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Stalk Strenght and Sugar Content of 55 Dual-Purpose Sorghum Inbreds

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TECHNICAL NOTE:

STALK STRENGTH AND SUGAR CONTENT OF 55 DUAL-PURPOSE SORGHUM INBREDS

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ABSTRACT. *In 2012, sorghum was approved by the U.S. Environmental Protection Agency (EPA) as an "advanced" bioenergy feedstock in cases where both the grain and stover are both used for energy production (USEPA, 2012). It is desirable, therefore, to develop taller varieties of sorghum to increase biomass yields. However the taller the plant gets, the more susceptible it becomes to lodging, reducing grain yield in the end. Additionally the ability to characterize the storage stability of new sorghum varieties in terms of moisture content and free sugars content is advantageous. In this study, high throughput assays to characterize stalk strength based on rind penetrometer resistance (RPR) and sugar content based on an enzymatic assay of new varieties of sorghum were demonstrated. RPR measurements and estimates of glucose and sucrose contents of the leaves and the stalks were conducted on 40 dwarf grain sorghum inbreds and 15 photoperiod sensitive sorghum inbreds. Results showed stalk strengths of dwarf grain sorghum ranged from 2.43 to 7.72 kgf while those of photoperiod sensitive sorghum ranged from 2.72 to 10.50 kgf. Dwarf grain sorghum contained 0.1% to 6.9% and 0.3% to 3% glucose in stalks and leaves; 0 to 15% and 0 to 6.5% sucrose in stalks and leaves, respectively. Photoperiod sensitive sorghum contained 0.6% to 12% and 0.3 to 1.7% glucose in stalks and leaves, while sucrose levels in stalks and leaves were 0.3% to 17% and 0 to 3.1%, respectively. These results provide a framework for stalk quality assessment in selecting inbreds with stronger and higher free sugar content.*

Keywords. *Glucose, Grain sorghum, Photoperiod sensitive sorghum, Rind penetrometer resistance, Sucrose.*

Sorghum (*Sorghum bicolor* (L.) Moench) is a dual-purpose bioenergy crop in which carbon yield from the vegetative stalk can be increased usually without sacrificing starch yield from the grain (Blümmel et al., 2003). Compared to maize, sugar cane, and sugar beet, sorghum has higher water-use efficiency and drought tolerance (Rooney et al., 2007; Zegada-Lizarazu and Monti, 2012). It is highly adaptable to a wide range of environments in tropical, subtropical, and temperate zones. In terms of ethanol yields, sorghum grain is comparable to maize grain (Wang et al., 2008).

Approximately one-third of the sorghum produced in United States is currently used for ethanol production (Shoemaker and Bransby, 2010). Ethanol is produced from non-structural carbohydrates (e.g., starch, glucose, fructose, lactose, and sucrose) and structural carbohydrates (e.g., hemicellulose, cellulose) after a series of processes, such as hydrolysis, conversion, saccharification, and fermentation. Sorghum grain, juice from the stalk, and sorghum bagasse can be used as feedstock for biofuel production. Grain, sweet, forage, and energy (or high-tonnage, high biomass) sorghum have been developed for a wide range of applications (Rooney et al., 2007; Shoemaker and Bransby, 2010). Grain sorghum is the fifth-most important cereal crop in the world and the third-most important in the United States. It is mainly used as food in tropical regions and the starch-rich grain provides a source for ethanol conversion. Sweet sorghum, on the other hand, contains 16% to 23% Brix in its juice and serves as an alternative to sugar cane (Reddy et al., 2005). Forage sorghum is grown mainly for silage, hay and grazing production for animal feed (Rooney et al., 2007). Biomass sorghum is specific type of sorghum with delayed flowering and prolonged vegetative growth (McCollum et al., 2005). Most biomass sorghums are photoperiod-sensitive hybrids derived from two photoperiod-insensitive parents (Rooney and Aydin, 1999).

Lodging resistance is an important trait for sorghum breeding programs. Lodging is a common phenomenon in cereal production and may be caused by combinations of wind, rain, soil type, irrigation, fertilizer, and crop disease (Rajkumara, 2008). Lodging of the stalks reduces the quality and quantity of crops yields as the crop fails to reach maturity or lacks sufficient nutrients needed for grain development. Also, lodged stalks are harder to harvest mechanically and result in harvest loss (Schertz et al., 1978; Rajkumara, 2008). Since lodging tends to be caused by compounding factors, a direct measurement of stalk strength may be a more efficient breeding phenotype to characterize than lodging itself.

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Stalk strength in maize and sugar cane have been determined using rind penetrometer resistance (RPR) measurements (Agarwal, 1969; Kang et al., 1990; Sibale et al., 1992; Martin et al., 2004). The procedure involves recording the maximum resistant force necessary to puncture the rind structure at different locations. Schertz et al. (1978) reported that sorghum stalk breaks could occur anywhere from the base of the peduncle (uppermost stalk internode) to the first internode above the ground. Accordingly, they measured RPR at four locations: 1) the base of the peduncle; 2) the center of the internode below the peduncle; 3) the peduncle 15 cm below the base of the panicle; and 4) the third internode above ground level. Their results showed that the RPR at the third internode from the ground was significantly correlated with lodging occurrence. However, due to the difficulty of finding the above-ground third internode of sorghum while growing in the field, Pedersen and Toy (1999) measured sorghum stalk RPR values at the peduncle and the lower stalk (2 cm above ground) at anthesis, and also the lower stalk at grain maturity. They reported RPR values of 45 entries at moderate maturity stage from 2.3 to 13.5 kgf. Average peduncle RPR at anthesis was 4 kgf which was much weaker than RPR at lower stalk at anthesis (average 9 kgf) and lower stalk at maturity (average 10.4 kgf).

