Predictive Models for Biomass Yield of Switchgrass Based On Morphological Traits

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INTRODUCTION

Switchgrass has many valuable characteristics as a biofuel feedstock; in order to become commercially viable further improvements must be made to improve biomass yield and consequently increase ethanol production. Direct selection for biomass yield in switchgrass has proven difficult due to the many factors influencing biomass yield. The identification of morphological traits associated with biomass yield could increase the efficiency of breeding efforts if these traits can be used as indirect selection criteria. By allowing increased screening and greater intensity of selection for biomass yield within spaced-plant nurseries, these results may impact how phenotypic selection is used for switchgrass cultivar development. **The objective of this research was to identify morphological traits in parent plants that are predictive of biomass yield within progeny plants.**

METHODS

From an advanced breeding nursery that had previously undergone selection for increased biomass yield, 140 parent plants were selected from 70 families. The selected parents plants were split into three pieces and transplanted to a separated nursery at Arlington, WI. Half-sib seed from each parent was used to conduct replicated seeded-plot yield trials at Arlington, WI and Marshfield, WI during 2009-2011. Plant morphological traits were measured on parent plants during 2010 and 2011.

Predictive models were generated to predict biomass yield at each location by year combination based on plant morphological traits using a best subset selection procedure and accounting for linear dependencies between traits. Models were also fitted to a best linear unbiased prediction (BLUP) of biomass yield based on all locations and years.

Figure 1. Morphological traits measured in replicated spaced-plant nursery of 140 parents

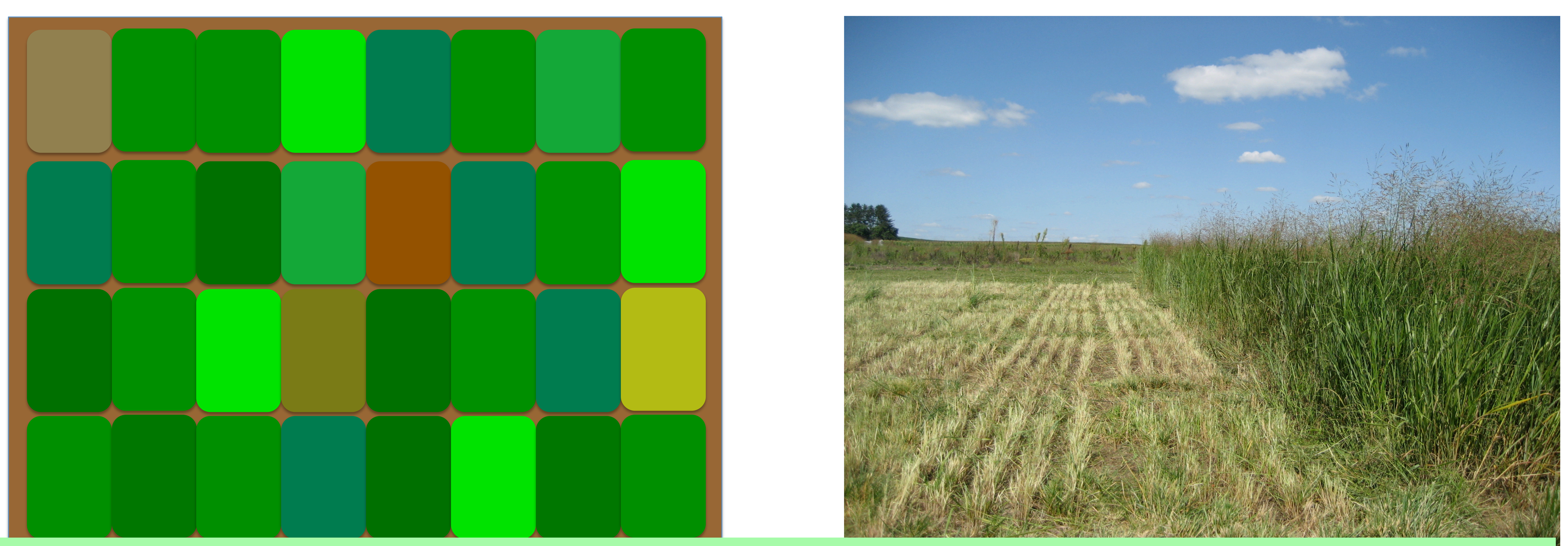

Figure 2. Replicated yield trial of half-sib progeny at two locations and three years

RESULTS

Variation was observed for all plant traits measured. Correlations between morphological traits ranged from -0.5 to 1. Correlations between individual traits and biomass yield were <0.2. Unique best models were identified for each location by year environment. Predictive capabilities were limited, based on adjusted R^2. Using BLUP estimates of biomass yield based on all environments resulted in greater predictive power. This trend was observed using multiple subsets of traits as predictors of BLUP estimates.

