Measurement Of Sorghum Stalk Strength Using The Missouri-Modified Electronic Rind Penetrometer

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MEASUREMENT OF SORGHUM STALK STRENGTH USING THE MISSOURI-MODIFIED ELECTRONIC RIND PENETROMETER[1]

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ABSTRACT - Resistance to lodging is critical in sorghum [*Sorghum bicolor* (L.) Moench] grown for grain, yet adequate tools for plant breeders to assess this character at or before anthesis have not been developed. The objective of this study was to evaluate whether an electronic penetrometer previously shown to be an effective tool for measuring stalk strength in maize (*Zea mays* L.) could be used to differentiate among grain sorghum hybrids. Entries in three commercial grain sorghum hybrid trials were evaluated for rind penetrometer resistance (RPR) of the peduncle, the lower stalk at anthesis, and the lower stalk at maturity. Actual lodging counts were also taken immediately prior to harvest. Significant differences were detected among hybrids for RPR of the peduncle and lower stalk at anthesis, and for actual lodging percentages in all three experiments. Rind penetrometer resistance of lower stalks at maturity differed significantly among hybrids in only one of the three experiments. Coefficients of variation (CVs) ranged from 8.9 to 11.2% for peduncle RPR at anthesis, 6.3 to 7.8% for lower stalk RPR at anthesis 10.4 to 14.0% for lower stalk RPR at maturity, and 85.4 to 116.0% for actual lodging percentages. Rind penetrometer resistance measurements allowed better separation of hybrids into groups with high or low RPR than did actual lodging scores. Correlation of RPR values with actual lodging scores was extremely low and were usually non-significant. Based on these results, RPR of peduncles and lower stalks at anthesis may have utility as a selection tool for direct improvement of sorghum stalk strength.

KEY WORDS: *Sorghum bicolor*; Stalk strength; Lodging; Penetrometer.

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INTRODUCTION

Resistance to lodging is critical in sorghum [*Sorghum bicolor* (L.) Moench] grown for grain, yet adequate tools for plant breeders to assess this character prior to anthesis have not been developed. SCHERTZ *et al.* (1978) compared various methods and plant sites for measuring stalk strength at physiological maturity. They concluded that the force required to penetrate non-dried stalks was least variable, and that measurements taken at the base of the stalk (-third internode from the ground) were most highly correlated with total stalk breakage in the field (r=0.77, $P \leq 0.05$). However, this technology has not been adopted and most assessments for susceptibility to lodging are done by visual observation in the field prior to harvest, or in nurseries where plants are allowed to remain standing in the field throughout the winter and then scored (NORDQUIST and PARTRIDGE, 1988).

Although visual scoring of lodging susceptibility in the field is extremely simple, it cannot be accomplished prior to anthesis and is highly variable. More rapid genetic gain would be possible if a reliable technique was available to predict sorghum lodging prior to anthesis. SIBALE *et al.* (1992) described an electronic penetrometer modified to measure maize (*Zea mays* L.) stalk strength that permitted rapid direct electronic data collection in the field. DARRAH (1995) later reported that the electronic penetrometer could be effectively utilized just before flowering in maize (allowing same-season recombination of selected individuals), with demonstrated gains in force required to penetrate stalks of 8.0%/cycle.

The objective of this study was to adapt and evaluate the electronic penetrometer for use on grain sorghum by assessing its ability to differentiate among sorghum hybrids.

TABLE 1 - *Simple statistics for rind penetrometer resistance (RPR) and lodging measurements in three commercial grain sorghum hybrid trials conducted in Galva, KS, in 1997.*

	Mean	Minimum	Maximum	F-test	C.V.
	load-kg			probability	%
Early maturity Group Hybrid Trial					
Peduncle RPR at anthesis (kg)	3.7	2.3	5.6	0.0001†	11.2
Lower Stalk RPR at anthesis (kg)	8.2	6.5	10.1	0.0001	6.3
Lower Stalk at maturity (kg)	9.9	5.5	14.4	0.1699	14.0
Actual lodging (%)	8.2	0.0	69.8	0.0359	116.0
Medium-maturity Group Hybrid Trial					
Peduncle RPR at anthesis (kg)	4.0	2.3	5.6	0.0001	9.8
Lower Stalk RPR at anthesis (kg)	9.0	7.0	11.0	0.0001	6.8
Lower Stalk at maturity (kg)	10.4	7.1	13.5	0.0001	10.4
Actual lodging (%)	7.9	0.0	59.0	0.0001	85.4
Late-maturity Group Hybrid Trial					
Peduncle RPR at anthesis (kg)	4.1	2.7	5.4	0.0001	8.9
Lower Stalk RPR at anthesis (kg)	8.8	6.8	11.7	0.0017	7.8
Lower Stalk at maturity (kg)	10.7	6.8	15.4	0.3234	13.2
Actual lodging (%)	11.1	0.0	77.9	0.0019	110.5

† Probability F for hybrids.

