THE CULTURE AND YIELD OF SORGHUM FOR FORAGE AND SUGAR IN NORTHLAND

G.J. Piggot and C.A. Farrell
Agricultural Research Division,
Ministry of Agriculture & Fisheries,
Whangarei and Kumeu

ABSTRACT

Sorghum, grown for forage or stalk sugar, was studied in Northland from 1979 to 1983. Trials were conducted on the effect of sowing date, seeding rate, row spacing, harvest regime, weed control, fertiliser requirements and the use of land during winter after sorghum. These results are summarised together with information on adaptation, phenology, disease and pest incidence, soil type effects, yield expectations, stalk juice composition, and farm scale production or sorghum silage.

Additional Key Words: Sorghum bicolor, management, stalk juice

INTRODUCTION

Sorghum and sorghum-sudan grass hybrids have been grown as summer forage for cattle in northern districts of New Zealand for over 70 years (Brown, 1916) and some forage yield evaluations have been documented to support this role (Cottier, 1973; Gerlach and Cottier, 1974; Taylor *et al,* 1974; Chu and Tillman, 1976; Rhodes, 1977). Sorghum was evaluated as a sugar crop last century (London, 1974), and recently for grain production (Gerlach, 1971; Taylor, 1973; Taylor *et al.*, 1974), although neither of these options became commercially successful. Our research programme began in response to the 'energy crisis' of the late 1970s (NZERDC, 1979) investigating sorghum as an ethanol source but latterly has investigated the dual use of sorghum as a source of sweetner and livestock feed (Piggot, 1983). Such a proposal is a specialised development of the "total plant utilisation" concept postulated in the USA (Creelman *et al.*, 1982).

The cultural requirements of sorghum for forage in New Zealand have not been evaluated. The purpose of this paper is to summarise trials which investigated the culture of sorghum for forage or sugar at a range of sites in Northland from 1979 to 1983. Such information will provide a valid basis for recommendations to farmers interested in sorghum as a summer forage or as a silage crop and, allied with yield expectations and stalk juice analyses, will enable a more informed evaluation of the prospects for the proposed sugar-and-forage industry (Piggot, 1983).

MATERIALS AND METHODS

The trials were conducted on 11 sites covering a range of arable soils. The principal sites were at Otakanini (on Yellow brown sand soil), Whangarei (on a volcanic red loam) and at Waimauku (on a Northern yellow brown earth clay soil).

With the exception of a farm-scale evaluation at three sites in 1982-83, all trials were small plot experiments laid out in single factor or multi-factorial randomised block designs. Although the experiments had differing objectives, many features were common namely:

(a) Seedbeds were cultivated out of pasture (except for direct drilling of some weed control trials).
(b) The standard seed-line used was a line of cv. "Sugar Drip" derived from seed harvested during the trial series conducted by Gerlach and Cottier (1974). Other seedlines were purchased as named hybrids (e.g. Sudax SX6, Solene 1, FS 26) or bulked, free from contaminating pollen, from importations direct from USDA.
(c) Seed was sown either by a tractor-mounted grain drill, e.g. Duncan Seedliner, or by a single row Planet Jr. operated by hand.
(d) Fertiliser was applied at sowing by broadcasting 30-50 kg P and K, and 50 kg N/ha as urea was broadcast at 6-10 weeks after sowing.
(e) Sowing date was from mid to late November (except in sowing date trials).
(f) Row widths were 30-45 cm (except in row spacing trials).
(g) Plots were at least 6 rows wide and at least 6 m long.
(h) The seeding rate aimed for was 30 plants/m^2 established (except in seeding rate trials).
(i) Atrazine (2.5 kg ai/ha) was applied pre-emergence and repeated where necessary, and no hand weeding was conducted.
(j) No insecticide was used at sowing or during crop growth.
(k) Crop sampling for yield determinations involved hand cutting to 10 cm stubble height of 1-2 m^2 quadrats depending on row width. Stalk measurements were taken after hand-stripping of leaves and excision of the seedhead.
(l) The refractable dissolved solids percent in juice from hand-squeezed stalks was measured from freshly sampled

crop by hand refractometer. Larger juice samples for analysis were collected from freshly harvested hand-stripped stalks milled through a small, three-roller mill in the field and were received in the laboratory within three hours. The methods by which juice composition was analysed is available on request. Dry matter (DM) percent analysis was conducted immediately following sampling.

