Evaluation of genetic gain for dynamic traits related to water stress tolerance in maize using nondestructive high-throughput phenotyping

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Introduction

- Yield gains in maize have been attributed to greater stress tolerance. Secondary traits such as a decreased anthesis-silking interval, a decreased propensity to root lodge, and increased functional chlorophyll late in the season have allowed maize to be grown in increasingly stressful environments (rain-fed, high plant density).
- Sensor technology has the ability to characterize many secondary traits throughout the growing season by calculating vegetative indices from hyperspectral reflectance data.

Hypothesis

- Genetic gain for grain yield is associated with differential response to water stress throughout the growing season.
- Non-destructive, sensor measurements can detect these differences in secondary, leaf-level traits related to drought tolerance.

Figure 1. High-throughput phenotyping technology. A) The leaf clip position on a leaf. B) The hyperspectral backpack system attached to the leaf clip.

Objectives

1) Asses genetic gain in traits related to drought tolerance by noting how they change across eras.
2) Analyze how certain secondary traits respond to environmental cues throughout the growing season.

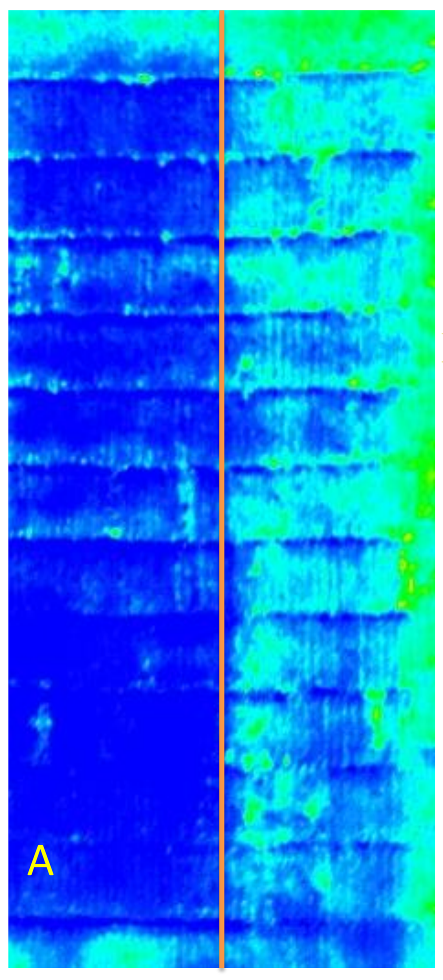
Pedigree	Year of Release
307HYB Pioneer	1936
WF9/38-11//Hy/L317	1948
NS 0	1948
Wf9/Hy//L289/I205	1950
329HYB Pioneer	1954
B37/B14//C103/Oh43	1958
N501D	1964
B37/OH43	1965
B37/B14//Mo17	1965
3390 Pioneer	1967
3334 Pioneer	1969
N7A/Mo17	1970
3366 Pioneer	1972
NS[RFS_NB]3_8	1972
B73/Mo17	1974
3541 Pioneer	1975

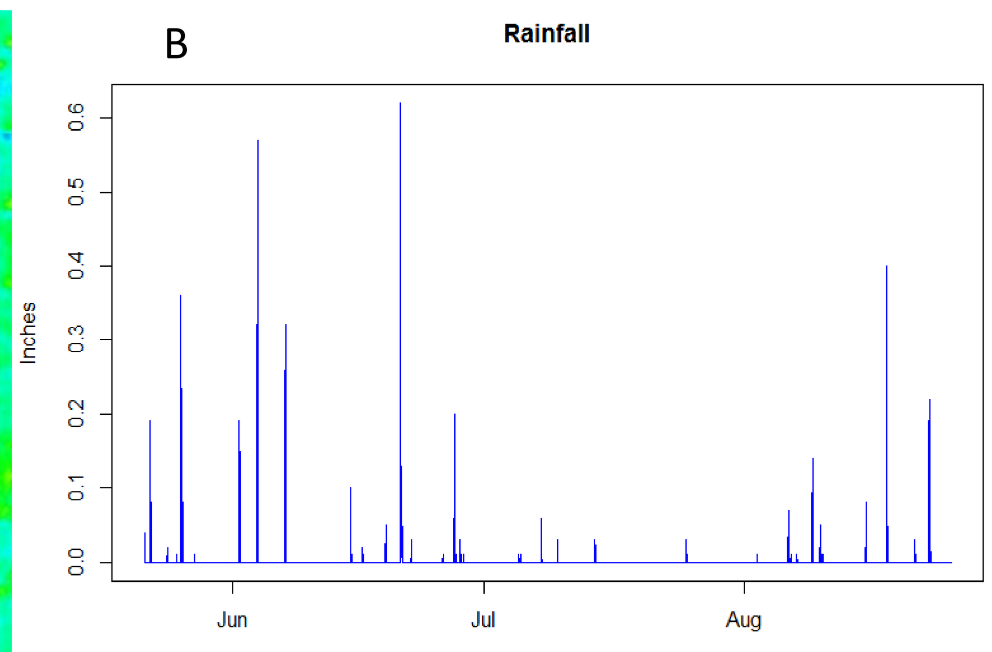
Pedigree	Year of Release
B73/LH39	1982
B73/LH51	1983
LH132/LH51	1985
LH156/MBS2333	1988
LH132/LH59	1988
3379 Pioneer	1988
LH192 /LH82	1991
3394 Pioneer	1991
33A14 Pioneer	1997
33P67 Pioneer	1999
33D49 Pioneer	2008
H-7949 Golden Harvest	2010
2A555 Mycogen	2010
P0876HR Pioneer	2010
P0987HR Pioneer	2010
7630RR Hoegemeyer	2011
7644 Hx/LL/RR Hoegemeyer	2012
N45P-4011 NK	2012

