Title: Exploring winter wheat canopy architecture for variety-specific management strategies

MWP Tracking Number: 21-08-05-BS

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Date: January 5, 2024

Project goals and value for Michigan Wheat Growers

This project is evaluating whether genotype effects should also be considered in planting date x seeding rate management decisions that growers make every year. Specifically, whether farmers should select varieties with erectophile vs. planophile canopy architectures at different planting dates and whether such varieties respond differently to seeding rate changes. The overall objective of this study is to determine whether genotype x management interactions can be exploited to produce reliable on-farm wheat yield increases. If successful, this approach could lead to improved yield and profitability for Michigan wheat growers by managing varieties according to their canopy architecture.

Results of Project

A genotype x planting date x seeding rate trial was conducted at the Michigan State University (MSU) at Mason farm in 2022-23 growing season. The experiment design was a randomized complete block in a split-plot arrangement with four replications. The main-plot factor consisted of 2 planting dates, while 8 varieties and 2 seeding rates comprised the sub-plot factors. The planting date factor included optimal (September 29) and late (October 24) planting. Varieties used included four planophile (AgriMAXX 513, Hilliard, DF 121R and Dyna-Gro 9070) and four erectophile varieties (Branson, MCIA Wharf, ISF 12203 and KWS 405). Seeding rates were 0.8 and 1.6 million seeds ac^{-1}. Each plot included 2 planter passes. One pass/plot was used for yield and the other for in-season destructive sampling. The crop was managed intensively for high yields following MSUE recommendations. Varieties and seeding rates were selected based on preliminary trials in 2021-22 and other research previously funded by MWP.

A second trial was conducted as part of Michigan Wheat Performance Trials program, at the Saginaw Valley Research and Extension Center (SVREC) and Monroe County. This experiment was laid out in a randomized complete block design with 4 replications at each location. Treatments consisted of the same 8 varieties used in the trial explained above. All other factors including seeding rate were similar to grower practices in the region.

Measurements at the Mason location included soil moisture and temperature from field sensors in a subset of plots, daily weather from closest MAWN (Michigan Automated Weather Network) station and precipitation from rain gauge, winter survival, plant stand (Feekes 1 and 11.4) canopy characterization, tiller angle measured with a protractor, % intercepted radiation using Sunscan Canopy Analysis System (Delta-T Devices, Cambridge, UK), radiation use efficiency by destructive in-season harvests (at three different times during the season: Feekes 7 to Feekes 10.5.1), yield, and grain quality. Prior to combine harvest, sections of the border rows (1-m in both outside rows, i.e. row 1 and row 6) were hand harvested in all plots to determine yield implication of inter-plot gap (i.e., border effect). Border rows were removed prior to harvest from all plots to also avoid possible bias due to varietal canopy.

As part of this project, we also evaluated a subset of varieties (with differing canopy architecture) from state yield trial at Mason. There was a difference in light interception when comparing droopy varieties with erect varieties, due to the differences in their canopy architecture (Figure 1). The droopy varieties (rating scale 1-3) have more light interception because they reach canopy closure more quickly and capture a larger amount of seasonal radiation compared to erect canopies (rating scale 3-5).

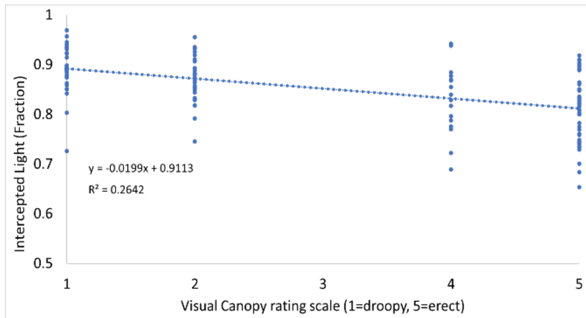

Figure 1: Light Interception in different canopy architectures (droopy and erect). In the rating scale, 1–3 is considered droopy and 3–5 is considered erect.

Light interception was also impacted by planting date, based on data from our main trial at Mason. Wheat planted in the early planting window intercepted more light compared to wheat planted on the late planting date (Figure 2). For timely-planted wheat, intercepted seasonal radiation was high due to increased tillering and larger leaves. Late-planted wheat has fewer tillers, smaller leaves, and takes longer to reach canopy closure compared to wheat planted during the optimal planting window. However, although the percent light interception in the planophile varieties tends to be greater than in the erectophile varieties during most of the season, the difference between planophile (AgriMAXX 513, Hilliard, DF 121R and Dyna-Gro 9070) and erectophile (Branson, MCIA Wharf, ISF 12203 and KWS 405) varieties was not significant for each planting date and seeding rate.