Comparing each season of the trial work with the climatic 'normal', the 1980-81 and 1981-82 seasons were near average except for higher daily minimum temperatures from January to March 1981 and low rainfall in December 1981 and January 1982. In 1982-83, the rainfall was well below average throughout the summer and sunshine hours were relatively low from February to May.

RESULTS AND DISCUSSION

Adaptation and Phenology

Northland has a moist and warm climate, frost free November to May and suited to warm zone species such as sorghum. Sugar (or sweet) and forage sorghums were used in this research, chosen principally on availability rather than proven adaptation. Of the three lines tested most widely, soft dough stage (Freeman *et al.*, 1973) was normally reached in early April for Sugar Drip (at 140 days from planting), with FS 26 reaching this stage 2 weeks earlier and Ramada 1 month earlier than FS 26. Such maturity rankings influence grazing dates and silage harvesting. More detailed observations of maturity rankings of US-bred sugar sorghums are needed but preliminary observations suggest that early maturing Ramada and late maturing Wray span a range for achievement of soft dough stage from early March to late May. Lack of grain set as observed in the Waikato (Taylor, 1973) did not occur, although bird damage to the seedhead often interfered with the definitive observation of grain maturity stages after the milky to soft dough stage.

Sowing Date

Although early summer has been the recommended sowing period (Brown, 1916), earlier sowing would be expected to result in higher yields during late summer when the forage is needed most on pastoral farms. Sowing date trials were conducted at three sites in consecutive years (Table 1) using Sudax in 1980-81 and Sugar Drip in 1981-82 at a range of seeding rates. In 1980-81 the late sowing established fewer plants, while the reverse occurred in 1981-82. Any significant plant establishment effects tended to follow through in subsequent tiller counts. At all sites in both years, the December-sown crops yielded significantly less DM in February. By the April harvest, yield was little affected by sowing date, and there was only a small effect of sowing date on regrowth, in May, of February-harvested plots. In 1981-82, there was little advantage to the earliest (late October) sowing; germination and early growth of these plots was slow presumably indicating a temperature inhibition of growth similar to early-sown soybeans (Piggot *et al.*, 1980). Also, additional weed control was required on October-sown plots.

Seeding rate

High seeding rates (>25 kg/ha) are normally recommended for forage sorghum cropping making seed cost a major factor. Seeding rate comparisons were made within the sowing date trials using a factorial treatment design. Seeding rate clearly influenced plant and tiller numbers (Table 2) and, to a lesser degree, DM yields for both sorghum types, particularly Sugar Drip. Seeding rate interactions with sowing dates occurred only with plant or tiller counts and were caused by plant establishment at lower seedling rate being more seriously impaired at unfavourable sowing dates. There appears to be little justification for using high seeding rates, and such rates probably only serve to reduce the detrimental effects on DM yield of poor management, such as sowing too late or not using residual herbicides.

TABLE 1: The effect of sowing date (at varying seeding rates) on the plant tiller population (per m^2) and crop DM (t/ha) averaged over 3 sites in 1980-81 and 1981-82.

