

High Throughput Characterization of Wheat Photosynthetic Efficiency, Biomass, and Yield



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Introduction

Wheat is the third largest acreage crop in the United States; roughly 58 million acres were planted domestically in 2014. In Michigan, soft red and white winter varieties face many potential risks for yield loss. Breeding wheat varieties with desirable characteristics for yield and disease resistance is necessary to cope with these challenges, but requires much time and resources. The MSU Wheat Breeding and Genetics Program measured photosynthetic parameters of Michigan wheat varieties using a handheld, high throughput system called PhotosynQ.

- Photosynthetic activity is a quantitative measure that can be correlated to biomass production, which is thought to contribute to yield.
- Key parameters measured with PhotosynQ include photosystem II (Phi2) efficiency and non-photochemical quenching (NPQ).
- Soft red and white winter wheat varieties were used.
- Field-plot based data such as Leaf Area Index (LAI) and foliar disease scores were also collected.

These data can help illustrate a comprehensive picture of crop performance under both biotic and abiotic stress.

Methods

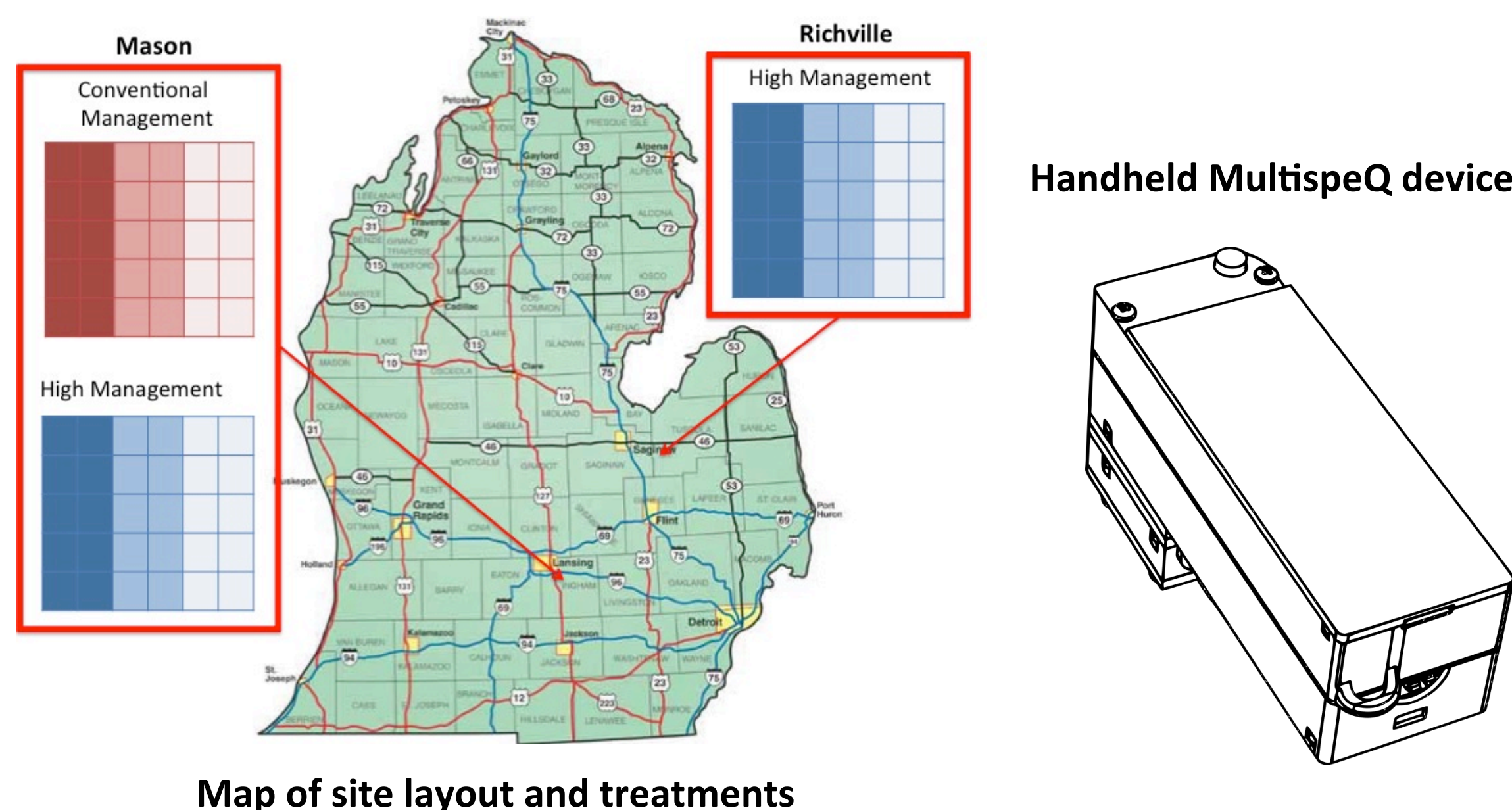
This study was done on the MSU Annual Yield Trial plots, which consist of 30 elite wheat varieties arranged in a completely randomized alpha lattice block design. The study was conducted in two of these yield trial locations, Mason and Richville, MI.

