AN EVALUATION OF SWEET SORGHUM AS A SUGAR CROP IN THE MIDLANDS MISTBELT

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Abstract

Three sweet sorghum (*Sorghum bicolor*, L. Moench) varieties, RIO, RAMADA and ROMA were grown experimentally from seed that was imported from the USA and subsequently from seed that was bulked locally, in the mistbelt of the Natal Midlands. ROMA, the tallest and latest maturing variety outyielded the other two sorghum cultivars in a variety trial and in observation and bulking plots. In another trial ROMA was sown on three dates in spring and the crop was harvested either at the hard-dough stage or one month later. Yields decreased rapidly with delays in sowing. This was due not only to a reduction in the growing period of the crop but also to a lower rate of growth per unit time. Sucrose yields remained fairly constant between harvests but juice purities and sucrose contents rose considerably when harvesting was delayed. Of the herbicides tested, atrazine sprayed pre-emergence at a rate of 3 kg ai/ha, was the most successful but gave limited control of grasses. Although in some respects the performance of sweet sorghum compared reasonably well with that of sugarcane in the Natal Midlands, it was concluded that sorghum would be of more use in the drier, warmer areas that are marginal for sugarcane.

Introduction

"Sorgo" is the vernacular in North America for the juiciest and sweetest variants found in many species of the genus *Sorghum* and for *S. bicolor* (L. Moench) in particular. Many of the original sweet sorghums introduced to the USA more than a century ago were from Africa, Natal being one of the most important sources (Coleman[4]). These tall sweet stemmed sorghums were described by one of the founders of Port Natal, as indigenous plants, highly favoured by the local natives (McMartin[8]). The indigenous *Sorghum saccharatum* or "imphe" which is so popular amongst rural tribesmen today, is almost certainly the same species.

The most important use of sweet sorghum in the USA has been for the production of table syrup and it was only during the Second World War that interest in this crop for sugar production was revived. There was a new drive to collect genetic material which would give higher stalk yields and contain less of the two compounds that prevented sugar crystallization, aconitic acid and starch. By 1970 over 4 000 lines had been assembled at Meridian, Mississippi (Coleman[4]). New techniques for reducing starch and aconitic acid concentrations in the juice, together with the development of better genotypes, has made the commercial production of sugar from sweet sorghum technically possible (Smith *et al*[12]).

Sweet sorghum stalks remain in a millable state for too short a period to justify a mill for this crop alone. It is foreseen that an off-season supply of 'sorgo' would be a welcome addition to keep beet or cane factories operating longer (Brandes[1]). This thought was probably in the minds of growers and millers in the Natal Midlands when they recently showed an interest in sweet sorghum. Another possibility would be to process sweet sorghum early in the milling season and allow sugarcane to mature more before milling. Factory scale tests in Mexico and Texas on sweet sorghum have proved reasonably successful but no commercial operations have yet been initiated (Coeto and Smith[3], Smith and Lime[13]).

This paper is based on data obtained from (1) observation plots established at Greytown by Pioneer Seed Company, (2) bulking plots established by members of the Union Co-operative at Dalton, and (3) three replicated trials conducted at Dalton in 1978/79 by staff of the Experiment Station.

Methods

The small plots at Pioneer Seed Co. of Greytown were sown to 11 sorghum varieties on the 2nd November 1977 and were well managed by the Company's staff. The plots were kept weed free and were treated several times against aphids. The aphid infestation was, however, fairly severe. The maize borer (*Buseola fusca*) that was prevalent after head emergence, appeared to have contributed to the large number of broken stalks that occurred in some plots.

The four bulking plots covered a total area of about 12 hectares. A basal fertilizer dressing of 750 kg/ha 2-3-2(22), was applied before planting in late November. A side dressing of 200 to 300 kg/ha limestone ammonium nitrate was applied in mid-January. The two plots of Roma sorghum and the plot of Ramada were kept reasonably free of weeds, but Rio sorghum suffered from weed competition during the early stages. Roma and Ramada started to lodge after head emergence because of a combination of high winds and wet soils.

