Exploring winter wheat canopy architecture for variety-specific management strategies

Cropping Systems Agronomy
MICHIGAN STATE UNIVERSITY

Project GREEEN

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Introduction

- Genotype and management interactions can be exploited to produce reliable on-farm yield increases in wheat (*Triticum aestivum* L.) and other crops.
- Wheat canopies can be described as either planophile or erectophile. This trait can influence their solar radiation interception, radiation use efficiency (RUE), and eventually yield potential.
- Planophile canopies, owing to more dense and horizontal upper leaves, shade lower leaves in the canopy, which *probably* lowers RUE. Erectophile canopies are slower to reach canopy closure but *probably* have greater RUE once after canopy closure.
- Management strategies that grower employ in their fields can be modified to maximize yield by pairing varietal canopy type with other factors. However, research is lacking in evaluating wheat varieties for their canopy architecture and under management factors such as planting date and seeding rate.
- Timely planting of winter wheat (soon after Hessian fly free date) in Michigan and other northern U.S. states has been shown to maximize yield. Under delayed planting, increasing the seeding rate may help minimize yield penalty but can also lower profits.
- Additionally, inter-plot gap is common in wheat small-plot research including breeding trials. Wheat varieties with differing canopy architecture might differ in yield advantage border rows might be able to accumulate based on these gaps and needs further evaluation.

Objectives

- Evaluate winter wheat varieties for differences in canopy architecture.
- Estimate canopy closure, radiation interception, and RUE differences in planophile vs erectophile canopies under variable management.
- Determine if wheat canopies respond differently to management decisions such as planting date and seeding rate.
- Quantify border effect and evaluate if it is more pronounced in planophile compared to erectophile varieties.

Materials and Methods

- Field trials were conducted at Michigan State University Agronomy Farm in Mason, MI during the 2021-2022 and 2022-2023 growing seasons (Fig. 1).
- Trials were laid out in a split plot design with four replications.
- Main plots. Planting dates (2): end September (September 29), end October (October 24).
- Sub plots. Combination of 2-4 seeding rates (1.98 to 4.94 million seeds ha^{-1}) and 8 varieties. Planophile (4): AgriMAXX 513, Hilliard, DF 121R and Dyna-Gro 9070; Erectophile (4): MCIA Wharf, Branson, ISF 12203 and KWS405).
- Canopeo app was used to measure canopy coverage at around 10 days interval until maximum canopy cover was achieved (Fig. 2).
- Before harvest, Sunscan canopy analysis system was used for measuring radiation interception three time during the season (Fig. 3), plants were harvested in same unique sections (4 rows, 0.5m each) for estimation of RUE.
- To characterize wheat canopies (Fig. 4), a visual rating scale was used initially but was deemed too subjective. Flag leaf angle was measured around anthesis but showed wide variability.
- Tiller angle (Fig. 5) was estimated, by measuring maximum distance between stems at 10 and 30 cm above soil surface.
- Wheat heads were collected from two 1-m section in outside rows (#1 and 6) to measure the border effect due to inter-plot gaps. Rest of plants in these rows were cut and removed.
- Plots were harvested using Kincaid 8-XP plot combine and data on yield, moisture, and test weight were collected.
- Data analysis was conducted in SAS 9.4 using Proc GLIMMIX (alpha = 0.10).

Figure 1. Wheat trial in 2023 with two planting dates.

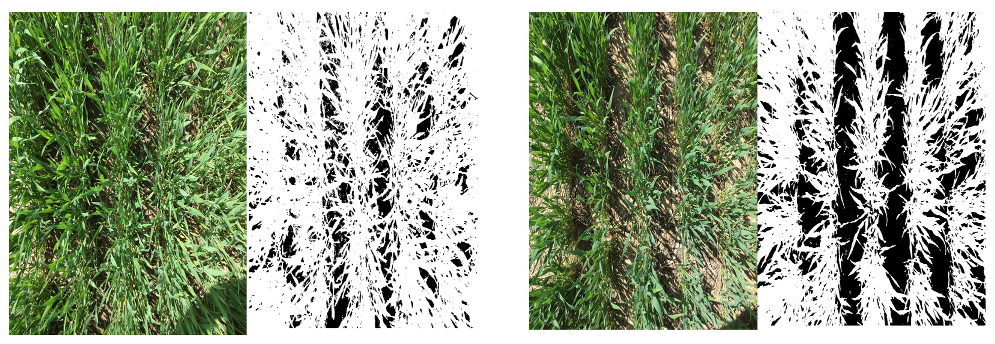

Figure 2. Canopeo app used for canopy cover data in planophile (left, 82%) vs. erectophile (right, 65%) on May 5, 2023.

