

CHAPTER 6

MANIPULATION OF TILLERS AND INFLORESCENCE TO INCREASE SUCROSE CONCENTRATION IN SWEET SORGHUM STEMS

6.1 ABSTRACT

Two field experiments were conducted at the experimental farm of the University of Pretoria during the 1996/97 growing season, to investigate the effect of deheading and removal of tillers on stem mass and juice quality of sweet sorghum. Five treatments were applied: a control, panicle removal at boot stage, at 100% flowering stage, at milk stage and removal of 50% florets at 100% flowering. In the investigation on removal of tillers, four treatments were applied: a control with no tillers removed, all tillers removed, one tiller retained per plant and two tillers retained per plant. Reduction in the number of developing seeds in the inflorescence improved juice quality. Deheaded plants were significantly higher in brix, purity, pol and sucrose than the control plants. Deheading at boot stage or at flowering increased the brix value and sucrose content in the stems more than in plants deheaded at milk stage or in plants with 50% florets removed at 100% flowering. However, the scars and branching resulting from panicle removal may render the stems unacceptable to consumers. Hence manipulation of florets might be a better option for improving juice quality. Removal of tillers did not cause any significant difference in the juice quality and in the stem mass of the four treatments. However, there was a tendency of the main stem without tillers to have higher stem mass, brix, purity, pol and sucrose content than the control. These results suggest that little competition between main stems and tillers for assimilates and need further investigations.

6.2 INTRODUCTION

The economic value of sweet sorghum is in the stem and not in the grain as in grain sorghum. In the characterisation exercise in Chapter 5 it was observed that seed production of some of the late maturing landraces of sweet sorghum compared well to grain sorghum, with up to 3893 seeds per panicle. If photosynthates used in grain formation and development could be diverted into the stems, stem yield and juice quality may be improved. In sugarcane it has been reported that inhibition of flowering with some chemicals resulted in considerable increases in cane and sugar yields (Humbert, Zamora & Frazer, 1967). However, in the Republic of South Africa, Donaldson & Van Staden (1989) did not observe any notable benefits after applying ethephon to two sugarcane varieties (N17 & N23) to prevent flowering.

Sweet sorghum stores starch as the principle nonstructural carbohydrate in grain, but primarily stores sucrose in stems. Differences in stem nonstructural carbohydrates between sweet sorghum and grain sorghum before physiological maturity, have been associated with larger grain yields in grain sorghum cultivars (Miller & Creelman, 1980). It is speculated that the smaller grain yield in sweet sorghum may be due to competition between elongating stems and preanthesis head development (Goldsworthy, 1970; Eastin, 1972; Willey & Basiime 1973). During sweet sorghum development and grain filling, photosynthates are available for dry matter production and after anthesis photosynthates are available for grain requirements and the excess accumulates as sugars or starch in the stem (Ferraris 1981b, Ferraris & Charles-Edwards 1986b).

In sweet sorghum the sugar, mainly sucrose, is accumulated in large amounts in the stem during the development of the inflorescence, when the panicle has formed and is emerging from the boot (Ventre, 1948; Wall, Sieglinger & Davies, 1948; McBee & Miller, 1982). During this period there is no competition between grain development and sugar accumulation (Lingle, 1987). Sucrose in the stem may increase or remain constant between the soft dough and the ripe stage of the grain, depending on variety or ripening conditions (Broadhead, 1972). Under most field conditions sucrose content in sweet sorghum stems is at its maximum during the dough stage (Coleman, 1970). However, distribution of sugars, starch and acid is not uniform throughout the sweet sorghum stalks (Ventre *et al*, 1939). The four top internodes representing about 18 % of the stalk weight, are higher in starch, titratable acidity and sucrose than the remainder of the stalk. Internodes near the ground level are high in invertible sugars (Coleman & Stokes, 1964).

Broadhead (1973) and Ferraris (1981b) observed that deheading sweet sorghum increased brix, sucrose and starch, but stems contained less juice than normal plants. In addition, Ferraris (1981b) also observed that leaves of deheaded plants remained green for longer and the stems were less prone to lodging. Coleman (1970) observed that the growth of stalks were not greatly influenced by limited seed production but the stalks produced a number of side branches. According to Stokes, (1958) limited seed production in sweet sorghum results in reduced lodging and hastened maturity.

Tillering in sweet sorghum could be profitable if all the tillers produced by crown buds developed to maturity. This would mean an increase in the number of stems and

prolonged harvesting period since the main shoot matures earlier than tillers. Tillering is also useful in that the roots that develop from the basal nodes lend physical support to the plant and reduce root lodging. However, not all tillers develop up to marketable size. At high population densities some tillers grow tall and thin and others die due to competition, constituting a loss in economic yield (Ferraris, 1988).

