NC STATE UNIVERSITY

Warming Nights: The Changing Climate's Effect on Crops & Pests

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Overview

The average mean temperature is rising. However, over crop-growing areas, nights are warming faster than days.

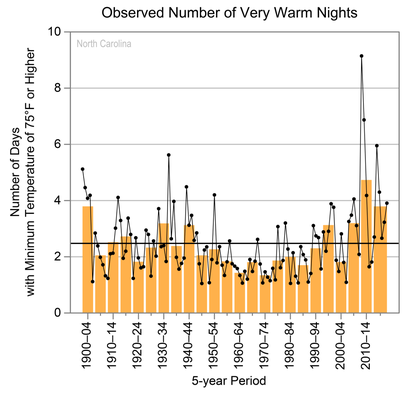
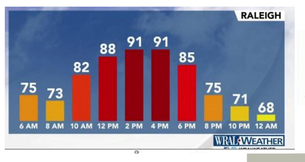


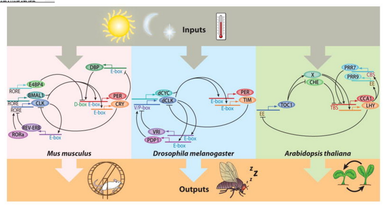
Figure 1: An increasing number of warm nights. Left: The number of warm nights (above 65°F) in Atlanta (Figure from Climate Central). Right: Number of days when the minimum (night) temperature was above 75°F (Figure from NOAA).

Recurring Patterns Dominate Life on Earth

We live in a world that is dominated by daily & annual cycles, both biotic and abiotic.



Because these cycles are so prevalent organisms with a functional, internal clock have an advantage. Therefore, most organisms have this internal, or circadian clock.



Warming Nights Harm Many Crops, but may Benefit Some Pathogens

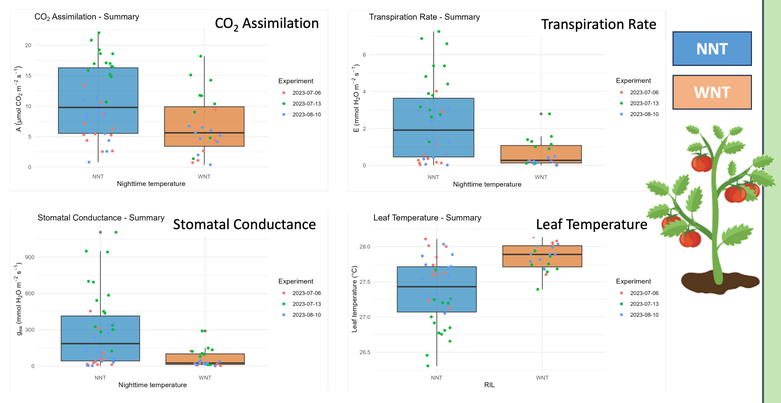


Figure 12: Tomato plants are also affected by WNTs. They have reduced carbon assimilation and increased leaf temperature.

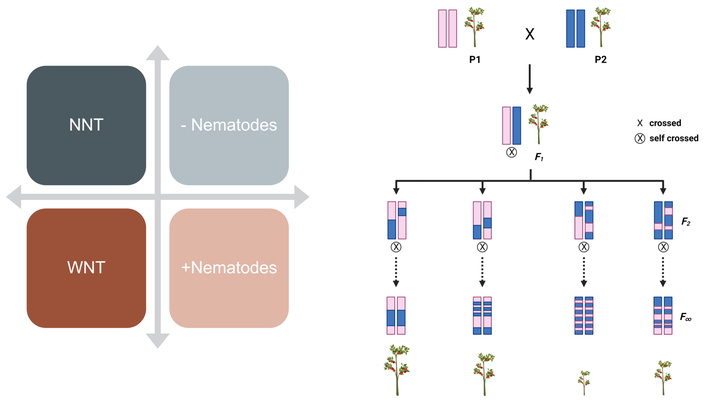


Figure 13: Using recombinant inbred lines of a wild tomato relative and a domestic tomato we are investigating the interaction between WNTs and nematode infections.

