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Total Sugar Content in Sorghum Stalks and Grains of Selected Cultivars from the World Germplasm Collection*

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ABSTRACT

Seventy sorghum cultivars from the world germplasm collection maintained at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) were screened for total sugar content of the stalks. The total sugar content in stalks harvested after physiological maturity ranged from 17·8 to 40·3% on dry weight basis. The total sugar content in grains of 15 selected cultivars ranged from 1·02 to 2·23%. Nine cultivars having more than 34% total sugar content in stalks showed consistency for sugar content when grown for two seasons. Juiciness of stalks from five cultivars as estimated by the quantity of juice extracted varied from 266 to 464 ml per kilogram of fresh stalks. The total sugar content in the juice of five cultivars varied from 7·0 to 15·9%.

Key words: Sugar content; sorghum stalks; world germplasm.

1 INTRODUCTION

Sorghum (*Sorghum bicolor* L.) has been used for sugar and alcohol production since the 17th century. Sorghum was considered to be best suited for alcohol production in countries such as Italy, Spain and France even in 1936; in Italy, 8000 hl of alcohol were manufactured in 1938 from sorghum stem.[1] A report from

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the United States Department of Agriculture (USDA) indicated that sorghum and other crops such as sugarbeet, sugarcane and corn have good potential for ethyl alcohol production.[2] Sweet sorghums can be used for alcohol production by adopting the technology available from the sugarcane industry.[3] Sweet sorghum lines also have some tolerance to drought; in addition, many of them are resistant to important sorghum diseases in the United States.[4] Further they may be useful as fodder, since a positive correlation for preference with total sugars in grazing studies has been observed.[5] Thus sweet sorghums may be very useful for developing fodder types in a breeding programme.

Sorghum landraces possessing sweet stalks are sparsely distributed in the sorghum-growing areas of Africa and Asia. The green stalks are often chewed in a manner similar to sugarcane, particularly in dry-land areas. A study of the sorghum world collection maintained at ICRISAT revealed the existence of sweet-stalk sorghums in collections from Botswana, Cameroun, Chad, Ethiopia, India, Kenya, Malawi, Niger, Nigeria, Somalia, South Africa, Sudan, Thailand, Uganda, United States of America, Zambia and Zimbabwe.[6] The present study was undertaken to identify the cultivars with high sugar content in their stalks in part of the world collection maintained at ICRISAT. These cultivars may be used in crop improvement programmes for incorporation of this trait into breeding lines.

2 EXPERIMENTAL

2.1 Stalk and grain samples

A part of the sorghum world germplasm collection of ICRISAT was screened initially for stalk sweetness by chewing the stalks at maturity. Seventy accessions that tasted sweet were planted in single 4-m-row plots with 30 plants per row in the rainy season (June–November) of 1980 at ICRISAT Center, Patancheru, India. The rainfall during the crop season of 148 days was 588 mm and the mean maximum and minimum temperatures were 30·5 and 21·0°C, respectively. Nine cultivars with a high sugar content in the stalk in the 1980 season were planted again in the 1981 rainy season in single 4-m-row plots. The rainfall during the growing season of 153 days was 1030 mm. The maximum and minimum temperatures during the above period were 29·5 and 21·0°C, respectively. A basal application of fertiliser (80 kg N ha^{-1} and 80 kg P_2O_5 ha^{-1}) was included in the seedbed; a topdressing of 40 kg N ha^{-1} was given 3 weeks after planting in both seasons. For sugar analysis at least two plants were harvested at full maturity (which is about 15 days after physiological maturity) from each accession for sugar analysis. Two cultivars, IS-6872 and IS-6896, were selected, and the plants were removed to study the variation in sugar content at different internodes. Different internodes (2nd, 4th, 6th and 8th) from the base of the plant were sampled and dried at 70°C. The dried material was ground in a Wiley mill (Arthur H. Thomas Co., Philadelphia, USA) to pass through a 0·5-mm screen. The plants from 70 cultivars were also harvested at full maturity. For uniformity of sampling and rapidity of

analysis for screening, the third internode from the base of the plant was removed and dried at 70°C and ground in a Wiley mill. The grains were collected from the panicles and ground in a Udy cyclone mill (UD Corporation, Boulder, Colorado, USA) to pass through a 0·4-mm screen. The flour was defatted for 6 h using *n*-hexane in a Soxhlet apparatus. The sugar content of the grain was determined only in 15 selected cultivars.