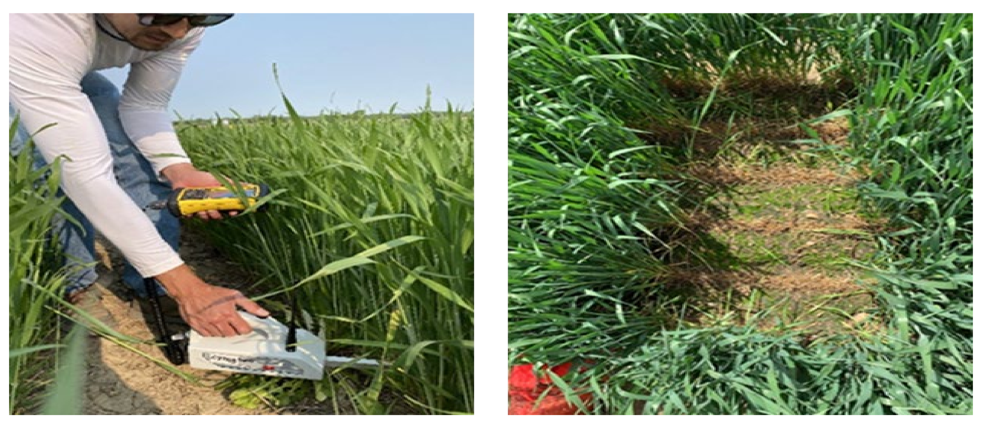

Figure 3. Radiation interception and use efficiency measurements.

Figure 4. Winter wheat canopy (left: planophile, right: erectophile).

Figure 5. Stem distance at 10 and 30 cm from the ground was measured to characterize canopy architecture. Planophile (left), Erectophile (right).

Results and Discussion

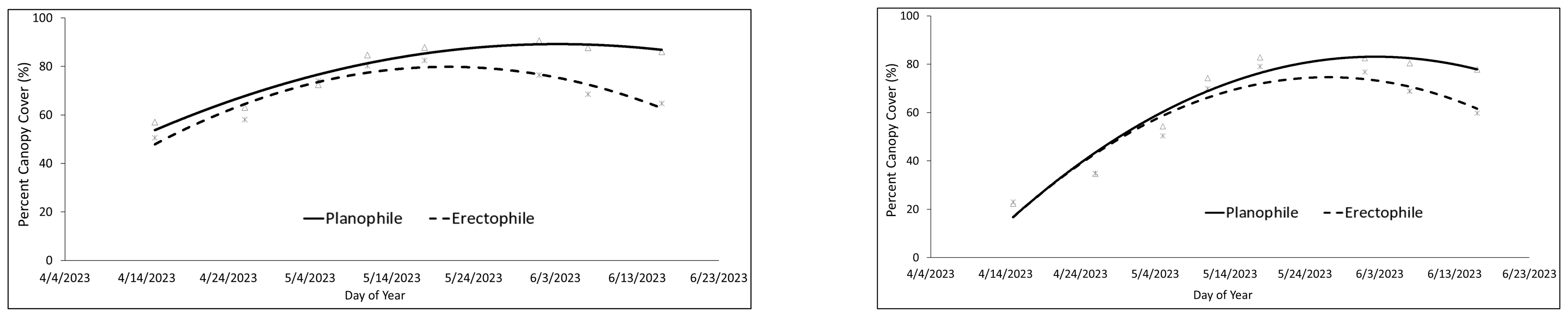

Figure 6. Canopy cover (%) for the two canopy types (averaged over varieties) in early (left panel) and late (right panel) planting date, averaged over both seeding rates.

- Canopy closure was achieved earlier in planophile compared to erectophile varieties in both planting dates (Fig. 6). As expected, erectophile varieties did not reach canopy closure during late planting.
- Earlier and greater canopy cover with planophile varieties can help improve yield potential under lower yield environments (such as delayed planting, wider rows, lower stand).

