Exploring winter wheat canopy architecture for variety-specific management strategies

Cropping Systems Agronomy
MICHIGAN STATE UNIVERSITY

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MICHIGAN WHEAT PROGRAM

Project GREEN

Introduction

- Winter wheat (*Triticum aestivum* L.) varieties differ in canopy architecture, and this trait can influence their solar radiation interception, radiation use efficiency (RUE), and seed yield.
- Management strategies can be modified to maximize yield by pairing varietal canopy with other factors. However, research is lacking in evaluating wheat varieties for their canopy type and performance under different management factors.
- Moreover, varieties with droopy canopies **(Planophiles)** predominate current breeding trials and farmer fields compared to the erect types **(Erectophiles)** (Fig 1).
- Border effect (i.e., inter-plot gaps) in variety trials can impact their performance, with planophiles taking greater advantage than erectophiles, leading to bias for the former.
- Therefore, research in needed in evaluating wheat varieties with differing canopies under similar conditions (e.g., without border effect), and how management factors such as planting dates and seeding rates might impact their performance and yield.

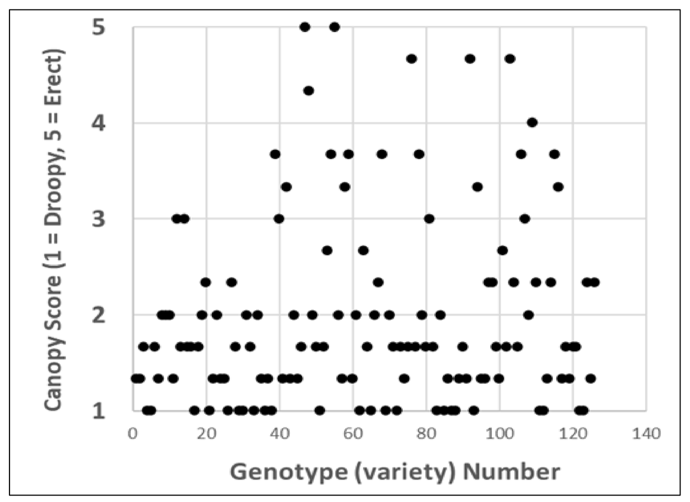


Figure 1. Distribution of canopy types in 2022 Michigan wheat variety trials (Planophile: 1; Erectophile: 5).

Objectives

- Evaluate canopy closure, radiation interception, and radiation use efficiency (RUE) for planophile and erectophile varieties across different planting dates and seeding rates.
- Examine yield difference for two canopy types across planting dates and seeding rate.
- Quantify border effect in planophile vs erectophile varieties across different environments.

Materials and Methods

- Field trials were conducted at Mason, Michigan over three growing seasons (2022 to 2024).
- Trials had two planting dates (late Sept. and late Oct.), two seeding rates (1.98 and 4.94 million seeds^{-1} ha), and eight varieties with two canopy types (planophile and erectophile, 4 in each group).
- Plots were arranged in a randomized complete block with planting dates as main plot factor and seeding rate and varieties as subplot factors with four replications.

Figure 2. Planting dates for wheat trials.

Figure 3. Winter wheat varietal canopy (left: Planophile, right: Erectophile).

Data Collection and Analysis

- Canopy cover (%) was measured at 10 days interval using Canopeo app until maximum canopy cover was achieved (Fig. 4).
- Interception of photosynthetic active radiation within canopy was measured at four layers and three times a year using Sunscan Canopy Analysis system (Fig. 5a).
- Plants biomass was collected from the same unique sections (Fig. 5b) for estimation of RUE, using dry biomass and radiation accumulated between two sampling points.
- To characterize wheat canopies, tiller angle (Fig. 6) was estimated, by measuring maximum distance between stems at 10 and 30 cm above soil surface.
- Wheat heads were collected from two 1-m sections from the border rows (rows 1 and 6) to measure the border effect due to inter-plot gaps (see Fig. 2).
- Border rows were then removed and 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 = 0.1).