Variable (units)	Max	Min	Mean	SD
Yield Arlington 2009(Mg/ha)	17.4	7.2	12.0	2.0
Yield Arlington 2010(Mg/ha)	36.6	9.5	20.2	5.2
Yield Arlington 2011(Mg/ha)	24.9	6.0	15.2	4.1
Yield Marshfield 2009(Mg/ha)	22.6	11.1	15.3	2.3
Yield Marshfield 2010(Mg/ha)	19.4	4.1	10.3	3.2
Yield Marshfield 2011(Mg/ha)	20.1	5.9	10.6	2.5
BLUP estimate	1.6	-1.4	0.0	0.6
Dry mass 5 tillers(g)	64.8	15.7	42.6	8.8
Single plant dry biomass(g)	1027	98	600	183
Flowering date(Days after June 30)	39.2	20.8	27.7	3.3
GDD to flowering (accumulated GDD base 50F)	1948	1516	1695	83
GDD to flowering(accumulated GDD base 32F)	4391	3635	3936	140
Plant height(cm)	222	145	184	15
Flag leaf height(cm)	154	87	124	12
Mean panicle height(cm)	151	99	125	11
Mean panicle length(cm)	77.8	42.7	60.1	7.4
Mean 2nd leaf length(cm)	59.5	29.6	47.8	4.9
Mean 2nd leaf width(mm)	14.4	8.3	10.9	1.1
Mean internode length(cm)	26.3	16.9	21.6	1.8
Mean # of nodes(count)	7.0	4.8	5.9	0.4
Mean stem diameter(mm)	4.8	2.8	3.8	0.4
Crown circumference(cm)	136	22	86	17
Tiller count(count)	313	46	112	38
Tiller density(tillers per sq m)	37	9	19	5

Table 1. Summary of plant morphological traits and biomass yield used for predictive model development.

