Identification of Canopy Cooling Traits for Heat Tolerance in Pea

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Introduction

- Pea (*Pisum sativum* L.) is a cool season legume crop adapted to semi-arid temperate conditions.
- Canada is a leading producer and exporter of dry peas accounting for more than 30% of global production.
- However, most of the existing pea cultivars are sensitive to heat stress, with warm summers causing short life cycles, abortion of flowers and pods, which result in significant yield loss.
- Pea germplasm has diverse canopy architecture, offering variation in leaf and canopy performance that can help in adaptation to stress.
- Yield loss can be minimized if we identify traits to maintain cooler canopy conditions under high air temperature.
- The main objective of this study was identification of leaf and canopy cooling traits to improve heat stress tolerance of peas.

Materials and Methods

- This experiment was carried out under field condition at two locations (Rosthern and Sutherland) in Saskatchewan, Canada, 2015.
- Twenty-four genotypes representing diverse plant characteristics including canopy color, leaf type, canopy habit and flower color, were tested for canopy cooling traits.
- The experiment was laid in randomized complete block design (RCBD) with four replications.
- A delayed seeding date was used so that peas would be exposed to high temperature during their flowering duration in late July and early August.
- In the field: various morphological, physiological and environmental variables were recorded.
- Pigments and wax extraction and quantification were performed in the lab according to Lichtenthaler (1987) and Sanchez et al. 2001 [originally adopted from Ebercon et al. (1977)].
- Statistical analyses were performed using the mixed and GLM procedures for ANOVA and contrast tests using SAS statistical software version 9.4 (SAS Institute, Inc., Cary, NC, USA).