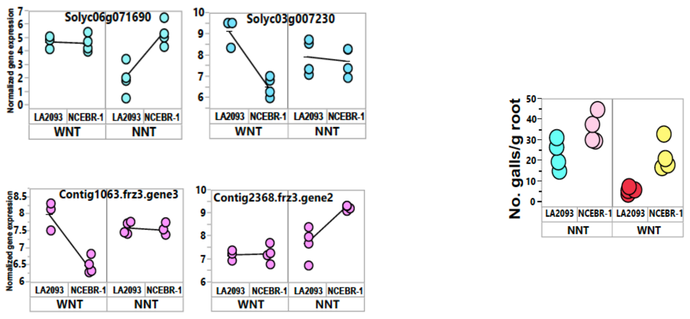
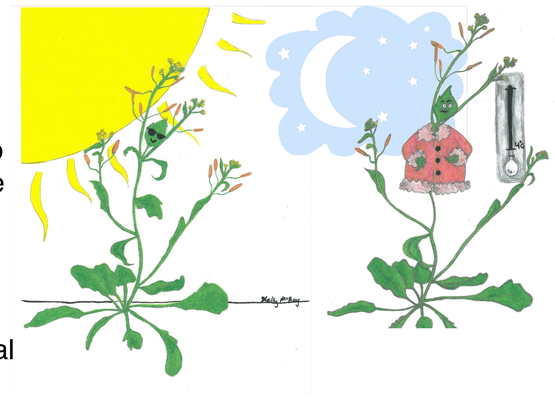


Figure 14: Interactions between WNTs and nematode responses have been observed in the tomato lines at the transcript level and the total number of galls made by the nematodes.

Altered Timing of a Stress can be Worse than Increases in Magnitude

Earlier springs, altered precipitation, & warmer nights are all new challenges, especially for crops. Many heat-sensitive plant molecular processes are relegated to nighttime periods to protect these sensitive processes from the heat of the day. Additionally, plant responses to heat (and other stresses) are regulated by the circadian clock. Thus, warming nights can reduce plant heat tolerance through several mechanisms.



Warmer night temperatures (WNTs) result in reduced yield and grain quality in rice and other crops.

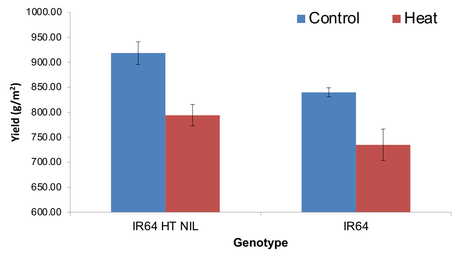


Figure 2: Yields are reduced by exposure to WNT (red) compared to controls (blue) in both the IR64 and the heat tolerant near-isogenic line.

WNTs Disrupt Global Gene Expression in Rice

Experimental Design

Figure 3: Field-grown rich in control (left and 3rd plots) and WNT heated (2nd and 4th plots). Ceramic heaters were used to increase the temperature of the rice in the WNT conditions only at night.

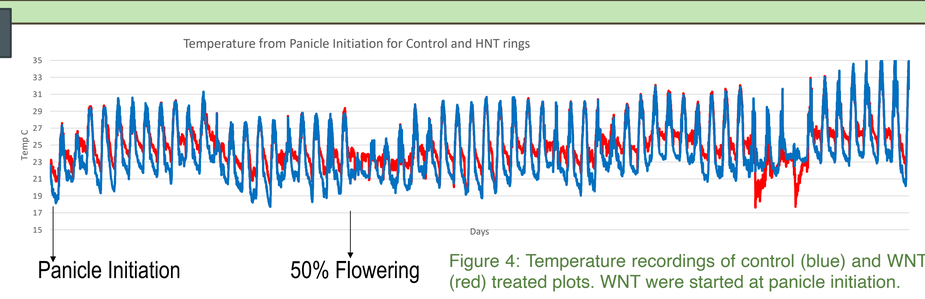


Figure 4: Temperature recordings of control (blue) and WNT (red) treated plots. WNT were started at panicle initiation.

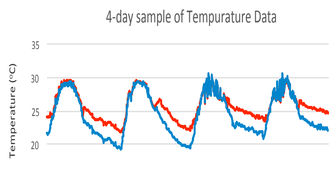


Figure 5: Treatment is only at night and is less than the day to night temperature difference.

