

# Progress in breeding to improve the ozone stress tolerance of crops

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# Introduction

- Adaptation to stressful climates includes development of stress tolerant crops.
- This presentation reports on our work to develop ozone-tolerant soybeans.
- Case for collaboration between plant physiologists and plant breeders.

## Part 1: Screening germplasm

- Identified foliar injury as an excellent screening method for rating ozone response.
- Thirty soybean ancestors representing 92% of the genetic base in North American soybean were screened for ozone tolerance in the greenhouse exposure chambers called continuously stirred tank reactors (CSTRs). [Burkey and Carter (2009) Field Crops Research 111:207-217]



Low  
Ozone  
Control

Six days  
75 ppb  
Ozone



Fiskeby III



PI88788

# Fiskeby soybeans identified as a source of tolerance to a diverse set of abiotic stresses

Selected Plant Introductions	Common Name	Ozone Foliar Injury (%)
PI 438471	Fiskeby III	9
PI 548352	Jogun	13
PI 548311	Capital	26
PI 548379	Mandarin (Ottawa)	40
PI 88788 [SCN resistance]		49

Fiskeby soybeans

- Developed in Sweden
- Used in Canada as source of cold tolerance
- Not a significant contributor to pedigree of US soybeans

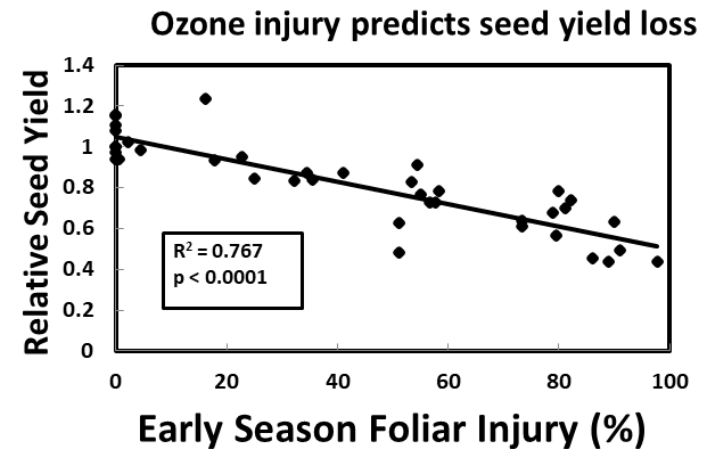
Fiskeby III tolerance to multiple abiotic stresses

- Ozone (Kent Burkey)
- Salt (Tommy Carter)
- Drought (Jim Orf)
- Iron deficiency chlorosis (Jim Orf)

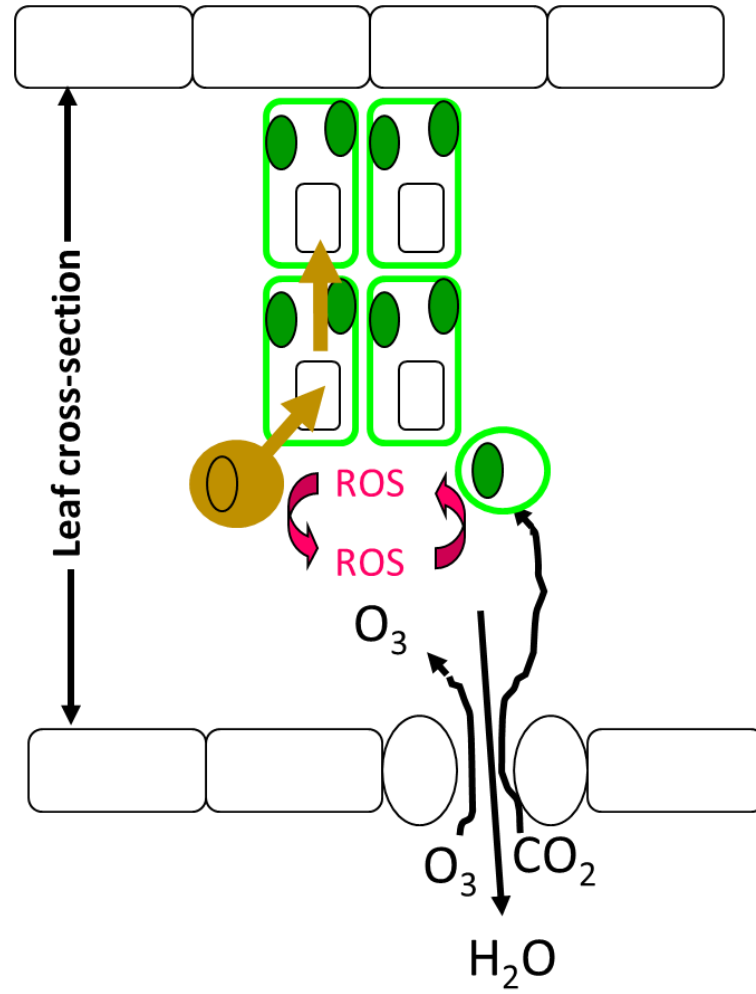
# Ozone foliar injury associated with yield loss

