Quality analysis of perennial grasses for use as bioenergy feedstock

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Introduction

Perennial grasses have potential for use as dedicated bioenergy crops in the Northeastern (NE) region of the US. Replicated small plot trials of both cool and warm season perennial grasses were established in 2007 in diverse locations in New York (NY). Currently, very little is known about the variability in biomass quality components in these grasses that may be important for emerging bioenergy industry conversion technologies. An objective of this project is to obtain information on the compositional characteristics of perennial grasses grown in different environments in NY.

Materials & Methods

Replicated perennial grass trials were established in 2007 in four counties in NY. Seed of five warm season and four cool season grass species (Tables 1 and 2) were planted with a Carter (Carter Manufacturing Co., Brookston, ID) small plot seeder. Twelve switchgrass varieties, four big bluestem, two indiangrass, one coastal panic grass and one eastern gamagrass variety were used for the study (Fig.1). Three wheatgrass varieties and two varieties each of tall fescue, reed canary and bromegrass were evaluated in the cool season grass trial (Fig.2). Perennial grass samples harvested from trials were oven dried, ground to a 1 mm particle size and scanned on a Foss NIR Systems spectrophotometer (Foss NIR Systems, Model 5000, Silver Spring, MD). Approximately 10% of the samples were selected for calibration by principal component analysis method using WINISI II software (Intrasoft International, Port Matilda, PA). These calibration samples were analyzed through wet-chemistry by Dairy One Forage Testing Laboratory, Ithaca, NY. NIR equations were then developed for the sample set using ISI software (Intrasoft International, CAL version 1.5 and higher, Port Matilda, PA) to predict values of all perennial grass samples.

Fig.1. Replicated warm season perennial grass trial

Table 1. Common and scientific names of warm season perennial grasses established in small plot trials in NY.

Common name	Species
big bluestem	*Andropogon gerardii*
coastal panic grass	*Panicum amarulum*
eastern gamagrass	*Tripsacum dactyloides*
indiangrass	*Sorghastrum nutans*
switchgrass	*Panicum virgatum*

Table 2. Common and scientific names of cool season perennial grasses established in small plot trials in NY.

Common name	Species
wheatgrass	*Thinopyrum ponticum*
tall fescue	*Festuca arundinacea*
reed canarygrass	*Phalaris arundinacea*
brome grass	*Bromus inersis*

Fig. 2. Replicated cool season perennial grass trial

Table 3. Yield dry tons/acre (dt/a) data of warm season perennial grasses, listed by variety and common name from plots harvested in Jefferson, Chemung, Tompkins and Genesee Counties in New York in 2008.

		Belleville Jefferson	Big Flats Chemung	Ithaca Tompkins	Pavilion Genesee
		- - - - - - - - 2008	- - - - - - - -		
Variety	Common name	17-Sep	24-Sep	24-Sep	7-Oct
		- - - - - tons per acre dry matter - - - - -			
Bonanza	big bluestem	1.18	1.23	1.66	1.08
Goldmine	big bluestem	0.94	1.16	1.79	1.42
Niagara	big bluestem	0.90	1.48	1.29	1.23
Atlantic	coastal panic	1.00	2.31	3.86	1.44
Pete	e.gamagrass	0.56	1.21	1.37	0.63
Blackwell	switchgrass	2.27	2.75	4.26	2.39
Carthage	switchgrass	1.63	2.35	4.05	1.71
CIR	switchgrass	1.51	2.77	4.49	1.86
CIR2*	switchgrass	1.99	3.25	4.31	1.55
Forestburg	switchgrass	0.94	1.12	2.04	1.10
Kanlow	switchgrass	1.08	1.59	4.33	1.49
Pathfinder	switchgrass	0.63	0.84	0.73	1.06
Shawnee	switchgrass	1.38	2.54	5.00	2.10
Shelter	switchgrass	1.84	2.30	3.97	1.79
Sunburst	switchgrass	0.81	1.25	1.79	1.74
Trailblazer	switchgrass	1.82	1.88	4.17	1.58
Nebraska 54	Indiangrass	2.47	1.52	3.17	1.80
Nebraska 28	switchgrass	0.74	1.34	2.49	0.83
Rumsey	Indiangrass	1.35	1.13	2.48	1.42
Pawnee	big bluestem	0.89	1.14	1.71	0.95
Mix1	CIR/Bonanza	1.48	2.37	4.61	1.91
Mix2	Sunburst/Niagara	0.78	1.38	2.49	1.08
Mix3	CIRRock/Pete	1.33	2.60	5.03	2.14
Mix4	Niagara/Pete	0.60	1.28	1.30	0.86
	Average	1.25	1.78	3.02	1.46
	LSD(.05)	0.70	0.66	0.61	0.45