		Sowing Date			
		late Oct.	mid Nov.	early Dec.	LSD 5%
1981 (cv. Sudax SX6)					
Jan.	Plants		36	28	5
Feb.	Tillers		67	57	9
	DM yield		14.6	11.4	1.1
Apr.	Tillers		60	53	7
	DM yield		20.3	18.7	1.4
Regrowth	Tillers		82	71	6
(Feb-May)	DM yield		8.7	7.7	0.7
1981-82 (cv. Sugar Drip)					
Jan.	Plants	38	38	46	7
Feb.	Tillers	52	54	59	10
	DM yield	12.3	11.2	8.2	1.5
Apr.	Tillers	40	41	48	8
	DM yield	19.1	19.0	19.7	2.1
Regrowth	[1]Tillers	70	63	82	12
(Feb-May)	DM yield	9.1	8.2	10.1	1.2

[1]Two sites only.

TABLE 2: The effect of seeding rates (at sowing dates of Table 1) on plant and tiller population (/m^2) and crop (t/ha) averaged over 3 sites in 1980-81 and 1981-82.

		1980-81 (Sudax)		1981-82 (Sugar Drip)	
Sowing rate (kg/ha)		12	32	12	25
Jan.	Plants	17	49 ***	32	49***
Feb.	Tillers	46	86 ***	47	63 ***
	DM yield	12.7	14.1 *	10.1	10.9 NS
Apr.	Tillers	41	76 ***	34	52 ***
	DM yield	18.7	19.8 NS	18.2	20.3 *
Regrowth	Tillers	63	96 ***	66	77*
(Feb-May)	DM yield	7.8	8.7 NS	9.2	9.0 NS

TABLE 3: Row spacing effects in 1981-82 meaned over 2 sites.

Row spacing (cm)	Seeding rate (kg/ha)	January Plants (/m²)	April Tillers (/m²)	April DM yield (t/ha)
25	15	38	44	22.4
50	7	29	36	20.4
50	15	33	31	18.0
	L.S.D 5%	9	5	3.9

Row spacing

Forage sorghum is normally sown in 30 cm rows with a standard grain drill but, by blocking off coulters, row spacing can be chosen in multiples of 15 cm. In a trial which investigated row spacing effects in Sugar Drip at two sites (Table 3), there was no advantage in DM yield to wider row spacing.

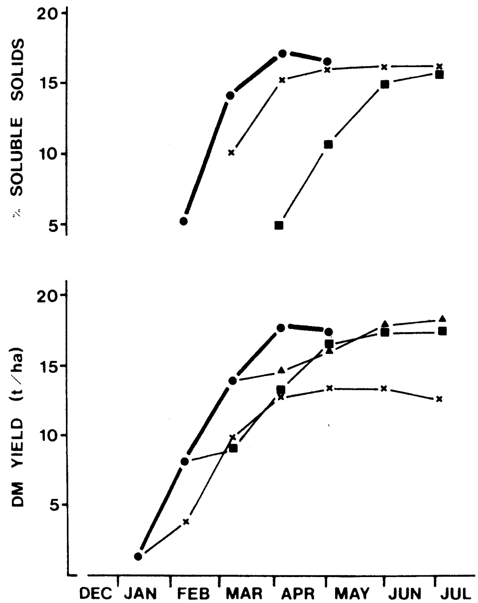

Figure 1: The growth curve of sorghum sown on 24 November 1982 at Otakanini (mean of Ramada and FS 26), and % soluble solids in stalk juice (of Ramada); and the regrowth following cutting in January (x), February (▲) and March (■).

Harvest regime

Since the summer feed crisis on pastoral farms usually occurs in late summer, it was of interest to determine the impact of an early cut to provide livestock feed followed by the later harvesting of regrowth. In one trial, FS 26 and Ramada were cut monthly and the regrowth was monitored. Both cultivars had a similar growth pattern and the mean DM curve of both cultivars is presented in Fig. 1 (SE values were 1 t DM/ha or less at each cutting date; and % soluble solids for Ramada only are from samples bulked over treatments). The regrowth from a January cutting provided a similar progress to maturity to the uncut crop for a markedly reduced total DM yield, while the regrowth from the March cutting was relatively low and was more severely damaged by late June frost than the other regrowths. The regrowth from February cutting matured much later, reached similar % soluble solids later than the uncut crop, and produced a similar total DM yield. This result indicates that sorghum could provide farmers with the option of maximising forage (and sugar yield) by harvesting the crop in April or they can harvest for forage in February and still obtain a silage (or sugar) harvest in late June yielding up to 2/3 of the single harvested regime.