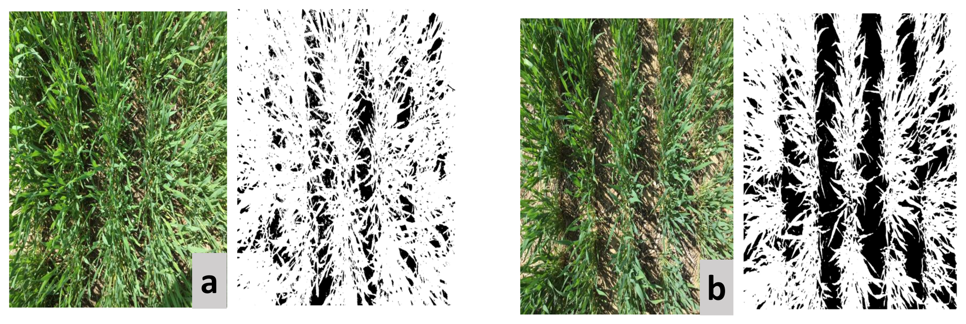


Figure 4. Canopy cover estimation using Canopeo app for (a) planophile variety showing 82% cover, and (b) erectophile variety showing 65% cover.

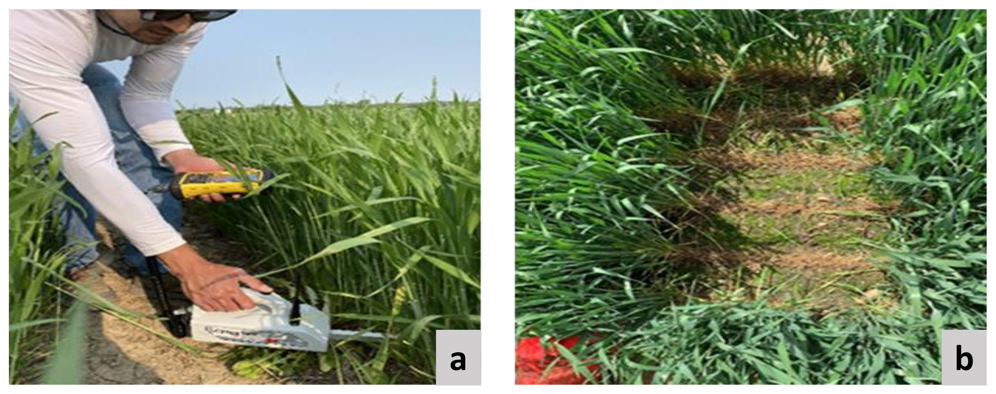


Figure 5. Light interception measurement within canopy (a), and biomass sampling (4 rows, 0.5m each) from the same location (b).

Figure 6. Stem distance at 10 and 30 cm from the ground was measured and converted to tiller angle for the planophile (left) and erectophile (right) varieties.

Results

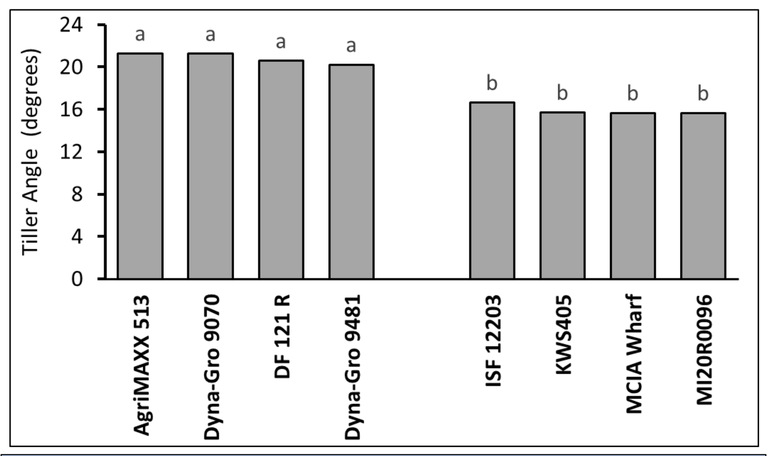


Figure 7. Tiller angle of varieties from 30cm height (left four: Planophile; right four: Erectophile).

