Plant breeding to increase productivity of organic wheat: Results from the Glenlea long-term study

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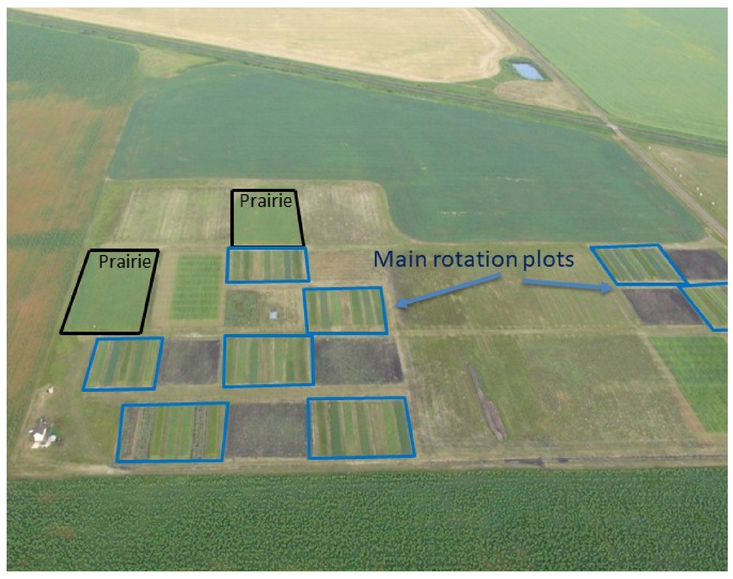
INTRODUCTION AND METHODS

The Glenlea rotation is Canada's oldest organic vs conventional comparison study, started in 1992. The experiment includes two crop rotations, an annual grain rotation (wheat-flax-oat-soybean or green manure in organic) and a perennial hay-grain rotation (alfalfa-alfalfa-wheat-flax). Two interventions in the organic systems are: perennial plots were split in 2007 with half the plots receiving manure to replenish soil P stocks; and the annual plots were split between 2015 and 2020 to insert a 5-year alfalfa crop to increase soil N status and control weeds. From 1992 to 2020, a common wheat cultivar was used in the organic and conventional plots. Details of rotation and input management are provided in Carkner et al. (2020).

Annual rotation: wheat - flax - oats- soybean (green manure)

Perennial rotation: wheat - flax- alfalfa- alfalfa



Breeding spring wheat for organic production started in Manitoba in 2004 (Kirk et al. 2012). In 2011, farmers were invited to participate in the organic wheat breeding process. F_3 populations from the AAFC Cereal Research Centre were made available to the farmers who selected on their organic farms for 3 consecutive years (F_3 to F_6). Yield testing showed that some of the farmer lines performed better than conventionally bred lines when grown under organic conditions, both in terms of grain yield and fusarium tolerance (Entz et al. 2018). Given this, one of the farmer selections (a cross between BW433 and BW430) has been grown in the organic plots at Glenlea since 2021. This "organic line" averaged 100 cm in height (compared with 82 for AAC Brandon) and was 1 day later in maturity (Entz et al. 2018).

Between 2021 and 2023, the farmer selected "organic" wheat line was grown in the organic plots while AAC Brandon (2021 and 2022) and AAC Starbuck (2023) were grown in conventional plots. We hypothesized that the organic line will result in less yield loss compared with conventional wheat plots that use a conventionally bred cultivar. This hypothesis was tested by calculating the "yield loss due to organic" for two time periods: 1) 2011-2021, when a common conventional cultivar (AAC Brandon) was used in organic and conventional plots and 2) 2021-2023, when an organic line was used in the organic plots and a conventional cultivar was used in the conventionally-managed plots. Note: Conventional wheat received typical crop input but no foliar fungicide was applied.

RESULTS

The average yields for all wheat treatments are shown in Table 1. Higher average yields during the 2011 to 2020 period were attributed to better growing conditions. Time period two (2021-2023) was characterized by extreme droughts in 2021 and 2023 and excess spring precipitation in 2022 (Fig. 1) which delayed spring planting and reduced yield potential.