- Open top chambers are used to assess yield over a range of ozone concentrations: charcoal filtered air (control), 12-hour means of 60 ppb, 80 ppb, and 100 ppb.
- Early season foliar injury is a good predictor of yield loss with sensitive genotypes at 80 and 100 ppb.
- Supports the use of short-term greenhouse screening as a first step.

Open Top Chambers



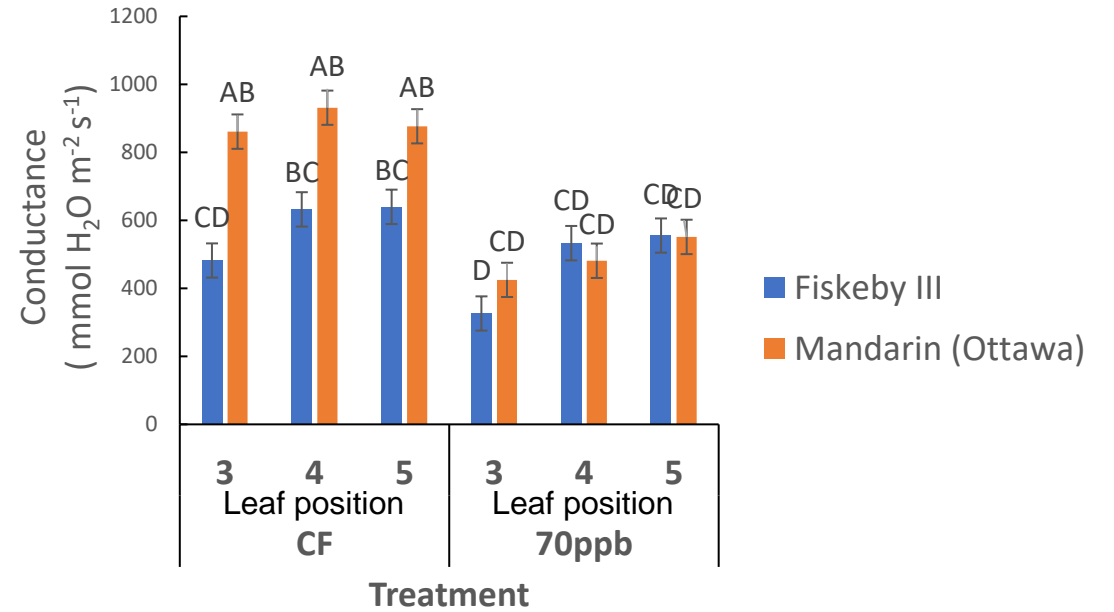
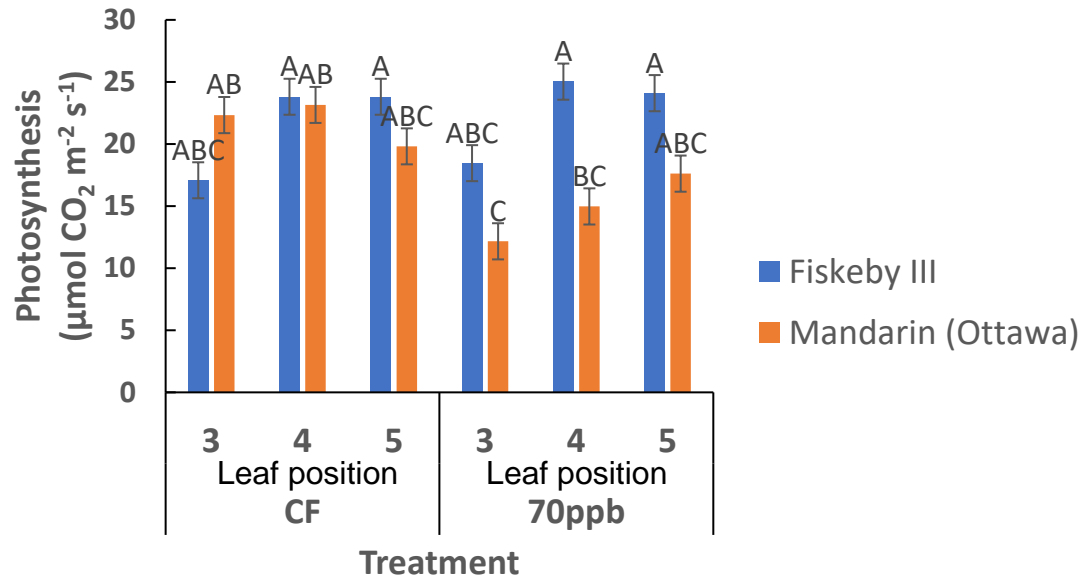
## Part 2: Leaf physiology associated with ozone stress tolerance



