

# SOME EFFECTS OF THE RIPENER FUSILADE SUPER AND DROUGHT STRESS ON STALK COMPONENTS AND LEAF EMERGENCE OF SUGARCANE

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## Abstract

Sugarcane stalks that were drought stressed and not stressed were sampled 50 days after applying Fusilade Super (fluazifop-butyl). The stalks were sectioned and analysed for structural (fibre) and soluble (brix) carbohydrates. Levels of sucrose, glucose and fructose were determined by HPLC. The data show that total stalk dry matter was not reduced by fluazifop-butyl, regardless of whether the cane was stressed or not. Increases of sucrose in sections of unstressed cane, which were also evident in the top section of stressed cane, were substantial. Lower levels of fibre, glucose and fructose were associated with increases in sucrose. The ripener restricted the emergence of new leaves of stressed and unstressed cane without reducing total green leaf area. From the data presented, some speculations on mechanisms leading to higher sucrose production in unstressed stalks from the application of fluazifop-butyl at a sub-lethal dose are made.

## Introduction

Low plant extractable water may retard growth rates and for a period have little effect on total dry matter assimilation. Depriving sugarcane of moisture before harvesting may raise the sucrose content and sucrose yields (Clements, 1962; Thompson and Boyce, 1968). An alternative method of ripening sugarcane is through the application of chemicals which modify growth and enhance the accumulation of sucrose in stalks. Fusilade Super (fluazifop-butyl), when applied at sub-lethal doses, is a very effective ripener of sugarcane, and usually increases sugar yields by more than one ton per hectare (Rostron, 1985; Sweet *et al.*, 1987; Leibbrandt, 1989; Donaldson and Van Staden, 1992).

Fluazifop-butyl belongs to the aryloxyphenoxypropionic acid group which inhibit *de novo* synthesis of fatty acids. Acetyl coenzyme-A carboxylase, which catalyses the conversion of acetyl-CoA to malonyl-CoA, is blocked by fluazifop-butyl (Gronwald, 1991). This disrupts the formation of cellular structures such as plasma membranes which require fatty acids or lipids. Thus meristematic tissues, particularly in the stalk apex and developing leaves, become necrotic and die. Fusilade Super is converted to an active acid form by esterase released in the plant. Stressed plants produce less esterase so that there is less conversion of fluazifop-butyl to the active acid form. Also, the higher levels of abscisic acid in stressed plants may bestow some protection against the action of some aryloxyphenoxypropionic acids (Dickson *et al.*, 1990).

The authors have previously shown that well watered sugarcane (LWP < -0,5 MPa) yielded 11,1 g sucrose per stalk more when treated with Fusilade Super and that the response from drought stressed sugarcane (LWP -1,5 MPa) to the ripener was 2,4 g sucrose per stalk (Donaldson and Van

Staden, 1993). This demonstrated the reduced activity of the chemical applied as a ripener to drought stressed sugarcane. The objective of this study was to investigate the effects that Fusilade Super had on leaves and dry matter components of stressed and unstressed sugarcane. The effect of ripener on the source-sink relationship is discussed as a possible mechanism by which sucrose storage is enhanced.

## Treatments and methods

The experiment was conducted at Pongola (27°23'S and 31°37'E) on a ratoon crop of NCo376 started on 26 July 1989. It was sited on a deep Hutton sandy clay with an estimated moisture holding capacity of 464 mm (Thompson, 1976). The crop was fertilised with 114 kg nitrogen and 114 kg potassium per hectare. An application of Sencor + diuron mixture and one hoeing was sufficient to maintain good weed control. After two monthly irrigations of 61 mm, irrigation was suspended in some plots and others were well irrigated by perforated pipes elevated above the crop canopy. At the time of applying the ripener (18 April 1990) the leaf water potentials (LWP), measured with a Scholander pressure chamber, were less than -0,5 MPa and -1,5 MPa in the unstressed and stressed cane, respectively. Stalks were marked at the time of spraying Fusilade Super so that they could be sectioned into five segments which were comparable for each treatment (Donaldson, 1993) at the time of spraying and 50 days later. Twenty-four stalks from each plot were divided into five sections as follows: segment one = top 200 mm + new growth, segment two = second 200 mm, segment three = third 200 mm, segment five = the 1 000 mm base and segment four = the remaining mid section. Sections were shredded and weighed, and the juice extracted was analysed in the conventional way for soluble solids (Brix) and sucrose content (Pol). Shredded material was oven-dried to determine the dry mass (DM) of cane. The mass of the water insoluble portion (fibre) of DM was calculated by difference (DM - mass of Brix). Juice from each segment of three replications was treated with mercuric chloride and frozen in sachets, stored and later analysed by HPLC for sucrose, glucose and fructose.

