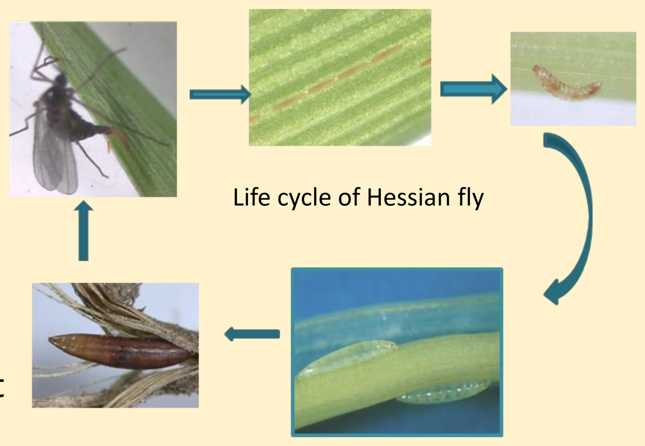
Research on Wheat-Hessian Fly Interaction at Fayetteville State University

Lieceng Zhu, Department of Biological Sciences.
1200 Murchison Road. Fayetteville, North Carolina. lzhu@uncfsu.edu.

Abstract: Our research focuses on the impact of heat stress on plant resistance and mechanisms of heat-induced loss of resistance to insects using wheat (*Triticum aestivum*) - Hessian fly (*Mayetiola destructor*) system as a model. The project also purported to engage students of underserved populations in scholarship to enhance their career success. We've identified heat-induced changes in wheat seedlings via a combination of phenotyping and phytohormone and polar lipid profiling, and in the process, engaged 27 students in research and publications since 2009. Currently we are investigating mechanisms of heat-induced loss of wheat resistance to Hessian fly using RNA-Seq and RT-qPCR analyses.

Introduction

- Hessian fly (HF, *Mayetiola destructor*) is a destructive insect pest of wheat plants.
- Plant resistance genes (*R* genes) have been used to combat HF infestation.
- Most *R* genes are temperature sensitive. Resistance may be compromised under higher than 'normal' temperatures (Tyler and Hatchett 1983, Buntin et al. 1990, Chen et al. 2014)



- Fayetteville State University (FSU) is a Historically Black Colleges and Universities (HBCU) and a home to ~ 6,000 students of which 63% are African Americans and 68% are females.
- The project carries the mission of training minority students in research and publication, promoting students success, and contributing to mobility and stability of the society.

Objectives

- To investigate impact of heat stress on resistance of wheat to HF.
- To engage students of underserved population in research and publications.

Materials

- Wheat: Molly (Resistant, contain *H13 R* gene) & Newton (susceptible).
- HF: Biotype GP.
- Molly is resistant to biotype GP under "normal" temperature.

Methodology

Phenotyping:
- Compared effectiveness of HF resistance in wheat seedlings under heat stress with that of control plants w/o heat stress.
- Compared effectiveness of HF resistance in wheat plants sprayed with 2mM 12-oxo-phytodienoic acid (OPDA) or salicylic acid (SA) solution with that of wheat seedlings w/o OPDA or SA application under heat stress.
- Resistance vs. Susceptibility: Resistant: **All** dead larvae. Susceptible: Live larva(e) found.

GC-MS analysis:
- Determined abundance of phytohormones and related metabolites.

ESI-tandem-MS:
- Analyzed polar lipid profiles.