Wheat grain yield and wheat aboveground biomass "losses due to organic" production are shown in Fig. 2 and 3. In the annual rotation, yield loss due to organic was similar for the two time periods. Therefore, there appeared to be no advantage of using the organic line. However, where the annual organic rotation was "improved", through a 5-year alfalfa crop, yield loss due to organic was reduced.

In the perennial rotation, yield and aboveground biomass loss due to organic was much less where the organic line was used (time period two) (Fig. 2 and 3). The positive effect of the organic line to lessen the yield loss from organic was especially noticeable where manure has been added to the perennial rotation; in this case there was virtually no yield loss from organic production.

	Yield (kg ha^{-1})		Crop Biomass (kg ha^{-1})	
Rotation	2011-2020	2021-2023	2011-2020	2021-2023
Annual Conventional	2788 a	2051 a	7419 a	4356 a
Annual Organic	1924 ab	1128 a	6014 a	3253 a
Annual Organic After Alfalfa	1804 ab	1419 a	5682 ab	4512 a
Perennial Conventional	2570 a	1675 a	7017 ab	4650 a
Perennial Organic +Manure	1864 ab	1621 a	6109 ab	4713 a
Perennial Organic -Manure	1117 b	1064 a	3870 b	3346 a

Table 1: Crop yield and crop biomass for all treatments. 2011-2020 has the same wheat variety in organic and conventional. 2021-2023 has an organically bred variety in the organic plots and a conventional variety in the conventional plots.

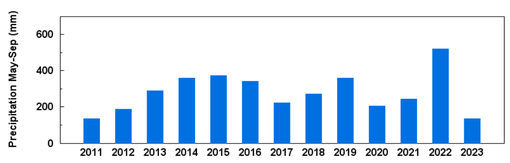
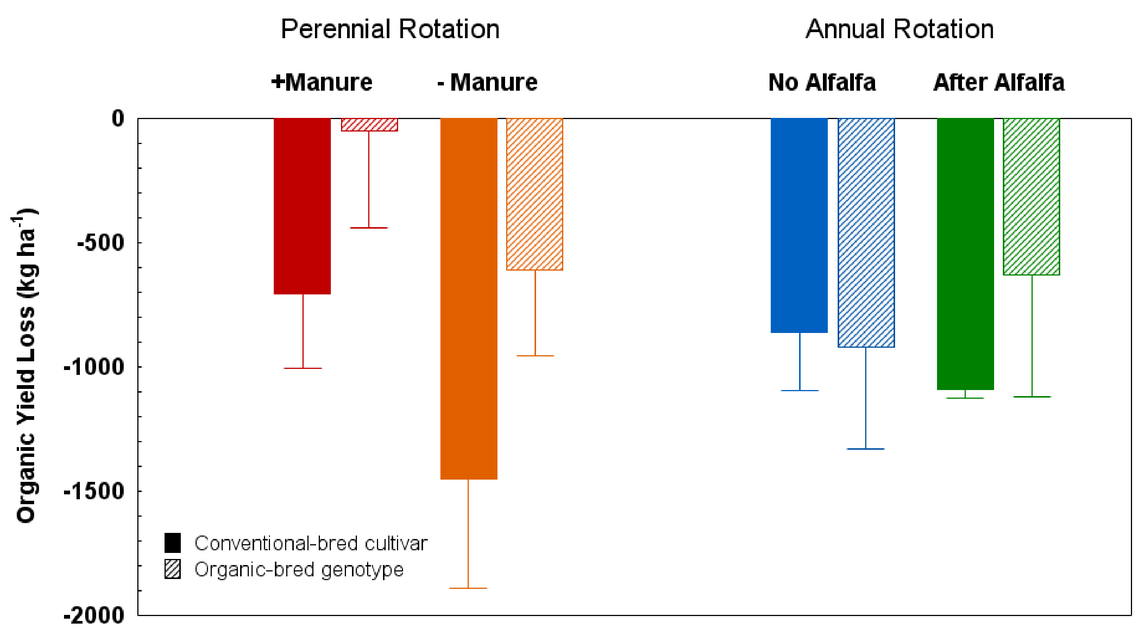


