Maximizing Canopy Conductance to Enhance Spring Wheat Yield Potential in the Upper Midwest

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What is canopy conductance?

Why is it important for growers, agronomists and breeders?

Project: Identifying genes maximizing yield benefits resulting from increasing canopy conductance.
Presentation key points

- What is canopy conductance?
- Why is it important for growers, agronomists and breeders?
- Project: Identifying genes maximizing yield benefits resulting from increasing canopy conductance
What is canopy conductance?

Why is it important for growers, agronomists and breeders?

**Project**: Identifying genes maximizing yield benefits resulting from increasing canopy conductance.
What is canopy conductance?
Water OUT

Transpiration

Holes in the leaf = stomata

Xylem tube

Water moves from soil into roots
Water OUT

CO₂ IN

Holes in the leaf = stomata

Xylem tube

Transpiration

Water moves from soil into roots
Advantages of a high-conductance cultivar

- More nutrients in: nitrogen, phosphorus, potassium, micronutrients
Advantages of a high-conductance cultivar

- **More nutrients in:** nitrogen, phosphorus, potassium, micronutrients
- **More carbon dioxide in:** needed for photosynthesis, sugars, building the plant, grain filling
Advantages of a high-conductance cultivar

- **More nutrients in**: nitrogen, phosphorus, potassium, micronutrients
- **More carbon dioxide in**: needed for photosynthesis, sugars, building the plant, grain filling
- **Cooler canopies** = protect photosynthesis from heat stress,
Is conductance related to yield increase?

Spring what MN yields 1992-2016 (USDA, NASS)

![Graph showing trend in yield increase from 1990 to 2020 with P-value less than 0.0001.](image)
Conductance related to yield increase in Minnesota

Canopy conductance on 17 spring wheat MN cultivars from 1992-2016

Spring what MN yields 1992-2016 (USDA, NASS)
Conductance related to yield increase in Australia

Kirkegaard and Hunt 2010
Conductance related to yield increase in Australia

Research objective

- Deliver Minnesota growers superior, high-yielding, high-conductance cultivars
  - Identify/capture favorable genes controlling canopy conductance
  - Integrate them in the U of M breeding program
A 3-Step Approach

1. Develop a high-throughput ‘precision phenotyping’ system to screen large populations (>300) for canopy conductance
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2. Phenotype all parents of the MN Nested Association Mapping Pop. & phenotype 3 families descending from 3 contrasted parents.
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1. Develop a high-throughput ‘precision phenotyping’ system to screen large populations (>300) for canopy conductance.

2. Phenotype all parents of the MN Nested Association Mapping Pop. & phenotype 3 families descending from 3 contrasted parents.

3. Identify and confirm favorable genes in the MN Nested Association Mapping pop. through QTL mapping.
Step#1: Phenotyping for canopy conductance

A needle-in-a-haystack problem!
Variation in wind speed
Variation in wind speed

Variation in temperature
Variation in wind speed

Variation in temperature

Variation in cloud cover
Step#1: Developing the phenotyping platform

Chamber#1
Step#1: Developing the phenotyping platform

- **Balances & Data loggers (x60)**: track transpiration
- **Chamber#1**
- **Fans (x2)**: make conditions uniform
- **Industrial humidifiers (x4)**: low RH
- **Programmable Industrial dehumidifier (x1)**
- **Temperature, relative humidity, light sensors (x3)**
Step#1: Developing the phenotyping platform

Examples

Slope = conductance

- **Genotype 24022**
  - Slope Low: 71.12
  - Slope High: 40.3
  - Y-int Low: -84.73
  - Y-int High: -8.72
  - R.sq Low: 0.94
  - R.sq High: 0.75
  - No. of data: 21
  - Bad: 0

- **Genotype 22005**
  - Slope Low: 26.2
  - Slope High: 29.4
  - Y-int Low: -8.86
  - Y-int High: -14.36
  - R.sq Low: 0.76
  - R.sq High: 0.65
  - No. of data: 21
  - Bad: 0

**Humid air**

**Dry air**
Step #1: Developing the phenotyping platform

**Examples**

Slope = conductance

**Top line:** TWICE the conductance of the bottom line

**Humid air**

**Dry air**
Step#2.1: Screening parents of MNAMP

- Screened 26 parents of the highly diverse MNAMP = substantial diversity in canopy conductance

Minnesota Nested Association Mapping Population
(MNAMP, 25 diverse founder lines)

Cross with RB07
Step #2.1: Screening parents of MNAMP

- **Selected highly contrasted** parents of 3 families to be phenotyped
Step#2.2: Screening 3 families

150 RILs = 450 plants

Family#24
RB07 x PI 519465

Family#14
RB07 x PI 220455

Family#22
RB07 x PI 430750

Number of values

Canopy conductance (mg H₂O m⁻² s⁻¹ kPa⁻¹)

- Family#24: 59% higher than RB07
- Family#14: 62% higher than RB07
- Family#22: 74% higher than RB07
Genetic analysis ongoing, but preliminary data encouraging: markers associated with traits
Moving forward: capturing/confirming all major genes

- Confirm year#1 finding: replicate experiments on same 3 families
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- Confirm year#1 finding: replicate experiments on same 3 families
- Screen 3 other contrasted families to ensure capture of most strong-effect QTL in MNAMP
Moving forward: capturing/confirming all major genes

- Confirm year#1 finding: replicate experiments on same 3 families
- Screen 3 other contrasted families to ensure capture of most strong-effect QTL in MNAMP
- Confirm MNAMP QTL in breeding populations
Conclusions on Year#1

- Canopy conductance: **valuable trait with multiple yield-related benefits**
Conclusions on year#1

- Identified parents of families to be screened for canopy conductance

Step#2.1: Screening parents of MNAMP

- Selected highly contrasted parents of 3 families to be phenotyped
Conclusions on year#1

- Identified parents of families to be screened for canopy conductance

- Successfully screened 3 families, revealing promising diversity
Conclusions on year#1

- Identified parents of families to be screened for canopy conductance
- Successfully screened 3 families, revealing promising diversity
- Genetic analysis (QTL) to identify favorable markers ongoing

Step#2.1: Screening parents of MNAMP

- Selected highly contrasted parents of 3 families to be phenotyped

Step#2.2: Screening 3 families

- 150 RILs = 450 plants

Step#3: QTL analysis (in progress)

- Genetic analysis ongoing, but preliminary data encouraging: markers associated with traits
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