Table 1. Pedigree or hybrid name and year of release for all cultivars used in this study. The different shades designate the six eras that the hybrids span.

Materials and Methods

- 34 popular commercial hybrids from the 1930's to present day.
- Two-row plots evaluated in Lincoln, NE during the summer of 2014.
- Randomized complete block design with three replications in irrigated (WW) conditions and three replications in rain-fed (WS) conditions.
- Environmental data collected with a WatchDog station.
- Soil moisture data collected with Watermark sensors.
- Phenotypic data collected with typical handheld instruments and visual scoring, and also by high-throughput technology with a hyperspectral backpack system (300 – 1020 nm).





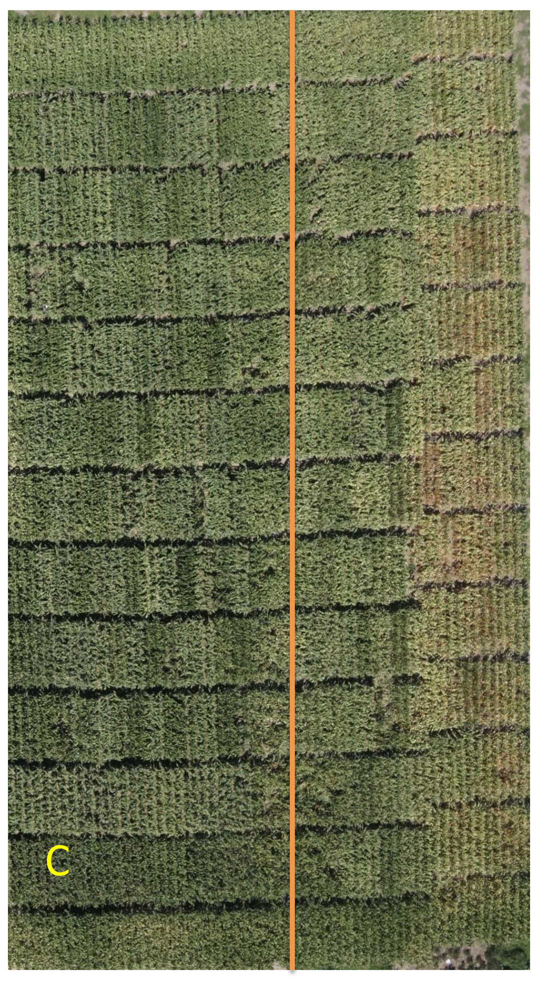


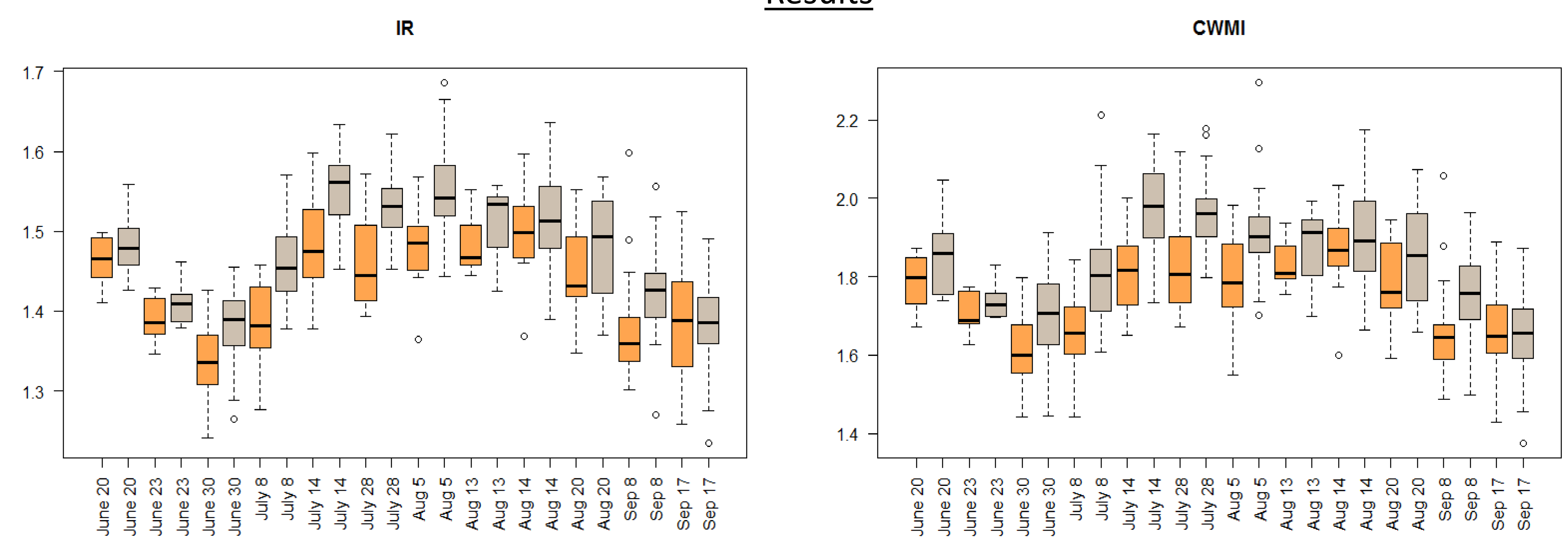
Figure 2. A) Thermal image of the WW(left) and WS(right) plots. B) Rainfall events throughout the summer. C) RGB image of the WW(left) and WS(right) plots.

Traits of Interest and Corresponding Vegetative Indices

Typically, in eastern Nebraska, rainfall can be expected periodically. As a result, maize should be selected for dehydration tolerance, or the ability to maintain growth during periods of stress. Certain traits correspond to this type of tolerance, and high-throughput phenotyping techniques can monitor these traits throughout the season.

- Maintained stomatal conductance: Although water is lost when the stomata are open, it allows carbon dioxide to be fixed and photosynthesis to continue. **Vegetative index to monitor trait = IR**
- Maintained water content: The ability of cells to maintain turgor pressure is extremely beneficial. **Vegetative index to monitor trait = CWMI**
- Maintained chlorophyll concentration (Stay-green): Combatting early senescence and chlorophyll destruction under stress will increase yield potential. **Vegetative index to monitor trait = Git**

