CHAPTER 8

EFFECT OF NITROGEN AND SPACING ON STEM YIELD AND JUICE QUALITY OF TWO SWEET SORGHUM LANDRACES

8.1 ABSTRACT

Main effects of nitrogen, landrace and spacing were studied at the Experimental Farm of the University of Pretoria during the 1998/99 growing season. The nitrogen rates adopted were 0 kg N ha^{-1}, 60 kg N ha^{-1} (applied early in the growing season), 60 kg N ha^{-1} (applied at boot stage) and 120 kg N ha^{-1} (applied early in the growing season). Intra-row spacings were 15 cm and 30 cm for both the early maturing (D) and late maturing (A11) landraces. Stem yields of the three nitrogen treatments were significantly higher than the yields of the unfertilized control. Similarly, sucrose content of the three nitrogen treatments were much higher than that of the zero nitrogen treatment. The wider intra-row spacing (30 cm) resulted in a significant increase in stem yield and sucrose content, compared to the closer intra-row spacing (15 cm). The late maturing landrace produced higher stem yields and sucrose content than the early maturing landrace. The best treatment combination (nitrogen x landrace x spacing interactions) for high stem yields per hectare with the late maturing landrace was 15 cm intra-row spacing with 120 kg N ha_{-1}; for the early maturing landrace it was at 15 cm intra-row spacing with 60 kg N ha_{-1}. It is concluded that nitrogen increases stem yields and sucrose content in sweet sorghum. Wider intra-row spacing (30 cm) increased both stem yields and sucrose content.

8.2 INTRODUCTION

No applicable information is available regarding the fertilization and spacing requirements of sweet sorghum as a cash crop for small scale farmers. In Botswana sweet sorghum is typically grown in mixtures with other crops and it's rarely planted in rows. This results in areas of high and low populations in the same field and thinning is rarely done in the densely populated areas. Most farmers do not fertilize their crops due to environmental unpredictability, traditional preferences and financial constraints. Specifically, farmers in Botswana do not fertilize the sweet sorghum crops because they believe that kraal manure and fertilizers reduce the sweetness of the juice.

Generally sweet sorghum responds well to fertilizers, especially nitrogen. However, it is critical that the amount of nitrogen applied does not lower the quality of the juice, as reported with sugarcane (Ojha, Singh & Ahmad, 1973). Results obtained from studies conducted to evaluate the effect of nitrogen fertilizer on the stem, syrup and juice yield in sweet sorghum are inconclusive as to how much N will give the highest yields. According to Broadhead, Freeman, Coleman & Zummo (1974) stalk and syrup yields increased with up to 90 kg N ha^{-1} fertilizer in Mississippi. Jordan-Karim (1979) also in Mississippi, reported significant dry matter and sugar yield responses with N fertilization up to 112 to 168 kg N ha^{-1}. Similarly, Jackson & Arthur (1980) reported yield responses with up to 112 kg N ha^{-1} in soils of Ohio. Ferraris (1988) reported that total yield of stem sugars increased with nitrogen to moderately high levels. Bennett (1982) compared the effectiveness of a legume cover crop and N fertilizer on several sweet sorghum cultivars. The results indicated that above ground biomass and juice sugar yield in a syrup cultivar of sweet sorghum were significantly higher with 168 kg N ha^{-1} fertilizer than with 84 kg N ha^{-1} fertilizer. A two year Alabama study on the effect of lime and fertilizer showed a significant increase in biomass, sugar content and juice extracted from stalks due to liming. In non limed soils, biomass and sugar yields decreased with high N where the P and K content of soils were low, but not with high P and K levels in the soil (Soileau & Bradford, 1985). Galani, Lomte & Choundhary (1991) reported an increase in juice yield and no response in juice brix in an experiment with increasing N rates (0, 40, 80 and 120 kg N ha^{-1}). Cowley & Smith (1972) did not find any correlation between nitrogen levels and sucrose content and purity. Detrimental effects on juice quality regarding timing of nitrogen application has been reported. For syrup production (and probably sugar production) late application of fertilizer, especially nitrogen, should be avoided as this interferes with juice quality (Freeman, Broadhead & Zummo, 1973). Recently, Utzurum, Fukai & Foale (1998) reported a longer growing period and increased biomass accumulation in grain sorghum as a result of late nitrogen application. This effect also might be applicable to sweet sorghum as a dryland crop of the semi-arid tropics.

The results obtained from the experiment at the University of Pretoria on plant density showed that high plant density (20 cm spacing) produced the best yields on a unit area basis (see Chapter 7). These results suggested that 20 cm intra row spacing may be recommended for sweet sorghum. In Botswana the spacing recommended for maize and grain sorghum is 30 cm between plants and 90 cm between rows. For quick adoption of spacing recommendations in sweet sorghum, recommending the same spacing as for the other crops would be advisable. Hence farmers could use the same planting equipment. The objective of this trial was to investigate the effect of nitrogen, and intra-row spacing (plant population) on the yield and juice quality of two sweet sorghum landraces.