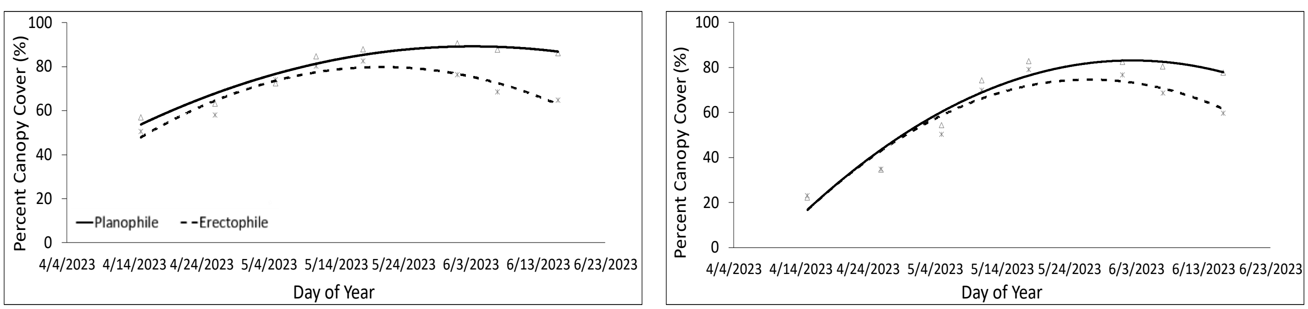

Figure 2: Canopy cover percentage for the two canopy types in each planting date, early planting date (left), late planting date (right) from 0.8 and 1.6 mill. seeds/ac treatment. The solid line showed the planophile and dashed line erectophile variety.

Tiller angle (Figure 3) was measured to characterize canopy architecture differences in planophile and erectophile varieties. It was estimated by measuring the width of tillers 10 and 30 cm above the ground for both canopy types, and then calculating the angle using trigonometry.

Planophiles showed higher values compared to erectophile varieties. Also, the flag leaf angle was measured, but it did not show any significant difference between canopy types. Based on these data, we concluded that tiller angle can be used as an easy and quantifiable way to assess wheat canopy type for any similar work in future.

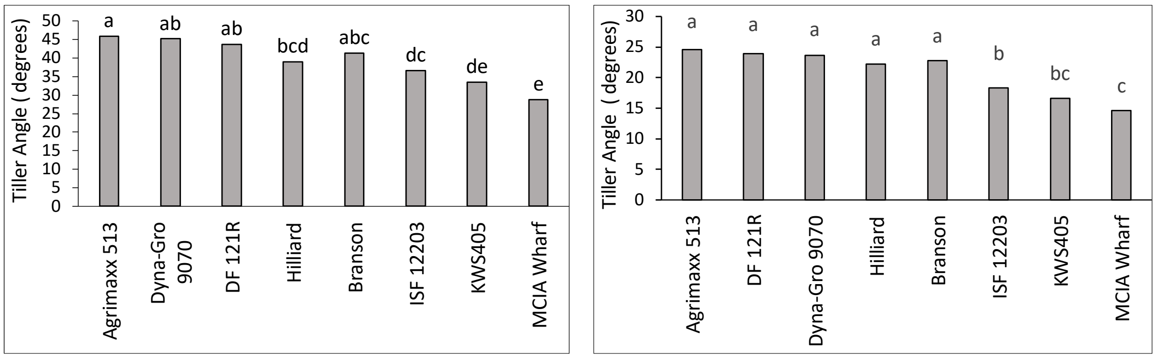

Figure 3: Tiller angle comparison by canopy type from 10 cm (left) and 30 cm (right) above the ground in the eight varieties.

During the growing season, we measured light interception and biomass samples were harvested from three spots in the sample plots to calculate radiation use efficiency (RUE). Under late planting, planophile varieties had greater radiation interception (Figure 4) when we measured it in 2022 growing season. However, erect varieties had greater RUE under early planting while achieving high radiation interception. Figure 5 shows the same RUE behavior for the same sampling time between both canopy types for 2023 growing season. The data from 2022 and 2023 shows that erectophile varieties were slower in reaching canopy closure but showed a greater RUE under high yield environments (e.g., early planting), while planophile varieties had earlier and greater canopy closure and radiation interception, beneficial traits for lower yield environments (e.g., late planting, lower seeding rate, plant stand).

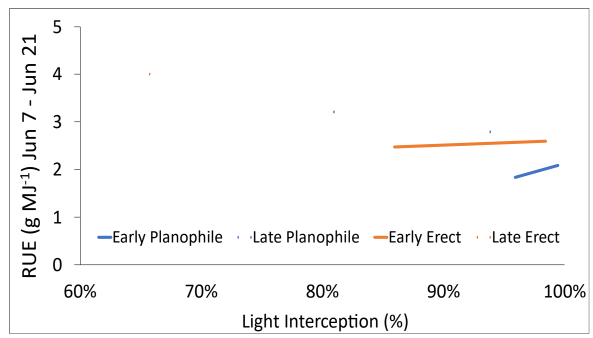

Figure 4: RUE vs radiation interception for both canopy types under early and late planting from 2022 growing season.