Other cultural aspects

Fertiliser Recommendations on fertilizer are assumed to be similar to those for maize (e.g. Steele, 1982), i.e. starter nitrogen and phosphorus with additional (side-dressed) nitrogen only to land with second or subsequent crops. Two fertilizer trials were conducted in 1980-81 and both supported this assumption on fertiliser requirements. In one trial cultivated out of permanent pasture, rates of side-dressing (of urea) from 0-200 kg N/ha gave no response on Sudax sown in early December and yielding 12.7 t DM/ha by mid February. In the other trial, a small response to the application of starter fertiliser (3.6 to 4.0 t DM/ha) and a strong response to side-dressed nitrogen (2.8 to 4.8 t DM/ha occurred in a third year Sudax crop sown in late November and sampled prior to grazing in late January.

Weed control While forage sorghums are normally sown by farmers following minimal cultivation, short fallows, and without chemical weed control, herbicide screening trials (Piggot, 1982) do not support such practises. Long fallows (up to 6 weeks) and residual herbicides such as atrazine can dramatically improve crop yield. However the present residual herbicide recommendations (Piggot, 1982) are only tentative and require further study.

Pests and disease Apart from aphids, no insects seriously infested the trial crops. Bird predation of seedheads developed into a serious problem in the second and subsequent crops at each site and this may be of importance when cropping sorghum for silage. Only one serious disease outbreak of anthracnose and red rot caused by the fungus *Colletotrichum graminicolum* occurred on a second year crop. The cultivar Sugar Drip is known to be susceptible (Freeman *et al.,* 1973) and the disease may not be significant in the newer, less susceptible, cultivars of sweet sorghum which should form the basis of future sugar or forage production.

Winter land use

Following the autumn cutting or grazing of sorghum, farmers have the option of regrassing or growing a winter forage crop. Three winter forage trials were conducted to evaluate alternative forage options (Table 4). From a comparison of 7 forages at a poorly drained alluvial clay site (Table 4a), the highest yielding species was fodder radish followed by oats and Tama ryegrass, while lupin was poorest. However, the lupin yield on well-drained soils (Table 4b) was outstanding and outyielded subterranean clover by 4 times on average. In a comparison of perennial (Ellet), biennial (Moata, Te Puna), and annual (Tama) ryegrasses, there were significant treatment differences in total plot yield but the yield of the sown ryegrasses did not differ significantly (Table 4c). These results suggest that winter forages can be chosen which are not graminaceous and thus prone to encourage the carryover of pests and disease (i.e. fodder radish on wetter soils, lupins on well-drained soils).

TABLE 4: Yields of winter forages in 3 trial series in Northland.

(a) Yield (t DM/ha) for forages direct drilled on 20 April 1979 and cut on 10 October 1979.

Fodder radish cv. Neris	5.3
Oats cv. Florida	4.1
Ryegrass cv. Grasslands Tama	3.6
Ryecorn cv. Rahu	2.2
Subterranean clover cv. Woogenellup	1.6
Wairoa brassica	1.6
Lupins cv. Uniwhite	1.2
S.E.	1.3

(b) Comparison of subterranean clover cv. Woogenellup and lupins cv. Uniharvest at 3 cultivated sites sown about 25 April 1981 and cut about 1 November 1981.