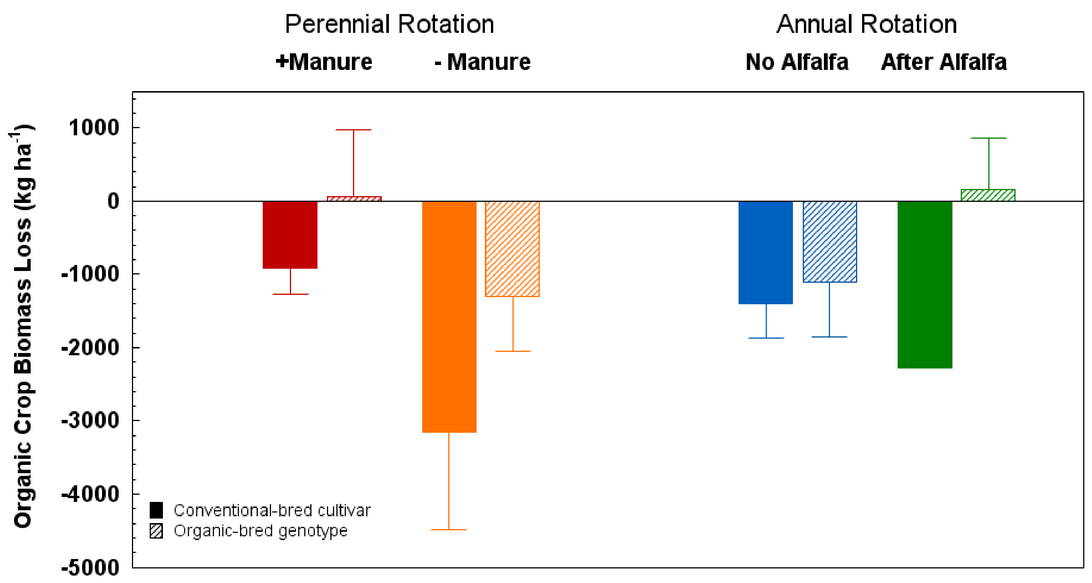
Fig. 1. Total precipitation from April to September (mm).

PAIRING ORGANIC-BRED GENOTYPE TO ORGANIC PRODUCTION MATTERS:



Organic - Conventional Wheat Yield Loss by Rotation

Fig. 2: Yield loss between conventional and organic management in annual and perennial rotations. A conventional wheat variety was grown in organic and conventional rotations from 2011-2020 (solid) (2019-2020 for annual after alfalfa). From 2021-2023 (dashed) an organic-bred genotype was grown in the organic rotation and a conventional variety was grown in the conventional rotation.



Conventional-Organic Wheat Crop Biomass Loss by Rotation

Fig. 3: Crop biomass loss between organic and conventional management in annual and perennial rotations. A conventional wheat variety was grown in organic and conventional rotations from 2011-2020 (solid) (2019-2020 for annual after alfalfa). From 2021-2023 (dashed) an organic-bred genotype was grown in the organic rotation and a conventional variety grown in the conventional rotation.

DISCUSSION AND CONCLUSIONS

Under the stressful conditions during time period two – the period when the organic plots were seeded to an organically selected wheat line – "yield loss due to organic" depended on the cropping system.

Under conditions of adequate nutrient supply (either from use of manure to eliminate P deficiency in the perennial rotation, or the inclusion of alfalfa to increase N supply in the annual grain rotation), the use of the organically bred line reduced the "yield loss to organic". In the perennial with manure system, there was no yield difference between organic and conventional wheat yields. This result demonstrates the value of breeding programs aimed specifically at organic production.

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