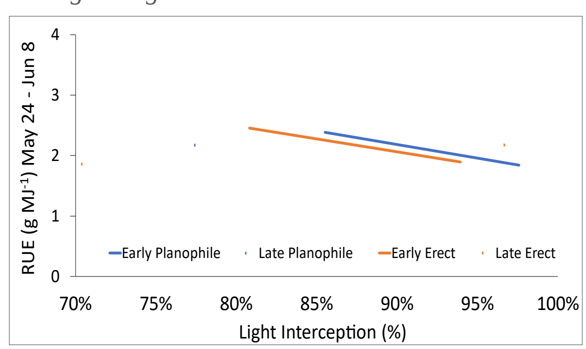

Figure 5: RUE vs radiation interception for both canopy types under early and late planting for 2023 growing season.

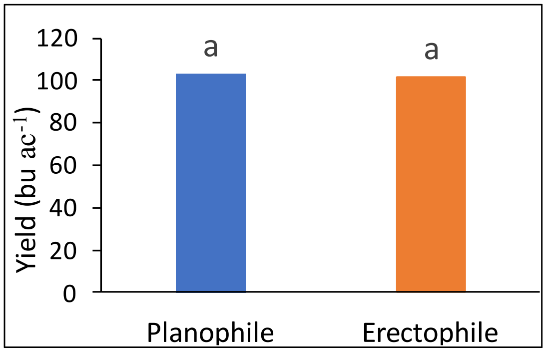

Figure 6: Yield vs. seeding rate for two seeding rates 0.8 million seed/acre and 1.6 million seed/acre.

In this study, canopy architecture did not impact yield (Figure 6) and had minimal interactions with planting date and seeding rate in determining yield. We also compared two seeding rates in both optimal and late planting dates for all varieties. There were not significant differences of yield in the two seeding rates across all varieties and yield remains similar across all seeding rates (Figure 7). Planting date showed significant impacts on yield in both growing seasons, with an average decline of

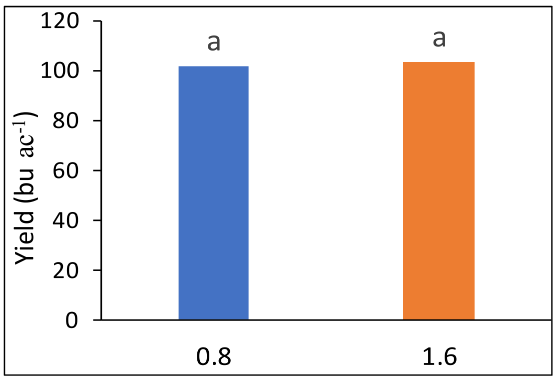

Figure 7: Yield of winter wheat at low (0.8 million seeds ac^{-1}) and high (1.6 million seeds ac^{-1}) seeding rates.

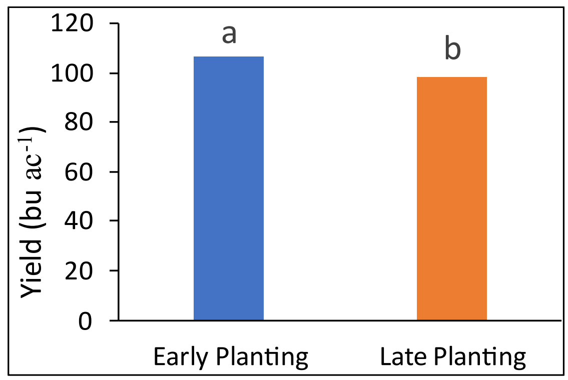

Figure 8: Wheat yield under early (September 29) and late (October 24) planting.

0.32 bu acre^{-1} day^{-1} across all canopy types and seeding rates (Figure 8). This data shows the importance of timely planting. Overall, planting date showed a greater impact on yield than variety canopy architecture and seeding rate. Future trials will include new varieties of each canopy type to further evaluate the importance of this trait in important management decisions such as planting date and seeding rate. We also plan to conduct a separate study in future years evaluating the impact of seeding rate (ranging from 0.4 to 1.6 million seeds/ac) and canopy type on growth and yield of winter wheat.

Varieties differed in their response to the existence of inter-plot gaps (border effect), common in small-plot wheat research. After wheat heads were collected from both border rows, we measure the border effect which quantifies the impact of the surrounding environment on plants situated at the plot edges. A multiplier was calculated to analyze the impact that the borders of the plot produce on the yield with an adjustment standard of 100% (green line). It was calculated by dividing non-border yield by total plot yield.