		DM (t/ha)
Sub. clover	Utak.	3.1
	Ruakaka	4.1
	Keri Keri	1.4
Lupins	Utak.	16.2
	Ruakaka	11.7
	Keri Keri	11.1
	C.V.	30%

(c) Comparison of ryegrass sown into cultivated ground 24 April 1983 and sampled by 5 cuts from cages shifted and pre-trimmed after each cut to 10 November 1983.

	DM yield (t/ha)	
	Total	Ryegrass
Ellett	6.6	4.9
Grasslands Moata	6.7	5.3
Grasslands Tama	6.2	5.2
Te Puna	7.1	5.2
M.S.D.	0.9	0.7

Yield and stalk juice composition

For well managed crops, estimated expectations of DM yield are provided in Table 5 for arbitrarily grouped soils used in this work. In recognition of the limited numbers of sites and seasons sampled in this work, such figures should only be used as a guide.

Raw juice extracted from sweet sorghum stalks is potentially a source of sweetner. Relevant yield data of plant components was collected annually at Otakanini and typical results are presented in Table 6 together with an analysis of the juice constituents. The juice extraction rate of 25% achieved by the field sampling mill provided a lower sugar yield than a factory extraction which uses multiple milling plus washing to maximise sugar extraction.

TABLE 5: Expectations of DM yield from sweet sorghum cv. Sugar Drip crops grown under good management on 3 groups of soils.

	Yield expectation tDM/ha	Seasonal range
Deep loams and well drained fertile clays	25	20-30
Dry friable soils	20	13-25
Poorly drained clays	15	12-18

Farm-scale trials

As a check on recommendations derived from the small plot experiments, 1 ha paddocks were sown by three farmers in 1982-83 on a dairy farm integrated with a maize silage operation, an intensive sheep farm, and on a dry land dairy farm. All sites were sprayed with paraquat prior to the farmer's cultivation. On the dry land dairy farm site, the paraquat was sprayed only within one week of cultivation and onto long pasture, and the resulting loose surface turf severely interfered with drilling and encouraged weed establishment. At the other sites, the seedbeds were in excellent condition at seeding. Drilling occurred about 23 November using FS 26 sown with 350 kg serpentine superphosphate/ha. Only at the sheep farm was post-emergence atrazine used. On 24 March 1983, prior to silage harvest, DM yields were 24.3, 15.1 and 5.8 t DM/ha at the three sites. The yield at the dry land dairy farm was far

TABLE 6: Crop composition parameters of cv. Ramada in late April 1983 at Otakanini (Extraction and juice yield in brackets refers to hypothetical factory-scale extraction results).

Crop dry matter (t/ha)	20	
Crop green yield (t/ha)	72	
Stripped stalk (t/ha)	52	
Juice extraction (% juice/stripped stalk)	25	(75)
Raw juice yield (t/ha)	13	
Saccharides (t/ha)	1.4	(4.0)

Composition of raw juice	g/100g	%
Sucrose	8.12	62.0
Dextrose	0.98	7.5
Fructose	0.20	1.5
Other saccharides	1.18	9.0
Soluble protein	0.98	7.5
Soluble ash	0.76	5.8
Suspended solids	0.88	6.7
	13.1	100

below expectation and the primary reasons were probably poor seedbed preparation and lack of weed control. The crops were most successfully harvested for silage when cut by disc mower, crimped and picked up in windrows by a fine chop forage harvester. The silage was made and stored in bunkers covered in plastic film. The resulting silage appeared satisfactory but was not favoured by untrained cows when compared with maize silage in the following winter. Likewise, untrained sheep did not accept the silage enthusiastically when it was fed as a supplement to a restricted pasture diet in February and March (prior to tupping) of the following year. However, fresh sorghum fed to a separate group of sheep run on the same pasture was consumed with little wastage. This preliminary monitoring places some doubt on the prospects of using sorghum silage as an occasional supplement to pasture feeding (Piggot, 1983). More research is needed before animal feeding regimes for sorghum silage on pastoral farms in Northland could be confidently recommended.