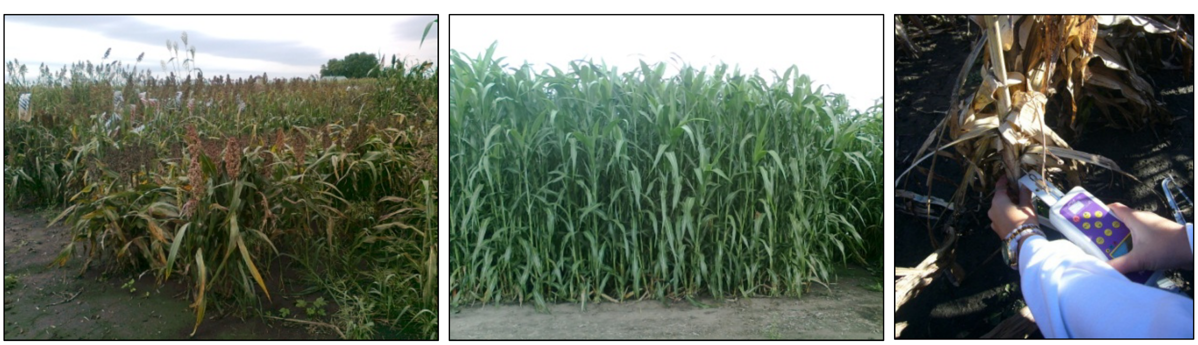
Because starch-based ethanol production competes with human food and animal feed, lignocellulosic biomass, crop residues, and sugary juice from crop stalks are widely studied as alternative feedstocks for energy production (Rooney et al., 2007). Sorghum stalk sugars consist mainly of sucrose and contain small amounts of glucose and fructose. Glucose and fructose are monosaccharides that can be directly fermented to ethanol, and sucrose is a disaccharide that needs to be hydrolyzed by acid invertase treatment before fermentation. It is advantageous to differentiate glucose and sucrose contents in sorghum varieties as these sugars affect the fermentability of the stalks. Also, by knowing the amount of sucrose and glucose content, the potential ethanol yield could be estimated. Murray et al. (2008) mentioned that the respective amounts of nonstructural carbohydrates in sweet sorghum were approximately 1.4 to 2.7 times than in grain sorghum, and sucrose content in sweet sorghum could be as high as 25%. Murray et al. (2008) also showed the sugars in sweet sorghum were comprised of 86% sucrose, 8% glucose, and 6% fructose; in grain sorghum, 66% sucrose, 18% glucose, and 16% fructose. In both cases, sucrose and glucose accounted for 84% to 94% of the fermentable free sugars. As more sorghum varieties are developed for bioenergy applications, the ability to differentiate varieties with high versus low free sugar contents can help decision making during storage and bioprocessing. Under similar storage conditions, varieties with lower sugar content will have longer shelf life (Bennett and Anex, 2009). Juice from varieties with high free sugar content needs to be extracted immediately for fermentation while the bagasse could be utilized for combustion and gasification.

During the development of new varieties and inbreds in a sorghum breeding program, stalk quality may be assessed not only as a direct measure of free sugar content, but also stalk strengths. In this study, stalk quality based on (a) stalk strength, based on RPR measurements of 40 dwarf grain sorghum inbreds and 15 photoperiod sensitive sorghum inbreds and (b) their corresponding glucose and sucrose contents based on an enzymatic assay were demonstrated. These measurement platforms allow sorghum breeders to quickly assess these properties in the field. The sorghum stalk strength data collected in this study also expands the literature on physical properties of sorghum varieties.

Materials and Methods

Sorghum Samples and Field Conditions

Dwarf grain sorghum and photoperiod-sensitive sorghum inbreds were planted in single row test plots that were 6 and 7.6 m in length, respectively; both with 0.76 m row spacing; and a plant density of 88,960 plants/ha at the Energy Biosciences Institute (EBI) Energy Farm at the University of Illinois in Urbana in May 2012 (fig. 1a, b). These plots were part of a three-year field study of more than 400 exotic sorghum inbreds aimed at examining the genetic control of flowering time and biomass yield in sorghum (Hawkins, 2014). For this report, 40 cultivars from dwarf grain sorghum (Sorghum Converted, SC lines) containing bicolor, caudatum, durra, kafir, and guinea races of sorghum, and 15 cultivars of photoperiod sensitive sorghum (Pre-Converted, PRE lines) were chosen for RPR measurements and sugar content determination. RPR



(a) (b) (c)

Figure 1. Two sorghum lines – (a) dwarf grain sorghum, SC, and (b) photoperiod sensitive sorghum, PRE, were sampled from the Energy Biosciences Institute Energy Farm at the University of Illinois in Urbana in October 2012. (c) Stalk strength was determined by measuring RPR using digital force gauge. In this photo, RPR1 was measured at 20.32 cm above ground.

measurements were conducted in the field during the 9 to 29 October 2012 timeframe. Immediately following RPR measurements, samples were hand-harvested, taken to the lab where stalks and leaves were hand-separated, dried, and prepared for glucose and sucrose testing.

RPR Measurements

A digital force gauge with 50 kgf capacity (Dillon GS-500, Avery Weigh-Tronix, LLC, Fairmont, Minn.) was used for RPR measurements. A stainless steel dispensing needle (2.7 mm i.d., 3.4 mm o.d.) was connected to the force gauge to penetrate the stalk. A stop bar, placed 90° from stalk upright direction to the needle axis, was used to ensure the rind penetrometer punctured the stalk perpendicularly (fig. 1c). RPR values (kgf) were taken from three locations of the stem. For SC lines, measurements were conducted at 20.32 cm above ground (RPR1), the base of the peduncle (RPR2), and the center of the internode below the peduncle (RPR3). As for PRE lines, since not all inbreds develop flower and grain, the values were measured at 20.32, 40.64, 60.96 cm above the ground (RPR1, RPR2, RPR3). RPR1 values were measured at 20.32 cm because sorghum stalks are usually cut at 15.24 to 20.32 cm above ground (Ghahraei et al., 2008). Diameters (D1, D2, D3, mm) at the penetration points were recorded. Height (H, m) and wet weight (W, kg) of each cultivar were also measured.

Sugar Content Determination

Three stems were cut from each cultivar and taken back to the lab, where the leaves and stalks were fractionated. Wet-basis moisture contents (MC_{wb}) measurements were determined following ANSI/ASABE Standard S358.3 (*ASABE Standards*, 2012). Samples were dried down at 55°C to less than 1 g weight difference between consecutive days. All the SC samples dried within 72 h but some of the PRE samples took 96 to 120 h to dry. Cultivars that needed longer drying time usually had greater stalk diameters (> 21 mm). After drying, materials were ground using a knife mill (SM2000, Retsch, Newtown, Pa.) and a 2 mm square opening screen. One gram dry sample (from either stalks or leaves) was added to 15 mL distilled water and autoclaved at 121°C for 15 min to extract sucrose and glucose. Glucose and sucrose contents were determined enzymatically using a Multiparameter Bioanalytical System (YSI 7100MBS, YSI Inc., Yellow Springs, Ohio). The MBS system can be outfitted simultaneously with a sucrose sensor and a glucose sensor, but a fructose sensor was not available for this instrument.

Data Analysis

Pearson correlation coefficients between stalk strength, sugar content, and cultivar and significance testing were computed in R environment (R Core Team, 2012). Two threshold values were then defined and used to identify cultivars with desirable stalk qualities. The first threshold was based on the observed average RPR1 values; cultivars with RPR1 values greater than this threshold were classified as having strong stalks. The second threshold was set at 12% sucrose content, which was the upper bound sucrose level in grain sorghum and average value for sweet sorghum (Murray et al., 2008). Cultivars that exceeded this threshold value were classified as high sugar inbreds. These threshold values were useful in identifying cultivars with desirable stalk qualities and potentially used for subsequent breeding of new sorghum varieties.