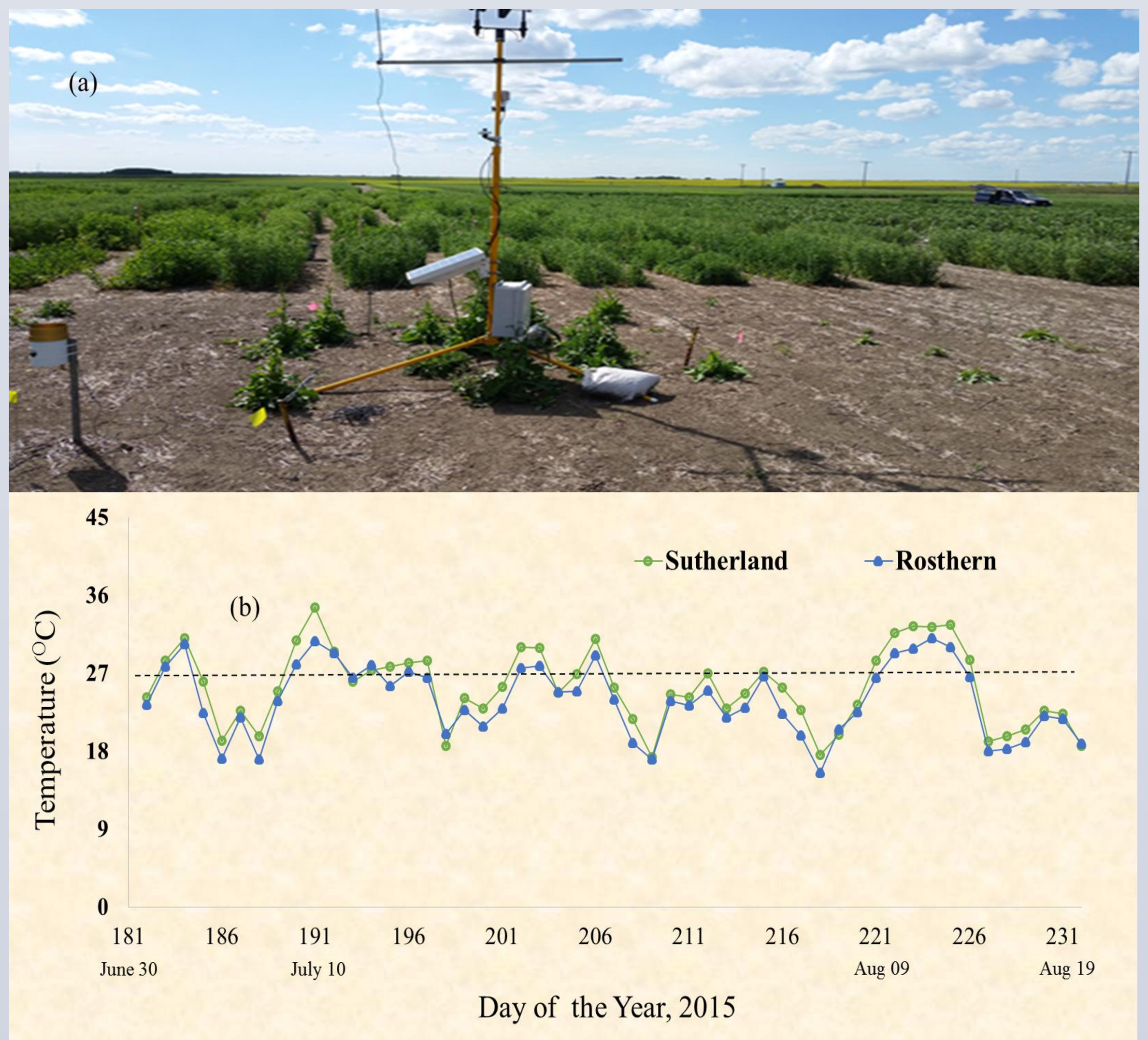

Fig 1. Field experiment station (a) and daily maximum air temperature of the two locations (b), 2015. Continuous measurement of weather information were obtained from the weather stations established at each experimental location.

Results

Table 1. Mean of traits and significance levels for genotypic differences at Rosthern and Sutherland, 2015.

Traits	Rosthern		Sutherland	
	Mean	P value	Mean	P value
Canopy T (°C)	28.3	0.013	26.8	0.0002
NDVI	0.78	0.001	0.76	0.13
Chlorophyll a (µg cm^{-2})	34	<0.001	31	<0.001
Chlorophyll b (µg cm^{-2})	11.6	<0.001	10.9	<0.001
Leaflet wax (µg cm^{-2})	21.0	<0.001	21.0	0.0047
Petiole wax (µg cm^{-2})	41	0.24	40	0.0027
Stem diameter (mm)	3.0	0.27	3.2	0.0021
Number of pods	8.7	<0.001	8.2	<0.001
Abortion %	37.2	<0.001	36.8	<0.001

- Genotypes varied significantly in most of morphological and physiological traits presented in the above table.
- Leaflet and petiole wax help to conserve moisture, and reflect excessive radiation in the visible and infrared longwave radiations.
- Thicker stem diameter helps to hold moisture and improve water conductance from the soil.

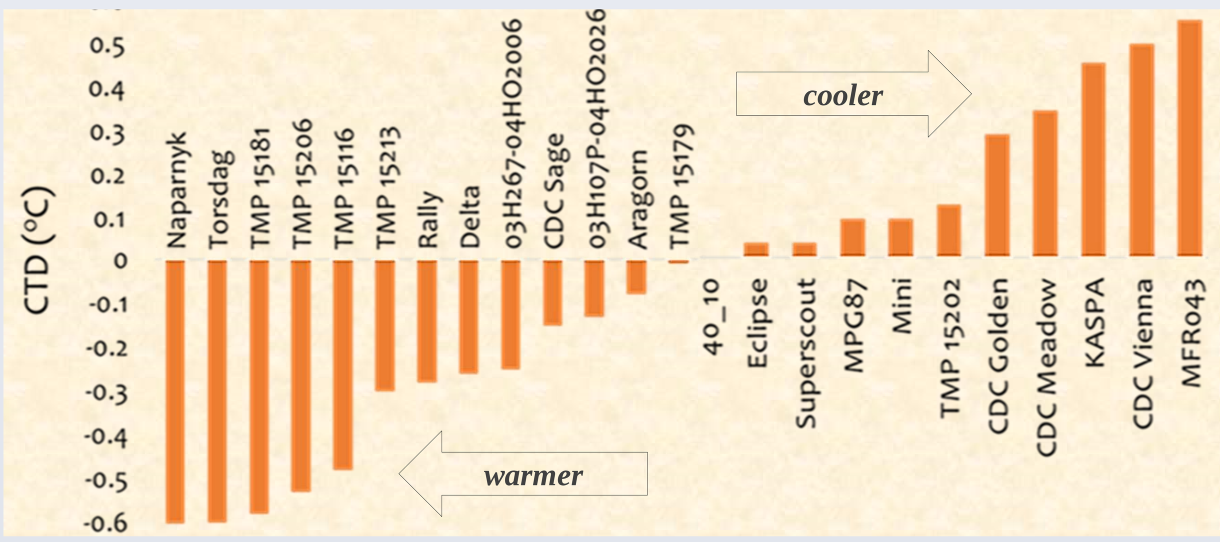

Fig 2. Canopy Temperature Depression (CTD) varied among genotypes at Rosthern, 2015, LSD (0.05)=0.66. CTD was calculated as Ta-Tc; Ta & Tc are air and canopy temperatures respectively