At the time of applying the ripener, leaf number one (the youngest leaf which was more than half unfolded) of each of twenty stalks was marked in each plot, of which five were analysed. The fresh and dry leaf mass and green area of leaves which unfolded after applying the ripener treatment and that of older green leaves were recorded 50 days after spraying Fusilade Super.

## Results

*Components of dry mass in stalk sections 50 days after spraying*

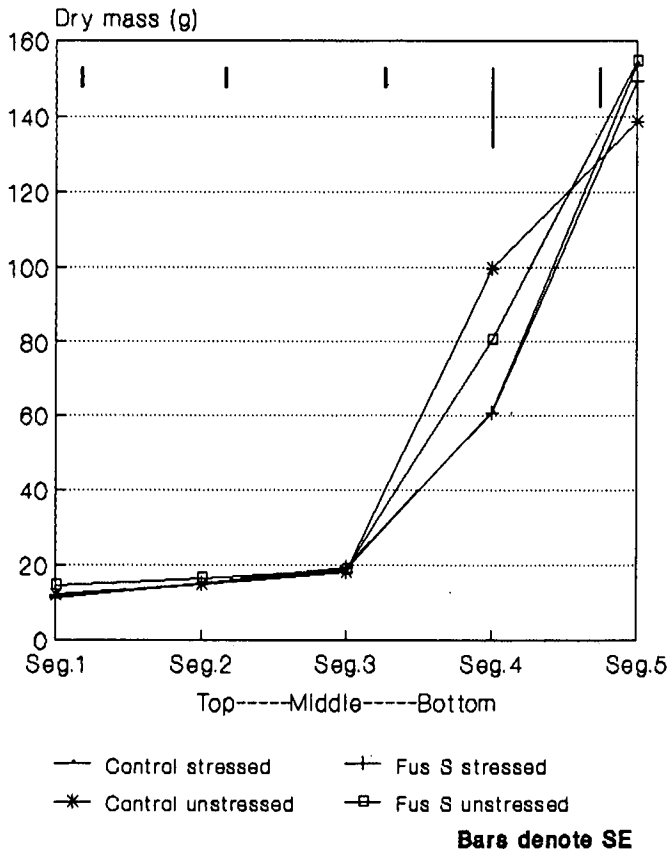


FIGURE 1 Dry mass of unstressed and stressed stalks 50 days after ripener application.

Stalk dry mass

The ripener had little effect on the total dry mass of both stressed and unstressed stalks 50 days after spraying (Figure 1). The lower mass of the ripened unstressed segment 4 was compensated for by the higher mass of segment 5.

Brix

Segments of stressed stalks had higher soluble solid content (brix) than unstressed stalks. Figure 2, however, shows that the brix levels of chemically ripened stalks were generally higher than in untreated stalks. The differences between chemically ripened and unripened stalks were substantial ( $P=0,05$ ) in all but segment 5 of unstressed stalks and were small in the top three segments of stressed stalks.

Fibre

Since fibre was derived by difference (total DM - brix) the effects of the ripener on the insoluble portion (fibre) are the mirror image of the soluble component (Brix), as reflected in Figure 3.

Pol

The correlation between sucrose % DM derived from HPLC and the standard saccharimeter methods was high ( $r^2 = 0,823, n=60$ ). However, since sucrose was determined by HPLC for only three replications, data from the standard method for which there were seven replications, are presented in Figures 4, 5a and 5b. Stressed stalks contained more sucrose in the top four segments than unstressed stalks which were not treated with the ripener (Figure 4). The reverse was true for the base of the stalk (segment 5). The sucrose