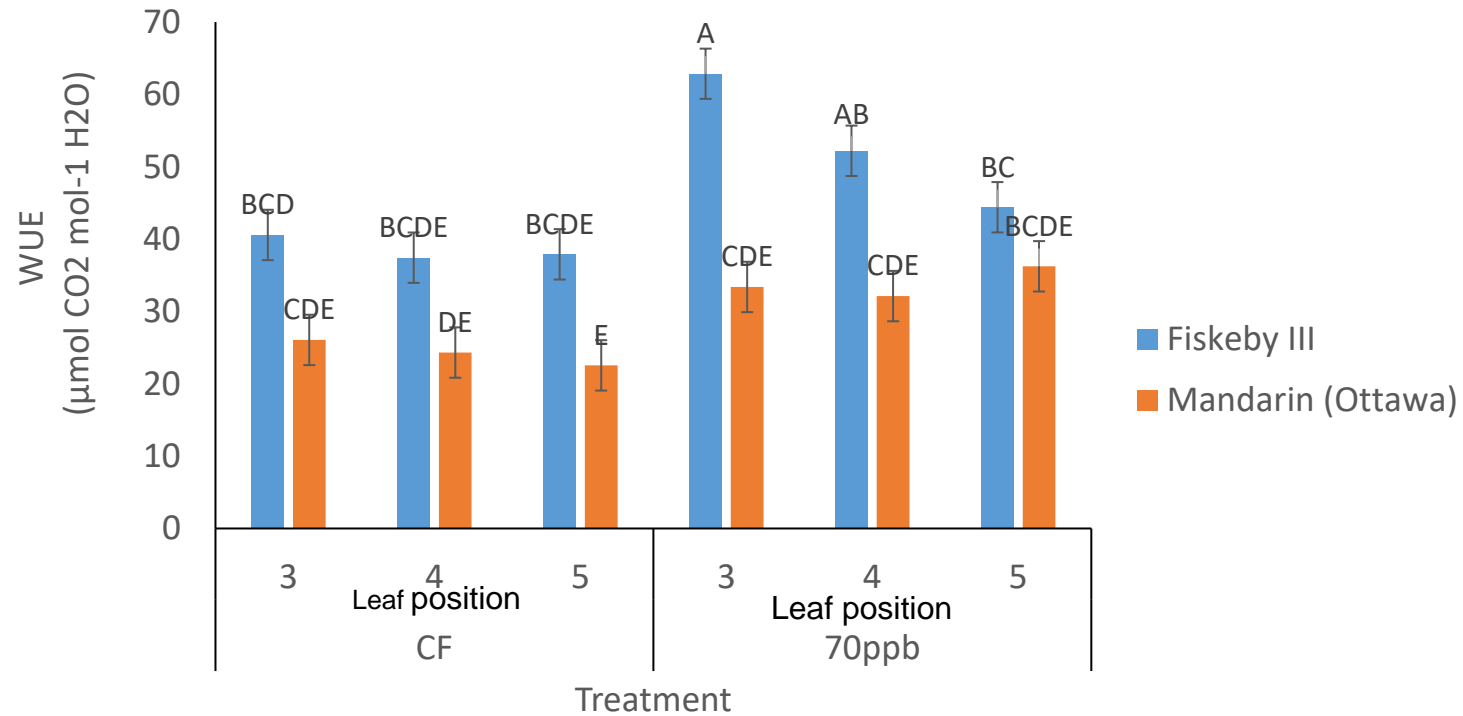
### Potential mechanisms

1. Stomatal control of ozone uptake
2. Regulation of ROS

# Gas exchange – ozone tolerance related reduced stomatal conductance



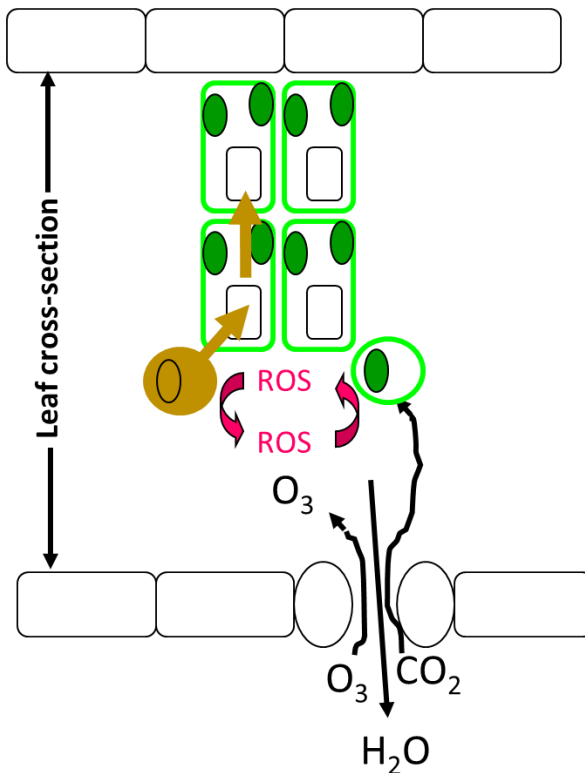
# Gas exchange – ozone tolerance linked to WUE trait (drought)





# Leaf physiology conclusions

- Fiskeby III ozone tolerance associated with reduced stomatal conductance – ozone exclusion mechanism.
- Reduced stomatal conductance while maintaining high rates of photosynthesis results in enhanced water use efficiency – linkage between ozone tolerance and drought tolerance.
- However, Fiskeby III has low yield potential.