- Two different treatments were used
 - Conventional Management: 90 lbs N/acre
 - High Management: 120 lbs N/acre + 2 foliar fungicide applications
- 4 measurements were taken on the flag leaf per collection day (2 morning + 2 afternoon)
- Measurements were taken at 4 growth stages (Table 1)

Table 1. Description of Feekes Development Stages and Measurement leaf

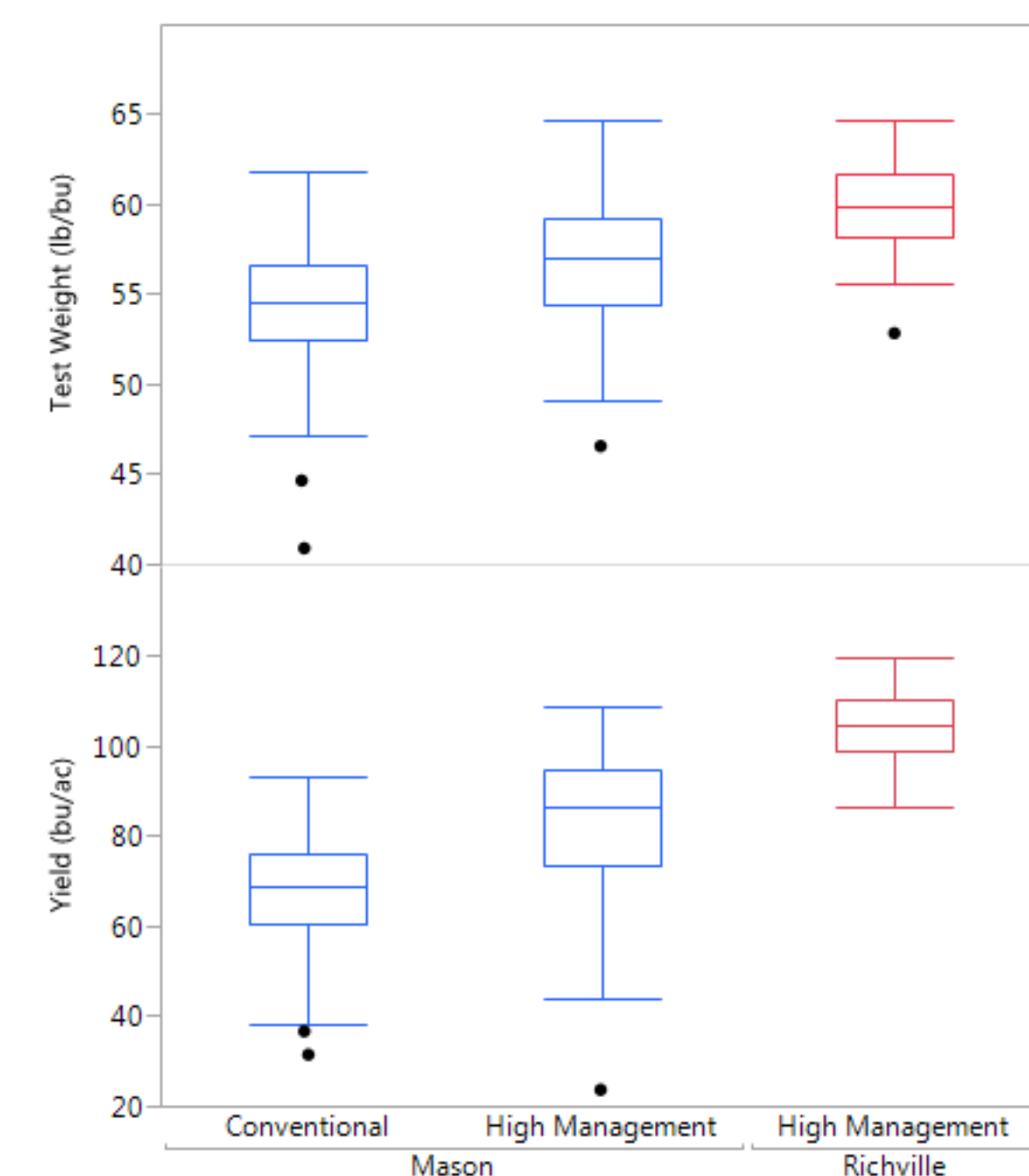
Stage	Feekes Scale	Description	Leaf
Stage 1	Feekes 9	Nearly done with stem extension	Flag -1
Stage 2	Feekes 10.5	Flowering	Flag
Stage 3	Feekes 11.1	Medium Milk	Flag
Stage 4	Feekes 11.2	Soft dough	Flag