Results



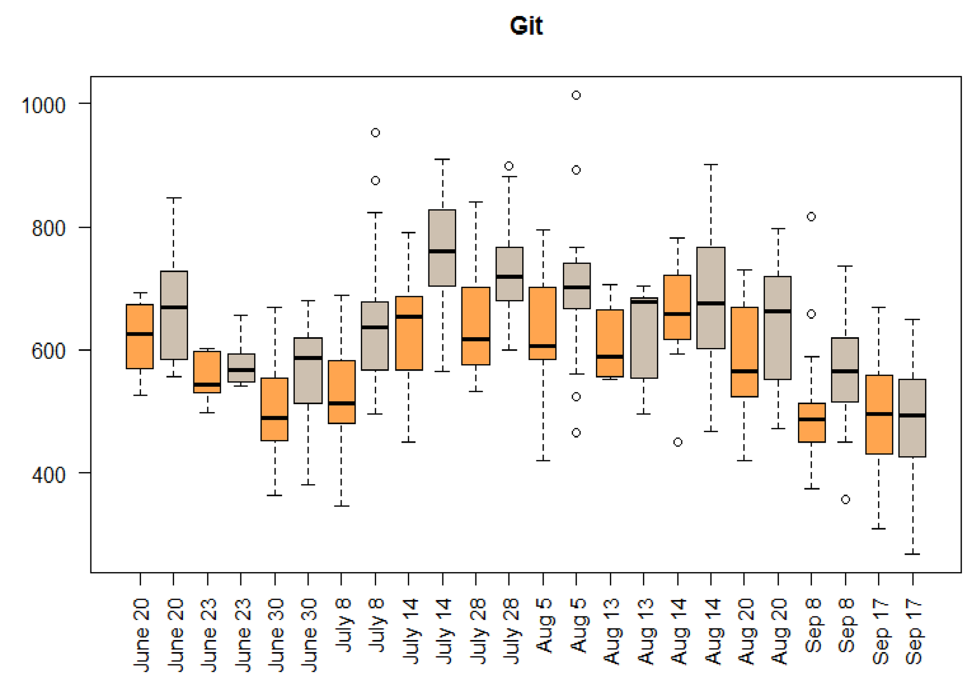
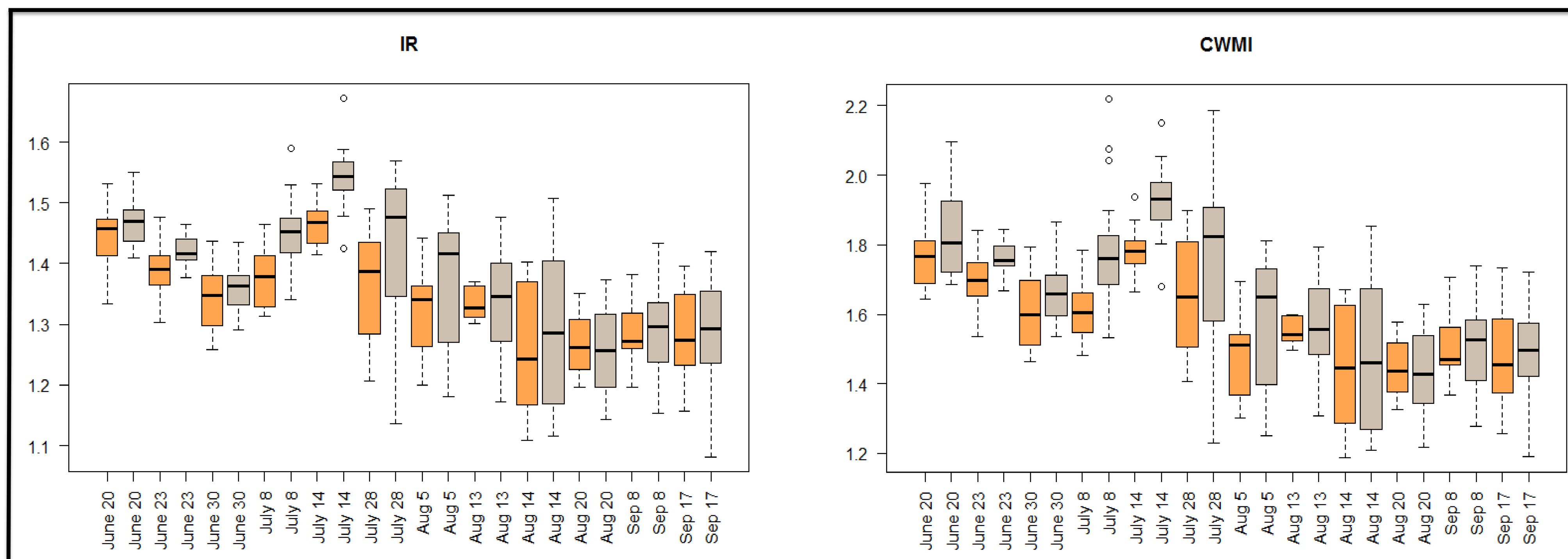


Figure 3. Vegetative indices of Era 1 (1936-1958) (Tan) and Era 6 (2008-2012) (Gray) hybrids under well-watered conditions measured throughout the growing season. For each index, a lower value corresponds to decreased stomatal conductance, decreased water content, and decreased chlorophyll content, respectively.