Results and Discussion

Stalk Strength

Samples from the PRE lines were taller and weighed more than samples from the SC lines (table 1). PRE line stalks had an average mass weight-to-height ratio of 0.175 ± 0.04 kg/m, which was higher than the SC line stalks' average ratio 0.165 ± 0.07 kg/m. Overall, more moisture was contained in stalks (76.3% ± 5.6% and 81.1% ± 6.6% in SC and PRE lines) than in leaves (54.4% ± 13.1% and 41.7% ± 17.6% in SC and PRE lines). Overall, PRE lines held 72.3% moisture content (in total, including leaves and stalks) which was more than that in SC lines, 67.1%.

For both lines, RPR1 measurements were highest amongst penetration locations, with an average value 4.91 kgf for SC and 6.47 kgf for PRE lines. The center of the internode below the peduncle for SC lines (2.78 kgf) and 60.96 cm above the ground (5.73 kgf) for PRE lines were the weakest amongst RPR measurements taken. There were 12 cultivars with larger RPRs than averaged values – SC0399, SC0209, SC0964, SC0798, SC0021, PRE0093, PRE0593, PRE1305, PRE0692, PRE0298, PRE0577, and PRE0451. Compared to previous studies, Pedersen and Toy (1999) reported RPR values of 7.1 to 13.5 kgf, with a mean of 10.4 kgf for 45 grain sorghum stalks, which were higher

Table 1. Summary[a] of physical properties of dwarf grain sorghum and photoperiod sensitive sorghum.

		Height (m)	Wet Weight (g)	Moisture Content MC_{wb} (%) Stalks	Leaves	Total	RPR (kgf) 1	2	3	Diameter (mm) 1	2	3	Glucose (%, w/w) Stalks	Leaves	Sucrose (%, w/w) Stalks	Leaves
Dwarf grain sorghum, SC lines (n=40)	Max	1.75	328.0	70.9	89.1	74.6	7.72	5.62	4.93	31.24	13.16	17.16	6.88	3.23	15.02	6.53
	Min	0.63	47.3	12.0	64.4	51.5	2.43	1.12	1.38	11.74	5.10	6.71	0.10	0.25	0.00	0.00
	Mean	0.96	150.6	54.4	76.3	67.1	4.91	3.00	2.78	18.74	9.20	10.66	2.81	1.10	5.75	1.22
	Std Dev	0.25	57.8	13.1	5.6	4.6	1.10	0.88	0.84	4.12	1.86	2.05	1.81	0.71	3.91	1.55
Photoperiod sensitive sorghum, PRE lines (n=15)	Max	3.69	734.7	69.9	90.0	80.4	10.50	9.60	8.42	23.63	28.22	26.60	11.99	1.71	17.40	3.14
	Min	1.63	229.7	6.3	65.7	55.9	2.72	2.30	2.68	16.65	17.16	17.09	0.61	0.27	0.26	0.00
	Mean	2.37	419.5	41.7	81.1	72.3	6.47	6.10	5.73	20.35	20.99	20.25	5.00	0.74	5.99	0.59
	Std Dev	0.53	145.7	17.6	6.6	6.5	2.30	2.09	1.79	2.31	2.71	2.74	2.72	0.38	4.33	0.83

[a] Detailed results of the samples' physical properties, including height, wet weight, MC_{wb}, RPR, the associated diameters for RPR measurement, glucose and sucrose contents are provided in Appendices 1 and 2.

than the RPR1 values found in this study. The differences may be attributed to the penetration location since their measurements were taken at 2 cm above the soil surface whereas our RPR1 measurements were taken at 20.32 cm above ground. Other researchers have reported RPR measurements of 2.00 to 10.02 kgf for maize stalks (Martin et al., 2004; Peiffer et al., 2013) and a mean of 6.13 kgf for 47 sugarcane stalks (Kang et al., 1990).

SUGAR CONTENT

Sugars are mainly stored in the grain and stalk, therefore, the leaves samples from both SC and PRE lines contained very little glucose and sucrose content (average 0.59% to 1.22%). For stalk samples, SC lines had an average sucrose content of 5.75% ± 3.91% while the PRE lines had an average sucrose content of 5.99% ± 4.33%. There were three cultivars that contained greater than 12% sucrose which included two SC lines, SC0170 and SC0964, and one PRE line, PRE0692. For the rest of samples, 12 cultivars had sucrose levels between 8% and 12% and 40 cultivars had less than 8% sucrose. Other researchers have reported similar values. Murray et al. (2008) determined that 3.6% to 6.4% sucrose contents for grain sorghum (BTx623) grown in three different location in Texas. Sucrose contents in sweet sorghum ranged from 9.4% to 26.93% (Almodares et al., 2008).

CORRELATION BETWEEN FACTORS

Since the SC lines had an average RPR1 value of 4.91 kgf, an RPR1 threshold was set at 5 kgf to identify cultivars with strong stalks. The sucrose threshold was initially set at 12%. Based on these threshold values, potential cultivars with stronger stalks and higher sugar contents were identified (table 2): SC0170, SC0964, and PRE0692. When the sucrose content threshold was lowered to 10%, samples SC0013, SC11426, PRE1305, and PRE0298 could also qualify as cultivars having strong stalks and high sucrose contents.

Pearson correlation and significance tests showed that, for SC lines, diameters (D1, D2, and D3) were negatively correlated with height and positively correlated with wet weight and MC_{wb} (table 3). It illustrated that the taller lines tend to have thinner stalks while thicker stalks contained more moisture. Correlation and significance were not found between diameters and RPR values. Wet weight demonstrated significant positive correlations ($p < 0.01$) with glucose in stalks (r = 0.53), glucose in leaves (r = 0.46) and sucrose in leaves (r = 0.45). Positive correlations and significance ($p < 0.01$) were also found between sucrose in stalks vs. glucose in stalks (r = 0.69) or glucose in leaves (r = 0.48), and sucrose in leaves vs. glucose in stalks (r = 0.59) or glucose in leaves (r = 0.87).