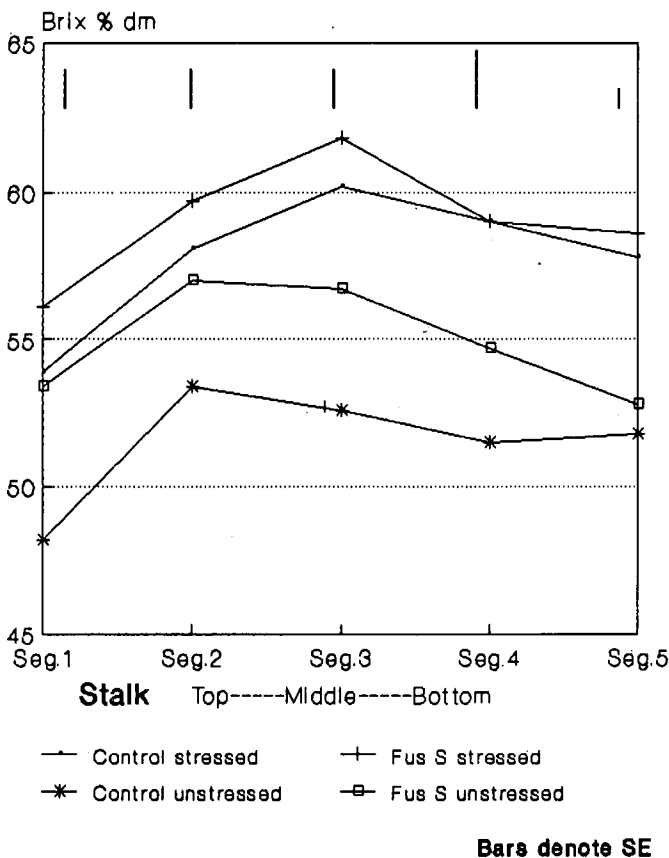


FIGURE 2 Soluble solids (Brix) as % dry mass in stalks 50 days after ripener application.

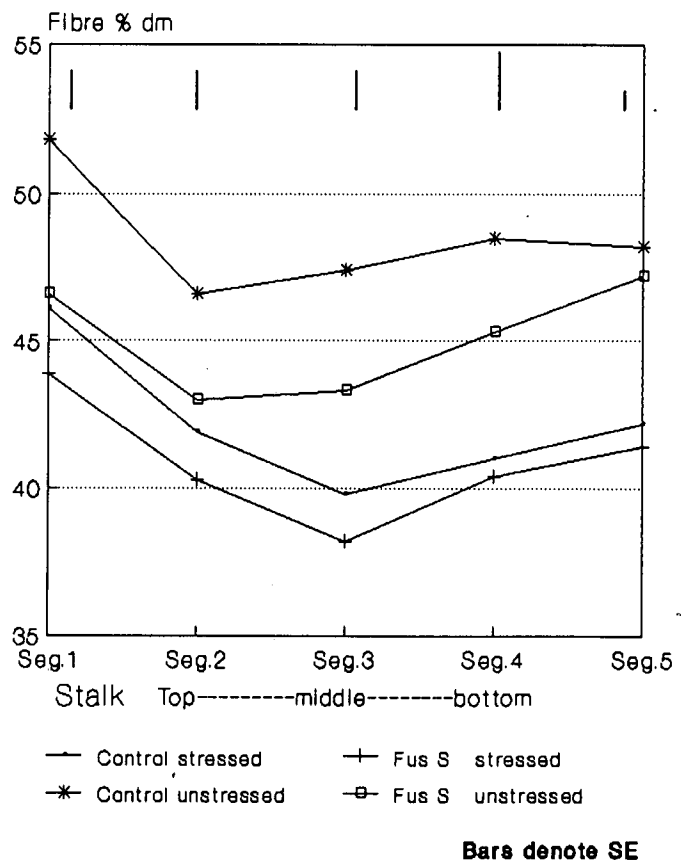


FIGURE 3 Insoluble solids (Fibre) as % dry mass in stalks 50 days after ripener application.

levels of chemically ripened stalks were significantly ( $P=0,05$ ) higher than unstressed stalks but not of stressed stalks. Differences in the levels of sucrose between chemically ripened and unripened stalks of unstressed and stressed cane are shown in Figures 5a and 5b, respectively. The ripener raised the sucrose content substantially in the top four segments of unstressed stalks (Figure 5a) and only affected segment 1 of stressed stalks ( $P=0,05$ ) (Figure 5b).