CIR* (Cave-in-Rock was stratified prior to planting)

Results & Discussion

There was a significant genotype by location interaction on warm season grass yields most likely due to differences in weed pressure at the field sites. The highest yields (average 3.02 dt/a) were obtained at the Tompkins County location in Ithaca, NY (Table 3). Tables 4 and 5 show ranking (top five from each trial location) of compositional characteristics of warm season grass varieties as predicted by PCA method using WINISI II software (Intrasoft International, Port Matilda, PA). Switchgrass varieties generally contained higher levels of lignin (L) (Key - Table 6), non-fibrous carbohydrates (NFC), and water soluble carbohydrates (WSC) than other warm season grasses evaluated. While big bluestem and indiangrass varieties had higher levels of cellulose (C) and hemi-cellulose (HC). Plant varieties showed a considerable amount of diversity in characteristics evaluated but for the most part had the same ranking for characteristics at the different locations. This indicates that genetics may have a greater influence on important quality characteristics than environment.

Cool season grasses evaluated had higher yields (Table 7) than the warm season grasses. However, cool season grasses were managed in a two-cut harvest system versus a one-cut for warm season grasses and nitrogen was applied after the first harvest. Cool season grasses had higher nitrogen, ash and mineral contents than the warm season grasses (Tables 8 and 9) and lower lignin.

Table 7. Yield dry tons/acre (dt/a) data of cool season perennial grasses, listed by variety and common name from plots harvested Tompkins County New York in 2008.

Variety		19-Jun	25-Sep	Season
		- - tons per acre dry matter - -		
Alkar	wheatgrass	2.66	1.52	4.18
Jose	wheatgrass	2.63	1.57	4.20
Largo	wheatgrass	2.56	1.98	4.54
Alkar	wheatgrass	2.82	1.68	4.49
Enhance	tall fescue	3.25	3.01	6.27
Bull	tall fescue	3.08	2.74	5.82
Bellevue	reed canary	2.59	2.75	5.34
Chiefton	reed canary	2.62	2.51	5.13
Peak	brome	3.05	2.07	5.12
York	brome	3.04	2.14	5.19
	Trial Mean (DT/A)	2.83	2.20	5.03
	LSD (.05)	0.32	0.26	0.45

Tables 4 and 5. Biomass quality components of warm season grass trials established in four locations in NY