2.2 Sugar analysis

The total soluble sugar was extracted with 80% ethanol from 100 mg of plant or grain material by the AOAC method.[7] The total sugar content in the extracts was determined using the phenol–sulphuric acid method of Dubois *et al.*[8] The analysis was carried out in duplicate for the 15 cultivars, and sugar content was determined in duplicate from each of the extracts; the mean values are reported. On the remaining 55 cultivars, duplicate determinations from single extracts were made.

2.3 Juice properties

To study the juiciness of stems, five cultivars with high stalk sugar content (above 34% on dry weight basis) were chosen. The plants were grown in the 1981 season and harvested from the field. After the leaves had been removed, the fresh stalk was weighed and crushed in a locally made sugarcane crusher to extract the juice. Care was taken to recover the juice quantitatively. After filtration through a sieve to remove chaff, etc., the volume of extracted juice was measured and expressed as extractability in millilitres per kilogram fresh weight of stalks. The specific gravity of juice (g ml^{-1}) was determined by weighing 100 ml juice. A quantity of 100 ml juice was taken in a porcelain dish and evaporated to dryness on a steam bath. The contents were then dried in an oven at 70°C to constant weight and expressed as the weight of total solids (g 100 ml^{-1}). The evaporated material was dissolved in water and the total sugar content was determined as described above and expressed as per cent of fresh juice. Two replicates were taken for all the above analyses, and mean values are given.

3 RESULTS AND DISCUSSION

The total sugar content in the internodes of the stem tends to decrease from the bottom to the top portion of the plants (Table 1). However, the variation of sugar content was small at the lower internodes of the plant. Hence for uniformity of sampling and rapid extraction, the analysis was carried out using the third internode from the base of the plant. Total sugar content in stems and grains of 15 selected cultivars was analysed taking duplicate samples for extraction and duplicated determinations from the extracts (Table 2). In order to have a rapid screening method for total sugar in stems, 55 cultivars were chosen and single extraction with two determinations of sugar was carried out (Table 3). The total sugar content for the 70 cultivars varied between 17·8 and 40·3% (Tables 2 and 3). The total sugar contents of the grains from 15 lines were low, with a mean value of 1·40% (Table 2) and with a range of 1·02 to 2·23%, and were within the range of

TABLE 1
Total Sugar Content at Different Internodal Regions of Sorghum Stalks, 1980 Crop

Internode no. from ground	*Total sugar (%)*[a]	
	IS-6872	*IS-6896*
2	31·7	34·7
4	31·5	36·1
6	28·6	38·3
8	25·1	31·4
10	22·1	—
Mean	27·8	35·1
±SE	1·86	1·29

[a]Dry weight basis; means of two separate extractions and determinations.

previously reported values.[9] The sugar content in the stalk and the grain did not show any significant relationship (r=0·22) to each other.

The mean sugar content in the stalks of nine cultivars grown in 1980 and 1981 varied (Table 4) by only about 3% between the two seasons, which indicates that differences between growing season may have little influence on the stalk sugar

TABLE 2
Total Sugar Content in Sorghum Stalks and Grains, 1980 Crop

IS No.	*Origin*	*Total sugar (%)*	
		Stalk	*Grain*
20888	Angola	24·8	1·35
14960	Cameroun	26·1	1·29
15428	Cameroun	33·5	1·24
22636	Cameroun	31·3	1·02
14594	Ethiopia	26·6	1·24
4617	India	23·0	1·33
4751	India	29·3	1·27
20963	Kenya	32·0	2·23
20984	Kenya	31·6	2·18
21023	Kenya	26·6	1·49
3552	Sudan	31·2	1·35
3569	Sudan	30·9	1·27
3572	Sudan	33·0	1·25
6928	Sudan	26·9	1·23
7077	Sudan	29·5	1·32
Mean		29·1	1·40
±SE		0·83	0·088

All values are on dry weight basis. The values are based on analysis of the 3rd internode from the base of the plant, and on the mean of two extractions and determinations.