Research Findings

1. **Dose of heat stress (degree x hours) and loss of resistance (percent of susceptible plants) exhibits a strong positive correlation with $R^2 = 0.9511$ (Fig. 1). The greater the heat dose, the greater loss of wheat resistance to HF.**

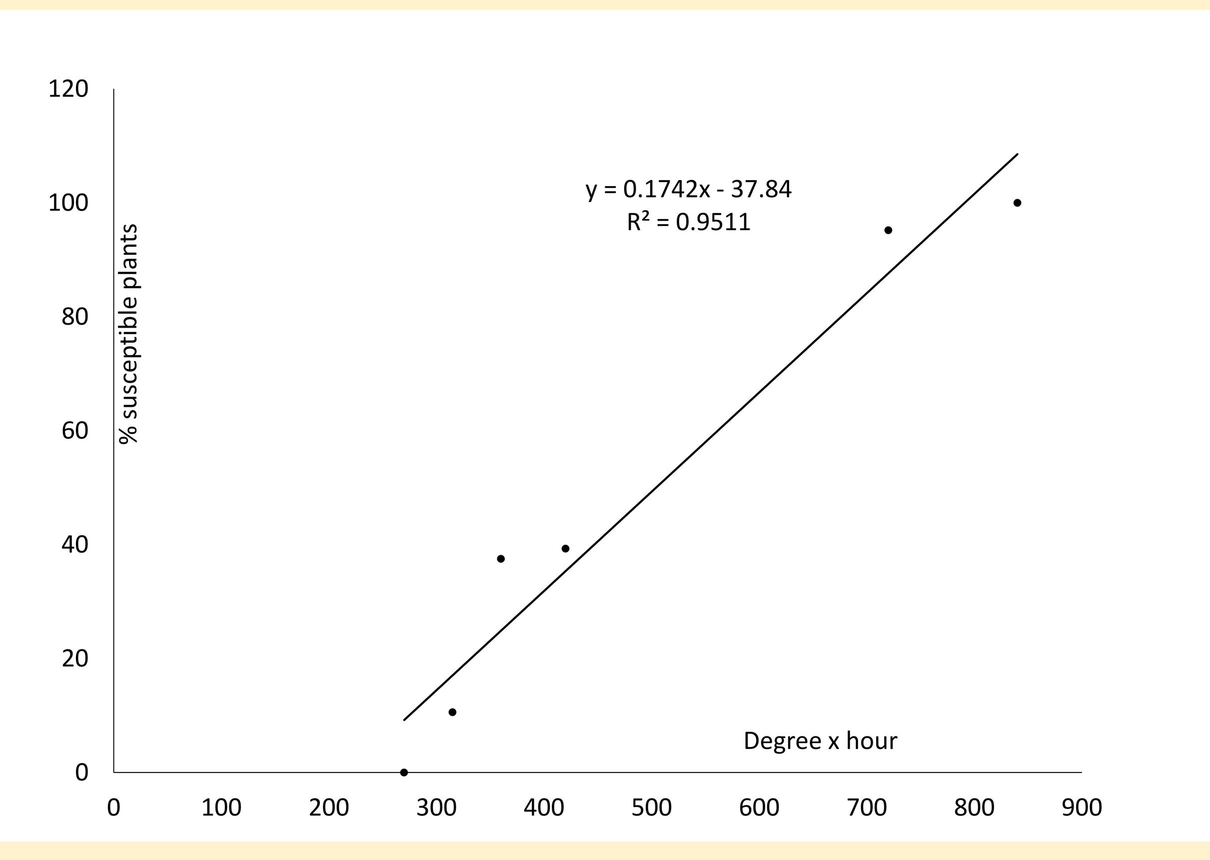


Fig. 1. Correlation between heat doses and percentages of susceptible plants . The equation was constructed using Simple Linear Regression Model (Montgomery et al. 2015).

Research Findings cont'd

2. **External application of either SA or OPDA enhances resistance of wheat under heat stress to HF** (Fig. 2 & 3).