	% N	Entry	%C	Entry	%HC	Entry	%L	Entry	%NFC	Entry	%WSC	Entry
Ithaca - Tompkins County												
	1.01	Pete	40.6	Nebraska54	33.8	Pete	8.4	Trailblazer	21.4	Atlantic	11.9	Atlantic
	0.82	Bonanza	39.4	Niagara	33.1	Mix4	7.6	Nebraska28	20.7	Shawnee	9.5	CIR1
	0.81	Mix4	39.2	Nebraska28	33.0	Niagara	7.3	Sunburst	19.7	CIR2	9.5	CIR2
	0.78	Pawnee	38.7	Mix4	32.4	Rumsey	7.2	Mix3	19.6	CIR1	9.4	Mix3
	0.78	Goldmine	38.6	Kanlow	32.4	Pawnee	7.2	Forestburg	19.6	Mix3	9.3	Shawnee
R^2	0.71		0.75		0.62		0.79		0.92		0.80	
LSD	0.11		0.21		1.21		0.70		0.89		1.36	
Belleville - Jefferson County												
	1.41	Pete	39.3	Nebraska54	34.6	Pete	5.9	Trailblazer	21.9	Shawnee	12.7	Shawnee
	1.16	Bonanza	38.0	Rumsey	33.8	Kanlow	5.7	Blackwell	21.2	CIR1	12.4	Mix3
	0.99	Mix4	37.2	Niagara	33.5	Mix4	5.6	Nebraska28	21.1	CIR2	12.2	CIR1
	0.98	Atlantic	36.3	Goldmine	33.2	Goldmine	5.6	Sunburst	21.0	Shelter	12.0	CIR2
	0.77	Kanlow	36.3	Bonanza	33.2	Rumsey	5.3	Shawnee	21.0	Mix3	11.7	Mix1
R^2	0.81		0.84		44		0.75		0.93		0.84	
LSD	0.09		1.35		0.87		0.43		0.78		1.03	
Big Flats – Chemung County												
	1.2	Pete	37.7	Nebraska54	34.6	Mix4	7.6	Sunburst	23.4	Shawnee	12.7	Mix1
	0.78	Mix4	37.5	Niagara	33.1	Pete	7.2	Forestburg	23.1	Atlantic	12.6	Goldmine
	0.75	Nebraska28	36.4	Rumsey	33.0	Niagara	7.2	Nebraska28	22.9	CIR2	12.6	Atlantic
	0.75	Atlantic	36.0	Pawnee	32.8	Pawnee	6.9	Blackwell	22.8	Shelter	12.5	CIR2
	0.73	Mix3	35.3	Mix2	32.6	Rumsey	6.8	Mix1	22.7	Mix1	12.5	Shawnee
R^2	0.70		0.81		0.67		0.77		0.86		0.70	
LSD	0.12		1.3		1.21		0.67		1.12		1.59	
Pavilion – Genesee County												
	1.30	Pete	39.7	Nebraska54	33.6	Pete	6.6	Trailblazer	20.7	Atlantic	11.0	Atlantic
	0.90	Mix4	38.7	Bonanza	32.9	Mix4	6.5	Sunburst	19.6	Shawnee	9.5	Shawnee
	0.83	CIR2	38.5	Niagara	32.9	Niagara	6.3	Mix3	19.5	CIR1	9.4	CIR2
	0.79	Goldmine	38.4	Sunburst	32.4	Kanlow	6.2	Forestburg	19.4	Mix3	9.4	Rumsey
	0.76	Atlantic	38.1	Pawnee	32.2	Atlantic	6.1	Blackwell	19.4	CIR2	9.0	CIR1
R^2	0.55		0.70		0.52		0.80		0.90		0.77	
LSD	0.15		1.8		1.20		0.52		0.78		1.4	