For PRE lines, height was highly correlated with wet weight and MC_{wb}. It indicated that a taller cultivar gained more weight but may contain less water. RPR1, RPR2, and RPR3 were all significantly correlated with height positively (r = 0.78, 0.63, and 0.7, respectively) and MC_{wb} negatively (r = -0.75, -0.54, and -0.61, respectively). Diameter at RPR1 also presented positive correlation with height (r = 0.54) and weight (r = 0.56). RPR1 also significantly presented positive correlation with weight (r = 0.66) while positive correlations were demonstrated between sucrose in stalks and RPR2 (r = 0.58), RPR3 (r = 0.61). It meant that the stronger the stalk at points 2 and 3, the higher the sucrose levels in the stalk. Sucrose in leaves was highly correlated with glucose in leaves. However, no correlation was found between sucrose and glucose in stalks.

CONCLUSION

Physical properties of 55 sorghum inbreds, such as height, wet weight, moisture contents, RPR, and associated diameters at three different locations (RPR1, 20.32 cm

Table 2. Summary of physical properties of select sorghum lines.

		RPR (kgf)			Glucose (% in, w/w)		Sucrose (%, w/w)	
Index	Cultivar	1	2	3	Stalks	Leaves	Stalks	Leaves
2	SC0170[a]	5.25 ± 0.48	3.45 ± 0.48	1.63 ± 0.09	6.29 ± 0.022	3.23 ± 0.109	15.02 ± 0.21	6.34 ± 0.50
5	SC1019	5.60 ± 0.89	3.47 ± 0.39	2.33 ± 0.24	6.88 ± 0.064	1.84 ± 0.015	8.42 ± 0.31	3.04 ± 0.11
7	SC0023	4.85 ± 0.63	3.60 ± 0.62	2.62 ± 0.62	6.53 ± 0.068	3.15 ± 0.206	9.96 ± 0.27	6.53 ± 0.55
10	SC0013[a]	5.79 ± 2.66	2.11 ± 0.51	2.29 ± 0.52	5.89 ± 0.195	2.16 ± 0.004	10.36 ± 0.41	3.78 ± 0.12
13	SC1014	6.33 ± 0.82	2.85 ± 0.52	2.67 ± 0.29	2.77 ± 0.060	1.22 ± 0.077	7.78 ± 0.15	1.09 ± 0.23
15	SC0929	3.89 ± 0.73	4.85 ± 1.18	3.64 ± 0.38	2.63 ± 0.098	0.82 ± 0.056	11.94 ± 0.51	0.87 ± 0.03
16	SC0301	3.81 ± 0.90	2.89 ± 0.17	1.83 ± 0.41	2.25 ± 0.056	0.68 ± 0.011	10.30 ± 0.50	0.04 ± 0.04
18	SC0145	6.26 ± 1.41	2.41 ± 0.20	3.21 ± 0.67	3.98 ± 0.000	1.37 ± 0.040	6.75 ± 0.00	2.38 ± 0.11
23	SC0079	3.65 ± 0.59	2.97 ± 0.45	1.76 ± 0.71	3.75 ± 0.079	0.63 ± 0.043	3.97 ± 0.14	0.21 ± 0.02
25	SC0293	2.43 ± 0.58	2.68 ± 0.20	1.98 ± 0.08	1.94 ± 0.053	0.78 ± 0.036	8.52 ± 0.05	0.13 ± 0.13
26	SC0627	4.09 ± 0.83	2.89 ± 0.32	3.71 ± 0.66	3.33 ± 0.319	0.68 ± 0.173	9.69 ± 0.64	0.14 ± 0.14
33	SC0964[a]	6.07 ± 1.13	3.13 ± 0.07	3.00 ± 0.36	4.95 ± 0.169	1.28 ± 0.029	13.10 ± 0.38	2.42 ± 0.08
34	SC1277	6.44 ± 0.87	2.87 ± 0.05	2.21 ± 0.09	6.23 ± 0.199	0.39 ± 0.060	7.83 ± 0.25	0.03 ± 0.02
39	SC1426[a]	5.31 ± 1.62	2.95 ± 0.29	2.65 ± 0.15	1.94 ± 0.113	0.92 ± 0.007	10.52 ± 0.31	1.80 ± 0.06
44	PRE0593	10.50 ± 2.23	6.57 ± 1.35	6.51 ± 1.35	6.15 ± 0.394	0.47 ± 0.018	2.07 ± 0.48	0.11 ± 0.04
45	PRE0496	2.72 ± 1.32	4.28 ± 1.90	4.53 ± 2.57	2.49 ± 0.079	1.06 ± 0.104	5.15 ± 0.21	0.90 ± 0.19
46	PRE0392	3.75 ± 0.61	3.82 ± 0.65	3.99 ± 0.44	0.61 ± 0.372	0.57 ± 0.348	0.26 ± 0.26	0.16 ± 0.16
49	PRE1305[a]	7.31 ± 0.42	6.16 ± 0.35	6.15 ± 0.92	11.99 ± 0.829	1.22 ± 0.013	10.25 ± 0.07	0.25 ± 0.05
50	PRE0692[a]	8.09 ± 1.14	8.79 ± 1.22	7.82 ± 0.77	4.40 ± 0.585	1.71 ± 0.019	17.40 ± 0.00	3.14 ± 0.44
51	PRE0298[a]	8.41 ± 1.99	8.13 ± 1.17	8.42 ± 0.55	4.72 ± 0.765	0.45 ± 0.072	11.94 ± 8.31	0.14 ± 0.07
53	PRE0577	7.89 ± 1.03	8.07 ± 0.13	6.93 ± 0.26	6.02 ± 0.390	0.27 ± 0.051	9.79 ± 0.51	0.00 ± 0.00
55	PRE0131	6.34 ± 1.64	5.48 ± 1.76	5.13 ± 0.52	4.85 ± 0.023	0.89 ± 0.042	4.99 ± 0.28	1.01 ± 0.09

[a] Cultivars with RPR1 > 5 kgf or stalk sucrose > 10%. These cultivars were deemed to have desirable stalk qualities for the sorghum breeding program at the University of Illinois.

Table 3. Correlation coefficients (*r*) between measured physical properties.