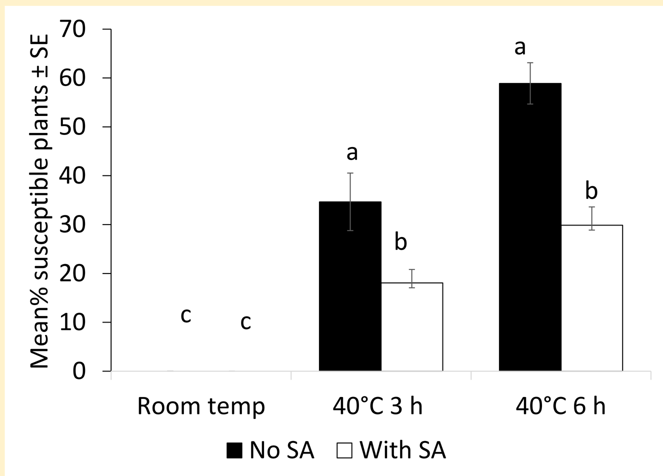


Fig. 2. Impact of SA application. Significantly less percent of Molly wheat seedlings became susceptible under 40° C heat stress when SA was applied compare with control plants w/o SA application. 3 h: 3 hours; 6 h: 6 hour. All plants were infested with an avirulent biotype type GP.

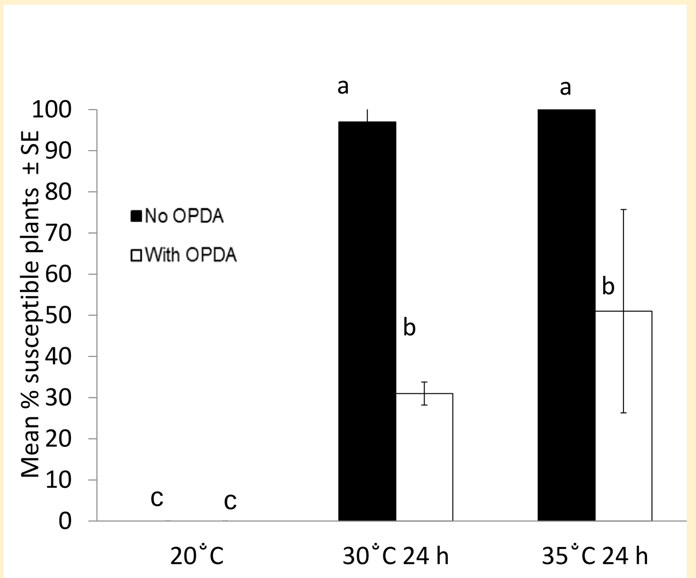


Fig. 3. Impact of external OPDA application. Significantly less percent of Molly wheat seedlings become susceptible under heat stress when OPDA was applied compare with control plants w/o OPDA. All plants were infested with an avirulent biotype type GP

3. **Heat stress reduces OPDA abundance in wheat tissue at HF feeding sites** (Fig. 4)

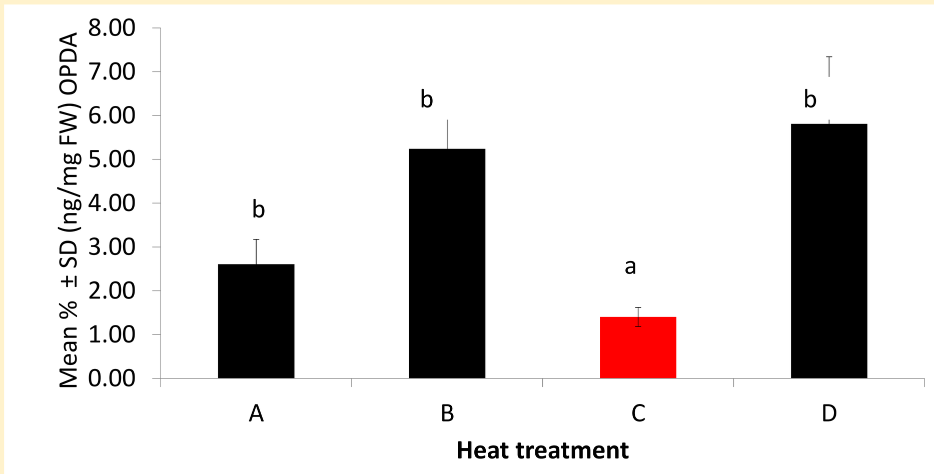


Fig. 4. Impact of heat stress on OPDA abundance in Molly wheat. (A) Room temperature with normal light and dark cycle; (B) room temperature, 6 h in the dark; (C) 6 h at 40° C heat treatment in the dark. Samples were collected immediately after the heat treatment; (D) 6 h at 40° C in the dark. Samples were collected at 12 h after completion of the heat treatment.