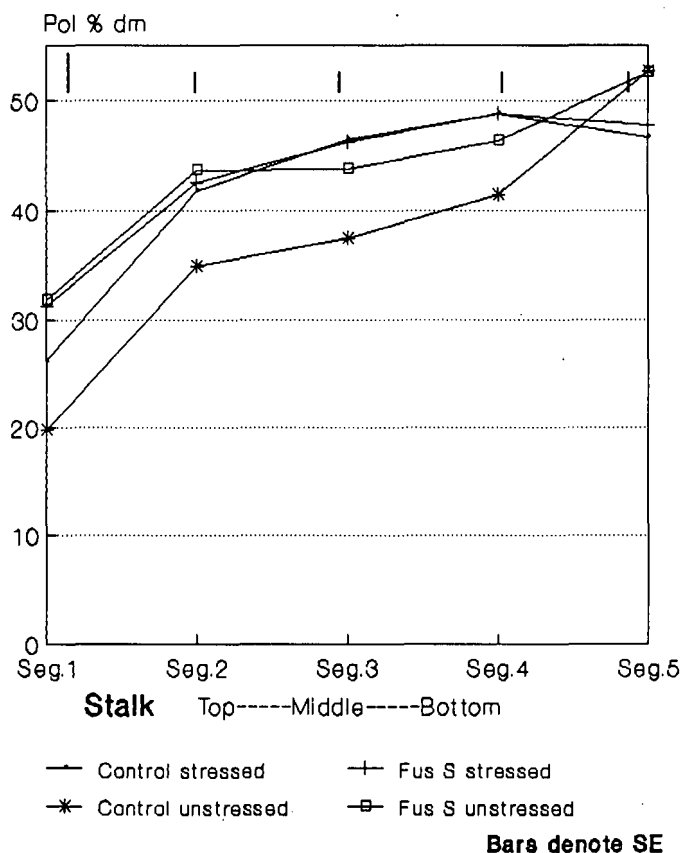


FIGURE 4 Sucrose (Pol) % dry mass in segments of unstressed and stressed stalks with and without ripener 50 days after application.

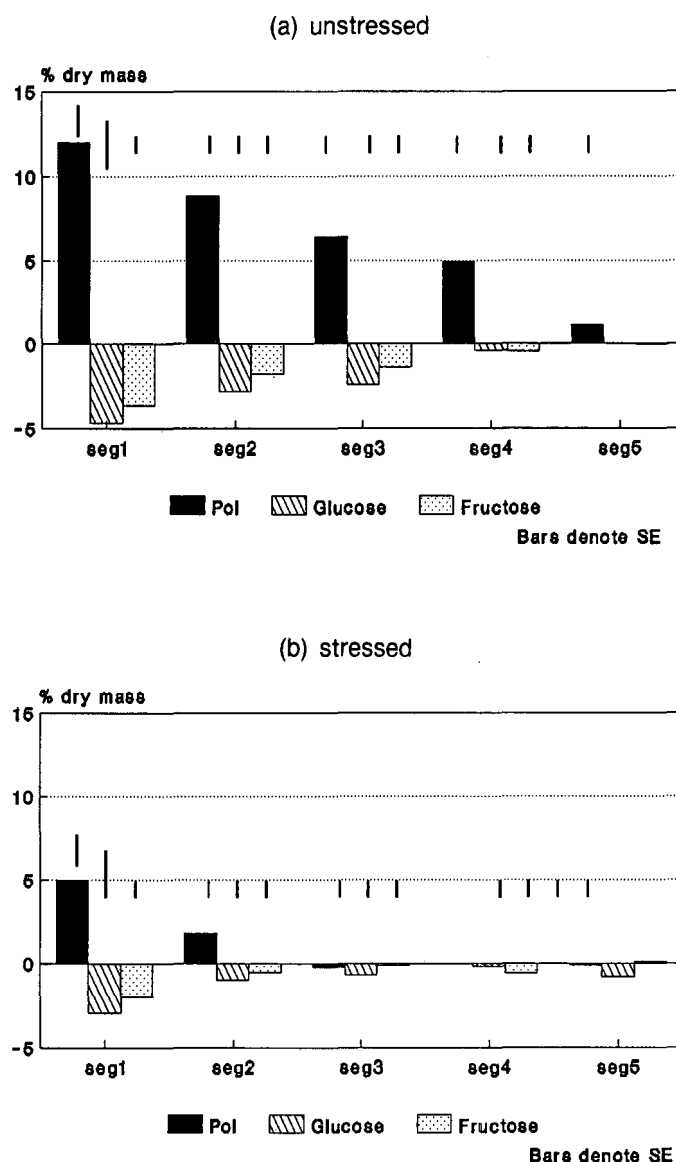


FIGURE 5 Effects of Fusilade Super on Pol, glucose and fructose % DM in segments of unstressed (a) and stressed (b) stalks 50 days after application.