The sorghum in plots at Greytown was sampled four times at fortnightly intervals after the soft-dough stage. The bulking plots were sampled on three occasions between the hard-dough and fully ripe stages, but only the means of the three sets of data are presented here. Each sample consisted of twenty stalks which were stripped of leaves and sheaths and topped about 100 mm below the seed head.

A variety trial, a sowing date trial and a herbicide trial were conducted in the 1978/79 season on a Farningham soil series, containing 34% clay, near Dalton. The experiment site received 50 kg N and K and 10 kg P per hectare in a fertilizer mixture, before the final seedbed preparation. The soil P level (66 ppm) and the pH (5,3) were satisfactory, prior to application.

Seeds obtained from the bulking plots and from Pioneer Seed Co. were drilled in 0,9 m rows. The seed of the varieties Rio and Ramada from the bulking plots germinated poorly and contributed little to the results. Seed of Rio, Ramada and Roma from Pioneer and the bulked seed of Roma germinated well and seedlings were later thinned to about 14 per metre of row. A side dressing of 70 kg N/ha was given when plants were about 0,6 m tall. Endosulphan was applied occasionally to control aphids and top grub and was reasonably effective. The variety trial was harvested at the hard-dough stage, the sowing date trial at either the hard-dough stage or one month thereafter, and the herbicide trial which was sown to Rio sorghum from the bulked seed was

TABLE 1

Quality and yield of sweet sorghum sown on 2.11.79 in observation plots at Greytown (4 sampling dates)

Variety	Days to flower	Juice Purity (%) 28/2	14/3	28/3	7/4	Sucrose % Stalk 28/2	14/3	28/3	7/4	Fibre % stalk	Stalk height (cm)*	Stalk mass (g)	Population '000/ha	Stalk (t/ha)	Sucrose (t/ha)	Borer rating †	Lodging rating ‡
Rio plot 1	83	43	70	60	56	3,0	6,3	7,2	5,3	13,9	161	173	139	24	1,7	5	1
plot 2	83	57	75	61	53	4,6	7,0	6,8	4,5	14,1	158	181	129	23	1,6	5	1
Rox orange	85	31	45	55	56	3,0	4,6	7,0	7,2	13,8	199	209	135	28	2,0	5	3
Ramada plot 1	87	62	70	61	53	5,3	6,8	7,0	6,4	15,0	178	197	131	26	1,8	3	1
plot 2	87	62	68	64	55	6,1	6,9	8,2	6,9	15,3	202	202	130	26	2,1	5	1
plot 3	87	69	77	68	59	7,6	8,2	8,5	7,8	14,6	200	228	153	35	3,0	5	1
Sart	88	13	22	28	23	0,8	1,2	2,2	1,9	13,5	206	284	124	35	0,8	5	2
Atlas	94	—	25	36	24	—	1,2	2,7	1,5	14,8	185	268	145	39	1,0	3	1
Theis	96	—	20	11	13	—	1,3	0,9	1,2	13,5	223	292	158	46	0,4	5	5
Roma plot 1	97	61	69	57	56	5,1	5,4	5,4	5,3	13,2	206	314	132	41	2,2	4	2
plot 2	97	68	78	71	63	6,5	7,2	8,2	7,1	14,0	240	360	131	47	3,8	4	2
Dale	103	—	27	34	21	—	2,3	3,3	1,8	11,6	244	383	123	47	1,6	5	4
Wiley	103	—	36	46	30	—	3,5	5,2	2,8	15,1	281	395	122	48	2,5	5	4
Brandes	103	—	—	33	23	—	—	3,2	1,9	10,1	—	180	225	40	1,3	2	2
Tracey	103	—	52	49	34	—	5,2	5,6	3,3	13,5	233	331	176	58	3,2	5	4

* Stalk height measured to the top-most collar † Borer rating 1 = no damage, 5 = maximum damage ‡ Lodging 1 = no lodging, 5 = fully lodged

not harvested as an experiment. Stalk quality was determined from samples prepared in the usual way. Stalk yields were obtained from weighing topped stalks, stripped of leaves but not of leaf sheaths.