	GE	Entry	K	Entry	S	Entry	Cl	Entry	Ash	Entry
Ithaca – Tompkins County										
	4643	Pawnee	1.2	Goldmine	0.11	Pete	0.23	Rumsey	6.2	Rumsey
	4638	Atlantic	1.1	Bonanza	0.08	Mix4	0.23	Kanlow	5.6	Pawnee
	4631	Bonanza	1.0	Pete	0.07	Nebraska28	0.21	Nebraska54	5.6	Bonanza
	4630	Carthage	1.0	Rumsey	0.06	Forestburg	0.19	Pawnee	5.4	Sunburst
	4627	Kanlow	1.0	Pawnee	0.06	Sunburst	0.19	Goldmine	5.4	Nebraska28
R^2	0.70		0.85		0.72		0.48		0.66	
LSD	22.8		0.11		0.01		0.04		0.67	
Belleville – Jefferson County										
	4650	Bonanza	1.16	Goldmine	0.12	Pete	0.16	Kanlow	7.1	Forestburg
	4644	Pawnee	1.0	Nebraska54	0.09	Mix4	0.15	Nebraska54	7.1	Rumsey
	4643	Atlantic	0.91	Bonanza	0.91	Nebraska28	0.14	Rumsey	6.8	Nebraska28
	4639	Goldmine	0.91	Kanlow	0.08	Kanlow	0.11	Atlantic	6.6	Nebraska54
	4635	Niagara	0.90	Atlantic	0.07	Atlantic	0.11	Mix4	6.3	Sunburst
R^2	.88		0.82		0.80		0.63		0.71	
LSD	18.7		0.10		0.01		0.03		0.58	
Big Flats – Chemung County										
	4690	Bonanza	0.78	Nebraska54	0.13	Pete	0.14	Sunburst	4.8	Forestburg
	4681	Atlantic	0.72	Pete	0.08	Forestburg	0.13	Rumsey	4.3	Pete
	4671	Goldmine	0.72	Goldmine	0.07	Kanlow	0.12	Kanlow	4.1	Nebraska28
	4666	Niagara	0.65	Pawnee	0.07	Sunburst	0.11	Nebraska54	4.0	Rumsey
	4664	Pawnee	0.63	Bonanza	0.07	Nebraska28	0.11	Nebraska28	3.8	Sunburst
R^2	0.73		0.60		0.79		0.52		0.64	
LSD	21.7		0.10		0.02		0.04		0.55	
Pavilion – Genesee County										
	4627	Atlantic	0.97	Goldmine	0.13	Pete	0.19	Nebraska54	6.4	Forestburg
	4620	Bonanza	0.88	Nebraska54	0.78	Forestburg	0.17	CIR1	6.0	Nebraska28
	4620	Niagara	0.88	Mix4	0.78	Nebraska28	0.16	Kanlow	5.5	Pete
	4618	Mix4	0.85	Bonanza	0.77	CIR1	0.16	Mix4	5.5	Sunburst
	4617	Pawnee	0.80	Rumsey	0.75	Mix4	0.16	Atlantic	5.5	CIR2
R^2	0.66		0.68		0.63		0.46		0.65	
LSD	30.8		0.17		0.02		0.05		0.72	

Table 6. Compositional analysis key

% N - nitrogen
% C - cellulose
% HC hemi - cellulose
% L - lignin
% NFC - non fibrous carbohydrates
%WSC water soluble carbohydrates
GE – Gross energy cal/g
% K - potassium
% S – Sulfur
Cl – chloride ion

Tables 8 and 9. Biomass quality components of cool season grass trials established in Tompkins County, NY

	% N	Entry	% C	Entry	% HC	Entry	% L	Entry	% NFC	Entry	% WSC	Entry
Ithaca - Tompkins County Harvest 1												
	1.75	Chiefton	39.5	Largo	31.0	Alkar2	5.4	York	17.6	Bull	10.9	Enhance
	1.68	Belleview	38.2	Alkar1	31.0	Alkar1	5.4	Peak	17.2	Peak	10.7	Peak
	1.55	Peak	38.1	Jose	30.5	Belleview	5.0	Bull	16.9	Enhance	10.7	Bull
	1.50	Alkar2	37.7	Alkar2	30.5	Jose	4.9	Chiefton	16.8	York	10.5	York
	1.50	York	34.9	Enhance	30.0	Chiefton	4.8	Belleview	14.7	Chiefton	7.4	Chiefton
	1.50	Largo	34.9	Bull	29.2	York	4.6	Largo	14.7	Belleview	7.4	Belleview
	1.50	Jose	34.1	Belleview	29.1	Peak	4.5	Enhance	12.9	Largo	7.0	Jose
	1.50	Alkar1	33.9	Chiefton	28.8	Enhance	4.4	Jose	12.8	Alkar2	6.8	Alkar1
	1.30	Bull	33.4	York	28.7	Largo	4.3	Alkar1	12.7	Jose	6.5	Alkar2
	1.30	Enhance	33.2	Peak	28.2	Bull	4.3	Alkar2	12.3	Alkar1	6.3	Largo
R^2	0.80		0.94		0.84		0.87		0.95		0.91	
LSD	0.10		0.75		0.60		0.02		0.60		0.81	
Ithaca - Tompkins County Harvest 2												
	1.4	Jose	38.1	Largo	27.4	Largo	5.6	Peak	25.9	Chiefton	24.6	Chiefton
	1.4	Alkar2	36.6	Alkar2	27.4	Bull	5.2	York	25.0	York	22.7	York
	1.3	Bull	36.6	Alkar1	26.9	Alkar2	4.9	Largo	24.9	Peak	21.8	Peak
	1.3	Alkar1	35.6	Jose	26.8	Enhance	4.8	Jose	24.1	Belleview	20.9	Belleview
	1.3	Enhance	34.6	Bull	26.8	Jose	4.7	Chiefton	20.4	Enhance	14.2	Enhance
	1.3	Largo	33.0	Enhance	26.5	Alkar1	4.4	Alkar1	19.2	Bull	11.8	Bull
	1.1	Belleview	30.4	Belleview	26.2	Belleview	4.4	Alkar2	18.5	Alkar1	11.6	Alkar1
	1.1	York	29.3	Peak	25.6	York	4.1	Belleview	17.9	Jose	11.1	Jose
	1.1	Peak	29.2	York	25.4	Peak	3.6	Bull	17.7	Alkar2	10.6	Alkar2
	1.1	Chiefton	29.1	Chiefton	25.1	Chiefton	3.5	Enhance	16.7	Largo	10.0	Largo
R^2	0.67		0.97		0.70		0.91		0.92		0.92	
LSD	0.18		0.03		1.00		0.40		1.73		2.73	