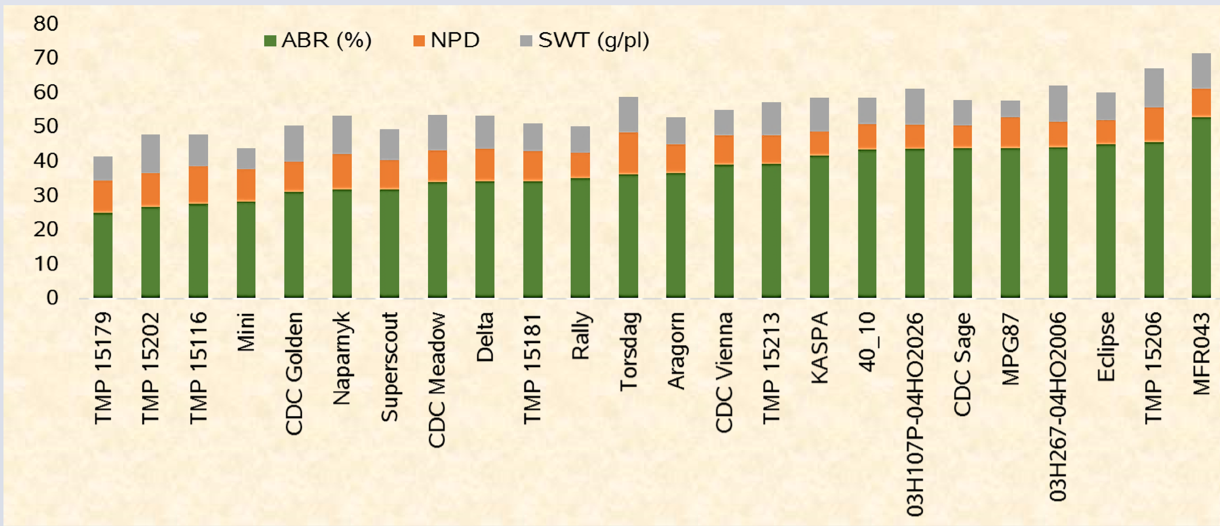

Fig 3. Abortion percentage (ABR , LSD = 10.7), Number of pods per plant (NPD, LSD = 1.7), and Seed weight per plant (SWT, LSD = 1.4) at Rosthern, 2015

- Genotypes significantly varied in yield parameters including abr %, NPD, and SWT.
- Our result suggests possibility of improving yield under heat stressed environment.

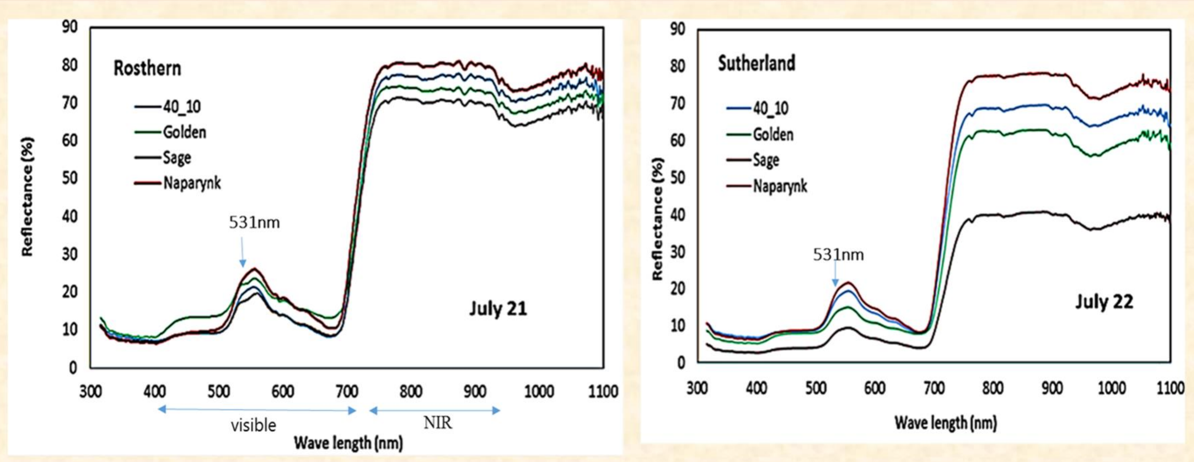

Fig 4. Spectral signatures of selected genotypes at Rosthern and Sutherland, 2015

- The spectral measurements were taken at noon on July 21st (no heat stress) and July 22nd (heat stressed) condition.
- Though the ranks of genotypes were consistent across the two locations; the spectral signatures on July 22 clearly shows the difference in their stress level.