	W	MC_{wb}	RPR1	RPR2	RPR3	D1	D2	D3	GS[a]	GL[b]	SS[c]	SL[d]
Dwarf Sorghum (SC lines)												
H	0.06	-0.28	-0.07	-0.28	-0.19	-0.35	-0.45*	-0.42*	0.08	-0.1	0.29	-0.14
W		0.43*	0.29	0.33	0.06	0.63*	0.48*	0.35	0.53*	0.46*	0.27	0.45*
MC_{wb}			0.09	0.43*	0.2	0.54*	0.57*	0.6*	0.04	-0.03	-0.11	-0.01
RPR1				0.26	0.43	0.14	0.05	0.08	0.42*	0.28	0.09	0.23
RPR2					0.55*	0.05	0.38	0.28	0.08	-0.02	-0.03	-0.04
RPR3						-0.16	0.02	0.09	-0.06	-0.14	-0.15	-0.18
D1							0.58*	0.5*	0.3	0.57*	0.2	0.62*
D2								0.85*	0.09	0.22	-0.16	0.25
D3									0.06	0.08	-0.16	0.09
GS										0.55*	0.69*	0.59*
GL											0.48*	0.87*
SS												0.56*
Photoperiod Sensitive Sorghum (PRE lines)												
	W	MC_{wb}	RPR1	RPR2	RPR3	D1	D2	D3	GS	GL	SS	SL
H	0.77*	-0.76*	0.78*	0.63	0.7*	0.54	0.17	0.28	0.44	-0.03	0.3	-0.14
W		-0.48	0.66*	0.37	0.45	0.56	0.24	0.37	0.65*	0.17	0.19	-0.12
MC_{wb}			-0.75*	-0.54	-0.61	-0.41	-0.18	-0.28	-0.4	-0.05	-0.44	-0.09
RPR1				0.78*	0.83*	0.45	0.02	0.16	0.43	-0.18	0.4	-0.16
RPR2					0.97*	0.24	-0.36	-0.25	0.17	-0.14	0.58	-0.08
RPR3						0.32	-0.3	-0.2	0.22	-0.1	0.61	-0.09
D1							-0.08	-0.08	0.46	-0.27	0.05	-0.43
D2								0.97*	0.23	0.54	-0.06	0.55
D3									0.32	0.49	-0.03	0.48
GS										0.19	0.32	-0.11
GL											0.49	0.87*
SS												0.5

[a] GS: Glucose in stalk.
[b] GL: Glucose in leaves.
[c] SS: Sucrose in stalk.
[d] SL: Sucrose in leaves.
* Statistical significance uses $p = 0.05$
** Statistical significance uses $p = 0.01$

above ground; RPR2, the base of the peduncle; and RPR3, the center of the internode below the peduncle for SC lines; 20.32, 40.64, 60.96 cm above ground), glucose and sucrose content in ground samples, of 40 dwarf grain sorghum (SC lines) and photoperiod sensitive sorghum (PRE line) were determined. Results showed RPR1s of SC (4.91 ± 1.1 kgf) and PRE (6.47 ± 2.3 kgf) lines were consistently greater than RPR2 and RPR3. Overall, PRE lines had higher stalk quality traits: average mass weight to height ratio (0.175 ± 0.04 kg/m vs 0.165±0.07 kg/m), moisture content (72.3 ± 6.5 kg vs. 67.1 ± 4.6 kg), glucose in stalks (5.00 ± 2.72 kg vs. 2.81±1.81 kg) and sucrose in stalks (5.99 ± 4.33 kg vs. 5.75 ± 3.91 kg) than SC lines. The following cultivars had RPR1 > 5 kgf and sucrose content > 10%: SC0170, SC0013, SC0964, SC11426, PRE1305, PRE0692, and PRE0298, which demonstrated the method for RPR1 measurement and enzymatic assays used in this study could be used in a sorghum breeding program to identify potential cultivars with stronger stalks and higher sugar contents. These results will need to be further investigated through multi-year and multi-location field tests to confirm the results from these selected inbreds.

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APPENDIX

Appendix 1. Physical properties (height, wet weight, moisture contents and diameters) of dwarf grain sorghum (SC line) and photoperiod sensitive sorghum (PRE line).