This chapter describes experiments on the effects of deheading, removal of florets and reduction of tillers on the juice quality of sweet sorghum stems.

6.3 MATERIALS AND METHODS

Experiments were conducted on the Experimental Farm of the University of Pretoria during the 1996/97 growing season. Sweet sorghum plants were grown on a sandy clay loam soil of the Hutton form. The soil was cultivated and disced to a fine tilth. Plot size was 4.0 m by 3.5 m, with four rows at 0.90 m spacing. Planting was done with a hand planter at a depth of 3 cm. Seeds were sown 0.3 m apart, with an inter-row spacing of 1.0 m. To eliminate the border effect only the two inside rows were harvested. After four weeks the plants were thinned to one plant per planting position, and then top dressed with LAN at the rate of 120 kg N ha⁻¹. Weeds were controlled using pre-emergence application of atrazine at the rate of 3 kg active ingredient per hectare.

Experiment 1

The purpose of this experiment was to quantify the effect of deheading on yield and quality of sweet sorghum stems. Deheading and removal of florets were done between the boot stage and milk stage. The design was completely randomized with five treatments replicated four times.

Treatments consisted of the following:

- (1) C= control
- (2) Pb=panicle removed at boot stage
- (3) Pf=panicle removed at 100% flowering
- (4) Pm=panicle removed at milk stage
- (5) Fr = removal of 50% of florets at 100% flowering

At boot stage the panicles were pulled off while at the full flowering (100% flowering) and milk stages, the panicles were severed with a knife. Florets were removed with a pair of scissors. At maturity a sample of 20 stalks randomly selected from each plot was harvested. The leaf sheaths and panicles were removed and the stalks were packed in polyethylene bags, sealed and sent to South African Sugar Association for standard juice analyses. Stalk samples awaiting transportation to the laboratories were kept in a cold room at 5°C. In most cases samples were transported over night when it was cool and analysed on arrival at the laboratories.

Experiment 2

This experiment was also planted in a completely randomised design with four treatments replicated three times. Sweet sorghum plants were left to grow up to the boot stage when the following four treatments were applied.

- (1) C= control
- (2) T0= all tillers removed and only the main stem left
- (3) T1= one tiller retained per plant
- (4) T2= two tillers retained per plant

All late developing tillers were removed until harvesting. At maturity a sample of 20

stalks was randomly selected, prepared and sent to the laboratories of SASA for juice analyses. Data of both experiments were analysed by the conventional analyses of variance and the significant differences between means were determined by Tukey's multiple range test (Steel & Torrie, 1985).

6.4 RESULTS AND DISCUSSION

Experiment 1

The effect of deheading and removal of florets on the juice quality of sweet sorghum is summarized in Table 6.1.

TABLE 6.1 Effect of deheading and floret removal on sweet sorghum stalks and juice quality (SASA)

Treatment	Stalk components			juice components			estimate d
	Stalk fresh mass (g)	Stem dry matter (g)	Stalk fibre %	Brix %	Juice purity %	Pol %	Sucrose / stalk (g)
C	331	23 b	11.1	11.6 b	56.0 b	6.5 b	21.8 b
Pb	360	26 a	11.5	14.6 a	64.6 a	9.5 a	33.9 a
Pf	352	26 a	11.5	14.6 a	68.3 a	10.0 a	35.1 a
Pm	289	25 a	12.2	14.3 a	68.6 a	9.8 a	28.3 a
Pr	299	26 a	11.8	14.2 a	67.8 a	9.7 a	28.8 a
LSDt (p=0.05)	N/S	3.09	N/S	2.09	8.51	2	10.97
C.V. (%)	12.17	5.38	6.39	6.7	5.8	12	16.47

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

C=control; Pb=panicle removal at boot stage; Pf=panicle removal at 100% flowering; Pm=panicle removal at milk stage; Pr=removal of 50% of florets at 100% flowering.

Fibre= non-solubles after washing with water for one hour (bagasse); brix = soluble solids; purity = a percentage ratio of pol to brix; pol = sucrose as measured by a polarimeter; sucrose = estimated pure disaccharide

There were no significant differences in stalks fresh mass among the treatments (Table 6.1). However, the stem dry mass of the control was significantly lower than stem dry

masses of the other treatments. According to the results, removal of the seed sink allowed for an additional 3g of dry matter to be stored in the stems. Although there were no significant differences between the treatments in stalk fibre content, stalk fibre in plants deheaded at milk stage was higher (12.2%) than in the other treatments.