Results and Discussion

Varieties

The juice quality of the varieties grown at Greytown was generally poor but the difference between the varieties that had been specially developed as sugar sorghums (Rio, Ramada and Roma) and the older syrup lines, was clear. Rox Orange was the only 'syrup' variety that would have qualified as a sugar sorghum on the strength of these results. (Table 1).

Stalk height and mass were directly related to the number of days to flowering, as would be expected (r = 0,83 and r = 0,93 respectively). The three 'sugar' sorghums, Rio, Ramada and Roma, performed better in the bulking plots than in the small plots at Greytown which were infected with aphids and stalk borer. Roma was clearly superior to Ramada and Rio in juice purity, sucrose content and estimated stalk yield (Table 2).

TABLE 2

Quality and yield of sweet sorghum grown in bulking plots on four farms in the Natal Midlands

Locality	Dalton	Dalton	Dalton	Seven Oaks
Farm	Arlington	Witte Mountain	Spitzkop	Venture
Variety	Ramada	Roma	Roma	Rio
Juice purity (%)	68	76	75	67
Sucrose (%)	8,9	9,9	9,5	7,2
Stalk mass (g/stalk)	308	404	415	236
Stalk population ('000/ha)	92	117	90	118
Est. stalk yield (t/ha)	25	44	37	25
Est. sucrose yield (t/ha)	2,6	4,4	4,1	2,0

The replicated variety trial conducted the following season, confirmed the superiority of Roma over the other two varieties in juice quality and stalk yield (Table 3). The rankings of these varieties according to sucrose content and stalk yield was the same at Dalton as it was at Weslaco, Texas (Table 4). The juice purity values at Dalton and Weslaco were also similar but sucrose contents and stalk yields of the sorghum grown at Dalton were much lower than for the same varieties grown in Texas. Climatic conditions in South Texas resemble those in the Western Free State which is perhaps more suited to sorghum production than the Midlands Misbelt. The contrast between the sugar sorghums and a 'sweet' forage sorghum, PNR989, that was included in the variety trial, is clear from the results in Table 3.

TABLE 3

Performance of the three Texan varieties and one locally bred variety in a replicated trial at Dalton

Variety Name	Roma	Ramada	Rio	PNR 989
Yield Component				
Age (months)	5,0	4,6	4,6	4,6
Fibre % stalk	14,2	14,9	15,9	18,6
Dry matter % stalk	27,3	25,5	27,8	21,1
Sucrose % stalk	9,3	6,0	9,0	0,4
ERS % stalk	6,7	2,8	6,7	0,0
Juice purity %	71,2	55,6	75,3	16,3
Stalk population ('000/ha)	88	92	80	—
Stalk length (m)	2,38	1,74	1,42	2,05
Stalk yield (t/ha)	37	20	14	25
DM yield (t/ha)	10,0	5,1	3,9	5,3
Sucrose yield (t/ha)	3,4	1,2	1,3	0

TABLE 4

Performance of three Texan varieties in a variety trial in Texas (Reeves, 1975)

Variety	Days to flower	Stalk height (m)	Juice purity %	Sucrose % stalk	Stalk yield t/ha
Rio	70	2,30	77,0	14,2	43
Ramada	94	2,49	72,0	11,1	51
Roma	88	2,52	73,2	11,7	61

TABLE 5
Influence of sowing and harvest dates on the yield and quality of the Roma variety of sweet sorghum