		Height	Wet Weight	Moisture Content, MC_{wb} (%)			Diameter at RPR Testing Site (mm)		
Index	Name	(m)	(g)	Stalks	Leaves	Total	1	2	3
1	SC0370	1.08 ± 0.13	133.31 ± 3.04	12.01	81.78	64.09 ± 0.53	16.06 ± 2.27	11.51 ± 1.48	10.81 ± 0.98
2	SC0170	0.83 ± 0.04	328.01 ± 14.50	69.72	73.16	69.82 ± 1.22	31.24 ± 0.67	12.06 ± 0.54	12.73 ± 1.27
3	SC0320	0.90 ± 0.04	140.43 ± 14.39	53.54	70.51	66.63 ± 13.15	22.28 ± 0.71	9.57 ± 1.44	10.47 ± 0.95
4	SC0399	0.88 ± 0.03	273.59 ± 8.11	54.50	82.47	71.36 ± 1.34	21.53 ± 1.67	11.97 ± 0.63	11.64 ± 0.05
5	SC1019	0.93 ± 0.04	252.11 ± 77.00	56.28	69.74	64.39 ± 1.18	19.68 ± 4.41	10.71 ± 2.21	11.51 ± 1.20
6	SC1124	1.43 ± 0.03	144.64 ± 26.00	48.60	75.07	61.37 ± 1.73	18.63 ± 2.57	7.36 ± 0.11	7.57 ± 0.18
7	SC0023	0.77 ± 0.07	234.83 ± 59.28	68.20	64.43	68.41 ± 2.30	26.04 ± 5.22	10.94 ± 2.10	10.51 ± 1.95
8	SC0006	1.00 ± 0.03	256.12 ± 28.94	68.93	89.08	74.60 ± 3.08	29.71 ± 1.88	9.05 ± 0.52	11.49 ± 1.16
9	SC0017	0.96 ± 0.09	136.94 ± 81.68	48.63	79.03	66.86 ± 0.38	19.68 ± 2.51	10.78 ± 1.56	11.32 ± 1.07
10	SC0013	0.90 ± 0.11	97.45 ± 67.54	56.95	76.23	64.84 ± 2.24	21.04 ± 2.20	8.27 ± 1.27	9.37 ± 1.33
11	SC1047	0.69 ± 0.02	126.17 ± 71.52	61.93	83.40	68.46 ± 1.86	24.62 ± 1.09	10.97 ± 0.89	12.86 ± 0.23
12	SC0690	0.65 ± 0.02	118.85 ± 70.68	70.93	72.95	72.50 ± 0.60	21.15 ± 1.31	10.79 ± 0.42	12.84 ± 2.02
13	SC1014	1.22 ± 0.06	166.04 ± 104.05	55.03	70.15	69.54 ± 3.48	19.05 ± 3.07	10.96 ± 1.76	12.09 ± 2.20
14	SC0991	0.68 ± 0.05	139.27 ± 76.64	67.37	82.57	69.53 ± 5.48	22.75 ± 1.35	13.16 ± 0.64	17.16 ± 1.93
15	SC0929	0.63 ± 0.08	120.94 ± 67.36	57.68	78.72	66.91 ± 1.75	20.95 ± 1.55	10.55 ± 0.94	12.69 ± 1.78
16	SC0301	1.18 ± 0.09	108.37 ± 62.25	63.10	80.48	74.41 ± 0.29	21.05 ± 8.31	8.75 ± 0.68	10.69 ± 0.61
17	SC0213	1.16 ± 0.04	146.97 ± 29.38	50.65	72.99	62.13 ± 2.41	14.92 ± 1.38	7.74 ± 0.35	9.04 ± 0.51
18	SC0145	0.75 ± 0.16	123.23 ± 22.36	55.38	79.76	66.93 ± 1.55	17.42 ± 3.09	8.28 ± 1.09	9.98 ± 0.52
19	SC0391	1.26 ± 0.22	163.89 ± 50.75	70.00	71.28	62.84 ± 8.27	16.74 ± 1.04	9.24 ± 1.21	10.90 ± 1.46
20	SC0115	0.90 ± 0.07	161.93 ± 34.63	55.92	77.57	65.00 ± 1.05	18.23 ± 2.00	6.76 ± 1.19	7.86 ± 1.05
21	SC0303	1.01 ± 0.20	57.19 ± 4.12	61.40	72.72	56.99 ± 7.26	11.87 ± 3.84	5.73 ± 0.49	8.06 ± 0.94
22	SC0200	0.76 ± 0.08	170.33 ± 15.82	55.07	84.27	71.52 ± 1.86	15.81 ± 1.86	10.49 ± 0.37	11.01 ± 0.42
23	SC0079	1.16 ± 0.16	161.53 ± 21.72	62.42	72.86	69.40 ± 1.71	17.78 ± 1.93	8.78 ± 0.79	10.84 ± 0.79
24	SC0066	0.89 ± 0.11	74.43 ± 24.99	48.11	69.86	61.53 ± 1.15	15.47 ± 3.45	6.94 ± 1.47	8.44 ± 1.73
25	SC0293	1.17 ± 0.10	115.75 ± 25.59	25.22	78.27	69.19 ± 2.12	14.08 ± 1.40	7.40 ± 0.41	9.70 ± 0.51
26	SC0627	1.24 ± 0.09	171.45 ± 58.35	50.05	70.88	64.63 ± 1.70	16.75 ± 1.84	7.72 ± 2.15	9.45 ± 1.67
27	SC0774	0.74 ± 0.05	175.55 ± 31.40	53.90	84.43	72.76 ± 0.79	19.06 ± 3.27	11.78 ± 4.63	13.91 ± 4.45
28	SC0322	0.97 ± 0.07	143.30 ± 37.70	51.99	83.20	72.93 ± 2.97	15.86 ± 2.42	7.69 ± 0.50	9.54 ± 0.87
29	SC0414	0.71 ± 0.02	149.60 ± 29.04	67.14	77.79	69.32 ± 1.90	22.04 ± 1.57	8.32 ± 0.54	9.87 ± 0.78
30	SC0437	0.65 ± 0.05	86.18 ± 24.73	67.34	73.73	68.46 ± 1.49	17.51 ± 3.15	8.78 ± 1.60	8.17 ± 1.51
31	SC0283	0.99 ± 0.06	47.29 ± 9.91	40.67	64.72	51.47 ± 2.94	11.74 ± 0.36	5.10 ± 0.39	6.92 ± 0.48
32	SC0209	1.00 ± 0.08	149.53 ± 39.38	56.27	76.02	66.32 ± 2.12	15.69 ± 2.29	9.53 ± 1.05	10.61 ± 2.02
33	SC0964	0.83 ± 0.03	178.16 ± 52.54	65.11	76.00	67.50 ± 2.44	18.34 ± 1.97	8.81 ± 1.58	11.76 ± 2.34
34	SC1277	1.34 ± 0.12	203.16 ± 51.44	17.06	75.44	64.88 ± 12.91	15.58 ± 2.52	8.69 ± 1.42	8.76 ± 1.03
35	SC0348	1.30 ± 0.24	178.83 ± 13.31	60.97	78.07	69.75 ± 1.49	17.25 ± 2.00	9.78 ± 2.38	13.95 ± 1.04
36	SC0798	1.01 ± 0.07	188.67 ± 13.00	62.65	78.47	71.91 ± 4.55	17.69 ± 1.51	8.07 ± 0.41	11.40 ± 1.59
37	SC1077	0.64 ± 0.03	112.05 ± 27.93	39.47	81.02	69.38 ± 7.26	18.75 ± 2.20	10.21 ± 1.28	11.31 ± 0.53
38	SC1154	0.74 ± 0.05	94.72 ± 7.72	52.05	81.75	70.05 ± 0.62	16.77 ± 1.86	10.68 ± 1.48	11.84 ± 1.64
39	SC1426	1.75 ± 0.11	114.95 ± 24.95	43.53	70.08	63.11 ± 3.11	14.02 ± 2.55	5.65 ± 0.40	6.71 ± 0.71
40	SC0021	0.68 ± 0.06	77.88 ± 29.02	51.56	70.50	63.89 ± 1.37	14.83 ± 0.74	8.63 ± 0.34	10.65 ± 1.42
41	PRE0100	1.89 ± 0.33	229.73 ± 67.65	51.57	85.56	76.77 ± 0.54	17.65 ± 1.52	28.22 ± 4.11	26.60 ± 3.47
42	PRE0762	1.67 ± 0.02	263.19 ± 69.46	55.56	87.75	74.42 ± 2.02	17.16 ± 2.70	19.25 ± 4.15	18.26 ± 3.15
43	PRE0093	3.69 ± 0.08	606.36 ± 15.36	33.10	65.71	55.92 ± 4.57	22.72 ± 0.31	22.96 ± 0.42	22.71 ± 0.59
44	PRE0593	2.62 ± 0.21	653.26 ± 161.86	33.76	80.00	67.54 ± 5.53	23.50 ± 2.96	23.01 ± 2.41	23.00 ± 2.47
45	PRE0496	1.63 ± 0.57	274.65 ± 153.25	58.19	85.49	77.74 ± 0.25	18.78 ± 3.17	18.56 ± 3.34	17.28 ± 2.95
46	PRE0392	2.19 ± 0.31	388.21 ± 118.48	30.75	89.98	80.41 ± 2.68	19.74 ± 1.77	19.83 ± 1.35	18.66 ± 0.80
47	PRE0530	2.39 ± 0.16	411.30 ± 76.67	48.49	82.07	77.30 ± 1.58	20.51 ± 0.54	19.45 ± 1.62	18.33 ± 1.02
48	PRE0347	1.64 ± 0.22	350.20 ± 31.91	63.08	83.87	80.04 ± 0.38	21.49 ± 1.42	21.40 ± 0.63	19.90 ± 1.36
49	PRE1305	2.92 ± 0.03	734.69 ± 99.31	33.00	77.65	70.89 ± 1.74	23.04 ± 3.04	21.82 ± 3.18	21.71 ± 2.47
50	PRE0692	2.63 ± 0.04	464.19 ± 55.09	56.22	72.16	63.74 ± 2.86	19.26 ± 3.08	23.04 ± 1.26	22.04 ± 1.21
51	PRE0298	2.60 ± 0.10	400.50 ± 71.74	45.84	76.89	72.73 ± 1.94	22.66 ± 2.40	18.38 ± 0.72	17.09 ± 1.42
52	PRE0285	2.46 ± 0.13	333.63 ± 93.99	25.54	85.94	66.85 ± 15.56	23.63 ± 1.65	19.88 ± 1.91	18.92 ± 2.23
53	PRE0577	2.09 ± 0.07	266.39 ± 38.95	6.32	76.61	69.86 ± 0.94	18.19 ± 1.07	17.16 ± 1.18	17.49 ± 1.81
54	PRE0451	2.65 ± 0.20	403.27 ± 136.16	14.70	77.53	75.43 ± 0.87	20.34 ± 1.20	18.78 ± 3.62	18.20 ± 1.78
55	PRE0131	2.54 ± 0.43	513.36 ± 140.32	69.92	89.41	74.84 ± 7.80	16.65 ± 0.78	23.09 ± 2.58	23.55 ± 3.51