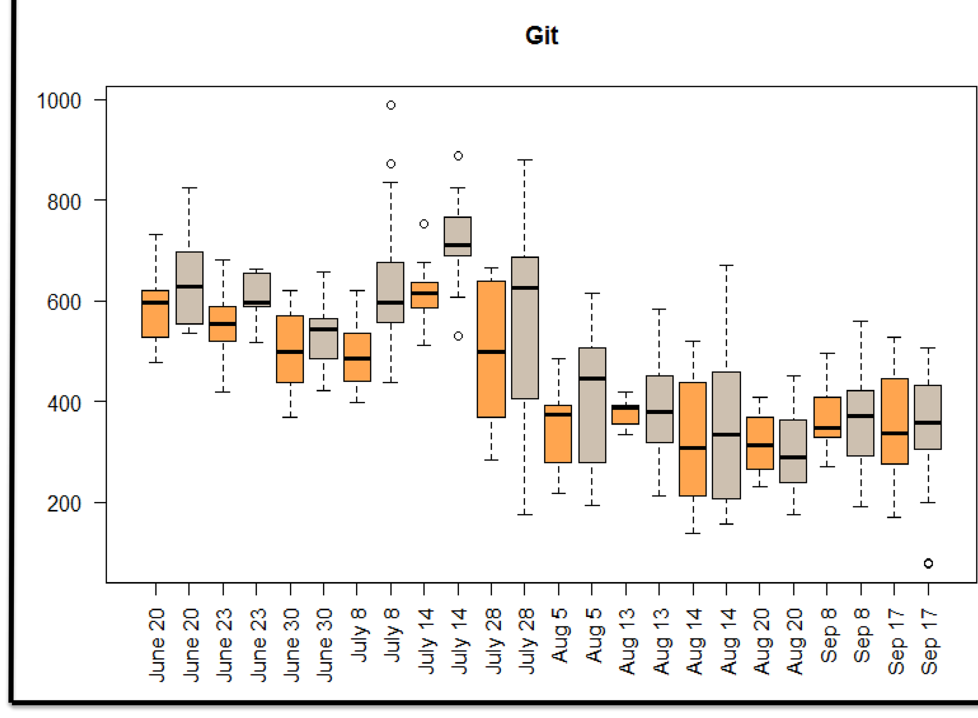


Figure 4. Vegetative indices of Era 1 (1936-1958) (Tan) and Era 6 (2008-2012) (Gray) hybrids under water stressed conditions measured throughout the growing season.

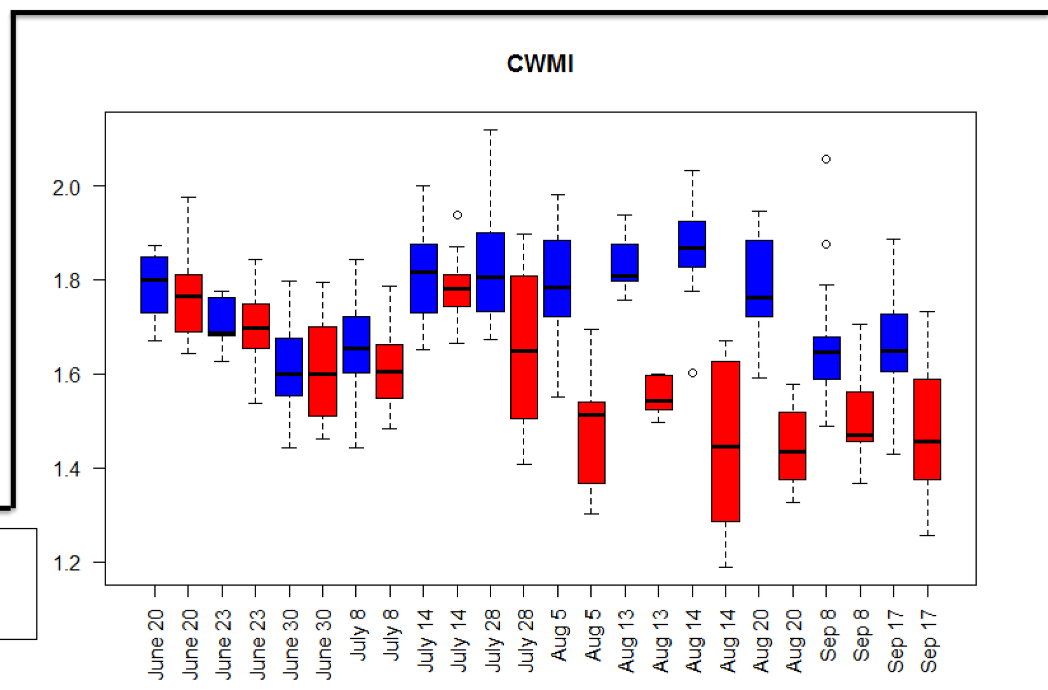


Figure 5. Water content of Era 1 hybrids between WW (blue) and WS (red) plots.

Conclusions

- The hyperspectral backpack system does detect differences between new and old hybrids for various traits related to drought tolerance. There has been genetic gain in these traits.
- The differences were most prominent later in the growing season (July-August).
- Irrigated verses rain-fed environments yield drastically different maize physiology.

Future Work

- Conduct further tests of significance on these vegetative indices.
- Correlate vegetative indices to other phenotypes we collected by hand.
- Repeat next year and use a multispectral UAV to obtain more measurements throughout the season.

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