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Source-Sink Manipulation and Its Impacts on Canola Seed Filling Period

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Summary
Canola yield production is driven by the balance between source (leaves) and sink (pods and seeds) activity during the reproductive period of a crop. However, previous literature has not reported the impact of source-sink limitations under different nitrogen (N) supplies, and its effect on seed filling. Therefore, the objectives of this study were to 1) explore the impact of source-sink manipulations during the seed filling period and its main parameters: duration and rate; and 2) understand the interactions between N supply and source-sink manipulations to explain variations in seed weight. With these objectives, a field experiment was conducted during 2019–2020 and 2020–2021 (Kansas, U.S.). One winter canola hybrid was tested under two N fertilization levels (0 and 134 lb/a), and three source-sink modifications (control; reduced sink, 50% pod removal at pod setting; and reduced source, 100% defoliation at pod setting). The reduced sink treatment resulted in a larger seed weight relative to the control. The duration of seed filling was longer for the control relative to the rest of the treatments. Even though no significant differences were found with different N fertilization, the highest seed weight values were obtained with the high N level (134 lb/a).

Introduction
Canola's (*Brassica napus* L.) planted area has grown in the United States from 155,000 to 1,824,000 acres for the 1991–2021 period (USDA-ERS, 2021). Due to its heart-healthy attributes (Lin et al., 2013) and industrial uses, canola demand is increasing. Canola oil produces one of the healthiest cooking oils due to its low saturated fat, high omega-3 fatty acid content (www.uscanola.com). In addition, canola is used as feedstock for biodiesel, renewable diesel, and jet biofuel (www.uscanola.com).

Canola offers several benefits for agricultural systems as well. One advantage is that it helps break pest and disease cycles when introduced in crop rotation systems where cereal is the main crop (Bushong et al., 2012). Additionally, the strong demand for this crop in the U.S. domestic market, which far outpaces the supply, emphasizes the relevance of its research.

To ensure optimal yield production of canola, it is important to consider the balance between source and sink activity. Source activity refers to the production of assimilates by the photosynthetic organs, while sink activity is the utilization of these assimilates by the seeds (Egli, 1998). Therefore, a comprehensive understanding of the source-sink relationship is essential for maximizing crop productivity. However, there is a clear knowledge gap in understanding the impact of source-sink limitations with different nitrogen (N) supplies for winter canola in the Great Plains region of the United States, and its impact on the seed filling period. The objectives of this study were to 1) explore the impact of source-sink manipulations during the seed filling period (SFP) and its main parameters: seed filling duration (SFD) and seed filling rate (SFR); and 2) understand the interactions between N supply and source-sink manipulations to explain seed weight variations.

Procedures

Sites and Measurements

Field experiments were conducted during 2019–2020 (North Agronomy Farm, Manhattan, KS) and 2020–2021 (Ashland Bottoms Research Farm, Manhattan, KS). The experimental design was a randomized complete block design (RCDB) with three replications. Factors and levels tested were 1) two N fertilization levels (0 and 134 lb/a), and 2) three source-sink manipulations: control, reduced sink (50% pod removal at pod setting), and reduced source (100% defoliation at pod setting). Plot size was 5 feet wide by 25 feet long and 10 inches of row spacing. A winter canola hybrid, Pioneer 46W94 (Johnston, IA, U.S.), was sown at a seeding rate of 3 lb/a.

During the vegetative stage, plants were divided into leaves and stem organs, and during the reproductive period, the same vegetative components, plus flowers (when available), pods, and seeds (seeds individualized during seed filling measurements). Three weeks after flowering the sampling started and continued in weekly intervals until the beginning of ripening. After that the sampling was performed twice per week. At all sampling times, the proportion of the pod and the rest of the plant was estimated to calculate the reproductive partition of the plant during the SFP.

During harvest, yield and its components (number of seeds, seed weight, and harvest index) and the number of branches per plant in each treatment as well as pods on the main stem versus branches were determined.

At each sampling, three consecutive plants were harvested. For each of these plants, one pod was sampled from the top, middle, and bottom of the main stem (9 pods in total). For each plant, one branch was selected to retrieve one pod from the bottom and one pod from the upper section (6 pods total). The seeds from both the main stem and branches were weighed and counted, values were averaged, and results expressed in weight per seed.

Results

The analysis of variance showed significant differences in grain weight for the source-sink manipulation treatments. No significant differences were found for the N fertilization treatment nor for the interactions between these variables. The control treatment had significantly lower grain weight than the reduced sink treatment. The control and the reduced source treatment did not present significant differences (Table 1).

Figures 1a and 1b show the values of maximum seed weight and effective seed filling duration (SFD) and rate (SFR) for the different source-sink manipulation treatments and two levels of N (0 and 134 lb/a). The maximum weight (maxW) was obtained with the reduced sink treatment (3.95 mg/seed), in which 50% of the pods were removed at the beginning of the pod formation stage (Figure 1a; 1b). The control treatment presented an intermediate maxW (3.45 mg/seed) and the reduced source treatment had the lowest maxW (3.36 mg/seed), all under the high N fertilizer rate level. The SFD was longest for the control treatment, intermediate for the reduced sink treatment, and shortest for the reduced source treatment. The control treatment exhibited the lowest SFR, as depicted in Figure 1a and 1b. However, these results revealed a compensatory relationship between SFD and SFR (Figure 1a). Treatments characterized by shorter SFD displayed higher rates, whereas those with extended SFD values showed a lower SFR.

