
| | 30-0-0 | 25.59b | 81.00c | 8.66c | 23.27cd | 49.80a |
| | 30-0-30 | 25.99b | 85.70a-c | 8.85bc | 24.21bc | 45.98ab |
| | 30-30-0 | 28.36a | 82.10bc | 9.49a-c | 24.80bc | 43.07ab |
| | 30-30-30 | 26.99b | 89.08a | 9.70a-c | 26.08ab | 42.89b |
| | 30-60-30 | 27.72b | 86.94ab | 10.17ab | 26.19ab | 39.83b |
| | 30-30-60 | 27.64b | 87.91a | 9.73a-c | 26.44ab | 44.13ab |
| | 60-60-60 | 27.29b | 91.03a | 10.76a | 27.32a | 42.54b |
| | LSD | 2.326 | 3.366 | 1.47 | 2.26 | 6.75 |

Means with the same letter in a column are not statistically different at $P \leq 0.05$, LSD= Fisher's least significant difference at $P \leq 0.05$, SV= Sedimentation Volume, V= vitreousness, DG= wet gluten content (%), DG= dry gluten content (%), GI= gluten index (%)