MATERIALS AND METHODS

Through a Memorandum of Understanding between the United States Department of Agriculture, Agricultural Research Service (USDA, ARS) and NC+ Hybrids Sorghum Research Center (207 E. Wichita, Colwich, KS 67030-0428, USA), the USDA, ARS was granted access to three commercial grain sorghum hybrid trials (early, medium, and late-maturity groups) planted at Galva, Kansas, in 1997. Pedigrees of the hybrids were considered proprietary information and were not divulged to the USDA, ARS. All hybrids were of "combine-height" and assumed to be 3 dwarf. Each hybrid trial was a randomized complete block, with three replications. The early-maturity group experiment included 15 entries, the medium-maturity group trial included 45 entries, and the late-maturity group trial included 55 entries. Seedbeds were well tilled, and fertilizer (90 kg/ha N, 28 kg/ha P) was incorporated prior to planting on 26 June Propachlor [2-chloro-N (1-methylethyl)-N-phenylaetamide/atrazine [6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5,-triazine-2,4,-diamine]] was applied at 9.4 L/ha immediately after planting for weed control. Plots include two rows 10.9 m long spaced 0.76 m apart. The average plant density was 100,000 plants/ha.

Five random plants per plot were evaluated for RPR of the exposed peduncle and of the stalk approximately 2 cm above the soil when anthers were exerted on the uppermost florets on the main panicle. This was done to ensure a uniform stage of maturity at sampling and would also allow sorghum breeders to make selections prior to anthesis for the majority of the florets on a panicle (in practice, the upper open florets can be easily excised). In addition, five random plants were evaluated for RPR of the stalk measured approximately 2 cm above the soil surface immediately prior to harvest on 4 November. Although SCHERTZ *et al.* (1978) showed a high correlation of stalk breakage with crushing and penetrometer resistance at the third internode above the ground using harvested plants, we found counting internodes above the ground very difficult in the field and utilized the penetrometer stop-bar as a rapid gauge of distance from the soil surface. The penetrometer used was a modified Accuforce Cadet digital force gauge, 18.1 kg capacity (AMETEK, Mansfield & Green Division, Largo, FL)[3] (SIBALE *et al.*, 1992). Actual lodging was also assessed immediately before harvest by counting the number of lodged plants in each plot.

Data from each experiment were analyzed independently using the General Linear Model procedure of SAS (SAS, 1990). Entries were considered random effects. Individual plant data were averaged within plots, and experiment results were analyzed using the SAS model: Force = Rep Entry; and residual error was used to test the significance of entry effects. Where significant entry effects were detected, Duncan's multiple range test (SAS, 1990) was used to group and separate means. Pearson correlations (simple) and Spearman (rank) correlations (SAS, 1990) were calculated to establish the degree of relationship between RPR and actual lodging.

RESULTS AND DISCUSSION

Significant differences were detected among hybrids for peduncle RPR and lower stalk RPR at anthesis, and for actual lodging percentages in all three experiments. Lower stalk RPR at maturity was significant only for the medium maturity hybrids. At anthesis, RPR of peduncles and lower stalks exhibited roughly a two-fold range of values (Table 1). Coeffi-

[3] Mention of a proprietary product does not constitute endorsement by the USDA-ARS, or the University of Nebraska-Lincoln and does not imply its approval to the exclusion of other products that also may be suitable.

TABLE 2 - *Early maturity grain sorghum hybrid means for rind penetrometer resistance (RPR) and lodging measurements in from a trial conducted in Galva, KS, in 1997.*

Anthesis						Maturity					
Peduncle RPR			Lower stalk RPR			Lower stalk RPR			Actual lodging		
Entry	load-kg		Entry	load-kg		Entry	load-kg		Entry	%	
15	5.3	a[†]	15	9.5	a	5	11.9	a	8	0.9	a
11	4.9	ab	8	9.3	ab	4	11.8	a	7	1.0	a
10	4.9	ab	11	9.2	ab	15	10.7	a	4	1.0	a
5	4.3	bc	4	8.7	abc	8	10.1	a	10	1.7	a
12	3.9	cd	13	8.7	abcd	11	10.0	a	11	2.2	a
8	3.9	cd	5	8.5	bcde	14	9.9	a	6	4.0	a
14	3.6	cde	14	8.1	cdef	7	9.9	a	1	5.6	a
4	3.5	de	10	8.1	cdef	1	9.8	a	5	5.9	a
1	3.5	de	2	8.0	cdef	10	9.5	a	12	9.4	a
6	3.4	de	6	7.9	cdef	2	9.4	a	3	10.3	a
13	3.3	def	7	7.8	cdefg	3	9.3	a	15	10.4	a
7	3.0	efg	12	7.7	defg	13	9.3	a	2	10.8	a
9	2.9	efg	3	7.5	efg	12	9.0	a	14	10.8	a
2	2.6	fg	1	7.4	fg	6	8.9	a	13	17.3	ab
3	2.5	g	9	7.0	g	9	8.4	a	9	32.0	b

[†] Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

cients of variation (CVs) ranged from 8.9 to 11.2% for peduncle RPR and 6.3 to 7.8% for lower stalk RPR at anthesis. Lower stalk RPR at maturity had CVs ranging from 10.4 to 13.2%. Actual lodging percentages had large CVs that ranged from 85.4 to 116.0%.