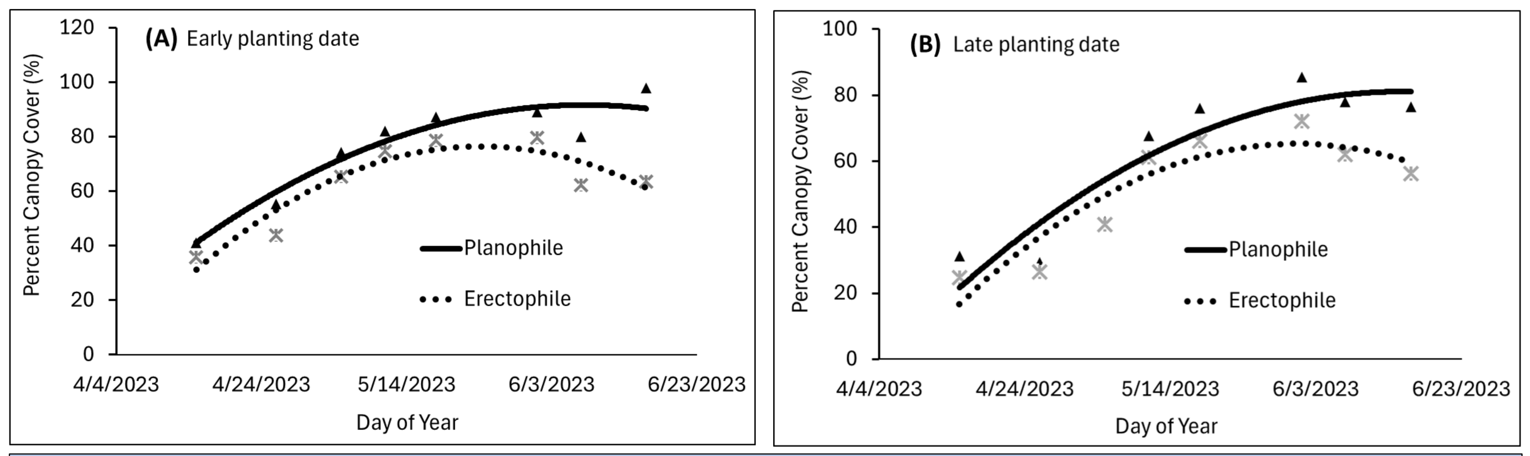


Figure 8. Canopy cover (%) over the growing season for two planting dates; Ealy planting (A) and Late planting date (B) and two canopy types (Planophile vs Erectophile, each averaged over four varieties).

- Tiller angle was greater in all planophile varieties compared to erectophile varieties used in this research (Fig. 7).
- Canopy closure was achieved earlier in planophile compared to erectophile varieties in both planting dates (Fig. 8). As expected, erectophile varieties did not reach canopy closure especially during late planting.
- Earlier and greater canopy cover with planophile varieties can help improve yield potential under environments where light interception is limiting (such as delayed planting, wider rows, lower plant stand).
- Erectophile canopies showed a lower percentage of light interception at the same canopy height compared to planophiles (Fig. 9), indicating that light can penetrate deeper into the lower layers of the canopy. This allows for greater light availability to lower leaves.
- In contrast, planophile canopies had a consistently higher percentage of light interception at all canopy heights, probably due to wider tiller angle and horizontally oriented leaves.

