CHAPTER 7

EFFECT OF PLANTING DATE AND SPACING ON STEM YIELD AND SUCROSE CONCENTRATION OF SWEET SORGHUM

7.1 ABSTRACT

The effects of planting date and spacing were studied at the Experimental Farm of the University of Pretoria during the 1996/97 growing season. Sweet sorghum seed were sown on 18 October, 18 November and 17 December at 60 cm, 40 cm and 20 cm intra-row spacings. Main stem height and thickness, stem fresh and dry mass, brix value, pol percentage and juice purity were determined. The October planting resulted in higher stem yields, more tillers and taller main stems than the November and December plantings. Brix value was not affected by planting date. The December planting had the highest pol percentage and juice purity. The 60 cm intra row spacing produced the highest stem yield per plant but stem yield per unit area was higher at 20 cm intra row spacing. Spacing did not affect main stem height, but the 20 cm intra row spacing produced thinner main stems. Similarly, spacing did not have any effect on pol percentage, juice purity, brix value and stalk fibre content. These results indicate that early planting increases stem yields but reduces juice quality. Spacing did not affect juice quality. Wider intra row spacing increased stem yield per plant but reduced stem yield per unit land area.

7.2 INTRODUCTION

In Botswana early planting is recommended because most farmers use late maturing varieties. However, planting as early as October or November is not always possible due to late rains or lack of ploughing facilities. This results in short growing seasons with sweet sorghum being harvested beginning of March up to the mid of May.

For a rainfed crop to be successful it is necessary that its growth cycle should be of such a duration that it is comfortably contained within the available growing period. Failure to match the existing conditions may result in the reduction of yield and quality. Son (1971), through manipulation of planting date, was able to attain the highest sugar yields by planting late cultivars of sugarcane early and early cultivars later. Thus in sweet sorghum it is important to understand the best planting dates to enable farmers to manipulate planting dates to have longer periods of sweet sorghum sales and utilize higher prices early and late in the season.

Physiological mechanisms in plants are capable of sensing differences in day length. Under most field conditions late planting is associated with a reduction in number of days to panicle initiation and flowering, which may be the effect of temperature and photoperiod (Pauli, Stickler & Lawless, 1964; Heskerth, Chase & Nanda 1969; Caddel & Weibel, 1971). Stickler, Pauli, Laude, Wilkins & Mingis (1961) showed that early planting in grain sorghum increased grain yields through increased tillering and number of heads per unit area in Kansas.

Many studies in sweet sorghum have shown that yields declined as planting date was delayed but results on brix value, sucrose content and purity levels are inconclusive.

According to Hipp, Cowley, Gerard & Smith (1969) and Broadhead (1972b), in Mississippi, yields of sweet sorghum stalks increased with early planting, but brix value, sucrose content and juice purity were not affected by planting date. Similarly Cowley & Smith (1972), in Texas, reported a decline in yields of stalk with late planting but did not find any correlation between planting dates, sucrose content, purity levels and brix value. In India Maheshwari *et al*, (1974) also reported a decline in yield of sweet sorghum stalks but juice quality like sucrose content, juice purity and brix value were improved with delay in planting date. In South Africa Inman-Bamber (1980) reported a rapid decline in the stalk and sucrose yield of sweet sorghum with delayed planting dates. A delay of 10 weeks resulted in a two and a half week's reduction in the time to maturity and this caused a drop in sucrose yields of about 40% (Inman-Bamber, 1980).

Similarly, Ferraris & Charles-Edward (1986b) in Australia, Petrini, Belletti & Salamini (1993) and Almodares, Sepali & Karve (1994) in Iran, reported higher yields of stalks, brix value, sucrose content and purity with early planting compared to late planting.

Information on the effect of plant density on yield and quality of sweet sorghum is limited. In grain crops plant density affects grain yield, total dry matter production, stem height, diameter and tiller production (Downey, 1971). Increase in yield with increase in plant density up to a point where yields per unit area approaches an upper limit due to competition, have been reported (Adams, Arkin & Burnett, 1976). As plant density increases the number of tillers and their contribution to grain yield tend to decline (Myers & Faole, 1980). In forage sorghum, Eilrich, Long, Stickler & Pauli (1964) reported that plant population or row width did not show any significant effect on soluble carbohydrate, but that soluble carbohydrate was higher in row system than in a drill system.