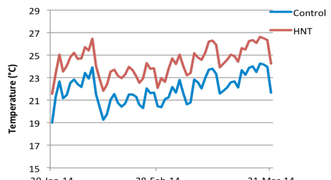


Figure 6: Temperatures at night maintained a consistent difference between treatment and control across the growing season.

WNTs Disrupt the Plant's Internal Timing

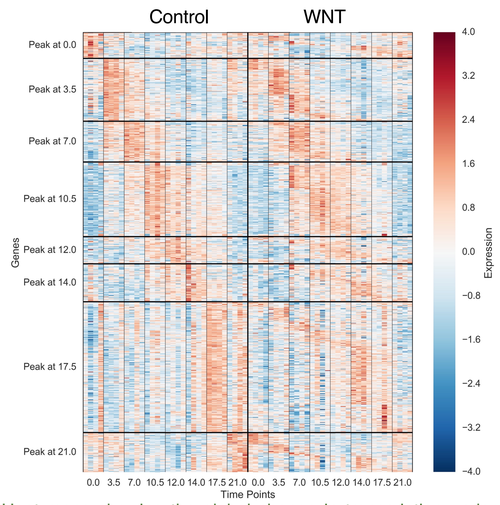
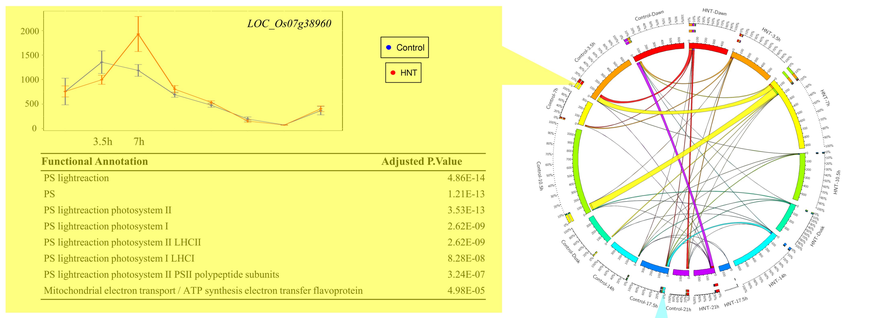


Figure 7: Heat maps showing the global change in transcription under WNT in field grown rice panicles. Each row is a transcript from a rice gene. All detectable transcripts are plotted. Each column is a replicate they are ordered by time of day starting at dawn. There are four replicates per time point. The samples on the left are in normal nighttime temperature and the samples on the right are in WNT. Red indicates the highest expression level for that transcript and blue the lowest. Rows are ordered by the peak of expression in control conditions.



Functional Annotation	Adjusted P.Value
PS lightreaction	4.86E-14
PS	1.21E-13
PS lightreaction photosystem II	3.53E-13
PS lightreaction photosystem I	2.62E-09
PS lightreaction photosystem II LHCII	2.62E-09
PS lightreaction photosystem I LHCI	8.28E-08
PS lightreaction photosystem II PSII polypeptide subunits	3.24E-07
Mitochondrial electron transport / ATP synthesis electron transfer flavoprotein	4.98E-05

Functional Annotations	Adjusted P.Value
Transport phosphate	1.54E-03
Protein degradation inhibitors	1.60E-03
Misc short chain dehydrogenase/reductase (SDR)	2.87E-03
Protein targeting secretory pathway unspecified	2.87E-03
Signalling MAP kinases	2.87E-03
Misc glutathione-S-transferases	2.87E-03

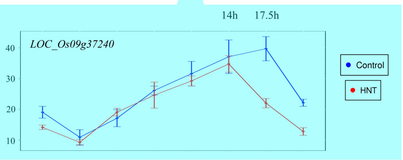


Figure 8: WNT results in expression pattern changes for many genes. Dawn-peaking genes show a "delayed start" and evening peaking genes show a phase advance.