Conclusion

The evaluated treatments showed that source-sink changes affected grain weight, seed fill duration, and seed fill rate. The maximum weight (maxW) was obtained with the reduced sink treatment, followed by the control treatment and the source treatment, in all cases under the high N rate level. The control treatment had the longest effective SFD and the lowest SFR. For both the reduced sink and source treatments, SFD and SFR compensated each other, with long SFD and shorter SFR. In this work, N fertilization did not show changes in seed weight or interaction with the treatments analyzed. Nonetheless, future research is needed to further explore these interactions and their overall impacts on final seed yield at farm scale.

Acknowledgments

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Table 1. Analysis of variance for grain weight

Treatment	Chi squared	DF	*P*-value
Source-sink manipulation (SS)	2276	3	***
N fertilization treatment (NF)	0.66	1	ns
SS × NF	0.22	2	ns

Treatment	Mean, mg/seed	SE	Group
Sink	2.7	0.09	A
Source	2.5	0.09	AB
Control	2.2	0.09	B

*** *P*-value < 0.001
ns = not significant.
DF = degree of freedom.
SE = standard error.

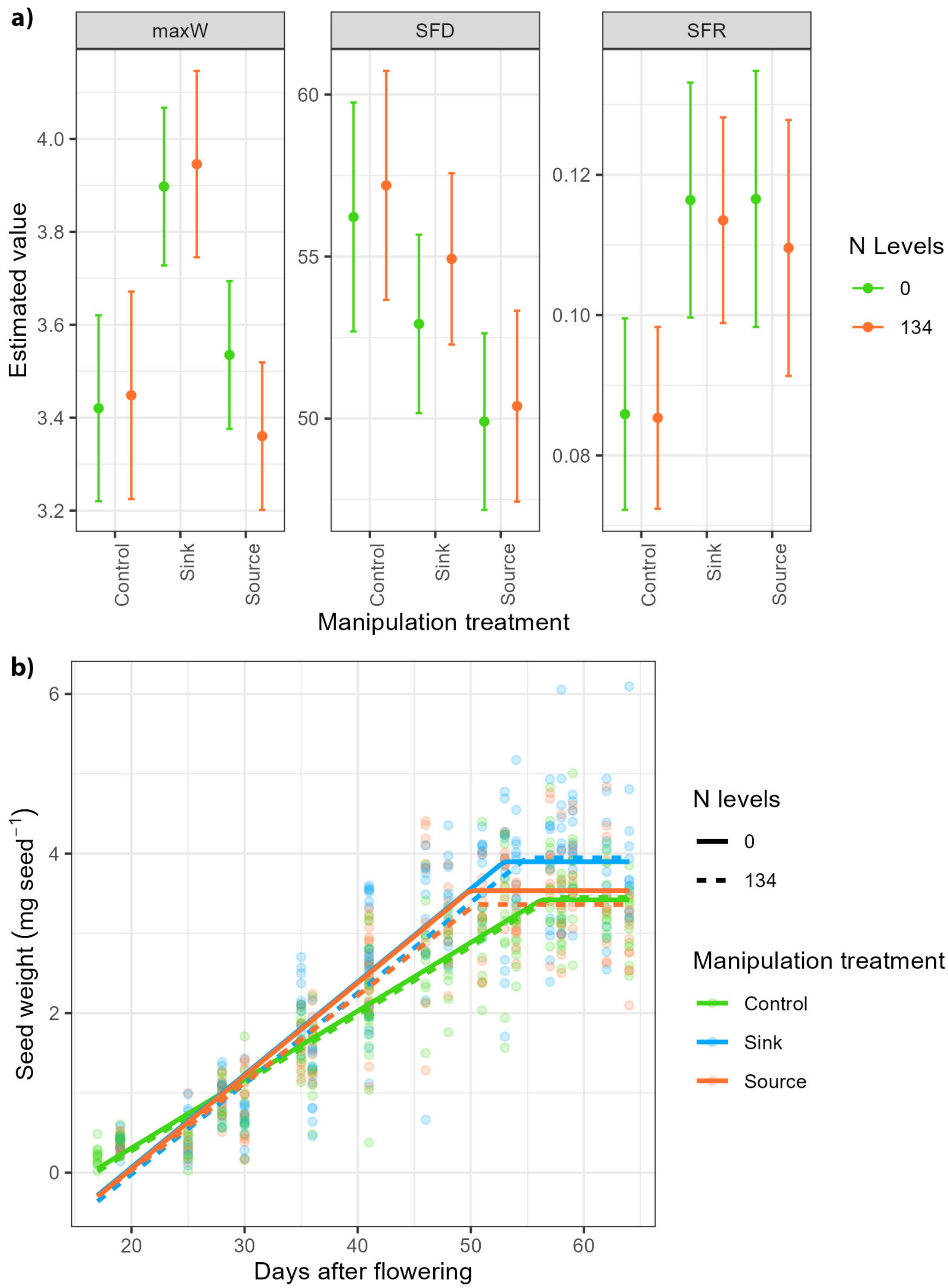

Figure 1. a) Values of maximum seed weight (in mg/seed), effective duration (SFD, in days) and rate (SFR, mg seed day^{-1}), for the different treatments analyzed (control, sink, and source) and two levels of N (0 and 134 lb/a). b) Seed weight per day after flowering for the different treatments analyzed (control, sink, and source) and two levels of N (0 and 134 lb/a).