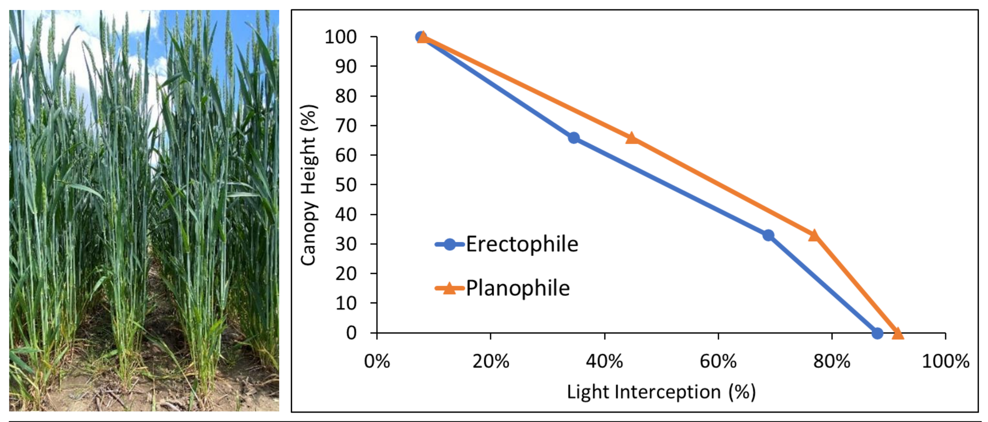
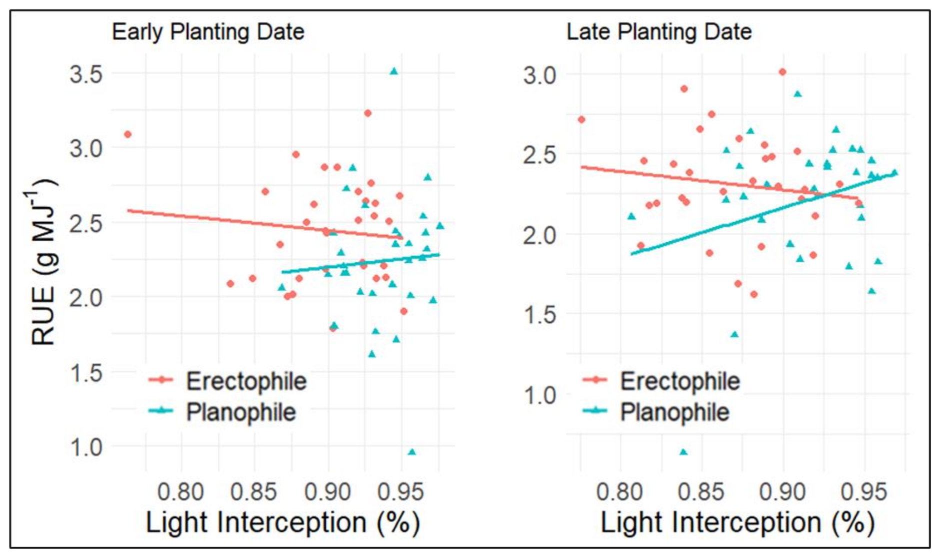


Figure 9. Light interception (%) in different canopy heights.

- However, erectophile varieties had greater RUE under early planting while also achieving high radiation interception (Fig. 10). This trait can be beneficial under higher yield environments (e.g., early planting, narrow rows, intensive management) where shading of lower canopy can lower RUE and potential yield.
- Early planting date significantly improved yield in all growing seasons (Fig. 11). Seeding rates did not impact yield (data not shown).

Figure 10. Radiation use efficiency (RUE) vs radiation interception for the two planting dates and canopy types.



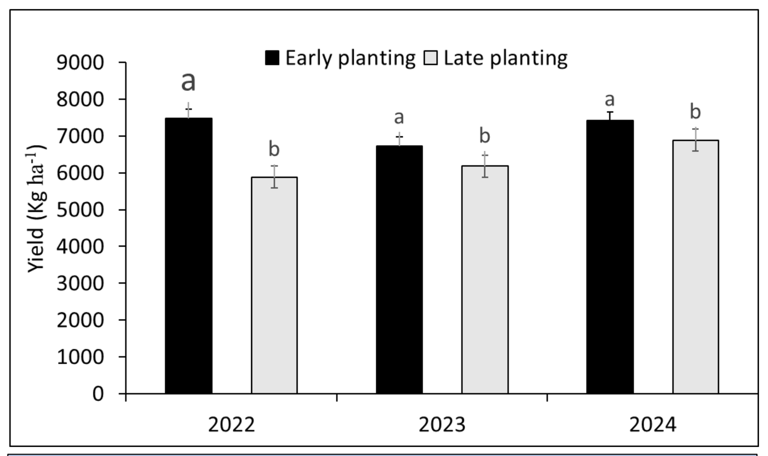


Figure 11. Wheat yield in 2022, 2023 and 2024 growing seasons for two planting dates.