TABLE 3

Total Sugar Content in Sorghum of Selected Cultivars, 1980 Crop

IS No.	*Origin*	*Total sugar (%)*	*IS No.*	*Origin*	*Total sugar (%)*
14970	Cameroun	34·0	7077	Sudan	28·1
14904	Cameroun	28·7	7080	Sudan	28·4
14942	Cameroun	23·7	9638	Sudan	29·2
15102	Cameroun	28·4	9639	Sudan	37·1
15448	Cameroun	33·0	9645	Sudan	32·5
15455	Cameroun	35·7	9699	Sudan	31·5
16054	Cameroun	32·3	9705	Sudan	25·2
11093	Ethiopia	27·5	9767	Sudan	31·9
11496	Ethiopia	31·8	9889	Sudan	35·1
12639	Ethiopia	27·5	9890	Sudan	36·5
14548	Ethiopia	31·9	9901	Sudan	38·1
4755	India	25·2	14446	Sudan	27·3
10050	India	26·8	14463	Sudan	31·5
21991	India	17·8	19130	Sudan	25·2
20962	Kenya	26·4	19261	Sudan	26·6
20974	Kenya	32·4	19273	Sudan	36·6
21005	Kenya	33·5	19587	Sudan	37·0
21100	Kenya	34·1	20503	Sudan	36·7
21229	Kenya	32·1	20510	Sudan	26·4
21235	Kenya	36·8	20557	Sudan	30·2
21260	Kenya	35·8	20583	Sudan	31·9
2331	Sudan	33·6	8157	Uganda	30·5
2325	Sudan	24·0	8218	Uganda	28·0
3524	Sudan	33·7	131	USA	32·3
3556	Sudan	30·6	12292	Zimbabwe	37·1
6936	Sudan	30·0	19674	Zimbabwe	40·3
6962	Sudan	35·6	Mean		31·27
6973	Sudan	33·5	±SE		0·59
7073	Sudan	32·5			

All values are on dry weight basis. Values are based on analysis of the 3rd internode from the base of the plant, and on single extraction and mean of two separate determinations.

content. Several cultivars had a high sugar content, and 43 cultivars which had more than 30% sugar in the stems (Table 2 and 3) may have a good potential for further use as sweet sorghum lines. It has been reported earlier that sweet sorghum fodders may contain up to 21% total sugars.[4]

There is a wide range of juiciness in sorghum. Stalks of some cultivars are juicy but are so hard that extraction is difficult.[4] The juiciness of stalks must be considered in addition to the quantity of sugars, as it influences the extractability of sugar and, in turn, the juice quality. The juice was extracted from stalks of five cultivars that had high sugar content. The volume of juice extracted from the stalks of IS-21235 and IS-9639 was low, whereas the stalks of IS-9890, IS-9901 and IS-19674 yielded higher quantities (Table 5). In addition, the stalks of IS-9901 and IS-19674 contained a greater quantity of sugar in their juice. The total solids were higher in the stalks of IS-9901 and IS-21235 than for IS-9890, which also had the

TABLE 4
Total Sugar Content in Sorghum from Two Seasons

IS No.	*Origin*	*Total sugar (%) in stalk*[a]	
		1980	*1981*
15455	Cameroun	35·7	40·5
21100	Kenya	34·1	36·3
21235	Kenya	36·8	34·8
9889	Sudan	35·1	39·0
9890	Sudan	36·5	35·8
9901	Sudan	38·1	42·7
19273	Sudan	36·6	34·6
12292	Zimbabwe	37·1	39·2
19674	Zimbabwe	40·3	38·5
Mean		36·7	37·9
±SE		0·59	0·92

Values between years are not significant ($P<0·05$) by paired t test.
[a]Dry weight basis; mean of two separate extractions and determinations.

TABLE 5
Characteristics of Juice from Sorghum Stalks

IS No.	*Origin*	*Extractability of juice (ml kg^{-1})*[a]	*Juice characteristics*		
			Specific gravity (g ml^{-1})	*total solids (g 100 ml^{-1})*[a]	*Total sugar (g 100 ml^{-1})*[a]
21235	Kenya	266	1·07	24·8	15·0
9639	Sudan	292	1·07	19·9	12·1
9890	Sudan	464	1·04	11·9	7·0
9901	Sudan	410	1·08	26·1	15·9
19674	Zimbabwe	407	1·07	20·7	12·2

[a]On fresh weight of stalk basis.[b]Obtained after evaporating fresh juice to dryness.

lowest sugar content. However, the quantity of juice in the stalks and the total sugar content may not be related. The density of the juice did not show appreciable variation among the cultivars. The present preliminary study indicated that genotypes that contained high quantities of sugar in their stalks varied in the juiciness of their stalks. Further detailed study with several cultivars of diverse geographic origin is required before definitive conclusions can be drawn.

Production of fermentable materials in sorghum appeared to be comparable with that of sugarcane in North Queensland.[10] The results of the present study indicated that some sweet sorghum cultivars have excellent potential as a source for producing fermentable material, and these sorghums may also be useful as good-quality fodder, as suggested by Gangstad.[5]

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