Sowing date	12.10.78		5.12.78		21.12.78		Mean	
Harvest date	21.3.79	25.4.79	25.4.79	30.5.79	11.5.79	30.5.79	Early	Late
Age (months)	5,3	6,4	4,6	5,8	4,7	5,3	4,8	5,8
Dry matter % stalk	29,0	31,0	28,5	34,3	26,4	29,4	28,0	31,6
Sucrose % stalk	10,4	12,0	10,9	11,7	10,3	11,0	10,5	11,6
ERS % stalk	7,8	9,9	8,8	9,6	8,0	9,0	8,2	9,5
Juice purity %	75,1	83,0	80,4	85,0	76,5	82,3	76,9	83,4
Stalk population	89	89	107	109	95	93	—	—
Stalk length (m)	2,11	2,11	2,37	2,24	2,10	2,34	—	—
Stalk yield (t/ha)	49	43	34	30	28	29	37	34
DM Yield (t/ha)	14,2	13,3	9,7	10,3	7,4	8,5	10,4	10,7
Sucrose yield (t/ha)	5,1	5,2	3,7	3,5	2,9	3,2	3,9	4,0
Yield per Month:								
Stalk t/ha	9,2	6,7	7,4	5,2	6,0	5,5	—	—
Sucrose t/ha	0,96	0,81	0,80	0,60	0,62	0,60	—	—

Sowing date

Cowley and Smith[5] planted Rio sweet sorghum in the lower Rio Grande Valley from March until August and found that the harvest period lasted from July to December. The highest stalk yields were obtained in crops planted in the middle of this period. The results of the sowing date trial at Dalton, using Roma sorghum, showed that yields declined rapidly as the sowing date was delayed (Table 5). This was due not only to a reduction in the time taken for the crop to mature but also to a lower rate of growth per unit time. Hipp, Cowley, Gerard and Smith[6] showed that the solar radiation received by plants between the boot and early seed formation stages accounted for 75% of the variation in yield. Early sowing in the Midlands will almost certainly result in a better synchronization of the radiation peak and the receptive phase of the sorghum plant than with later sowing.

It is interesting that the 2,3 month delay in sowing resulted in only a two and a half week (11%) reduction in the time to maturity, but caused a drop in sucrose yield of about 40%. This reduction could be attributed to the radiation effect or to temperatures during the ripening phase being lower in late than in early plantings.

The poor germination in this trial of the early maturing Rio variety was unfortunate because a variety × sowing date interaction would probably have occurred. Son[14] in Korea, obtained the highest sugar yields by sowing late cultivars on the 15th April and early cultivars on the 15th May. Other authors report that yields generally decline as the sowing date is delayed (Broadhead[2], Ricaud[10]).

Harvest date

Juice purities and sucrose contents in stalks of sweet sorghum have generally been found to increase rapidly during the grain filling period. Juice quality may improve or deteriorate slowly after the hard-dough stage but will deteriorate rapidly after seed is fully ripe (Broadhead[2], Ricaud[10], Selim *et al*[11]).

The results of sampling in the bulking plots in 1978 and of serial harvesting in the sowing date trial in 1979 showed that sucrose contents and juice purities increased after the hard-dough stage.

In the first and second plantings of the sowing date trial, the increase in the sucrose content of stalks was due mainly to their desiccation. The last crop to be planted still had a considerable amount of green leaf after the first harvest and may have experienced the apparent small net gain in sucrose yield that was evident in the results (Table 5).

The hard-dough stage of the sweet sorghum seed appears to indicate, fairly consistently, the stage at which stalks reach an acceptable quality for milling. Unless stalks are subsequently damaged by pests or become severely lodged they seem to maintain a high juice quality for at least one month after the hard-dough stage. The cool, dry conditions that prevail in the Midlands at this time may permit a longer harvest period than was tested.

The time from planting to maturity in sweet sorghum grown in the Midlands was clearly longer than maturing times recorded elsewhere in the world. At Weslaco, Texas, Rio is expected to mature in 3,5 months and Ramada and Roma in 4,0 months (Sund *et al*[15]).