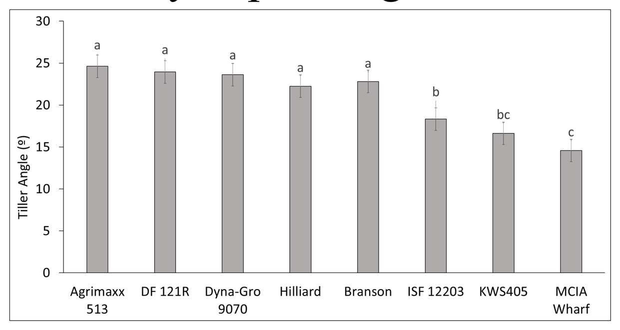

Figure 7. Tiller angle of varieties (left four: planophile; right four: erectophile) used in this research.

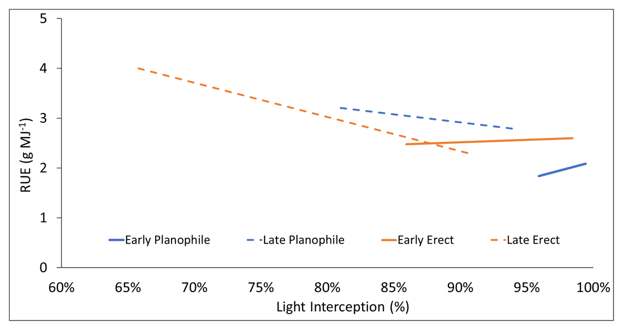

Figure 8. Radiation use efficiency (RUE) vs radiation interception for both canopy types under early and late planting.

- Tiller angle was greater in most planophile varieties compared to erectophile varieties used in this research (Fig. 7). Flag leaf angle was also measured but did not show difference between canopy types.
- Under late planting, planophile varieties had greater radiation interception (Fig. 8). However, erectophile varieties had greater RUE under early planting while achieving high radiation interception. This trait can be beneficial under higher yield environments (such as narrow rows, high fertility).

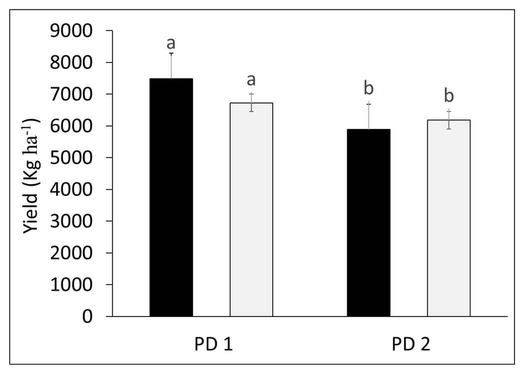

Figure 9. Wheat yield as impacted by planting date (PD1: early; PD2: late). 2022: black bars; 2023: white bars.

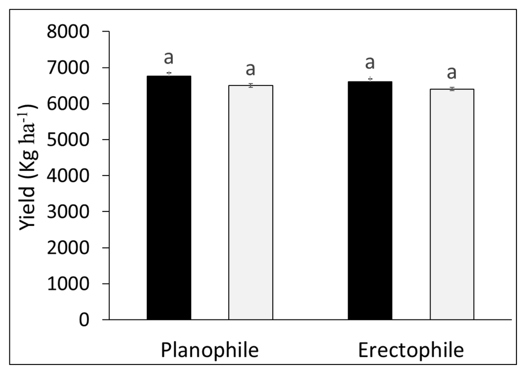

Figure 10. Wheat yield as impacted by canopy type (2022: black bars; 2023: white bars).

- Planting date showed significant impacts on yield (Fig. 9) in both growing seasons, with average decline of 22 kg ha^{-1} day^{-1} across all canopy types and seeding rates. These data shows the importance of timely planting.
- Canopy architecture did not impact yield (Fig. 10) and had minimal interactions with planting date or seeding rate. Continued research on these and other factors is warranted for improved understanding of interactions with canopy type.