## Part 3: Moving tolerance genes into cultivars farmers can use

**Fiskeby III**: poor yield potential, ozone and drought tolerant, **MG 00**

**Holladay**: elite cultivar, good agronomic traits, ozone and drought sensitive, **MG V**

Fiskeby III x Holladay



Develop breeding lines (bulk breeding)



Screen breeding lines for with good agronomic characteristics (800 selected)



Test 120 breeding lines for slow wilting trait under drought stress in the field (11 identified)



Test breeding lines for ozone tolerance (2019 greenhouse and OTC results)

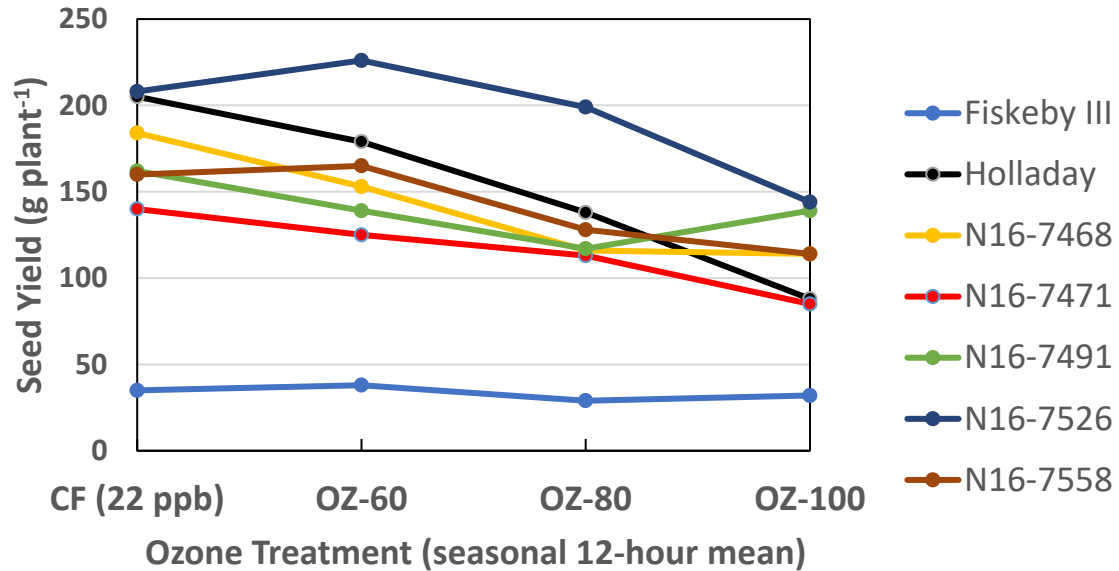
# Results from 2019 testing of Fiskeby III x Holladay breeding lines