Table 2. Contrast analysis to determine effects of canopy color, flower color, leaf type and plant habit on performance of morpho-physiological traits at Rosthern, 2015

Contrasts	Levels	CTD (°C)	SPAD	PRI	Wax (µg cm^{-2})	N Pod	Abr %
Canopy color	bg	0.02*	46.4***	-0.02***	22.9*	8.5	36.6
	rg	-0.24	42.8	-0.03	19.3	9.0*	38.0
Flower color	col	-0.13	44	-0.025	21.4	7.6	41.8*
	wh	0.03	45.2	-0.024	21.4	9.1**	35.7
Plant habit	u	0.06*	46.0***	-0.024	23.2**	8.2	39.9
	v	-0.3	43.3	-0.026	18.7	9.4*	33.5
Leaf type	e	-0.18	44	-0.027	19.6	9.1	35.4
	sl	0.01	45.7*	-0.022	23.3*	8.3	39.0

Note: CTD (canopy temperature depression), N Pod (number of pods), Abr (abortion), bg (blue-green), rg (red- green), col (colored), wh (white), u (up-right), v (vining), e (entire), sl (semi-leafless)

- Contrast analysis (Table 2) revealed genotypes with blue-green canopy color, upright habit, and semi-leafless leaf type were superior over genotype with red-green canopy color, vining habit and entire leaf type in heat tolerance traits including CTD, SPAD, PRI, wax, and abortion % performance.
- However, higher number of pods were obtained from vining and red-green canopy color genotypes.

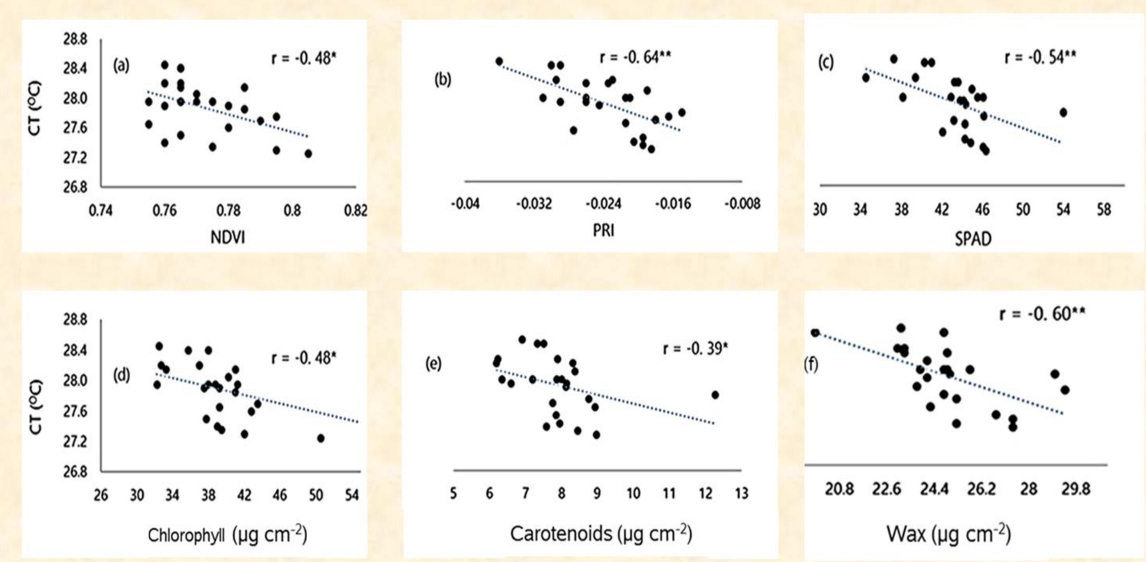

Fig 5. Canopy temperature (CT) was negatively correlated with vegetation indices, pigments and wax. Values are means of genotypes from Rosthern and Sutherland, 2015.

- The significant negative correlation of pigment and wax with CT suggests pigments and wax contributes for canopy cooling.

Conclusions

- Genotypes varied significantly in their heat tolerance and sensitivity.
- Plant characteristics such as canopy color, leaf type and plant habit affect heat tolerance of pea.
- Genotypes with dark-green leaves, and an upright plant habit were more tolerant of heat stress than red-green, and vining genotypes respectively.
- Peas with semi leafless leaves were superior over peas with normal leaves in overall pigment and wax performance.
- Canopy temperature negatively correlated with most pigments and wax suggesting pigments and waxes contribute to cooler canopy under hot environments.

References

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Acknowledgments

Saskatchewan Pulse Crop Development Board (SPG)
Western Grain Research Foundation
- Technical support from pulse and crop physiology crew