8.3 MATERIALS AND METHODS

The experiment was conducted on the Experimental Farm of the University of Pretoria, during the 1998 / 1999 growing season. Sweet sorghum seeds were planted on sandy clay loam soil of the Hutton form. The soil was cultivated and disced to fine tilth before planting. The experimental design was a split-plot with four nitrogen levels randomly allocated to the main plots, two landraces allocated to subplots and two spacing treatments to sub-sub-plots. There were four replications. The main plot size was 25.6 m long by 8 m wide and the subplot size was 6.4 m by 4 m and sub-subplots were 3.2 m by 4 m each. Seeds were planted in rows of 90 cm and no base fertilizer was applied. Plants were thinned thirty days after emergence to the required intra row spacing. Plots were irrigated to maintain growth whenever there were dry spells. Weeds were controlled by a pre-emergence application of atrazine at a rate of 3 kg active ingredient per hectare and hand weeding was done as necessary. There were no serious disease problems but aphids were a problem and were sprayed with an aphicide.

Nitrogen treatments:

N0 = control (0 N kg N ha^{-1})

N1 = 60 kg N ha^{-1} (early)

N2 = 120 kg N ha^{-1} (early)

N3 = 60 kg N ha^{-1} (late)

In treatments N1 and N2 nitrogen was applied 40 days after emergence and in treatment N3 it was applied at boot stage.

Spacing treatments :

S1 = 15 cm intra-row spacing

S2 = 30 cm intra-row spacing

Landraces :

L1 = early maturing landrace (D according to Chapter 3 codes)

L2 = late maturing landrace (A11 according to Chapter 3 codes)

Plants were serially harvested at two week intervals, from 40 to 96 days after emergence.

At each harvest three plants were cut at the base and combined into one sample. The plants were measured for height, number of leaves, leaf area and number of tillers. To determine dry mass the leaves and stems were oven dried at 70°C to a constant mass. During the final harvest at 96 days after emergence an additional sample of 20 stalks was harvested per plot and sent to the South African Sugar Association (SASA) for standard juice analysis. The juice was tested for soluble solids content (brix), sucrose content (pol), juice purity and fibre according to standard sugar cane technology methods. Samples awaiting transport were stored in a cool room at a temperature of 5°C to minimize conversion of sucrose to glucose.

Data was analysed by the conventional analyses of variance and the significant differences between the means were determined by Tukey's Multiple Range Test (Steel & Torrie, 1985).

8.4 RESULTS AND DISCUSSION

The main effects of nitrogen, spacing and landrace on the stem yield and juice quality of sweet sorghum are presented in Table 8.1 and the significant nitrogen x landrace x spacing interactions in Table 8.2. Significant first order interactions are summarised in Tables A8.2 - A8.6 in the appendix, but not discussed. In the presentation of the results the emphasis is on stem yield and juice quality. Data on the number of leaves, leaf area, leaf dry mass and main stem height are presented in Table A8.1 in the appendix and are not discussed in the text.

Stem yields

The N1 treatment (60 kg N ha^{-1} applied early resulted in higher stem yields than the unfertilized control (N0), with no differences between the other three nitrogen treatments (Table 8.1). These results are consistent with the findings of Broadhead *et al,* 1963; Jordan-Karim (1979) and Jackson & Arthur (1980) who reported increased stem dry mass with increasing nitrogen. In this trial it was observed that plants that received nitrogen at boot stage remained greener and maintained their leaves for a longer period than plants that received nitrogen earlier. Urtzurrum *et al,* (1998) reported similar observations of later senenscense in grain sorghum plants fertilized at flag leaf stage than those which received nitrogen early. In the production of sweet sorghum for stem sales, this effect of late nitrogen application may be valuable because there is better demand for tall green stems in the market. Stem fibre percentage followed the same trend as stem yields in reaction to the nitrogen treatments, with higher fibre content associated with higher stem yields.

The intra-row spacing significantly affected yields per plant, with much higher dry stem yields (481g per plant) obtained from the 30 cm intra-row spacing than with the 15 cm intra-row spacing (289 g per plant). The higher yield in the wider spacing is the result of more tillers (2.9 tillers per plant) than in the closer intra-row spacing which had only 1.6 tillers per plant. Under conditions of 37,000 (S2) and 74,000 (S1) plants per hectare, respectively, this is equivalent to yields of 17.8 and 21.3 t ha^{-1} dry stems (74 and 88 t ha^{-1} fresh stems). These results indicate that the higher yield per plant at the wider spacing did not compensate enough for the fewer number of plants.