The quality of juice improved with deheading. Deheaded plants produced much higher brix values and pol percentages (Table 6.1). Similarly the juice purity and estimated sucrose content followed the same pattern as brix and pol values. These results are consistent with those of Broadhead (1973) and Ferraris (1981b) who reported higher brix values, sucrose and starch content from deheaded plants than in the control plants. Broadhead (1973) attributed the increase in brix value and sucrose content in deheaded plants to decreased juiciness in deheaded plants.

Although the juice quality did not differ significantly between deheading treatments, plants deheaded at boot stage and at 100% flowering stage produced somewhat higher brix values compared to plants deheaded at milk stage and those which had 50% florets removed. The pol percentage was slightly higher in plants deheaded at 100% flowering stage. These results are consistent to those of Broadhead (1973) who reported an increase of sucrose content in plants deheaded at boot stage compared to plants deheaded at later stages. Generally, results show that reduction in the number of developing seed in the inflorescence improves juice quality.

From these results it was observed that juice quality was generally better in plants deheaded at early stages compared to plants deheaded at the late developmental stages. Better juice quality in plants deheaded at early stages may be due to the fact that accumulation of sugar in sweet sorghum stems begins during the development of

inflorescence as indicated by McBee & Miller 1982. Therefore, plants deheaded at later seed developmental stages are expected to have less sugars in the stem because some assimilates would have been used in supporting the developing seeds.

Plants that were deheaded developed side branches as illustrated in Fig 6.1 (a-b) and those with 50% florets removed did not produce side branches Fig 6.2 (a-b). It was also observed that deheaded plants lodged less than normal plants Fig 6.3b and fully developed panicles caused extreme lodging Fig. 6.3c. Coleman (1970) and Broadhead (1973) also reported side branching and less lodging in deheaded plants. Deheaded plants also remained greener for a longer time than the control plants as observed by Ferraris (1981b). Henzell & Gillieron (1973) attributed the delay in senescence to removal of hormonal control. Thus removal of florets was included to improve the stalk quality by preventing development of branches in the stem, and minimize stem damage caused by deheading.

Deheading may improve juice quality but the scars and side branches reduce the value of the stalk. A 50% removal of the florets might be a better option as it improved juice quality (Table 6.1) without affecting stem quality. Inducing barrenness by chemicals may be an answer rather than mechanical practice which is time consuming and tedious.



(a)



(b)

Fig 6.1 (a – b) Profuse branching due to deheading.



(a)



(b)

Fig 6.2 (a – b) No branching in stems of plants with 50% florets removed.



Fig 6.3 (a)



Fig 6.3 (b)



Fig 6.3 (c)

Fig 6.3 (a – c) Differential lodging due to tiller removal and panicle pruning NOTE extreme lodging of main stems with tillers (a), less lodging (b) due to pruning of florets (inner row) and absence of lodging in deheaded plants (outer row). Extreme lodging due to fully developed panicle (c).

Removal of tillers did not cause any significant difference in the juice quality of the main stems (Table 6.2). However, the stem fresh mass and juice quality tended to be somewhat higher in the main stems where all tillers were removed. These results indicate that there might be some competition for assimilates between tillers and main stem, but additional investigations will be required.

TABLE 6.2 The effect of tiller removal on juice quality of the main stem of sweet sorghum (SASA)

Treatment	Stalk components			Juice components			estimated
	Stalk fresh matter (g)	Stem dry matter (g)	stalk Fibre %	Brix %	Juice Purity %	Pol %	Sucrose / stalk (g)
C	381	23	11.1	12.1	52.6	6.4	24.3
T0	434	24	10.3	13.7	55.4	7.6	33.0
T1	419	23	10.1	13.2	51.1	6.8	27.9
T2	367	24	10.9	13.3	54.7	7.3	26.6
C.V.	12.65	3.24	5.39	7.14	7.67	12.67	16.38
	N/S	N/S	N/S	N/S	N/S	N/S	N/S

C=control; T0= all tillers removed and only the main stem left; T1=one tiller retained per plant; T2=two tillers retained per plant.

Fibre= non-solubles after washing with water for one hour (bagasse); brix = soluble solids; purity=a percentage ratio of pol to brix; pol=sucrose as measured by a polarimeter; sucrose = estimated pure disaccharide

Main stems with less or no tillers became prone to lodging Fig 6.3a. Removal of tillers results in decreased number of stalks per hectare, resulting in the reduction of the economic yield. Thus from the producers point of view the disadvantages of manipulating a sweet sorghum crop by removal of panicles or tillers outweigh the possible advantages. However, this does not exclude the possibility that breeding and selection for small panicles and reduced tillering may benefit stem size and quality. It may also justify research by plant breeders to determine whether male sterile varieties may be sweeter and juicier than male fertile varieties.