Son[14] in Korea found the average optimum growing period of early, mid-season and late cultivars of sweet sorghum for sugar production to be 3,9; 4,3 and 4,6 months respectively. The crop at Dalton took 4,6 to 6,0 months to mature and juice quality improved up to 6,4 months after planting. The low maturing rates reflect the sub-optimum climatic conditions for sweet sorghum in the Midlands Mistbelt.

Herbicides

The margin of selectivity of many herbicides used in grain sorghums is rather narrow and varieties differ widely in their sensitivity to these herbicides (Marshall and Nel[7]). The newly bred sweet sorghums seem to exhibit even less tolerance to herbicides than the grain sorghums and the Weslaco researchers have had to develop safe and effective weed control programmes specifically for this crop (Sund *et al*[15]). The chemicals tested at Dalton (Table 6) were essentially the same as those tested by Reeves[9] at Weslaco. Rio sweet sorghum is probably more sensitive to herbicides than Ramada or Roma and it was therefore used at Dalton in the herbicide trial. The sorghum germinated poorly however and it was not possible to make reliable assessments of phytotoxicity. The best control of all weeds was achieved by a pre-emergence application of atrazine at 3 kg ai per hectare. Post-emergence applications of atrazine, bendioxide and bromfenoxim all gave excellent control of broadleaf weeds but they had little effect on grasses. Propachlor sprayed pre-emergence gave acceptable grass control but it was clearly toxic to Rio sorghum. The only chemical that can be used with reasonable safety and effectiveness at present is atrazine applied pre-emergence. Grasses and *Cyperus* species would have to be controlled mechanically until more is known about herbicides for this crop.

TABLE 6

EWRS* rating on the efficacy of herbicides on classes of weeds

Herbicide	Rate of product per hectare	Days after pre-emergence application 21			42		Comments
Pre-emergence		Grass	B/L†	Conv.‡	Grass	B/L	
Igran . . . . . . (50% Terbutryn) . .	2ℓ 4ℓ	6,2 3,5	4,2 2,0	8,5 7,0	8,8 7,8	8,0 5,0	Commelina + Xanthium tolerant
Gesaprim . . . . . (50% Atrazine) . . .	4 kg 6 kg	2,0 1,5	1,2 1,8	1,5 1,2	4,2 3,8	2,0 2,0	
Gesamil . . . . . (50% Propazine) . .	4 kg 8 kg	7,8 4,0	1,5 1,2	2,0 1,2	8,8 5,5	2,0 2,0	Commelina + Xanthium tolerant
Ramrod . . . . . (65% Propachlor) . .	4 kg 6 kg	1,0 1,0	6,0 2,8	8,8 9,0	3,8 2,5	8,0 7,0	Clearly toxic to sorghum
Post-emergence							
Gesaprim	4 kg 6 kg				8,8 8,8	1,2 1,0	
Faneron . . . . . (50% Bromfenoxim) .	1,5 kg 2,5 kg				9,0 9,0	2,8 1,8	
Basagran . . . . . (48% Bendioxide) . .	2ℓ 3ℓ				9,0 9,0	2,2 1,0	

* European Weed Research Society: 1 = full weed control, 4 = just commercially acceptable control, 9 = no control.

† Broad leaf weeds: *Amaranthus* sp., *Xanthium* sp., *Commelina benghalensis*.

‡ *Convolvulus* sp.

Conclusions

Sweet sorghum grown in the Midlands Misbelt is not likely to accumulate sucrose at the high rates that have been recorded in the lower Rio Grande Valley, in Texas. The maximum sucrose yields at Dalton (about 5 t/ha) were lower and the period from planting to harvest (about five months) was longer than for the same varieties grown in Texas. Rates of sucrose accumulation greater than 0,8 t/ha per month obtained from Roma sweet sorghum in the Midlands compare reasonably well with corresponding values obtained in sugarcane. Sweet sorghum could possibly match sugarcane in terms of dry matter accumulation rate, a factor that would be of significance in the production of ethanol. However, the annual sweet sorghum crop would perhaps be best used in droughty soils or frost pockets that are marginal for cane production.

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