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Appendix 2. Physical properties (RPR and glucose/sucrose in leaves/stalks) of dwarf grain sorghum (SC line) and photoperiod sensitive sorghum (PRE line).

		RPR (kgf)			Glucose (%, w/w)		Sucrose (%, w/w)	
Index	Name	RPR1	RPR2	RPR3	Stalks	Leaves	Stalks	Leaves
1	SC0370	2.72 ± 0.45	2.65 ± 0.59	1.82 ± 0.59	0.29 ± 0.014	0.47 ± 0.016	0.55 ± 0.05	0.00 ± 0.00
2	SC0170	5.25 ± 0.48	3.45 ± 0.48	1.63 ± 0.09	6.29 ± 0.022	3.23 ± 0.109	15.02 ± 0.21	6.34 ± 0.50
3	SC0320	3.62 ± 0.55	1.75 ± 0.22	2.83 ± 0.17	1.61 ± 0.063	1.07 ± 0.129	7.56 ± 0.38	2.61 ± 0.33
4	SC0399	5.91 ± 0.78	4.55 ± 0.61	3.45 ± 0.45	2.00 ± 0.083	1.18 ± 0.036	1.06 ± 0.08	0.75 ± 0.05
5	SC1019	5.60 ± 0.89	3.47 ± 0.39	2.33 ± 0.24	6.88 ± 0.064	1.84 ± 0.015	8.42 ± 0.31	3.04 ± 0.11
6	SC1124	4.64 ± 1.19	1.87 ± 0.20	2.00 ± 0.58	2.21 ± 0.105	1.54 ± 0.013	8.69 ± 0.27	2.15 ± 0.13
7	SC0023	4.85 ± 0.63	3.60 ± 0.62	2.62 ± 0.62	6.53 ± 0.068	3.15 ± 0.206	9.96 ± 0.27	6.53 ± 0.55
8	SC0006	5.25 ± 0.47	2.20 ± 0.18	2.28 ± 0.44	1.42 ± 0.002	1.13 ± 0.171	1.17 ± 0.10	0.73 ± 0.11
9	SC0017	4.89 ± 0.64	2.23 ± 0.40	3.00 ± 0.25	3.01 ± 0.083	1.20 ± 0.075	5.28 ± 0.19	1.08 ± 0.12
10	SC0013	5.79 ± 2.66	2.11 ± 0.51	2.29 ± 0.52	5.89 ± 0.195	2.16 ± 0.004	10.36 ± 0.41	3.78 ± 0.12
11	SC1047	5.93 ± 0.89	2.57 ± 0.64	2.77 ± 0.17	2.27 ± 0.008	1.66 ± 0.060	3.30 ± 0.00	2.14 ± 0.03
12	SC0690	4.64 ± 0.24	2.19 ± 0.21	2.01 ± 0.93	3.84 ± 0.098	0.80 ± 0.054	4.59 ± 0.52	1.01 ± 0.02
13	SC1014	6.33 ± 0.82	2.85 ± 0.52	2.67 ± 0.29	2.77 ± 0.060	1.22 ± 0.077	7.78 ± 0.15	1.09 ± 0.23
14	SC0991	4.84 ± 0.58	2.55 ± 0.47	1.38 ± 0.08	2.30 ± 0.431	1.31 ± 0.633	2.59 ± 0.38	1.08 ± 1.08
15	SC0929	3.89 ± 0.73	4.85 ± 1.18	3.64 ± 0.38	2.63 ± 0.098	0.82 ± 0.056	11.94 ± 0.51	0.87 ± 0.03
16	SC0301	3.81 ± 0.90	2.89 ± 0.17	1.83 ± 0.41	2.25 ± 0.056	0.68 ± 0.011	10.30 ± 0.50	0.04 ± 0.04
17	SC0213	4.40 ± 0.49	2.33 ± 0.23	3.27 ± 0.51	3.46 ± 0.165	0.89 ± 0.042	5.92 ± 0.23	0.47 ± 0.01
18	SC0145	6.26 ± 1.41	2.41 ± 0.20	3.21 ± 0.67	3.98 ± 0.000	1.37 ± 0.040	6.75 ± 0.00	2.38 ± 0.11
19	SC0391	5.26 ± 2.21	2.86 ± 0.43	2.52 ± 0.34	3.37 ± 0.218	2.31 ± 0.011	7.33 ± 0.74	2.15 ± 0.34
20	SC0115	5.67 ± 0.95	2.98 ± 1.39	3.77 ± 0.44	3.16 ± 0.191	2.44 ± 0.034	5.96 ± 0.48	0.79 ± 0.13
21	SC0303	5.23 ± 0.79	2.10 ± 0.44	2.25 ± 0.28	0.55 ± 0.000	0.72 ± 0.000	1.28 ± 0.00	0.04 ± 0.00
22	SC0200	5.49 ± 0.26	5.62 ± 0.82	4.28 ± 0.62	1.11 ± 0.083	0.46 ± 0.002	1.46 ± 0.16	0.04 ± 0.01
23	SC0079	3.65 ± 0.59	2.97 ± 0.45	1.76 ± 0.71	3.75 ± 0.079	0.63 ± 0.043	3.97 ± 0.14	0.21 ± 0.02
24	SC0066	3.38 ± 0.39	2.65 ± 0.64	1.88 ± 0.27	0.78 ± 0.054	0.58 ± 0.010	1.20 ± 0.22	0.07 ± 0.03
25	SC0293	2.43 ± 0.58	2.68 ± 0.20	1.98 ± 0.08	1.94 ± 0.053	0.78 ± 0.036	8.52 ± 0.05	0.13 ± 0.13
26	SC0627	4.09 ± 0.83	2.89 ± 0.32	3.71 ± 0.66	3.33 ± 0.319	0.68 ± 0.173	9.69 ± 0.64	0.14 ± 0.14