4. **Heat stress uniquely altered polar lipid profile in Molly wheat attacked by an avirulent biotype HF GP (Fig. 5)**

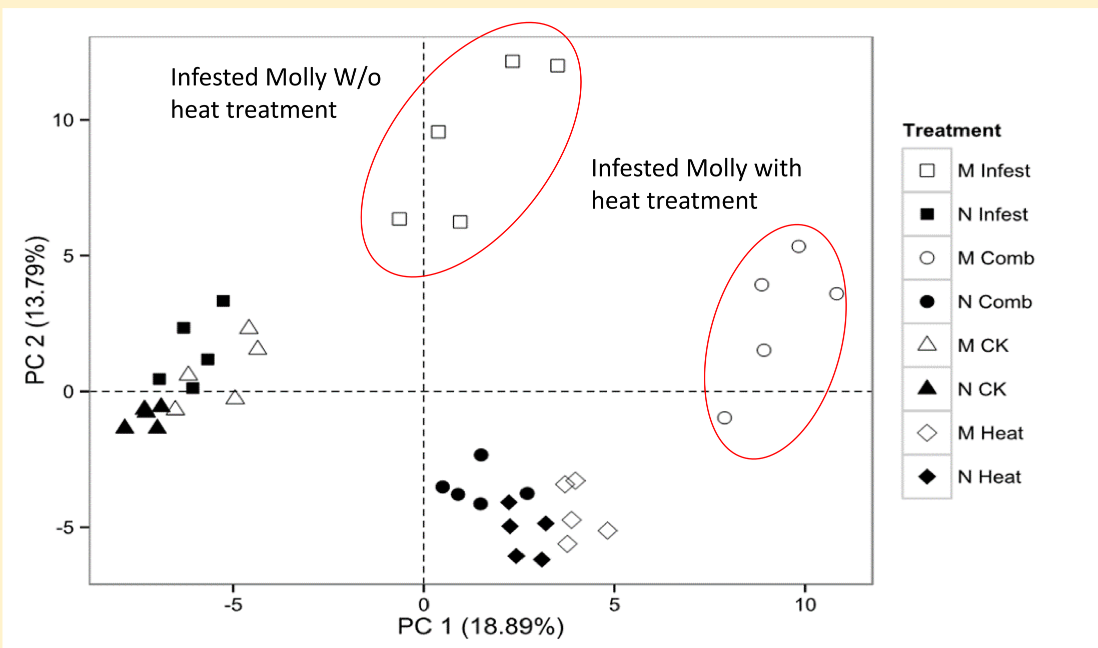


Fig. 5. Principal analysis (PCA) plot derived from PCA on mole percentage of 156 lipid species of wheat seedlings. M CK, Molly control; N CK, Newton control; M Heat, Molly heat stressed at 40°C for 6 h; N Heat, Newton heat stressed at 40°C for 6 h; M Infest, Molly infested ; N Infest, Newton infested; M Comb, Molly treated with heat and infestation, N Comb, Newton treated with heat and infestation.

Research Findings cont'd

5. **OPDA abundance was maintained in infested Molly wheat treated with SA (Fig. 6 A) or OPDA** (Fig. 6 B). Note that the OPDA abundance in the infested Molly wheat treated with the combination of heat (35°C for 24 h) and SA (Fig. 6 A. SA & Heat) or the combination of heat and OPDA (Fig. 6 B, OPDA & Heat) were comparable with Molly wheat in the incompatible interactions (Fig. 6 A, CK24 & 6 B, CK 24, respectively).

