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RESEARCH ARTICLE

Effect of Source-Sink Manipulation on Photosynthetic Characteristics of Flag Leaf and the Remobilization of Dry Mass and Nitrogen in Vegetative Organs of Wheat

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Abstract

The photosynthetic characteristics of flag leaf and the accumulation and remobilization of pre-anthesis dry mass (DM) and nitrogen (N) in vegetable organs in nine wheat cultivars under different source-sink manipulation treatments including defoliation (DF), spike shading (SS) and half spikelets removal (SR) were investigated. Results showed that the SS treatment increased the photosynthetic rate (P_n) of flag leaf in source limited cultivar, but had no significant effect on sink limited cultivar. The SR treatment decreased the P_n of flag leaf. Grain DM accumulation was limited by source in some cultivars, in other cultivars, it was limited by sink. Grain N accumulation was mainly limited by source supply. The contribution of pre-anthesis dry mass to grain yield from high to low was stem, leaf and chaff, while the contribution of pre-anthesis N to grain N from high to low was leaf, stem and chaff. Cultivars S7221 and TA9818 can increase the contribution of remobilization of DM and N to grain at the maximum ratio under reducing source treatments, which may be the major reason for these cultivars having lower decrease in grain yield and N content under reducing source treatments.

Key words: genotypic variation, remobilization of pre-anthesis dry mass and nitrogen, source-sink treatment, wheat

INTRODUCTION

Grain growth in wheat is supported by photosynthetic activities of leaves and non-leaf organs (ear, inter-node and sheath) (Singal *et al*. 1986) and by remobilization of reserves stored in the stem and other parts (Pheloung and Siddique 1991). Whereas most of the carbohydrates are provided by current photosynthesis (Wardlaw 1990), the major fraction of grain nitrogen (N) is derived by mobilization of N accumulated before anthesis in vegetative organs (Cartelle *et al*. 2006). It was reported that over 80% of the final N content is presented in plants at anthesis (Papakosta and Gagianas 1991) and N accumulated before anthesis in winter wheat account for as much as 75-90% of the final grain N content (Cox *et al*. 1985; Heitholt *et al*. 1990). The extent of N accumulation is determined by the relationships between the uptake capacity of the plants and the amount of remobilized N (Fageria and Baligar 2005). The remobilization of carbohydrates and N to grain during the grain filling period depends on genotype, environment, planting date, planting density, nutrients, and water supply.

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Manipulation of source and sink relationships in wheat is used to identify physiological traits suitable for genetic selection and modification of grain yield, which is limited by the source strength, the sink capacity or both (Borrás *et al*. 2004). Sink manipulation experiments performed in winter wheat suggested that grain size is mostly sink-limited under non-limiting growing conditions (Jenner *et al*. 1991; Slafer and Savin 1994; Borrás *et al*. 2004; Cartelle *et al*. 2006). However, in rainfed environments grain size often increases in response to a sink reduction treatment (Blum *et al*. 1988), which is interpreted as the result of a source limitation for grain growth. Defoliation after anthesis resulted in the reduction of the C and N supply, which finally led to a decrease in single grain weight and grain number (Ma *et al*. 1996; Zhang *et al*. 2012). This is also an example of source limitation for grain growth. Different cultivars may have different responses to source and sink manipulation. Currently, the effects of source and sink manipulation on the remobilization of dry mass (DM) and N in vegetative organs and the photosynthetic characteristics of flag leaf in different wheat cultivars have not been well understood.

We think source and sink manipulation may first affect the remobilization of DM and N in vegetative organs and the photosynthetic characteristics of flag leaf and then affect grain yield and N content. So, the objective of this study was to investigate (1) the cultivar differences of DM and N remobilization under different sources and sink treatments; (2) the effect of source and sink manipulation on the photosynthetic rate and chlorophyll content of flag leaf during grain filling.

RESULTS AND DISCUSSION

Effect of source and sink manipulation on final grain yield, grain number per ear and single grain weight in different cultivars

There was significant difference among cultivars in grain yield, grain number and single grain weight. In the control, grain yield per ear varied from 1.0 (YN15) to 1.8 g (W62036), grain number per ear changed from 26.0 (DF611) to 36.9 (W62036) and single grain weight varied from 34.6 (YN15) to 49.0 mg (W62036) (Fig. 1).

The reducing source treatments (defoliation (DF) and spike shading (SS)) significantly decreased grain yield and single grain weight in all cultivars (Fig. 1), compared to the control. The decrease in grain yield was mainly due to the decrease in single grain weight, because there was no significant difference in grain number per ear between SS or DF and CK. In the SS treatment, grain yield decreased by 3.3 to 34.2%, and the higher decrease occurred in DF611 and TA9818, the lower decrease occurred in W62036 and HN341. In the DF treatment, grain yield decreased by 19.4 to 47.3%, and the higher decrease occurred in JN17, YN15 and SJZ8, the lower decrease occurred in DF611 and W62036. Previous studies showed that defoliation after anthesis resulted in the reduction of the carbon and nitrogen supply (Fischer and HilleRisLambers 1978; Guitman *et al*. 1991), which finally led to a decrease in single grain weight and grain number (Smimmons *et al*. 1982). However, in this study, defoliation didn't affect grain number (Fig. 1).

According to the decreased extent of grain yield in DF and SS treatments, the nine cultivars can be classified into two groups. JN17, YN15, W62036, and SJZ8 belonged to the group that the contribution of leaf photosynthesis was significantly higher than ear photosynthesis. For these cultivars, it needed to delay the senescence of leaf to further increase grain yield. DF611, S7221, GY503, TA9818, and HN341 belonged to the group that the contribution of ear photosynthesis to grain yield was comparable to leaf photosynthesis. For these cultivars, increasing the ear photosynthetic area by increasing ear density may be a good way to further improve grain yield.

In the reducing spikelets removal (SR), grain number per ear decreased by 44.4 to 55.3% (ave. 49.5%), grain yield decreased by 38.9 to 62.6% (ave. 47.8%), compared to the control (Fig. 1). In JN17, DF611, GY503, TA9818, HN341, and SJZ8, the decreased extent of grain yield was lower than that of grain number, which was due to the compensatory increase of single grain weight in these cultivars. In YN15, S7221 and W62036, there is no increase in single grain weight. According to the previous report, after increased source/sink ratio by removing spikelets, those grains that had an increase in weight were considered source limited, while those that had no increase in weight were considered sink limited (Fischer and HilleRisLambers 1978; Ma *et al*. 1996). In this study, JN17, DF611, GY503, TA9818, HN341, and