- Measurements were taken on the most apically dominant leaf, 2/3 of the way down leaf length toward the leaf tip.



Results

Figure 1. Box plot analysis of yield and test weight at both locations



- High management results in higher test weight and yield averages.
- There is a negative correlation between average foliar disease and yield ($r^2 = 0.31$, $p < 0.0001$)

Figure 2. Scatterplot of yield vs average foliar disease

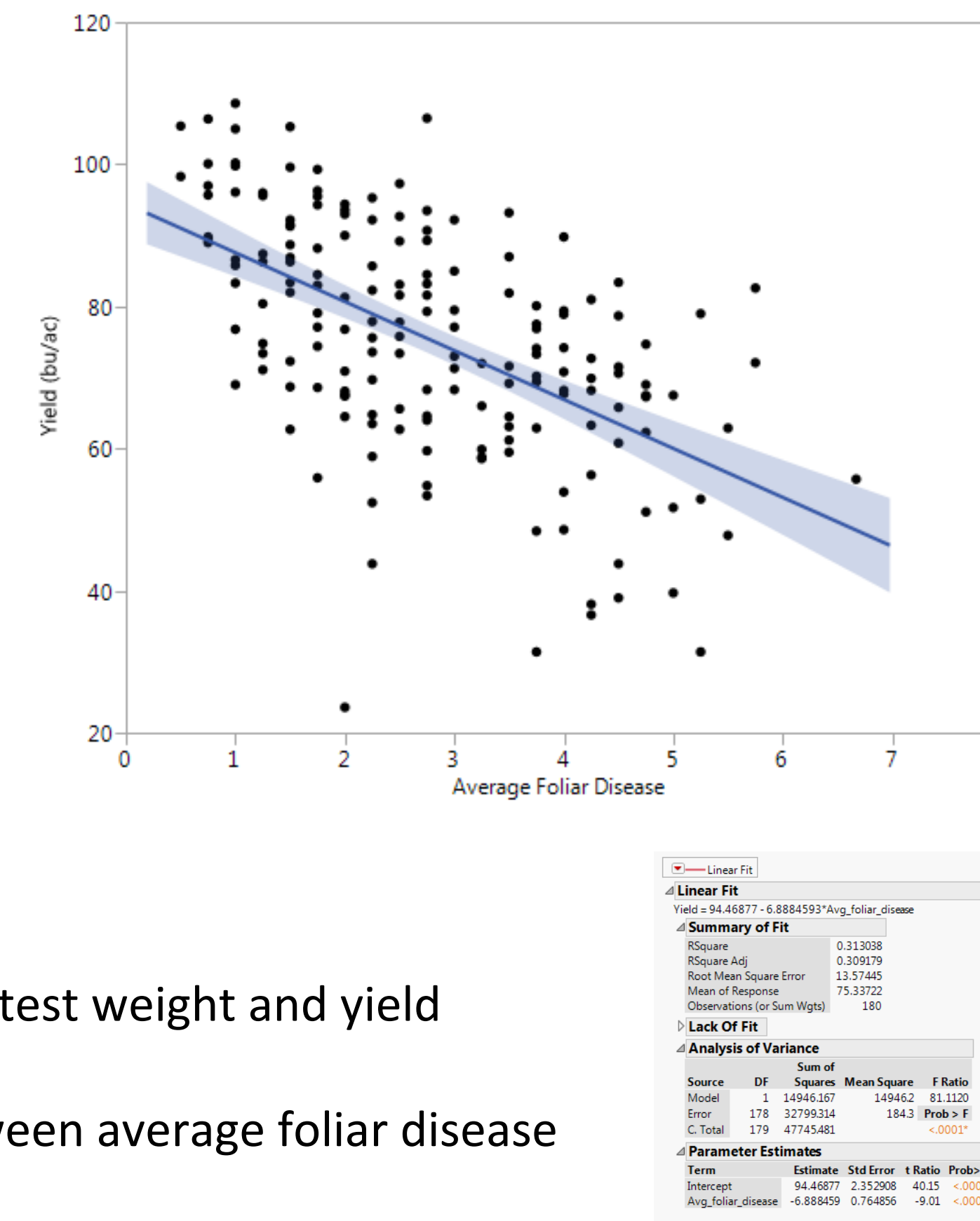
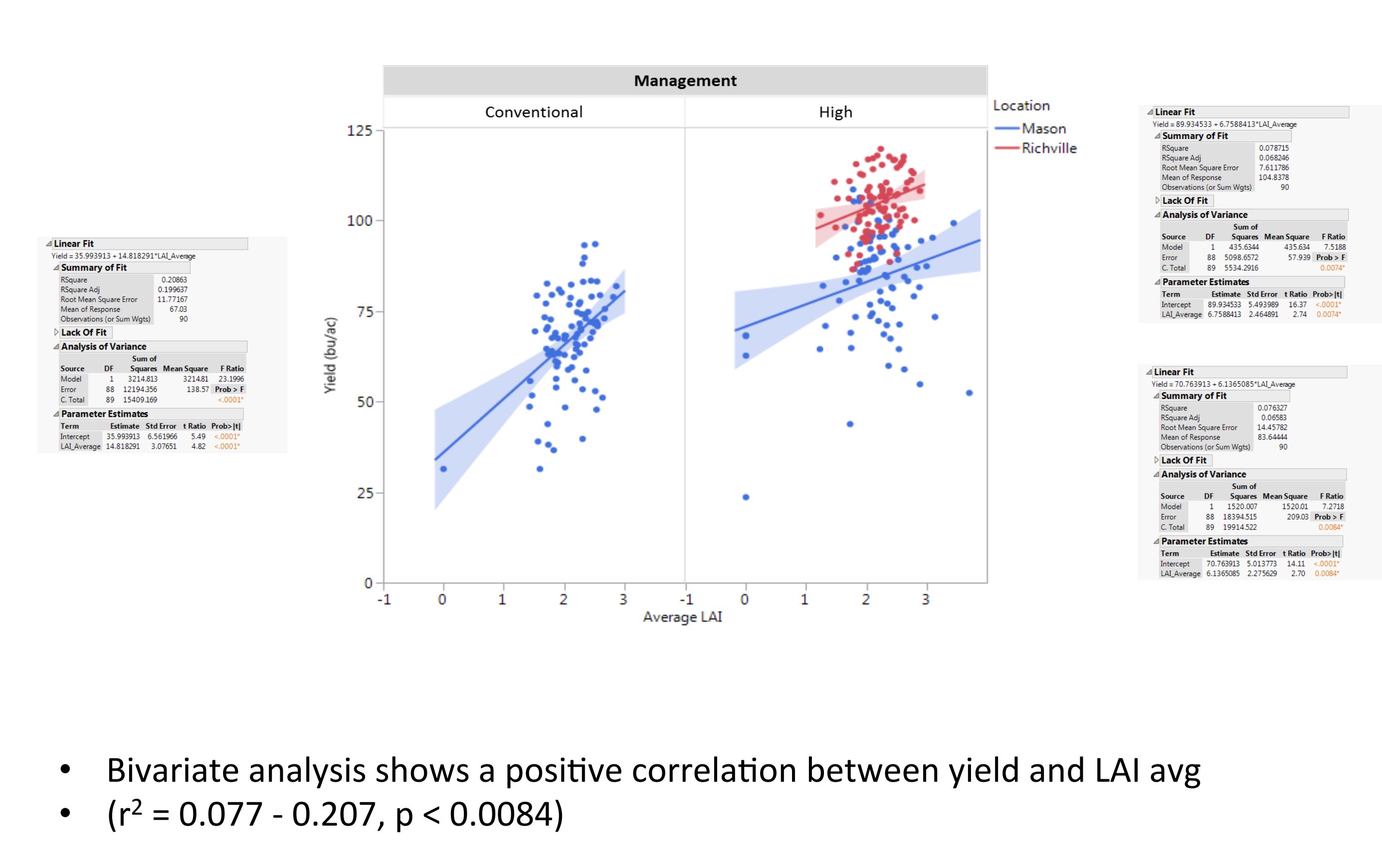