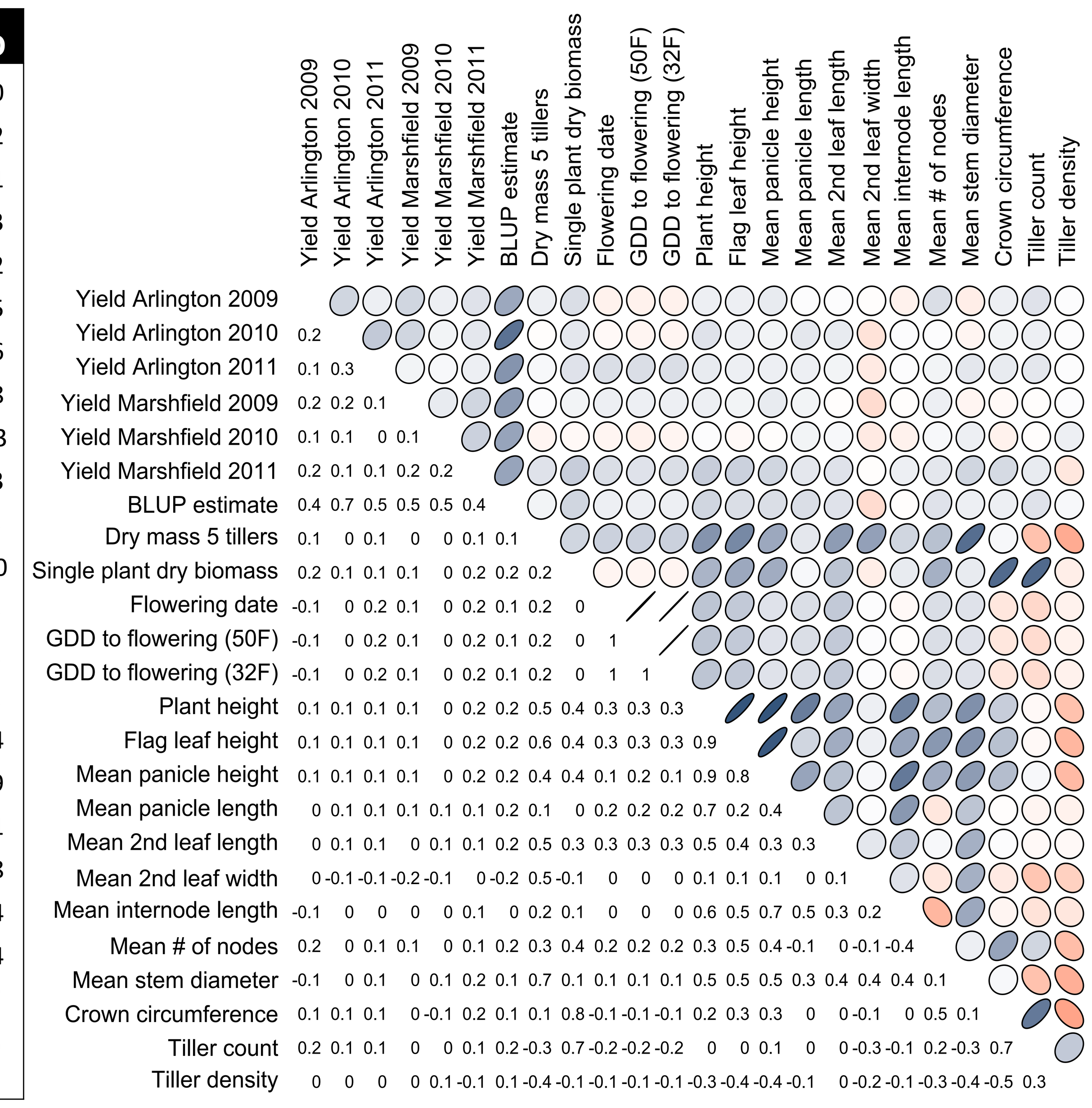

Figure 3. Pearson correlation coefficients of plant morphological traits and biomass yield. Red figures indicate negative corelations and blue positive. Shape indicates the strength of correlation.

	ARL2011	ARL2010	ARL2009	MSH2011	MSH2010	MSH2009	BLUP1	BLUP2	BLUP3	BLUP4	BLUP5	BLUP6	BLUP7	BLUP8	BLUP9	BLUP10
Adjusted R^2	0.075	0.025	0.049	0.974	0.034	0.022	0.080	0.079	0.086	0.071	0.084	0.077	0.091	0.075	0.089	0.082
Residual standard error	3.791	5.131	1.909	2.351	3.177	2.236	0.567	0.567	0.565	0.569	0.565	0.568	0.563	0.568	0.564	0.566
Residual degrees of freedom	135	137	136	136	135	138	136	136	135	137	135	136	134	136	134	135
Overall f-value	3.84	2.75	3.41	6.00	2.21	4.08	5.02	4.96	4.25	6.28	4.20	4.85	3.79	4.77	3.73	4.09
Overall p-value	0.006	0.068	0.019	0.001	0.071	0.045	0.002	0.003	0.003	0.002	0.003	0.003	0.003	0.003	0.003	0.004
Selected Traits																
Crown circumference													■			
5 tiller dry weight			■		■											
Flowering date (days after June 30)	■			■												
Width 2nd leaf (mean	■	■				■	■	■	■	■	■	■	■	■	■	■
# of nodes (mean)					■											
Stem diameter (mean)			■	■	■											
Plant height	■	■					■	■	■	■	■		■	■	■	■
# of tillers	■		■											■		■
Internode length (mean)							■		■		■		■		■	■
Panicle length (mean)												■				
Tiller density					■				■						■	
Dry biomass (individual plant)				■				■			■	■	■		■	

Table 2. Traits selected and model descriptives for best model for each location by year combination, and the ten best models based on BLUP estimates of biomass yield. Filled boxes indicate inclusion of a trait within each model.

CONCLUSIONS

The results of this research demonstrate the challenges of selecting for increased biomass yield in switchgrass within spaced plant nurseries. While limited predictive ability was observed using individual and combinations of plant morphological traits, models using multiple subsets of traits were highly significant. This result suggests that a variety of traits likely contribute to biomass yield and may be valuable as selection criteria especially under high selection intensity. Specifically it was observed that increased plant height, reduced 2nd leaf width, and decreased internode length were factors in multiple best models. Future work will include the evaluation of direct selection for specific traits and heritability estimation of morphological traits.

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