Broadhead *et al*,(1963) in Mississippi, indicated that populations ranging from 46,000 to 65000 ha-' were optimum for stem yield and juice quality of sweet sorghum. Broadhead *et al*, (1963) also reported a decrease in sweet sorghum yields of stalk and syrup per hectare once plants were spaced wider than 15 to 20 cm apart. In addition it was reported that closer spacings than 15 to 20 cm resulted in thin stems which lodged readily and matured unevenly. Flemming & Wood (1967) found similar results in maize and reported increased height as plant density increased.

In sweet sorghum Martin & Kelleher (1984) in Australia, reported increased dry matter and water-soluble carbohydrate yields with denser spacing. They also reported less internodes and thicker stems in wider spacings than closer spacings, whilst in closer spacings thinner stems with slightly more tillers were reported. McBee & Miller (1982) reported a significant increase in starch at anthesis in plants grown at 10 cm spacing compared to wider spacings, while Cowley (1969) reported that sucrose content and purity levels were not affected by spacing. Hence there is a need to determine optimum plant densities in sweet sorghum.

The objective of this study was to evaluate the effect of planting date and spacing on the stem yield and juice quality in sweet sorghum.

7.3 MATERIALS AND METHODS

Experiments were conducted on the Experimental Farm of the University of Pretoria, during the 1996/97 growing season. Sweet sorghum landrace (G1) was planted on a sandy clay loam soil of the Hutton form. The soil was cultivated and disced to fine tilth. The experimental design was a split-plot design with three replications. Planting date treatments were randomly allocated to the main plots and spacing treatments to subplots. The main plot size was 34.2 m long by 8 m wide and the subplots were 3.8 m by 8m each. In each subplot there were four rows and to eliminate border effects the two middle rows were harvested. At each planting date the seedbed was ploughed and disced to a fine tilth and the seed was planted with a hand planter at a distance of 0.9 m between rows. Thirty days after emergence plants were thinned to the required intrarow spacings. No base fertilizer was applied at planting, but at forty days after emergence plants were top dressed with LAN at the rate of 120 kg N ha^{-1}. Plots were irrigated whenever there were dry spells to maintain growth. Weeds were controlled by a pre-emergence application of atrazine at a rate of 3kg active ingredient per hectare and hand weeding was done as necessary. There were no serious diseases, but aphids were a problem and they were sprayed with an aphicide.

There were three planting date treatments:

(i) October 18

(ii) November 18

(iii) December 17

The intrarow spacing treatments were:

(i) 20 cm

(ii) 40 cm

(iii) 60 cm

During the growth period two sample harvests were taken from each subplot, one at panicle initiation and the second at boot stage. Three representative plants were sampled from each subplot to estimate plant height, stem diameter, number of leaves per plant, leaf area per plant and number of tillers. Dry mass of leaves and stems were determined after oven drying at 70°C to a constant mass. Duration to panicle initiation and boot stage were recorded as the number of days from emergence until 50% of the plants were at the specific stage of development.

During the final harvest at the hard dough stage a sample of 20 stalks per subplot was harvested. Stalks were stripped, wrapped in large polythene bags, weighed and sent to the South African Sugar Association (SASA) for standard juice analysis. Samples waiting to be transported to SASA were stored in a cold room at a temperature of 5°C.

Data were 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).

7.4 RESULTS AND DISCUSSION

Data collected at the panicle initiation stage and the boot stage is summarized in the Appendix Table A7.1 and A7.2**.** The growing periods to panicle initiation, boot stage and hard dough stage are shown in Table 7.1. The planting date x spacing interaction was not significant therefore, main effects are discussed. The main effects of planting date and spacing on the stem fresh and dry mass, moisture content, number of tillers, main stem height and thickness and juice quality are presented in Tables 7.2 and 7.3.

Planting date

Days to panicle initiation and boot stage decreased with later planting dates (Table 7.1). This may be the result of lower temperature and shorter day length experienced by plants in the later plantings (Caddel & Weibel, 1971). Days from boot stage to hard dough stage increased with late planting probably due to the lower temperatures during seed filling of later planted crops. This was also observed in Chapter 4 where seeds reached maximum maturity faster under warmer conditions.