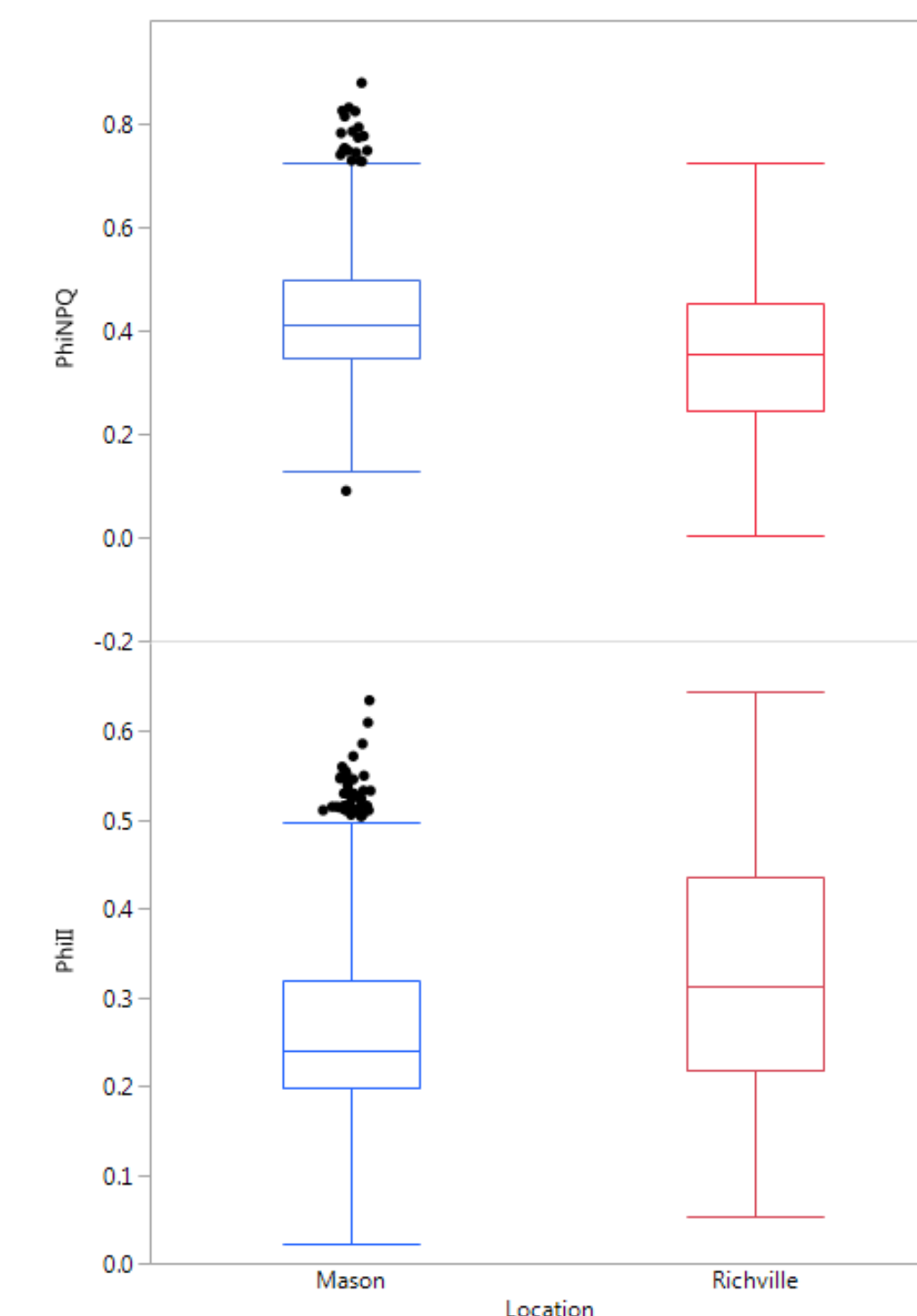
Figure 3. Scatterplot of yield vs LAI score average