Practical differences in RPR data and actual lodging data are apparent. For simplicity of discussion and brevity, individual hybrid data are shown for only the early-maturity group experiment (Table 2). However, the conclusions drawn from this smaller

TABLE 3 - *Simple (below diagonal) and rank (above diagonal) correlations for rind penetrometer resistance (RPR) and lodging measurements in three commercial grain sorghum hybrid trials conducted in Galva, KS, in 1997.*

	Peduncle	Stalk at anthesis	Stalk at maturity	Actual lodging
Early-maturity Group Hybrid Trial				
Peduncle	–	–0.55*	0.36*	–0.23
Stalk at anthesis	0.57*	–	–0.39*	–0.28
Stalk at maturity	0.26	–0.38*	–	–0.27
Actual lodging	–0.20	–0.32*	–0.30*	–
Medium-maturity Group Hybrid Trial				
Peduncle	–	0.35*	0.25*	0.11
Stalk at anthesis	0.42*	–	–0.44*	–0.07
Stalk at maturity	0.31*	0.45*		–0.07
Actual lodging	0.05	–0.05	–0.14	–
Late-maturity Group Hybrid Trial				
Peduncle	–	0.40*	0.03	–0.02
Stalk at anthesis	0.45*	–	–0.10	–0.08
Stalk at maturity	0.07	0.11	–	–0.05
Actual lodging	0.00	–0.02	–0.05	–

* Significant at $P \leq 0.05$.

set of hybrids are consistent with the data (not shown) for the larger medium-maturity and late-maturity group experiments. Data from actual lodging counts tended to clearly identify those hybrids with severe lodging susceptibility, but most hybrids exhibited little or no lodging. Little separation of hybrid means was possible, with the exception of identifying those with extremely high lodging scores. In practice, such data would allow breeders to evaluate lines or hybrids for unacceptable lodging susceptibility, but would be of little use in identifying lines with clearly superior lodging resistance.

Peduncle RPR and lower stalk RPR at anthesis values clearly separated hybrids with high and low RPR (Table 2). In practice, such information could be used by breeders to identify and select lines or hybrids with high stalk strength as determined by RPR. The precision of RPR as indicated by the relatively low CVs, combined with the ability to measure RPR prior to pollination, should make RPR an efficient tool for increasing stalk strength in grain sorghum.

The value of using RPR as a predictor of lodging in advanced grain sorghum hybrid yield trials appears questionable. In these three commercial hybrid yield trials, most entries exhibited low lodging percentages, and mean separation tests were relatively ineffective at identifying differences among hybrids for percent lodging. As would be expected, simple correlation of RPR values with actual lodging scores were extremely low in all three experiments and with the exception of the early maturity group experiment, correlations were non-significant at P=0.05 (Table 3). Rank correlations were non-significant in all three experiments. Similarly, in actual sorghum breeding nurseries at Mead, Nebraska, RPR values were low for a line (PI431592) observed to have extremely strong stalks and excellent resistance to lodging. When used to measure plants from PI431592, the penetrometer tip caused the stalk to fracture vertically rather than provide resistance to penetrometer.

In conclusion, RPR of the peduncle and lower stalk at anthesis, and lower stalk at maturity are not reliable predictors of lodging resistance in advanced hybrid trials, or in actual breeding nurseries. Incidence of actual lodging in the field is quite variable and complex and is related to many factors including weather events, disease damage, insect damage, stalk strength, and other factors. Measurement of RPR of sorghum peduncles and lower stalks at the beginning of anthesis is simple, precise, and allows rapid data collection in the field prior to pollination of the lower florets on a panicle. It would therefore be possible to conduct a breeding program to increase RPR in sorghum. Based on results observed in maize, increased stalk strength would be anticipated. However, the value of increasing RPR as a mechanism to increase lodging resistance of sorghum has yet to be demonstrated.

REFERENCES

DARRAH L.L., 1995 Comparison of two selection methods for improving stalk strength in maize. Agronomy Abstracts. p. 70.

NORDQUIST P.T., J.E. PARTRIDGE, 1988 Registration of sorghum germplasm lines selected for improved stalk strength. Crop Sci. **28:** 203.

SAS INSTITUTE, 1990 SAS/STAT user's guide. Version 6. Fourth ed. SAS Inst., Cary, NC.

SCHERTZ K.F., F.A. AL-TAYAR, D.T. ROSENOW, 1978 Comparison of methods for evaluating stalk strength of sorghum. Crop Sci. **18:** 453-456.

SIBALE E.M., L.L. DARRAH, M.S. ZUBER, 1992 Comparison of stalk strength in maize. Maydica **37:** 111-114.