CONCLUSION

Sorghum, while well adapted as a forage species to Northland, will develop and yield variably depending on the cultivar or hybrid chosen, the soil type and the season. Crop management can strongly influence growth and development. The key requirements are probably the correct sowing date (generally about mid November) and a weed-free seedbed accomplished either by sowing into well-fallowed land or by using residual herbicides. Since the crop has notable regrowth characteristics, flexible harvesting or grazing regimes can be devised to provide multiple harvests. Sorghum can also be integrated with plans for regrassing in autumn or for growing of winter forage crops. Based on crop yield data, regimes involving sugar or silage production appear promising but have yet to be commercially proven.

ACKNOWLEDGEMENTS

H.M. Morgan and S.B. Barclay provided valuable field assistance, while the owners of the sites are thanked for their interest and cooperation. New Zealand Starch Products Ltd technical staff are also thanked for their assistance with juice analysis.

REFERENCES

Brown, J. 1916. Summer forage crops for northern districts. *N.Z. Journal of Agriculture 8:* 200-204.

Cottier, K. 1973. Experiments with warm-zone crops for summer green feed in Waikato. *Proceedings Agronomy Society of N.Z. 3:* 25-31.

Chu, A.C.P., Tillman, R.F. 1976. Growth of a forage sorghum hybrid under two soil moisture regimes in the Manawatu. *N.Z. Journal of Experimental Agriculture 4:* 351-355.

Creelman, R.A., Rooney, L.W., Miller, F.R. 1982. Sorghum. *In* "Cereals. A Renewable Resource. Theory and Practice". Eds. Y. Pomoranz and L. Munck. American Association of Cereal Chemists. St Paul, Minnesota. pp. 395-426.

Freeman, K.C., Broadhead, D.M., Zummo, N. 1973. Culture of sweet sorghum for syrup production. Agricultural Handbook No. 411. Agricultural Research Service, U.S. Department of Agriculture. 30p.

Gerlach, J.C. 1971. Sorghums. *In* "Research in the New Zealand Department of Agriculture". Annual Report of Research Division 1970-71. p 126.

Gerlach, J.C., Cottier, K. 1974. The use of sorghums as forage crops. *Proceedings Agronomy Society of N.Z. 4:* 83-85.

London, H.D. 1974. A sugar industry of Opotiki, 1882. *Historical Review,* Whakatane and Districts Historical Society. *20(2):* 81-110.

N.Z.E.R.D.C. 1979. The potential of energy farming for transport fuels in New Zealand. Report No. 46. N.Z. Energy Research and Development Committee.

Piggot, G.J. 1982. Weed control for sorghum with minimum tillage. *Proceedings 35th N.Z. Weed and Pest Control Conference:* 219-221.

Piggot, G.J. 1983. Integrating livestock and sugar-ethanol production and the dairy industry in Northland - a concept. *Proceedings N.Z. Society of Animal Production 43:* 107-109.

Piggot, G.J., Farrell, C.A., Honore, E.N. 1980. Soybean production in Northland. *Proceedings Agronomy Society of N.Z. 10:* 39-41.

Rhodes, P.J. 1977. Summer and early autumn forage yields of maize, sorghums and millets in Nelson and Marlborough. *Proceedings Agronomy Society of N.Z. 7:* 31-35.

Steele, K.W. 1982. Maize. *In* "Fertiliser and Lime Recommendations For Pastures and Crops in New Zealand". Eds. I.S. Cornforth, A.G. Sinclair, Ministry of Agriculture and Fisheries, Wellington. pp. 28-29.

Taylor, A.O. 1973. An environmental problem with grain sorghums. *Proceedings Agronomy Society of N.Z. 3:* 74-78.

Taylor, A.O., Rowley, J.A. Esson, M.J., Eastin, J.D., Wallace, R. 1974. Sorghums for conserved feed in Northland. *Proceedings Agronomy Society of N.Z. 4:* 74-78.