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Genotypic Variation in Dry Weight and Nitrogen Concentration of Wheat Plant Parts; Relations to Grain Yield and Grain Protein Concentration

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Abstract

This study aimed at investigating genotypic variability in nitrogen (N) concentration and dry weight of wheat plant parts and their relation with grain yield and protein concentration. Sixteen Nordic and three Pakistani wheat genotypes were grown in controlled climate chambers. Plant parts such as shoot, roots and grains were collected after harvesting, weighed and N concentration was determined. The results showed a large genetic variation for dry weight and N concentration in the various plant parts. Grain weight (GW) was negatively correlated with biomass in the vegetative parts of the plant and with grain N concentration (GNC). A spread distribution was found among the investigated genotypes related with the correlation between different investigated parameters. From a breeding perspective, the genotypes APU and Møystad were of interest due to both a relatively high GW and GNC. Lanor, Saffran, Auqab and Lavett were interesting genotypes, the two first ones combining high GW, and the two last ones combining high GNC, with low RNC and high RW. By combining information of dry weight and N concentration in various plant parts of a genotype, options are increased for a successful breeding of environmentally sound cultivars with high grain yield and high grain protein concentration.

Keywords: grain nitrogen concentration, grain weight, breeding, *Triticum aestivum*

1. Introduction

Grain yield and grain protein concentration are among the most important characters in wheat production (Kramer, 1979; Groos et al., 2003). Grain yield is a major determinant of farmer's income, while grain protein concentration is important for bread quality (Groos et al., 2003). Genetic variation exists for both grain yield and protein concentration and the inheritance of each of the two traits is complex. However, the heritability for both characteristics (i.e. grain yield and protein concentration) is high enough in order to expect some progress from selection (Barraclough et al., 2010). Besides the influence of genetic factors and cultivation practices on the grain yield, biotic and abiotic stresses also determine largely the grain yield potential of a crop (Finckh, 2008; Mergoum et al., 2009). Genetically determined factors known to influence the grain yield in wheat are e.g. root size and biomass size, photosynthesis and assimilation rates, growth habit of plants, transport and accumulation mechanisms within the plant (Jenner et al., 1991). Increased nitrogen (N) partitioning to grains could theoretically be increased by reducing competition from alternative sinks, especially during stem elongation when the grain number is determined (Fischer, 1985; Kirby, 1988). Genetic differences have been found for variation in roots, grains etc. in relation to N partitioning (Oyanagi et al., 1998; Reynolds et al., 2009).

The aim of the present investigation was to evaluate genotypic variation in dry weight and N concentration between wheat plant parts in order to understand the genetically determined background factors for yield and grain protein concentration.

2. Method

A total of nineteen wheat genotypes were selected in the present investigation. Sixteen of these genotypes were of Nordic origin and were selected to represent a broad genetic variation (about 90%) in the Nordic spring wheat material (Hysing et al., 2008). Additionally three Pakistani genotypes were included in order to evaluate a totally different genetic background. Wheat genotypes were cultivated according to Andersson et al. (2004) in controlled climate chambers in the Biotron. The harvesting was done when the plants were fully ripened. The plant parts were separated and oven dried (70°C) for five days and thereafter weighed. After weighing, the separate plant parts of each replicates of each genotype were grinded in a 1093 Cyclotec Sample Mill. After grinding, samples were weighed (3 - 7 mg) and analyzed for N concentration. The N concentration was determined according to the Dumas method using a Carlo Erba NA 1500 elemental analyzer (Carlo Erba Strumentazione, Milan, Italy). The Statistical Analysis System, version 9.1.2 (SAS, 2004) and MS-Excel programs and procedures were used for data analyses and evaluation.

3. Results

3.1 Dry Weights of Plant Parts

A large variation was seen in dry weights of various plant parts in the investigated wheat genotypes. The root weight (RW) and shoot weight (SW) ranged from 0.64 to 2.25 and 2.19 to7.12 g/plant, respectively. The dry grain weight (GW) ranged from 2.47 g/plant for Lanor to 3.71 g/plant for APU (Figure 1).

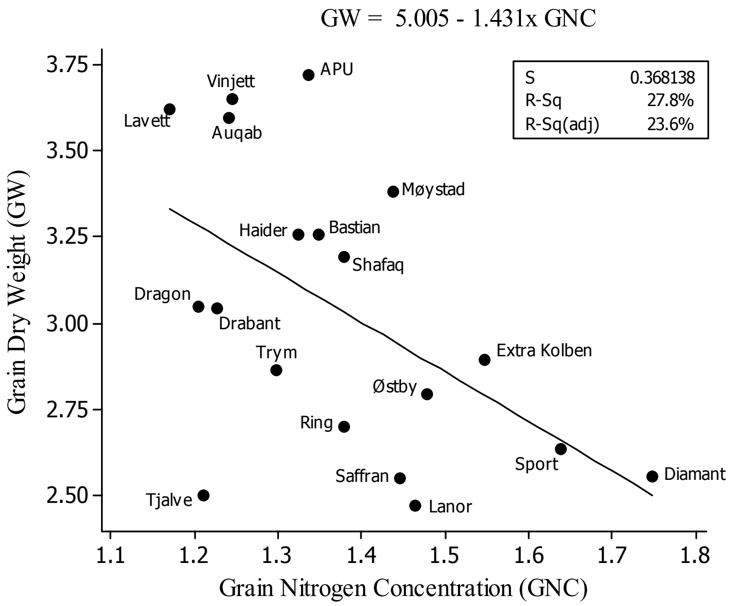

Figure 1. Scatter plot with regression (fitted plot line) between grain weight (GW, g) and grain nitrogen concentration (GNC, %) of nineteen wheat genotypes, at maturity