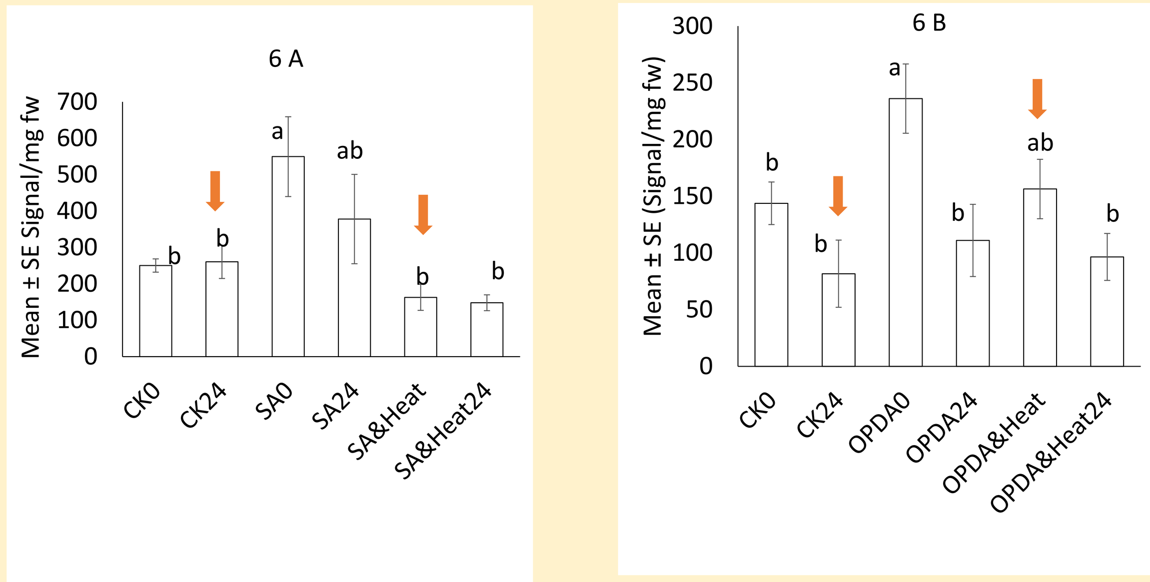


Fig.6. OPDA abundance at Hessian fly feeding site tissue in Molly wheat seedlings plants treated with exogenous SA (6 A) OPDA (6 B).

Conclusions

- Heat stress has a dosage impact on resistance of wheat plants to HF.
- Heat stress caused significant changes in lipid and phytohormone metabolisms of wheat plants.
- The loss of wheat resistance may be related to the heat-induced reduction in OPDA abundance and changes in lipid metabolism.
- Externally applied SA and OPDA may prevent reduction of OPDA abundance in heat-stressed wheat plants, leading to the enhanced resistance.

Summary of Educational Outcomes

Hessian fly project has become an effective vehicle to promote student success at FSU.

- 27 students have been trained in research and publication since 2009 including 8 MS students, 10 undergraduates, and 9 high school interns.
- 10 students co-anchored 3 publications and 1 manuscript in JEE.
- 10 conference presentations were given by students.
- The project has made positive impacts on students' career and life.

Ongoing Project

Mechanism of heat induced loss of wheat resistance to Hessian fly. (2017-2020). $295,149. NSF-HBCUP-Research Initiative Award.

Overall research goal

- Use a combination of phenotyping, RNA-seq, bioinformatical analysis, and RT-QPCR to reveal mechanisms of heat-induced loss of host plant resistance to insects using wheat-Hessian fly system as a model.
- Advance understanding of plant-insect interaction and co-evolution in the context of environmental change and global warming.

Overall educational goal

- Promote undergraduate students success in science via engaging them in process of research, discovery, and information sharing.
- Enhance research capacity of FSU in STEM disciplines.

Collaborators

- Ming-Shun Chen, KSU.
- Fred Gould & Xinxia Peng, NCSU.
- John (Jiazheng) Yuan, FSU

Undergraduate researchers

- Daria Brown, Amaiah McKoy, Jordan Oneal
  (Left to right in the picture)