TABLE 8.1 The effect of nitrogen, spacing and landrace on stem fresh mass, stem dry mass, number of tillers, stalk fibre, pol percent, brix value and juice purity

Treatments	Stem fresh mass per plant (g)	Stem dry mass per plant (g)	Number of tillers per plant	Stem fibre (%)	Pol (%)	Brix (%)	Purity (%)
Nitrogen							
N0	1435.7 b	345.1 b	2.1a	9.2 b	5.2 c	13.8 a	37.8 b
N1	1752.8 a	429.1 a	2.5a	10.4 a	6.8 a	14.4 a	47.2 a
N2	1611.3 ab	371.5 ab	2.1a	9.8 ab	6.1 b	14.0 a	42.0 b
N3	1533.8 ab	395.8 ab	2.4 a	10.4 a	6.8 a	14.0 a	47.6 a
LSDt (p=0.05)	305.9	69.0	NS	0.8	0.7	NS	5.2
Spacing							
S1	1168.3 b	289.5 b	1.6 b	9.7 a	5.8 b	13.8 b	40.2 b
S2	1998.5 a	481.3 a	2.9 a	10.6 a	6.7 a	14.4 a	47.2 a
LSDt (p=0.05)	163.3	36.95	0.31	0.5	0.35	0.38	2.79
Landraces							
L1	1323.1 b	334.5 b	2.3 a	9.2 b	5.6 b	14.5 a	38.0 b
L2	1843.7 a	423.3 a	2.3 a	10.6 a	6.9 a	13.6 b	49.3 a
LSDt (p=0.05)	163.3	36.9	NS	0.83	0.7	0.7	5.2
C.V. (%)	20.5	19.0	26.9	8.9	11.3	5.3	12.7

+ Means followed by different letters are significantly different at the 5% level by Tukey's Multiple Range Test. Pol % = sucrose as measured by a polarimeter ; Brix = soluble solids ; Purity = a percentage ratio of pol and brix; fibre = non solubles after washing with water for one hour as % of stem. Treatments; N0 = 0 kg N ha^{-1}) N1 = 60 kg N ha^{-1} (early application), N2 =120 kg N ha^{-1} (early application), N3 = 60 kg N ha^{-1} (late application), S1 = 15 cm intra-row spacing, S2 = 30 cm intra -row spacing L1=early maturing landrace,
L2 = late maturing landrace

There were no significant differences between intra-row spacing in stem fibre content, but the wider intra-row spacing had a tendency of producing higher stalk fibre (10.6%) than the closer intra-row spacing (9.2%).

The late maturing landrace (L2) yielded significantly more than the early landrace (L1) despite the fact that they both produced an average of 2.3 tillers (Table 8.1). Stems of the late landrace were taller than those of the early landrace. Ferraris (1981a) reported that late maturing cultivars of sweet sorghum tend to have tall and thick stems compared to early maturing types. The large stem yields in the late maturing landrace is attributed to a longer growing period which resulted in plants producing more vegetative material than the early maturing landrace.

The nitrogen fertilizer x landrace x spacing interaction was significant for stem yield as shown in Table 8.2. The late maturing landrace (L2) at 30 cm intra-row spacing (S2) consistently produced the highest stem yields per plant at the different nitrogen treatments. The highest yield of (672 g per plant) was obtained with 60 kg N ha^{-1} applied early in the growing season (N1L2S2). On a unit area basis the late maturing landrace produced the highest stem yield per hectare (27 t ha^{-1}) at 15 cm intra-row spacing with 120 kg N ha^{-1} (N2L2S1). The lowest stem yield (257 g per plant and 19.0 t ha^{-1}) was observed with the unfertilized control at 15 cm intra-row spacing (N0L2S1).

In the early maturing landrace (L1) the highest stem yield per plant (455 g) was obtained at 30 cm intra-row spacing with 60 kg N ha^{-1} applied early in the growing season (N1L1S2) and the highest stem yield per hectare (19.8 t ha^{-1}) was obtained at 15 cm intra -row spacing with 60 kg N ha^{-1} applied early (N1L1S1). The lowest stem yield per plant (216 g) was observed at 15 cm intra-row spacing with 120 kg N ha^{-1} (N2L1S1) and lowest stem yield per hectare of (13.1 t ha^{-1}) was observed at 30 cm intra-row spacing with unfertilized control (N0L1S2).

