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Siberian wildrye seed yield limited by assimilate source

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ABSTRACT

Siberian wildrye (*Elymus sibiricus* L.) is a cool-season, perennial bunchgrass widely used to increase forage production of semi-arid grasslands and to restore degraded lands. It is drought and cold tolerant, and has high yield potential and livestock acceptability. However, seed yield is low and variable and there is little information on the physiological processes limiting its seed yield. A split plot experiment was conducted to determine the effect of source-sink treatments under different nitrogen (N) applications on seed weight, seed setting rate, and dry matter and N remobilization during three successive growing seasons. The main plots were N level (0, 90, 180 kg N ha^{-1}) and sub plots were source sink treatments (half trimmed and unaltered spikes). Leaf, stem, and spike dry weights and N concentration were measured at anthesis and seed physiological maturity, while seed weight and seed setting rate were measured at seed physiological maturity and milk stage respectively. Stem and spike dry weights were increased, whereas leaf dry weight was decreased between anthesis and maturity. N application significantly increased all plant parts of Siberian wildrye dry weight and seed weight compared with 0 kg N ha^{-1} application. The half-spike treatment increased seed weight and seed setting rate across all N levels, and stem dry weight accumulation, but there was no significant influence on N translocation. The results of this study indicate that Siberian wildrye seed yield is source limited since seed weight and seed setting rate were increased in the half-spike treatment with N application. Stem dry weight increased after anthesis suggesting that stems were sinks and competed for assimilates with spikes. Therefore, breeding for increased photosynthesis and partitioning of assimilates from stems to spikes may result in increased and more consistent seed yield.

1. Introduction

Siberian wildrye (*Elymus sibiricus* L.) is one of the most globally important perennial bunchgrass species. It is native to alpine areas of China and widely distributed in Europe, Asia, and North America (Klebesadel, 1969). Due to its drought resistance, cold tolerance, high yield potential, and livestock palatability (Mao et al., 2003), it is used to increase forage production of semi-arid grasslands (rangelands) and to restore degraded lands. However, seed yield of Siberian wildrye is low and variable (Yu et al., 2011; Zhao et al., 2012), only about 20% of its potential is obtained even in suitable conditions (Han et al., 2013). Seed development and subsequent yield may be limited by the availability of substrate (source-limited) or by the capacity of the spikelets to utilize available substrate for seed growth (sink-limited) (Patrick, 1998; Cruz-Aguado et al., 1999; Ahmadi et al., 2009).

Field experiments used to determine if seed growth is source- or sink-limited have shown variable results. Acreche and Slafer (2009) found that seed yield of the modern wheat cultivar ‘ID-2151’ was sink-limited during the seed filling period. Average seed weight was significantly increased by trimming half of the spikelets during anthesis, doubling the availability of assimilates per spikelet. In contrast, Ahmadi et al. (2009) reported that partial defoliation did not increase seed weight significantly and proposed that grain yield of the wheat cultivar ‘Ghods’ was more controlled by sink strength than source strength. Subsequent experiments conducted with various wheat cultivars (Pedro et al., 2011; Foulkes et al., 2011; Serrago et al., 2013) showing inconsistent results suggest that the relative limitation of yield by source or sink needs to be further investigated.

Stems of forage seed crops serve a variable source-sink role in the seed developmental proccess depending on phenological stage and growing conditions. During early stages of seed growth, stems are a stronger sink than seeds. Later in development, seeds are a stronger sink

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(Griffith, 1992). At the mature seed development stage, stems once again accumulate more assimilates than seeds (Trethewey and Rolston, 2009); as much as 70% of the labelled ^{13}C fixed during anthesis is translocated to stems (Warringa and Marinissen, 1997). When the assimilate source is reduced by shading (Warringa and Marinissen, 1996), defoliation (Griffith, 1992), or lodging (Griffith, 2000), stems will partition more assimilate to seeds. If the source is greatly reduced, seed set will be reduced (Griffith, 1992). Although Guitman et al. (1991) reported dry matter and N remobilization changes due to source:sink ratios for seed growth in wheat, there is little information on these relationships in forage seed crops.