According to data in Figure 9, there was a difference in the border row effect between the varieties. This 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 planophile which can be due to this bias against erectophile varieties and shows the potential need for changes in small-plot breeding research. We will continue testing this effect across the same quantity of varieties in future trials.

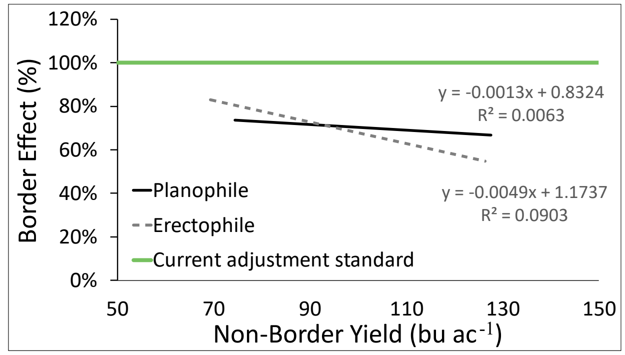

Figure 9: Multiplier calculated to determine impact on border effect in the different varieties across optimal and late planting date at Mason.

Data analyses are ongoing on multiple other variables from field trials associated with this project and results will be presented in future meetings and reports.

Summary

The anticipated relationship between canopy architecture and yield across various planting dates and seeding rates has not shown consistent and significant differences as we expected. However, to comprehensively test our objectives and hypotheses, additional years and the addition of new wheat varieties are essential. Canopy architecture plays an important role in determining the total seasonal radiation intercepted and the efficiency with which this intercepted radiation is used and converted to biomass and grain. Therefore, we anticipate that this factor will have an influence on yield, for strategic management approaches to benefit growers. The planting date has been shown as a crucial factor impacting yield significantly, while the impact of seeding rates, though not consistently significant, suggests potential opportunities for reduced rates and seed costs.

Planophile varieties reached canopy closure faster compared to erect varieties, but these varieties may shade lower leaves in the canopy due to the tiller angle structure. Planophile varieties showed higher tiller angle compared to erect varieties, leading to greater light interception values. However erect canopies were slower to reach canopy closure, but had greater radiation use efficiency. Overall, erectophile varieties were slower in reaching canopy closure but showed a greater RUE which would be beneficial 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 seeding rates). Canopy architecture showed similar yield potential, however planophile varieties took better advantage of inter-plot gaps and allude to potential positive bias in breeding programs.

Data from the past two years of these trials has confirmed some of our hypotheses and our ongoing data collection across multiple site-years seeks to refine these results and develop recommendations for growers. Multi site-years of data are critical to reach final conclusions.

Future Work

A similar project was submitted to project GREEEN to support a graduate student who can lead extensive data collection involved with project objectives. That effort was successful, and we received $99,123 that is supporting a graduate student (Paulo Arias) till Summer 2025.

Continued funding from MWP will be used to cover most expenses related to conducting the field trials. Future USDA and MWP submissions will also involve targeted breeding efforts based on canopy architecture and explore other management decisions (e.g., row spacing). A planter was purchased at KBS with the ability to plant in 5" row spacing for such work (costing ~$150,000, funded by USDA's LTAR project).

Project Changes
Changes for the upcoming year will include the replacement of two varieties that were exhibiting canopy architectures between planophile and erectophile: one planophile (Dynagro 9481 will replace Hilliard) and one erectophile (a breeding line MI 2040096 will replace Branson) variety. We will also keep working with Agrimaxx 513, MCIA Wharf, DF 121R, Dynagro 9070, ISF 12203 and KW405 in the 2023-2024 growing season. Since past research has consistently shown minimal impact of seeding rate on yield, and no difference between seeding rates is expected in this research, we will continue to use the same two seeding rates (0.8 and 1.6 million seeds ac^{-1}) in the main trial and planning to conduct another seeding rate trial involving differing wheat canopies in future years. We will also plant varieties (under one planting date and seeding rate) at two off-campus state yield trial locations (SVREC and Monroe) to collect data from more variable environments and potential impact on yield and the border effect.

Budget Narrative. As described in the proposal.

Intellectual Property. None.

Approach to Disseminate Research
Project findings were shared with growers at multiple field events and extension meetings/field days organized by MWP and MSUE. Data from this project was also presented at the American Society of Agronomy's 2023 annual meetings in St. Louis, Missouri. Research results will be posted on the MSU Agronomy webpage (agronomy.msu.edu), as well as presented at winter grower meetings and field days. We plan to submit an article for the Wheat Wisdom newsletter in future as well.