3.2 Nitrogen Concentration of Plant Parts

For N concentration in different plant parts (% of dry matter), a large variation was seen among the different wheat genotypes evaluated in the present investigation; 0.55 to 0.91% for root nitrogen concentration (RNC) and 0.17 to 0.32% for shoot nitrogen concentration (SNC). The genotypes ranged in between 1.17 % (Lavett) and 1.74 % (Diamant) for grain nitrogen concentration (GNC; Figure 1).

3.3 Relationships between Different Parameters

A negative correlation was observed between GW and SW (P=0.01), as well as between GW and RW (P=0.002). A negative correlation was also found between GW and GNC (P=0.04). No other significant correlations were found for GNC versus weight and N concentration of the rest of the plant parts. While observing scatter plots after regression analyses of the various analyzed parameters, the investigated genotypes were generally found diverging for all characters. The genotypes APU and Møystad were for example found to have high GW and relatively high GNC (Figure 1). Genotypes with relatively high GW, low RNC and high RW were Auquab and Lavett (Figure 2a). Genotypes with relatively high GNC, low RNC and high RW were Lanor and Saffran (Figure 2b).

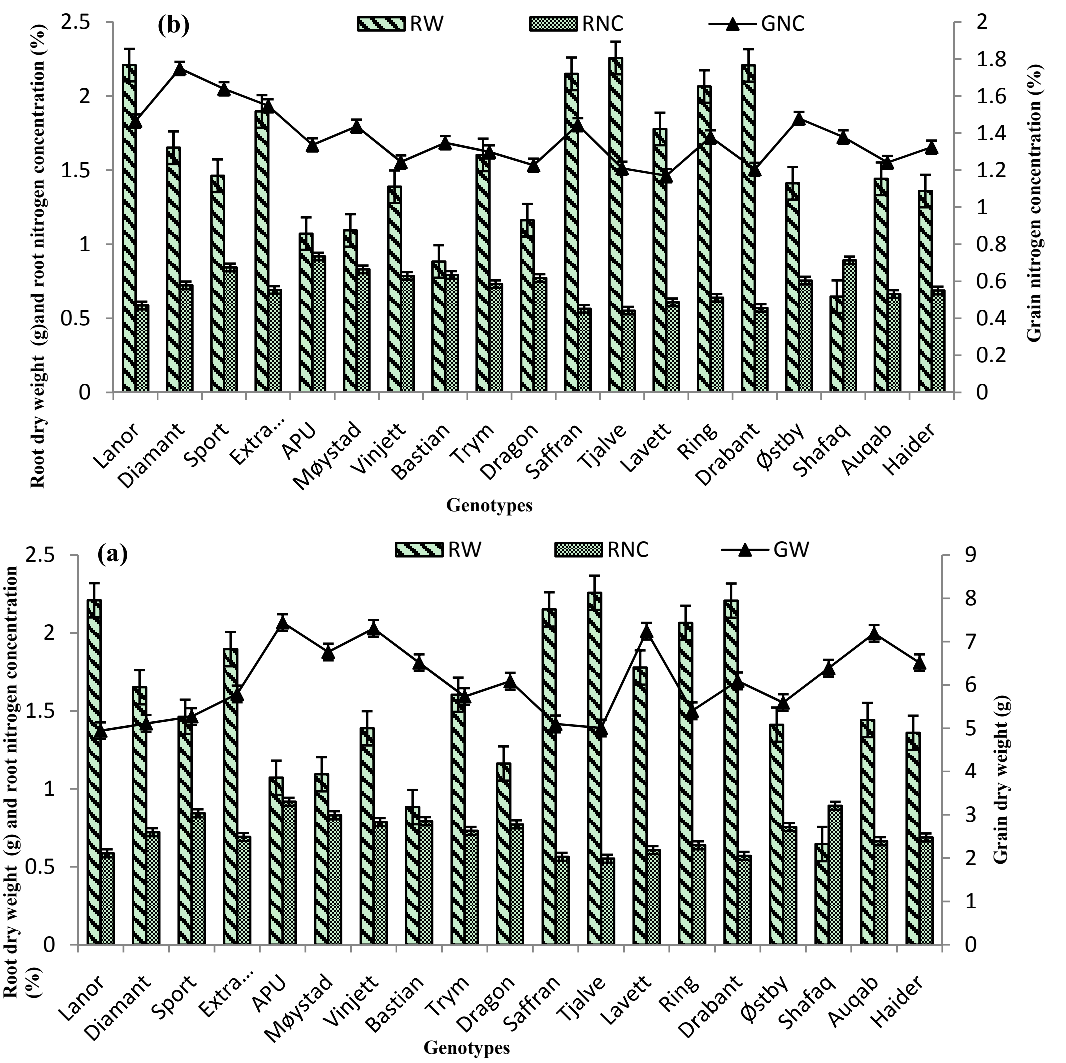

Figure 2. Mean values (a) root dry weight (RW, g), grain dry weight (GW, g) and root nitrogen concentration (RNC, %) (b) Root nitrogen concentration (RNC, %), grain nitrogen concentration (GNC, %) and root dry weight (RW, g) of 19 wheat genotypes, at maturity