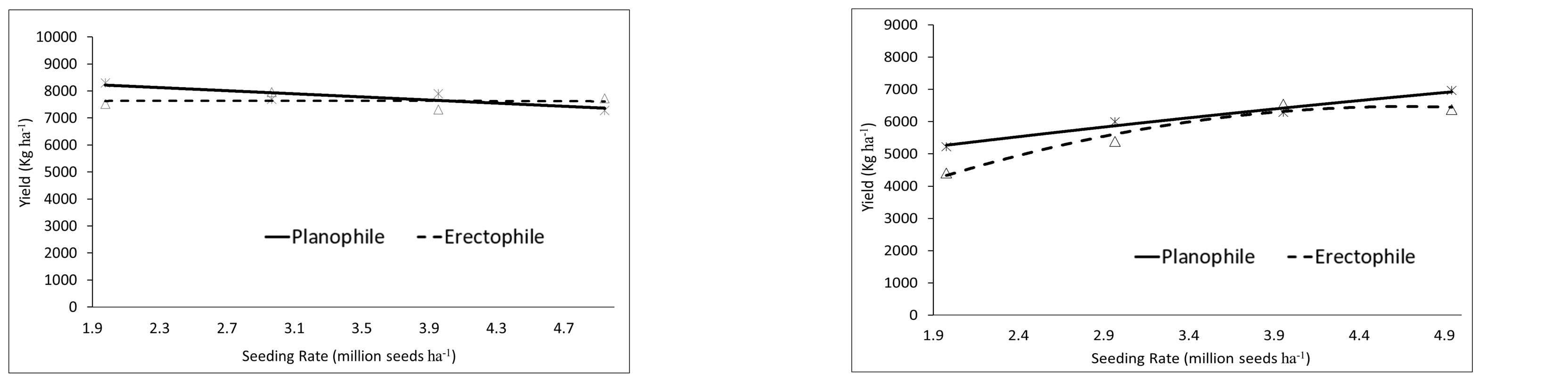

Figure 11. Response of wheat yield to seeding rates (ranging from 1.98 to 4.94 million seeds ha^{-1}) for both canopy types during early (left panel) and late (right panel) planting in 2022.

- Seeding rate response was minimal under early planting (Fig. 11), with erectophiles showing some advantage of higher seeding rate. Planophile varieties showed yield advantage across seeding rates under delayed planting conditions. These data shows the potential of lowering seeding rates in planophiles under early planting.
- Varieties differed in their response to the existence of inter-plot gaps (border effect), common in small-plot wheat research. Planophile varieties took more advantage of these gaps under high yielding conditions, probably by capturing more radiation.
- These data alludes to the presence of bias (artificial yield enhancement) in favor of planophile varieties in wheat breeding programs. Most winter wheat varieties in Michigan are planophiles which can be due to this bias against erectophile varieties and shows the potential need for changes in small-plot breeding research.

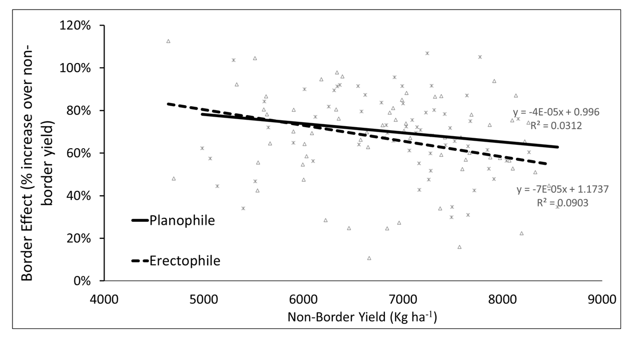

Figure 12. Effect of canopy type and yield potential on inter-plot gap (border effect).

Conclusions and Future Directions

- Planophile varieties had greater tiller angle compared to erectophile varieties, showing differences in wheat canopies.
- Erectophile varieties were slower in reaching canopy closure but showed a greater RUE under high yield environments (e.g., early planting). Planophile varieties had earlier and greater canopy closure and radiation interception, beneficial traits for lower yield environments (e.g., late planting, lower plant stand).
- Canopy architecture showed similar yield potential across environments. Timely planting was most critical for higher yields. Future research need to include other factors (e.g., row spacing).
- Planophile varieties took better advantage of inter-plot gaps, and allude to potential positive bias in breeding programs.
- Overall, benefits of early-season planting might be improved by using erect varieties without pushing for high seeding rates, while profits might be maximized under delayed planting using planophile varieties with higher seeding rates.