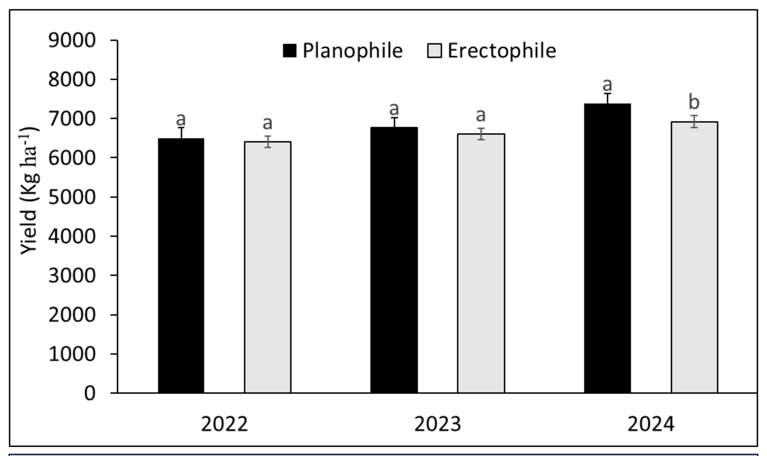


Figure 12. Wheat yield in 2022, 2023 and 2024 growing seasons for two canopy types.

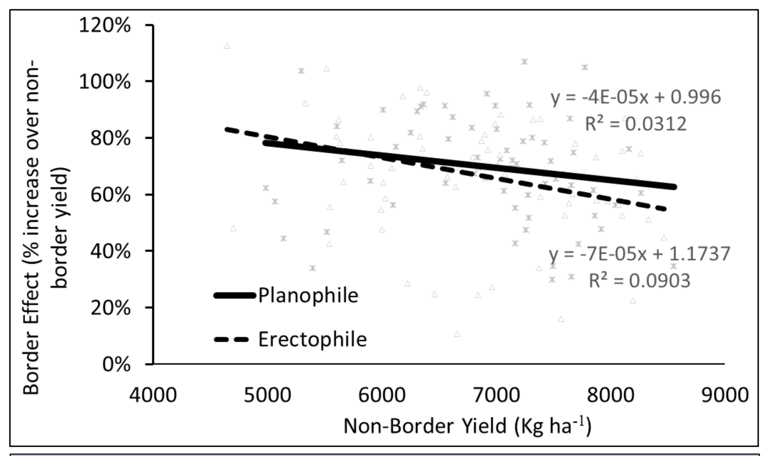


Figure 13. Effect of canopy type and yield potential on the border effect (inter-plot gaps).

- Canopy architecture did not impact yield in the 2022 and 2023 seasons (Fig. 12) and showed minimal interaction with planting date or seeding rate. However, in 2024 season, planophile varieties had 7% greater yield compared to the erectophile varieties.
- Varieties differed in their response to the presence of border effect, common in small-plot wheat research due to inter-plot gaps. Planophile varieties took greater advantage of these gaps under high yielding conditions (Fig. 13), 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 (Fig. 1) which can be due to this bias against erectophile varieties and shows the potential need for changes in small-plot breeding research.

Conclusions and Future Directions

- Planophile varieties had greater tiller angle compared to erectophile varieties, showing differences in wheat varieties.
- Erectophile varieties were slower in reaching canopy closure but showed a greater RUE under high yield environments such as early planting. Planophile varieties had earlier and greater canopy closure, beneficial traits for lower yield environments (e.g., late planting, lower plant stand, wider row spacings).
- Planophile varieties took better advantage of inter-plot gaps and allude to potential positive bias in breeding programs.
- Timely planting was most critical for higher yields in this research while lowering seeding rates did not impact yield. We conclude growers can maximize profits from early-season wheat plantings by using erect varieties and lower seeding rates, while planophile varieties and higher seeding rates can minimize losses in late plantings.
- Future research should evaluate wheat germplasm in the absence of border effect and evaluate interactions among varietal canopies and other management factors such as row spacing and intensive management.