- Bivariate analysis shows a positive correlation between yield and LAI avg
- ($r^2 = 0.077 - 0.207$, $p < 0.0084$)

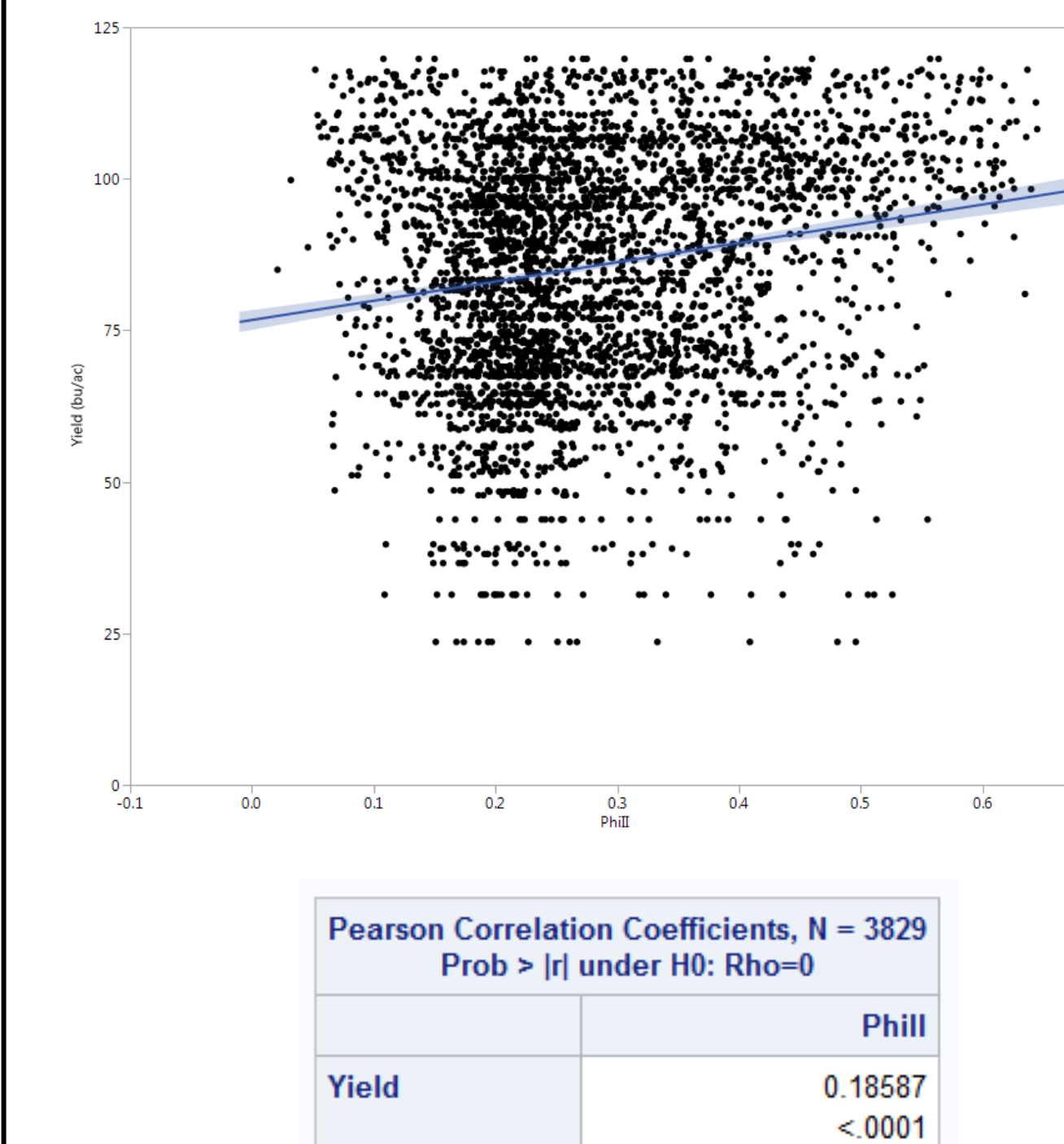
Figure 4. Effects of location on Phi2 and PhiNPQ