27	SC0774	3.92 ± 0.62	3.62 ± 0.41	3.64 ± 0.50	1.38 ± 0.087	0.54 ± 0.140	1.68 ± 0.07	0.04 ± 0.04
28	SC0322	3.91 ± 0.25	3.03 ± 0.08	2.88 ± 0.39	3.23 ± 0.341	0.74 ± 0.000	6.48 ± 0.78	0.01 ± 0.00
29	SC0414	5.33 ± 0.35	2.84 ± 0.51	3.43 ± 0.55	1.62 ± 0.030	0.79 ± 0.029	4.23 ± 0.15	2.16 ± 0.17
30	SC0437	5.00 ± 0.62	3.15 ± 0.81	2.11 ± 0.23	0.46 ± 0.042	0.30 ± 0.016	0.81 ± 0.07	0.02 ± 0.02
31	SC0283	3.63 ± 0.72	1.12 ± 0.23	1.53 ± 0.29	1.91 ± 0.749	0.46 ± 0.005	6.90 ± 0.05	0.28 ± 0.13
32	SC0209	4.98 ± 0.81	4.38 ± 0.52	3.21 ± 0.36	3.17 ± 0.135	0.73 ± 0.030	7.17 ± 0.37	0.77 ± 0.01
33	SC0209	6.07 ± 1.13	3.13 ± 0.07	3.00 ± 0.36	4.95 ± 0.169	1.28 ± 0.029	13.10 ± 0.38	2.42 ± 0.08
34	SC1277	6.44 ± 0.87	2.87 ± 0.05	2.21 ± 0.09	6.23 ± 0.199	0.39 ± 0.060	7.83 ± 0.25	0.03 ± 0.02
35	SC0348	4.89 ± 0.98	2.45 ± 0.53	3.87 ± 0.65	1.62 ± 0.015	0.25 ± 0.014	1.05 ± 0.00	0.00 ± 0.00
36	SC0798	7.72 ± 0.74	4.51 ± 0.58	4.39 ± 0.46	5.84 ± 0.270	0.60 ± 0.000	7.20 ± 0.32	0.11 ± 0.11
37	SC1077	3.83 ± 0.77	3.37 ± 0.46	3.13 ± 0.41	0.86 ± 0.077	0.32 ± 0.005	0.52 ± 0.08	0.00 ± 0.00
38	SC1154	4.65 ± 0.29	3.79 ± 0.67	3.07 ± 0.36	0.10 ± 0.000	1.13 ± 0.475	0.00 ± 0.00	0.89 ± 0.89
39	SC1426	5.31 ± 1.62	2.95 ± 0.29	2.65 ± 0.15	1.94 ± 0.113	0.92 ± 0.007	10.52 ± 0.31	1.80 ± 0.06
40	SC0021	6.83 ± 0.12	3.62 ± 0.58	4.93 ± 0.52	1.64 ± 0.212	1.05 ± 0.385	1.92 ± 0.23	0.77 ± 0.77
41	PRE0100	3.79 ± 1.17	2.30 ± 1.03	2.68 ± 0.76	3.87 ± 0.041	1.13 ± 0.038	3.53 ± 0.14	1.76 ± 0.10
42	PRE0762	5.25 ± 1.43	5.00 ± 0.38	4.58 ± 0.56	3.10 ± 0.064	0.65 ± 0.029	2.80 ± 0.19	0.44 ± 0.10
43	PRE0093	10.11 ± 1.45	8.13 ± 0.34	7.97 ± 0.25	8.31 ± 0.056	0.63 ± 0.001	5.77 ± 0.20	0.16 ± 0.01
44	PRE0593	10.50 ± 2.23	6.57 ± 1.35	6.51 ± 1.35	6.15 ± 0.394	0.47 ± 0.018	2.07 ± 0.48	0.11 ± 0.04
45	PRE0496	2.72 ± 1.32	4.28 ± 1.90	4.53 ± 2.57	2.49 ± 0.079	1.06 ± 0.104	5.15 ± 0.21	0.90 ± 0.19
46	PRE0392	3.75 ± 0.61	3.82 ± 0.65	3.99 ± 0.44	0.61 ± 0.372	0.57 ± 0.348	0.26 ± 0.26	0.16 ± 0.16
47	PRE0530	6.98 ± 1.58	6.89 ± 2.82	5.67 ± 1.29	3.83 ± 0.236	0.53 ± 0.026	4.10 ± 0.24	0.12 ± 0.07
48	PRE0347	3.52 ± 1.06	3.54 ± 1.19	3.11 ± 0.75	8.18 ± 0.008	0.79 ± 0.026	3.39 ± 0.30	0.65 ± 0.04
49	PRE1305	7.31 ± 0.42	6.16 ± 0.35	6.15 ± 0.92	11.99 ± 0.829	1.22 ± 0.013	10.25 ± 0.07	0.25 ± 0.05
50	PRE0692	8.09 ± 1.14	8.79 ± 1.22	7.82 ± 0.77	4.40 ± 0.585	1.71 ± 0.019	17.40 ± 0.00	3.14 ± 0.44
51	PRE0298	8.41 ± 1.99	8.13 ± 1.17	8.42 ± 0.55	4.72 ± 0.765	0.45 ± 0.072	11.94 ± 8.31	0.14 ± 0.07
52	PRE0285	5.43 ± 1.12	4.79 ± 0.93	4.43 ± 1.18	3.53 ± 0.037	0.32 ± 0.008	4.02 ± 0.11	0.00 ± 0.00
53	PRE0577	7.89 ± 1.03	8.07 ± 0.13	6.93 ± 0.26	6.02 ± 0.390	0.27 ± 0.051	9.79 ± 0.51	0.00 ± 0.00
54	PRE0451	6.95 ± 2.14	9.60 ± 3.54	8.06 ± 2.62	2.98 ± 0.289	0.46 ± 0.021	4.46 ± 0.40	0.06 ± 0.05
55	PRE0131	6.34 ± 1.64	5.48 ± 1.76	5.13 ± 0.52	4.85 ± 0.023	0.89 ± 0.042	4.99 ± 0.28	1.01 ± 0.09

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