Table 1

Glucose (Glu) and Fructose (Fru) % dry mass of unstressed (W1) and stressed (W2) stalk segments with (R) and without (C) ripener

Segment	1		2		3		4		5	
	Glu	Fru	Glu	Fru	Glu	Fru	Glu	Flu	Glu	Fru
CW1	12,7	8,8	5,7	4,1	5,9	4,3	1,9	1,9	0,3	0,4
RW1	8,0	5,2	2,8	2,3	3,4	2,9	1,5	1,5	0,3	0,4
CW2	10,6	7,6	5,9	4,3	5,9	3,9	2,2	1,9	1,0	0,7
RW2	7,7	5,7	4,9	3,8	5,2	3,8	2,1	1,3	0,8	0,8
Mean	9,7	6,8	4,8	3,6	5,1	3,7	1,9	1,6	0,6	0,6
CV%	28,3	19,7	29,8	25,2	27,6	23,2	60,2	67,2	62,6	71
SE±	2,8	1,4	1,4	0,9	1,4	0,9	1,2	1,1	0,4	0,4
LSD 5%	5,5	2,7	2,9	1,8	2,8	1,7	0,9	2,2	0,8	0,8

**Glucose and fructose**

Levels of glucose and fructose were very variable (coefficient of variation 20 to 67%) (Table 1). Glucose was significantly lower ( $P=0,05$ ) in segments 1 and 2 of unstressed chemically ripened cane, and the differences between chemically ripened and unripened stalks are shown in Figures 5a and 5b for unstressed and stressed cane, respectively. The general trend is towards a reduction of both glucose and fructose as the gain in sucrose increases higher up the stalk in response to the ripener. The association between increased sucrose and decreased invert sugars is clearer ( $r^2 = 0,815$ ,  $n=10$ ) when the glucose and fructose are considered collectively as total invert sugars.

**Leaf development after spraying**

The average green area of individual leaves on stalks 50 days after the ripener was applied are shown in Figure 6. Leaves A, B and C are those that unfolded in unstressed cane after the day of spraying. Leaf A unfolded from the leaf spindles of stressed stalks after the day of spraying. The newly emerged leaves of stressed stalks consequently presented smaller green areas, which were reduced further by the ripener (Table 2). In unstressed cane the area of newly emerged green leaves was reduced substantially by Fusilade Super, but the reduction was similar to that of stressed cane when expressed as a percentage of the area of untreated stalks. The green area of the older leaves of chemically ripened stalks was greater than untreated cane. This appeared to compensate for the loss of leaf area at the top of the stalk so that the total green leaf areas of treated and untreated stalks were similar (Table 2).

**Table 2**

**Green leaf areas (dm<sup>2</sup>) 50 days after ripener application**

Treatments	New leaves (A,B,C)*	Older leaves (1 to 11)	Total	SE ±
<b>Unstressed</b>				
Control	2,26 (A + B)*	22,55 (1-11)**	24,81	11,41
Fusilade S	1,33 (A + B)	24,20 (1-11)	25,53	10,61
<b>Stressed</b>				
Control	1,43 (A)	15,52 (1-9)	16,95	9,80
Fusilade S	0,91 (A)	19,35 (1-9)	20,26	10,12

