Introgression of Novel Disease Resistance Genes from *Miscanthus* into Energycane

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Project Goals: Our long-term goal is to improve energycane productivity and sustainability by providing resistance to key diseases with novel genes from *Miscanthus*.

1) **In miscane BC_1 populations (sugarcane x (sugarcane x *Miscanthus*)), identify molecular markers associated with novel genes from *Miscanthus* that confer resistance to at least two out of four of the following economically important diseases of sugarcane: ratoon stunt, yellow leaf, orange rust, and smut.**
2) **Compare effectiveness of different molecular marker analysis methods for selecting disease resistance alleles in miscane backcross populations. In particular, compare the pseudo-testcross QTL mapping strategy with genomic selection.**
3) **Screen germplasm collections of *M. sinensis* and *M. sacchariflorus* for resistance to ratoon stunt, yellow leaf, orange rust, and smut to confirm that *Miscanthus* is uniformly immune to these diseases as prior data suggest or to quantify genetic variation for resistance if not all accessions are resistant.**

Sugarcane is among the world's leading bioenergy crops. Modern sugarcane cultivars are derived from a relatively small set of founder genotypes, which has contributed to cultivar susceptibility to diseases. Modern sugarcane cultivars originated in the late 1800's when cultivars of *Saccharum officinarum* with high sugar yield potential but disease-susceptibility were crossed with the undomesticated, non-sugar producing but disease-resistant *S. spontaneum*, then backcrossed to *S. officinarum* to recover sugar yield. Recent efforts to improve sugarcane for disease resistance, pest resistance, and abiotic stress tolerance have continued to rely primarily on introgressions from *S. spontaneum*. Similarly, energycanes (sugarcanes bred specifically for energy) are also bred from modern sugarcane cultivars and *S. spontaneum*.

Yet, diseases are the primary constraints to cane productivity in commercial fields. Sugarcane is a perennial crop but a planting's commercial productivity in the U.S. is typically limited to 3-5 years because disease pressure reduces yield and decreases stand via plant death each year. Moreover, the utility of a successful cane cultivar for commercial production is typically ended by the emergence of a virulent strain of a common pathogen, resulting in reduced yields. Though many diseases affect sugarcane, the following four are of especially great concern (Rice, 2007): 1) ratoon stunt (bacterium *Leifsonia xyli* subsp. *xyli*.); 2) sugarcane yellow leaf (virus, *Sugar Cane Yellow Leaf Virus* (*SCYLV*); 3) orange rust (fungus *Puccinia kuehnii*); and, 4) smut (fungus *Sporisorium scitamineum*).

Arguably, *Miscanthus* would be a better source of genes for improving sugarcane than *S. spontaneum* because the former is highly resistant to diseases and pests, is more broadly adapted to diverse environments, and is more genetically distant from *S. officinarum* (thus providing more novel alleles). However, the use of *Miscanthus* for improvement of sugarcane has been limited, perhaps in large part due to prior lack of access to *Miscanthus* germplasm. PIs Sacks and Yamada have developed large and diverse *Miscanthus* germplasm collections. Recently, we have obtained more than a dozen F_1 hybrids between sugarcane and *Miscanthus* (including hybrids between cane × *M. sinensis* and cane × *M. sacchariflorus*). Backcrosses to sugarcane have been made and will soon be germinated.

Disease screenings were conducted in 2017 on miscane F_1 progeny, and core collections of *M. sinensis* and *M. sacchariflorus*. For the most part, our hypotheses of ubiquitous resistance in *Misccanthus* were confirmed. For smut, all of the 66 *Misccanthus* genotypes tested were fully resistant, and for orange rust all but one of the *Misccanthus* genotypes tested were fully resistant. For ratoon stunt disease, only two *Misccanthus* genotypes were susceptible and these were much less susceptible that the sugarcane positive control. Response of *Misccanthus* to sugarcane yellow leaf virus was more variable than for the other diseases tested, with 14/31 *M. sacchariflorus* and 24/35 *M. sinensis* fully resistant, but the remainder were partially to fully susceptible. Of six miscane genotypes tested to date, one was fully resistant to all four diseases, six were fully resistant to orange rust and smut, four were resistant to ratoon stunt, and three were resistant to sugarcane yellow leaf virus.

Subsequently, backcross progeny will be evaluated for disease-resistance and we will compare the standard QTL analysis method for sugarcane with genomic selection. To facilitate this comparison, we are developing optimized statistical models for relating genotype to phenotype in backcross (introgression) populations of polyploid plant species. In this work, we have simulated traits with contrasting genetic architectures in biparental crosses from multiple polyploid plant species, including sugarcane, and then compared the ability of markers that tag QTL to predict trait values to that using genome-wide marker sets. We expect these results to provide guidance on when it will be most appropriate to focus resources towards obtaining whole-genome marker sets versus sequencing only regions in the vicinity of QTL peaks.

Because disease susceptibility is a major limitation for cane production, cultivar durability, and sustainability, the introgression of effective and durable resistances to major cane diseases into energycane from *Miscanthus* is expected to increase the economic and environmental benefits of energycane while reducing costs and supply-side risks. Such benefits should promote further investment by industry in energycane production and processing capacity.

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