Table 7.1 Effect of planting date on sweet sorghum phenology

Planting date	Days from emergence to Panicle initiation stage	Days from panicle initiation to boot stage	Days from boot stage to hard dough stage	Days from emergence to hard dough stage
18-10-96	56	31	21	108
18-11-96	50	26	30	106
17-12-96	48	23	41	112

The highest stem yields were observed in the October planting (Table 7.2). There was no significant difference in stem yield between the November and December plantings. The high stem yields in the October planting is associated with an increase in the growing period from emergence to panicle initiation and boot stage; and increases in tiller numbers and stem height.

These results are consistent with the findings of Inman-Bamber (1980), Ferraris (1988) and Almodares, Sepali & Karve (1994) who reported increased stem dry mass with early planting as compared to late plantings. They attributed the decrease in dry mass with delayed planting to a reduction of the growth period in sweet sorghum (Inman-Bamber, 1980).

TABLE 7.2 The main effect of planting date and spacing on the stem fresh and dry mass, stem moisture content, number of tillers, plant height and main stem girth at hard dough stage (harvesting time)

Treatment	Stem fresh mass per plant (g)	Stem dry mass per plant (g)	Stem moisture content %	Number of tillers per plant	Main stem height (cm)	Main stem girth (cm)
Planting Date						
Oct.	1779a	508a	73.4b	4.1a	278.0a	8.1a
Nov.	952b	203b	76.4a	2.0b	213.0b	8.1a
Dec.	1019b	297b	70.6c	1.8b	227.0b	7.4a
LSDt (p=0.05)	619	108	2.3	1.5	22	NS
C.V. (%)	41	27	2.5	45.3	7.4	11.0
Spacing						
20 cm	867b	247b	73.2a	1.9a	249.0a	7.1b
40 cm	1236a	363a	74.0a	3.3a	240.0a	8.1ab
60 cm	1646a	398a	73.1a	2.7a	229.0a	8.3a
LSDt (p= 0. 05)	619	108	NS	NS	NS	1.16
C.V. (%)	41	27	2.5	45.3	7.4	11.0

\+ Means followed by different letters are significantly different at the 5% level by Tukey's Multiple Range Test.

Hipp, *et al*,(1969) related differences in stem yield from different planting dates to differences in solar radiation received by the plants. In southern Africa solar radiation is high throughout the summer months indicating that it may not be a limiting factor in sweet sorghum growth and yields. In the trial on the Experimental Farm of the University of Pretoria the October planting reached seed formation stages in January during the time when solar radiation was at 29M Jm^2/day, the November planting in February when solar radiation was 27 M Jm^2/day and the December plantings in March when solar radiation was 26 M Jm^2/day (Schulze, 1997). This indicates that there was little variation in solar radiation between the three months and it is highly unlikely that the differences in stem yield were due to solar radiation.

Stems from the November planting were significantly higher in moisture content than those from the October and December plantings (Table 7.2). The lowest moisture content was recorded in the December planting. This difference in stem moisture content might explain the poor juice quality observed in the October and November plantings (Table 7.3). High moisture content in the stem may tend to dilute concentration of sucrose content, lowering pol percentage, brix value and juice purity.

The October planting produced 4.1 tillers per plant and the two later planting dates 2.0 and 1.8 tillers per plant. These results are in agreement with those of Stickler *et al,* (1961) who reported more tillers with early planting. The high number of tillers in the October planting contributed to the high stem yields. Highest main stem height was recorded in the early planting, (Table 7.2). However, planting date did not affect the main stem thickness.

These results indicate that early planting improves main stem size through increasing main stem heights. Sucrose percentage (pol %) increased with delay in planting (Table 7.3). The highest sucrose content of 8.0% was recorded with the December planting date and the lowest of 4.0% with the October planting date. Similarly the juice purity of the three planting date treatments followed the same pattern as the sucrose percentage (Table 7.3). These results are consistent with the results of Maheswari *et al,* (1974) who reported increased sucrose content and juice purity with late planting. On the contrary Almodares *et al, (*1994) reported higher pol, brix and purity in early plantings. There were no significant differences between the planting date treatments regarding the brix value (Table 7.3). This is in agreement with the observation of Broadhead (1972) who reported that brix was not affected by planting date. The December planting resulted in a somewhat higher stem fibre content than the October and November planting dates.