Model Information	Type 3 Tests of Fixed Effects
Data Set: WORK_WHEATSUB	Effect: Location Sum of Squares Mean Square F Value Pr > F
Dependent Variable: PhiNPQ	Location 1 0.0011 0.0011 0.9711
Covariance Structure: Variance Components	Least Squares Means
Estimation Method: REML	Effect: Location Estimate Standard Error DF t Value Pr > t
Residual Variance Method: Profile	Location M R 0.2327 0.00772 4 30.40 <.0001
Fixed Effects SE Method: Model-Based	Location M R 0.2076 0.00791 4 26.47 <.0001
Degrees of Freedom Method: Containment	Differences of Least Squares Means
	Effect: Location Location Estimate Standard Error DF t Value Pr > t
	Location M R 0.07917 0.00827 4 9.51 0.0011



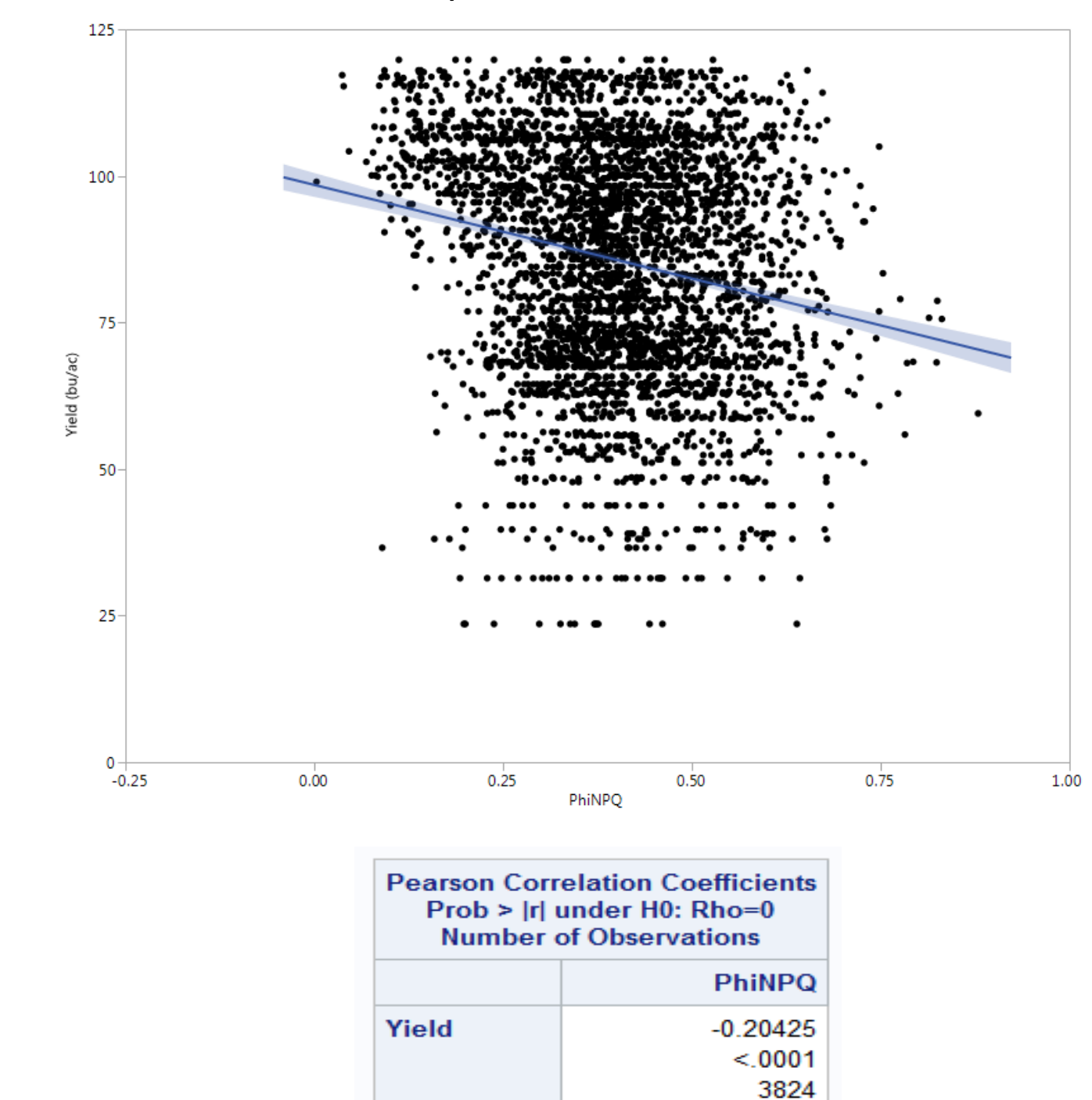
- Management had no statistical significance on Phi2 or PhiNPQ
- Location, however, did significantly affect Phi2 ($p < 0.0051$) and PhiNPQ ($p < 0.0011$)

Figure 5. Pearson Correlation of yield and Phi2 across all varieties, locations and treatments



Pearson Correlation Coefficients, N = 3829	
Prob > r under H0: Rho=0	
Yield	Phi2
	0.18587
	<.0001

Figure 6. Pearson Correlation of yield and PhiNPQ across all varieties, locations and treatments



Pearson Correlation Coefficients	
Prob > r under H0: Rho=0	
Yield	PhiNPQ
	-0.20425
	<.0001

- Overall positive correlation between Phi2 and yield

Conclusions

- High management had significant positive correlation to yield; foliar disease negatively correlated to yield.
- Higher LAI scores positively correlate to yield.
- Location significantly impacted Phi2 and PhiNPQ.
- Phi2 and PhiNPQ are the major destinations for absorbed sunlight, and are indicative photosynthetic parameters of overall yield and productivity.
- The PhotosynQ system would be a valuable selection tool to complement the phenotypic and genotypic selection of a breeding program, saving time and resources.
- Improvements are being made to the affordable handheld MultispeQ and cloud-based database structure.

References

1. Photosynq.org, Kramer Lab, Michigan State University
2. USDA. National Agricultural Statistics Service. Crop Production 2014 Summary. Ed. Michael T. Scuse and James M. Harris. USDA, Jan. 2015. Web. Nov. 2015.

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