The aim of this study was to determine responsiveness of seed development, dry matter accumulation, and N remobilization to increased assimilate source in Siberian wildrye grown with three N levels.

2. Materials and methods

2.1. Experimental site

The field experiment was conducted at the Grassland Research Station of China Agricultural University located at the Yuershan farm in Hebei Province, China (41°44′ N, 116°8′ E; 1455 m elevation) during the 2013, 2014, and 2015 growing seasons. There was 46.5 mg kg^{-1} available N, 1.3 mg kg^{1} available phosphorus (P), and 60.3 mg kg^{-1} available potassium (K) in the soil (0–30 cm) before sowing. Weather data (maximum and minimum temperatures and precipitation) were recorded daily at the experimental site and reported as mean monthly values for the growing season (Fig. 1). Highest rainfall occurred in July of 2013 and 2015 and June in 2014. At this location, July is the typical period of the early seed development stage (Zadoks growth stages (GS) 69–85; Zadoks et al., 1974). Average monthly temperature varied little across years with highest temperatures observed in July each year.

2.2. Treatments and experimental design

The experiment was arranged in a completely randomized split-plot design with four blocks where N applications were main plots and source sink treatments were the sub-plots. The experimental unit was the 18 m^2 (3 × 6 m) sub-plot. Seeds were sown in rows 0.30 m apart on July 9, 2012 at a rate of 33 kg ha^{-1} (purity 96.8% and germination 71%). At sowing, 60 kg ha^{-1} P_2O_5 was applied as superphosphate. Plots were hand weeded when their height exceeded that of Siberian wildrye prior to heading stage. No pesticides were applied due to low incidence of diseases and no evidence of insect damage.

The N treatments [0,90, and 180 kg N ha^{-1}] were imposed in 2013, 2014, and 2015 at the tillering stage (GS 21). N fertilizer (urea, 46% N) was applied in a furrow (4–5 cm) between the rows and covered immediately with soil. After N application, plots were irrigated (60 mm), after which no further supplemental irrigation was provided.

The source-sink manipulation treatments consisted of a control and a treatment that increased the source:sink ratio. At anthesis (GS 65–69), all spikelets from the upper half of the spike were excised to create half spikes (T) as the increased source treatment, while the unaltered spikes served as the whole spike checks (CK; Fig. 2; Acreche and Slafer, 2009).

Fig. 2. Photograph of trimmed and unaltered spikes of Siberian wildrye: (A) half spike; (B) whole spike.

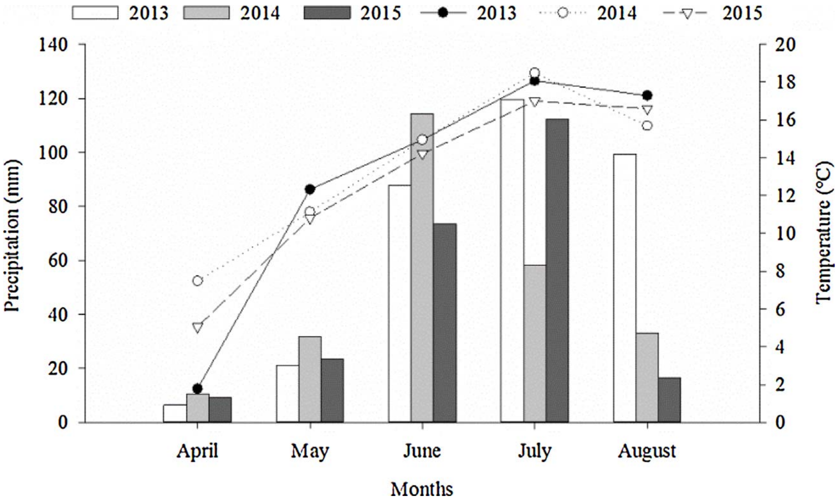

Fig. 1. Monthly means of precipitation (mm) and temperature (°C) for the 2013, 2014, and 2015 growing seasons at the experimental site: Yuershan, Hebei Province. Bars designate precipitation and lines designate temperature.

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