Acknowledgements

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United States Department of Agriculture

National Institute of Food and Agriculture

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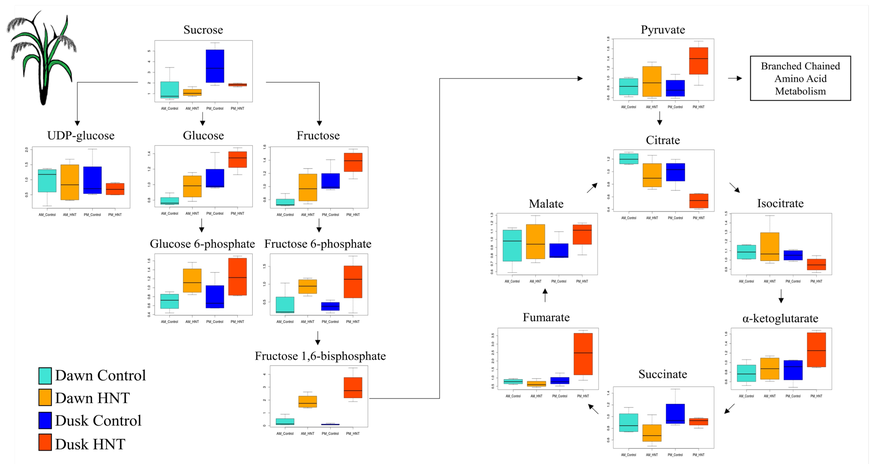
Mimetics assisted with the transcript analysis and visualization of the rice data.

Metabolism is disrupted by WNTs

Figure 9: Metabolite levels are altered under WNT. Both glycolysis and the TCA cycle, components of primary metabolism, are affected by WNTs.



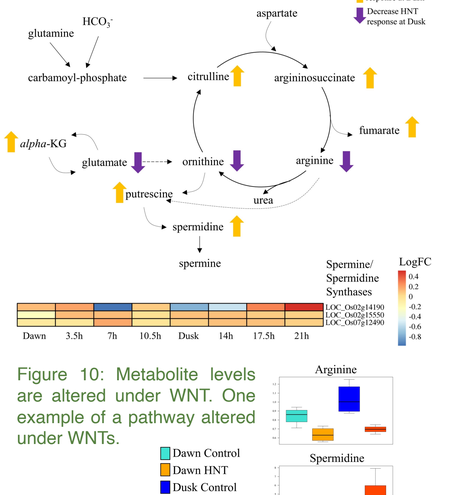


Figure 10: Metabolite levels are altered under WNT. One example of a pathway altered under WNTs.

Transcript-Metabolite Cluster Relationship

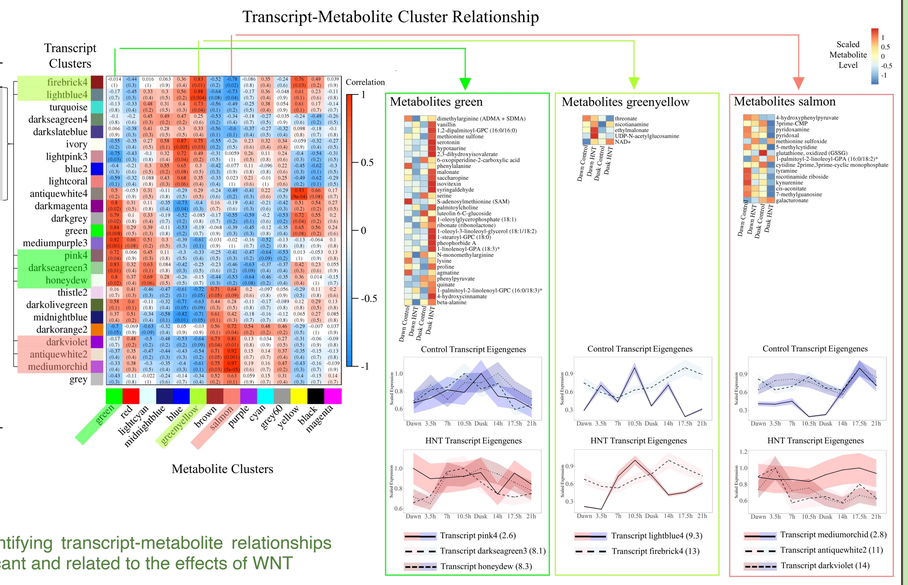


Figure 11: Identifying transcript-metabolite relationships that are significant and related to the effects of WNT