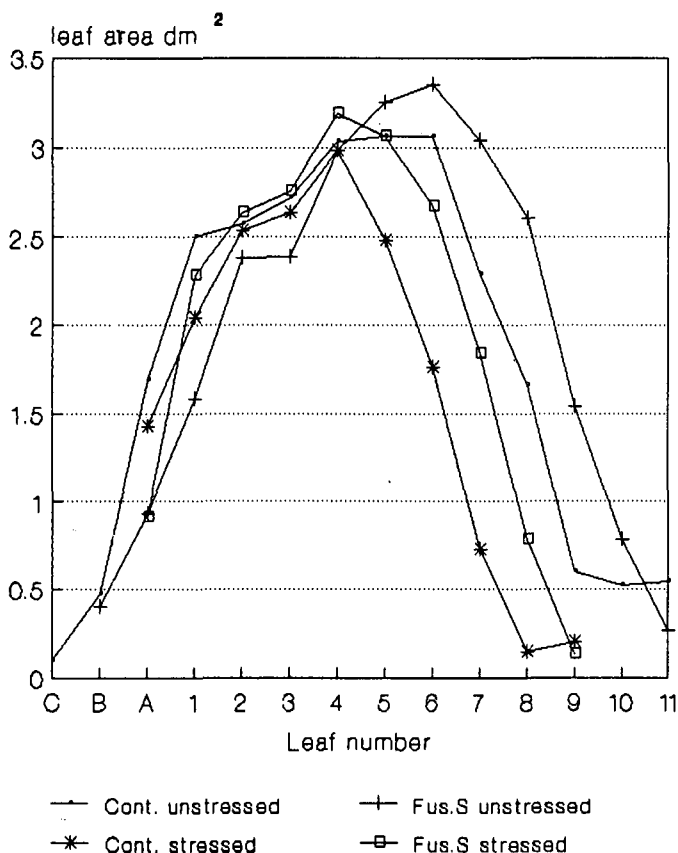
\* Area of two new leaves – See Figure 6.  
 \*\* Area of 11 older leaves.

Dry mass of new leaves was reduced by 11% and 18% in unstressed and stressed cane, respectively (Table 3).

**Table 3**

**Dry mass of marked leaf + new leaves produced on five stalks between 18 April and 8 June**

Treatment	Unstressed		Stressed	
	Control	Fusilade S	Control	Fusilade S
Dry mass ± SE	63,9 ± 12,0	53,2 ± 4,6	± 59,2 ± 21,2	4,7 ± 4,7



**FIGURE 6** Area of newly emerged leaves (A to C) and older leaves on stressed and unstressed stalks with and without ripener.

**Discussion**

The data presented show that fluazifop-butyl reduced the emergence of new leaves, which retarded senescence of the older green leaves. The total green leaf area was no different from untreated stalks for at least the first 50 days after application of the ripener. Dry mass of stalks was not affected by the ripener and the gains in sucrose appear to have been achieved through more favourable partitioning of photosynthate. Lower fibre accompanied by increases in sucrose suggests that the ripener causes the assimilate to be diverted away from the formation of insoluble solids towards soluble solids. A trend of lowered invert sugars where sucrose was raised suggests metabolic changes such as higher consumption of invert sugars or reduced hydrolysis of sucrose. The effects were very much lower in stressed cane. Glyphosate (sodium sesqui salt of N-(phosphonomethyl) glycine), which is also an effective ripener of sugarcane, immobilises newly formed sucrose in storage cells, decreases the amount of invert sugars in young storage cells and channels less photosynthate into cell wall components (Maretzki and Thom, 1978). It is probable that lower levels of invert sugars reflect the arrested expansion growth of the stalk, which is a utilisation sink. In fully expanded sections of the stalk, invert sugars were not affected following application of the ripener.

The glyphosates target an enzyme in the shikimate pathway (Herrmann, 1995). This pathway leads to formation of aromatic amino acids which are precursors of secondary metabolites, of which lignin is the most important. Fluazifop-butyl interrupts the production of fatty acids required in the formation of waxes, suberin and cutin (Gronwald, 1991). These two ripeners therefore have in common the reduction of substances in cell walls which retard sucrose

movement into storage parenchyma cells (Jacobsen *et al.*, 1992). It is possible that, by reducing lignin and suberin in cell walls, these ripeners may keep the passage between cells open so that sucrose unloading from phloem to storage parenchyma is unhindered.

Young developing leaves and the stalk apex are primary utilisation sinks and will have first call on assimilate. The fully developed leaves which are the source of the assimilate are initially unaffected by the ripener. When the two primary sinks (new leaves and stalk apex) are neutralised by the ripener the storage sink in the stalk is left to compete with fewer sinks; the respiratory processes and the mature root system (both utilisation sinks) being the main competitors for assimilate. By neutralising competing sinks the import rate to the stalk storage sink may be altered (Ho, 1988). These changes in the source-sink balance, together with less impedance of sucrose translocation into storage sites, may account for the enhanced sucrose production of a crop ripened with Fusilade Super.

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