TABLE 7.3 The main effect of planting date and spacing on the juice quality of sweet sorghum

Treatment	Pol %	Purity %	Brix %	Stalk Fibre %
Planting Date				
Oct.	4.0c	32.6c	12.1a	10.2b
Nov.	6.8b	53.5b	12.6a	10.1b
Dec.	8.0a	61.3a	13.1a	11.4a
LSDt (p=0.05)	1.2	5.7	NS	1.0
C.V. (%)	15.1	9.5	8.2	7.7
Spacing				
20 cm	6.3a	49.7a	12.6a	10.9a
40 cm	5.9a	47.4a	12.4a	10.3a
60 cm	6.5a	50.2a	12.8a	10.5a
LSDt (p=0.05)	NS	NS	NS	NS
C.V.(%)	15.1	9.5	8.2	7.7

\+ Means followed by different letters are significantly different at the 5% level by Tukey's Multiple Range Test. T1=October planting, T2=November planting, T3=December planting, S1=20 cm, S2=40 cm, S3 = 60 cm

Generally, these results indicate that early planting in sweet sorghum increased stalk yields through increased number of tillers and main stem heights, but reduced juice quality. Although the acceptability of sweet sorghum to the consumer is mainly determined by size and appearance of the stems, there is need to improve juice quality. This negative relationship between stem yield and juice quality requires more research in order to optimise yield and quality. Observations in this Chapter are based on the reaction of only one landrace. It would therefore, be necessary to screen other promising landraces in order to ascertain whether there are genotypes that partition assimilates towards sucrose accumulation rather than vegetative or reproductive growth when planted early.

Spacing

Higher stem yields per plant were observed in the 60cm and 40 cm spacing treatments (Table 7.2). Increased stalk yields per plant with increased spacing results from less interplant competition for radiation, water and /or nutrients. Although the number of tillers per plant did not differ between the spacing treatments the tendency was that the 40 cm and 60cm spacings produced more tillers than the 20 cm spacing (Table 7.2). This could account for higher stem yields per plant in the widely spaced plants. On a unit area basis the 20 cm spacing produced 4.8 kg m^{-2} of fresh stems, compared to 2.8 kg m^{-2} in the case of the 60 cm treatment (Table 7.4). These results are consistent with the findings of Martin & Kelleher (1984) who reported increased dry mass yields at higher plant densities.

Table 7.4 Effect of row spacing on population and fresh stem yield per unit area

Intra row spacing (cm)	population per square metre	Stem yield per square metre (kg m^{-2})
20	5.5	4.8
40	2,7	3.3
60	1,7	2.8

Spacing did not influence stem moisture content and main stem height (Table 7.2). The spacing treatments did not differ in the number of tillers per plant and this is contrary to the results of Kelleher (1984) who reported slightly more tillers in wider spacings.

Similarly, there were no significant differences in main stem heights between the treatments, however, the main stems of the 20 cm spacing were thinner than those of the 40 cm and 60cm spacings. These results are consistent with the findings of Broadhead *et al,* (1963) who reported thinner stems with higher densities.

Spacing did not have any significant effect on juice quality (Table 7.3). However, there was a tendency for stems from the 60 cm spacing to be higher in sucrose content (pol %), juice purity and brix compared to the other spacing treatments (Table 7.3). These results support those of Cowley (1969) who reported that sucrose and purity values were not affected by spacing.

The results obtained from the experiment at the University of Pretoria indicated that juice quality was not affected by spacing per se. Although wider spacing resulted in somewhat shorter and thicker stems on a unit area base the higher plant population (20 cm spacing) produced the highest yields. Based on these results the 20 cm spacing can be recommended for sweet sorghum production in pure stands. Since these results can not be extrapolated to Botswana conditions where sweet sorghum is broadcasted with other crops, there is a need for more experiments on cultural practices including planting date and spacing under local conditions.