4. Discussion

The present study showed highly significant variation among wheat genotypes in relation to GW, SW, and RW as well as of N concentration in the grain i.e. GNC, and other plant parts. For commercial production of wheat, the most interesting characters are grain yield and grain protein concentration (Oury & Godin, 2007). Among the investigated genotypes in this study, the highest GW was observed for the genotype APU which is an old (1949) genotype of Finish origin. Another genotype with high GW was Vinjett which is a rather modern genotype (1998) of Swedish origin. The lowest GW was found for the genotype Lanor which is a tall Norwegian genotype being not too old (1970). For GNC, the highest amount was found for Diamant, an old (1928) Swedish genotype, and Sport, a Swedish genotype bred in 1991 for high grain protein concentration. Lavett, a Swedish wheat genotype bred in 1992 for high gluten strength, was among the genotypes with the lowest GNC. Generally, none of the genotypes with high GW were found amongst those with high GNC. It is also well known from the literature that several authors have reported a negative correlation between yield and grain protein concentration of wheat (Slafer et al., 1990; Jenner et al., 1991; Peterson et al., 1992). Such a negative correlation between yield and grain protein concentration was found also in the present study. Yield is primarily determined by the starch accumulation in the grain. Further, starch and protein accumulation, in the wheat grain, are separate events that are not connected with each other (Jenner et al., 1991). Therefore, one could have expected that the broad genetic variation in the present wheat material should have created options to find genotypes with both high GW and GNC. The investigated wheat genotypes were well scattered regarding GW and GNC relationship. The most promising genotypes in the present study for having both high GW and GNC were APU and Møystad (1971). GW, in the present study, was negatively correlated to the SW and especially to the RW. Previous studies have indicated that large biomass during early growth stages are positively correlated with high yield (Arega et al., 2010). However, the used wheat material, in the present study with large genetic variation, showed that a low biomass below the spike in mature wheat is beneficial for a high yield. A low biomass at harvest might be positively correlated with low biomass at plant development, but it might also be related to a larger transport of sugars from the vegetative parts of the wheat plant to produce starch in the grain. A high starch synthesis in the wheat grain is of relevance for high GW and is dependent on transport of sufficient sugars from the vegetative parts and varies with genotypes (Jenner et al., 1991).

Besides the negative correlation with GW, the GNC did not correlate with any of the other measured parameters. GNC is well known to be related to amounts of late available N during the plant development (Johansson et al., 2004; Malik et al., 2011). In the present investigation, all the genotypes were attributed to the same level during their development, so such differences could not explain differences in GNC among the genotypes. Further, a genetic variation in maturation time has been found to correlate with GNC (Malik et al., 2011). Variation in maturation time might have been present among the investigated genotypes, although maturation time was not recorded in the present investigation. A third variable influencing GNC is the amount of N reallocated from the biomass to the grain, which might vary among the genotypes (Andersson et al., 2005). Reallocation of N from the leaves and stem to the grain was used as a certain breeding criteria when the genotype Sport was bred (Oscarson, 1996). However, in the present investigation the genotype Sport was not found to have very low SNC.

Although, GNC did not correlate to any other of the measured parameters beside GW, some of the other parameters might be of relevance in breeding for high grain yield and protein concentration. A low RW might contribute to a less stable wheat plant in terms of lodging etc. and a smaller root volume might also contribute to fewer options for the plant to reach the important nutrients in the soil for a good development of the crop (Hoad et al., 2001). High RNC is not desirable as it might contribute to N losses from the roots to the soil after harvesting by the mineralization process (Andersson et al., 2005) and i.e. higher N leaching (Riley et al., 2001). In the present study, the genotypes Lanor, Saffran, Auqab and Lavett were of interest due to high GW or GNC combined with low RNC and high RW.

5. Conclusion

A large genetic variation was found among the wheat genotypes for dry weights of plant parts, grain yield and grain protein concentration. The genotypes APU and Møystad were those genotypes in the present investigation which were having the best combination of high yield and high grain protein concentration. Lanor, Saffran, Auqab and Lavett were interesting genotypes combining high GW or GNC with low RNC and high RW. Grain yield was negatively correlated with biomass in the vegetative parts of the mature plant indicating a high sugar transport from vegetative parts to the grain. Grain protein concentration was found to be more related to N availability during plant development than to dry weight or N concentration in various plant parts.

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