TABLE 8.2 Interaction between nitrogen x landrace × spacing on stem fresh and dry mass, yield per unit area and pol%

Treatments			Attributes			
Nitrogen	Landraces	Spacing	Stem fresh mass per plant (g)	Stem dry mass per plant (g)	Stem dry mass tons per ha-	Pol %
N0	L1	S1	955	256	18.9	4.24
N0	L1	S2	1397	354	13.1	6.50
N1	L1	S1	1049	268	19.8	5.73
N1	L1	S2	1701	455	16.8	7.02
N1	L2	S1	1309	323	23.9	6.69
N1	L2	S2	2953	672	24.9	7.77
N2	L1	S1	800	216	16.0	5.77
N2	L1	S2	1900	449	16.6	6.10
N2	L2	S1	1600	373	27.6	7.02
N2	L2	S2	2147	546	20.2	8.25
N3	L1	S1	1005	265	19.6	4.20
N3	L1	S2	1778	414	15.3	5.16
N3	L2	S1	1548	359	26.6	6.90
N3	L2	S2	1804	448	16.6	8.08
			**	**	**	**

** significant at P = 0.01
Pol % = sucrose as measured by a polarimeter; Treatments: N0 =0 kg ha_N, N1 = 60 kg ha_N (early application), N2 =120 kg ha_N (early application), N3 = 60 kg ha_N (late application), S1 = 15 cm intra-row spacing, S2 = 30 cm intra -row spacing; L1 = early maturing landrace, L2 = late maturing landrace

Juice Quality

The juice characteristics (pol, brix and purity percentages) are presented in Table 8.1 for the main effect treatments and in Table 8.2 for the individual treatment combinations. The three nitrogen fertilizer treatments (N1, N2 and N3) resulted in higher pol percentages than the unfertilized treatment. The brix value is an indication of the percentage soluble solutes in the juice. No differences in the brix value occurred as a result of the nitrogen treatments. The effect of the nitrogen treatments on juice purity followed the same pattern as in pol percentage. These results indicate that sucrose content and juice purity were increased by nitrogen fertilizer and with the best effect obtained with the 60 kg N ha^{-1} applied early in the growing season. This is consistent with the findings of Galani *et al*, (1991) who reported an increase in juice yield but no response in juice brix value with increase in nitrogen fertilisation. The effects of late nitrogen application (60 kg N ha^{-1}) on juice quality was similar to that of the 60 kg N ha^{-1} applied early in the growing season, with the juice quality better than that of the unfertilized treatment. This contradicts the findings of Freeman, *et al*, *(*1973) who reported that late application of fertilizers, especially nitrogen, has a negative effect on juice quality. These results suggest that it may be possible for sweet sorghum growers to increase the sucrose content by applying nitrogen even at late development stages rather than not at all.

Wider intra-row spacing (30 cm intra-row spacing) produced much higher pol, brix and juice purity values than the closer intra-row spacing. These results contradict the findings of Broadhead *et al*, (1963) who reported that spacing did not affect sucrose, brix and juice purity values. However, the results are in agreement with McBee & Miller (1982) and Ferraris & Charles-Edwards (1986b) who reported some increase of the concentrated soluble sugars with lower populations. However, in Chapter 7 spacing did not have any significant effect on juice quality but there was a tendency for stems from the 60 cm spacing to be higher in sucrose content, purity and brix value compared to the other spacing treatments. From the results of the two experiments, it can be inferred that wider intra-row spacing may contribute towards better juice quality. The late maturing landrace(L2) had better juice quality characteristics than the early maturing landrace (L1) as shown in Table 8.1. Ferraris (1981a) reported similar results of high solubles and sugar yields for late maturing, tall and thick-stemmed cultivars compared to early maturing cultivars. The early maturing landrace had the highest percentage of soluble solutes (brix).

The nitrogen fertilization x landrace x spacing interactions were only significant for pol percentage (Table 8.2). Both early and late maturing landraces produced the highest pol percentage at 30 cm intra-row spacing in all the nitrogen treatments. For the late maturing landrace the highest pol percentage of 8.25was observed at 30 cm intra-row spacing with the 120 kg N ha^{-1} treatment (N2L2S2), while the highest pol percentage of 7.02 in the early maturing landrace was observed at 30 cm intra-row spacing with 60 kg N ha^{-1} (N1L1S2).

Generally the results obtained from this experiment suggest that the 60 kg N ha^{-1}, whether applied early or late, increased stem yields per plant, juice purity and pol percentage (sucrose) more than the 120 kg N ha^{-1} treatment. Based on these results the rate of 60 kg N ha^{-1} can be recommended for sweet sorghum production in pure stands. However, for small scale farmers in Botswana fertilization with readily available organic manures (kraal, poultry) may be preferred and therefore needs investigation.

The late maturing landrace (L2) had higher stem yields and better juice quality characteristics than the early maturing landrace (L1), but the early maturing landrace was higher in brix value. Both early and late maturing landraces produced the highest pol % at wider spacing in all nitrogen treatments.