Genotype	Foliar Injury (%)
N16-7561	74 ± 7 <sup>A</sup>
N16-7617	70 ± 7 <sup>A</sup>
N16-7471	66 ± 7 <sup>A</sup>
<b>Holladay (O<sub>3</sub> sensitive)</b>	<b>61 ± 7<sup>A</sup></b>
N16-7644	61 ± 7 <sup>A</sup>
N16-7468	60 ± 7 <sup>A</sup>
N16-7661	58 ± 7 <sup>AB</sup>
N16-7631	51 ± 7 <sup>ABC</sup>
N16-7629	39 ± 7 <sup>ABCD</sup>
N16-7491	22 ± 7 <sup>BCD</sup>
<b>N16-7526</b>	<b>21 ± 7<sup>DC</sup></b>
<b>N16-7558</b>	<b>15 ± 7<sup>DC</sup></b>
<b>Fiskeby III (O<sub>3</sub> tolerant)</b>	<b>6 ± 7<sup>D</sup></b>

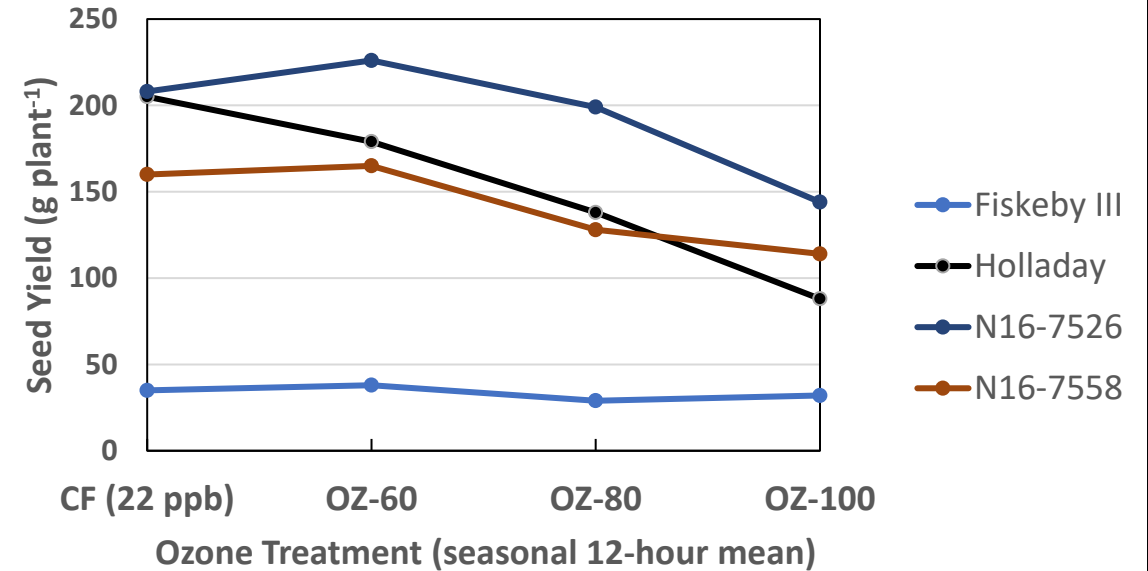


# Results from 2019 testing of Fiskeby III x Holladay breeding lines

Fiskeby III x Holladay Breeding Lines  
2019 Open-top Chamber Study



Fiskeby III x Holladay Breeding Lines  
2019 Open-top Chamber Study



## Some final thoughts and conclusions...

- Breeding for ozone tolerance is possible. Soybean breeding lines (N16-7526, N16-7558) with enhanced ozone tolerance have been developed using traditional plant breeding methods by a team of plant physiologists and plant breeders.
- Foliar injury provides a simple phenotyping method for initial screening of germplasm to identify leaf traits associated with ozone tolerance. Approach will not detect tolerance traits associated with direct effects of ozone on reproductive processes (pollen viability, etc.).
- A leaf gas exchange trait has been identified in soybean that is associated with both ozone and drought tolerance. Suggests that simultaneous breeding for multiple stress tolerances is possible.

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