	GE	Entry	%K	Entry	% S	Entry	% Cl	Entry	% Ash	Entry
Ithaca – Tompkins County Harvest 1										
	4654	Peak	2.6	Chiefton	0.16	Chiefton	0.49	Bull	7.6	Belleview
	4650	York	2.5	Enhance	0.16	Belleview	0.48	Largo	7.5	Chiefton
	4649	Alkar1	2.5	Belleview	0.12	Bull	0.47	Chiefton	7.2	Enhance
	4644	Chiefton	2.3	Bull	0.12	York	0.47	Enhance	6.8	Bull
	4642	Jose	2.2	Largo	0.12	Peak	0.46	Belleview	6.4	Peak
	4642	Alkar2	2.2	Alkar1	0.12	Alkar2	0.46	Alkar1	6.4	York
	4631	Largo	2.2	Alkar2	0.12	Jose	0.46	Jose	6.1	Alkar1
	4630	Belleview	2.2	Jose	0.11	Alkar1	0.44	Alkar2	6.1	Jose
	4503	Bull	2.2	Peak	0.11	Enhance	0.36	York	6.0	Alkar2
	4498	Enhance	2.2	York	0.11	Largo	0.35	Peak	5.9	Largo
R^2	0.95		0.82		0.76		0.66		0.88	
LSD	17.2		0.10		0.01		0.05		0.31	
Ithaca – Tompkins County Harvest 2										
	4599	Alkar2	2.2	Enhance	0.14	Belleview	0.47	Enhance	9.3	Enhance
	4592	Alkar1	2.0	Bull	0.14	Bull	0.45	Bull	9.2	Bull
	4591	Jose	1.9	Alkar2	0.13	Chiefton	0.43	Largo	8.3	Belleview
	4587	Peak	1.9	Jose	0.12	Alkar2	0.42	Alkar2	7.7	Jose
	4574	York	1.8	Alkar1	0.12	Jose	0.39	Belleview	7.6	Alkar2
	4569	Largo	1.7	Largo	0.12	Enhance	0.39	Alkar1	7.4	Chiefton
	4456	Chiefton	1.3	Chiefton	0.11	Alkar1	0.39	Jose	7.3	Alkar1
	4448	Belleview	1.2	Peak	0.11	Largo	0.38	Chiefton	6.7	Largo
	4420	Bull	1.2	York	0.10	York	0.26	York	6.2	York
	4395	Enhance	1.1	Belleview	0.08	Peak	0.24	Peak	6.0	Peak
R^2	0.97		0.91		0.76		0.75		0.89	
LSD	25.3		0.21		0.02		0.09		0.78	

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