SOME EFFECTS OF ENVIRONMENT, AGE AND GROWTH REGULATING COMPOUNDS ON THE GROWTH, YIELD AND QUALITY OF SUGARCANE IN SOUTHERN AFRICA

BY

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SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN THE DEPARTMENT OF CROP SCIENCE, FACULTY OF AGRICULTURE, UNIVERSITY OF NATAL, PIETERMARITZBURG

1974

TABLE OF CONTENTS

A B S T R A C T

An assessment has been made of the potential for increasing yields of well grown irrigated sugarcane crops beyond their present maxima. The effects of age at harvest and artificial growth regulators on yield have also been investigated.

Measurement of the apparent maximum yield of cane fresh weight (tc/ha) and total dry matter (t.dm/ha) of three varieties grown on a specially prepared site, indicated that actual cane yields were 63-70% of the estimated potential maximum. Differences in morphology between two extreme varieties, NCo 376 and CB 36/14, were insufficient to affect growth and yield under good growing conditions. The average productivity over a period of one year of plant and first ratoon crops of three varieties was 65 t.dm/ha and 150 tc/ha. This is a crop growth rate of 17,0 $g/m^2/dy$, representing an average conversion into plant dry matter of 1,9% of total incident radiation (r_i) or 4,3% of visible ri. This level of productivity is equivalent to rates reported for sugarcane growing in more favourable parts of the world and for other highly productive crops.

In an experiment in which a series of crops were ratooned at different times of the year and harvested at ages ranging from 32 to 72 weeks, sugar yield and all measures of cane quality were closely correlated with cane yield for crops of all ages. Sugar yield varied with age at harvest, according to the cycle of weather conditions experienced by the crop. Crops ratooned in January and February produced the highest yields of 23 tons estimated recoverable sugar per hectare (ters/ha) at 64-72 weeks of age. The average rate of sugar production at this time ranged from 1,3-1,5 ters/ha/month. At 12 months of age crops ratooned in July and September had the highest yields of 17,2 ters/ha, but they then made little further growth. High rates of sugar production of 1,4-1,6 ters/ha/month were obtained from crops ratooned between June and September and harvested between May and August at 40-56 weeks of age. Considering data for all crops, cane yield was correlated with weather conditions only up to 40 weeks of age. After this, increments of cane yield were correlated better with the amount of growth already made than with either crop age or the average weather conditions experienced.

Artificial chemical ripening was successful on young immature crops harvested in May at the beginning of the milling season, but there was only a small response under less favourable growing conditions and when the crop was older and more mature. Ethrel and Polaris were the most successful of several ripeners tested, Ethrel being more active than Polaris. Cane quality was improved and sucrose storage was increased despite reductions in rates of photosynthesis and sheath and lamina size. The ripening response varied with variety, condition of the crop at the time of spraying, rate of chemical application and the time interval between spraying and harvesting.

From this work it is concluded that it will probably be easier to raise the sugar yield of existing high yielding varieties by altering the proportioning of photosynthate in favour of sucrose storage, rather than by increasing cane yield.

CHAPTER I

GENERAL INTRODUCTION

1.1 Motivation

To counteract rapidly rising costs of production, sugarcane farmers in South Africa must either receive a higher price for their sugar, obtain higher yields of sugar per hectare, or utilize their resources more efficiently.

Prices received by South African sugar producers increase slowly because the local retail price of sugar is Government controlled, and much of the sugar exported is under long term agreements in which the price is fixed for a specified period. It is therefore necessary for farmers to try to obtain the highest possible yield of sugar per unit of invested capital in order either to maintain or improve their profit margins.

In this thesis ways of modifying management practices in order to increase sugar yield per hectare per unit time have been investigated. An assessment has also been made of the potential for further increasing the yields of South African sugarcane varieties.

It is a relatively easy task to improve crop yields when they are low, by such practices as improved fertilization and better weed control, but with the adoption of better cultural practices and the attainment of higher yields it becomes more difficult to improve them further. Many soil, plant and weather factors affect crop yields, and it may be possible to improve existing yields in any one of several ways. In the work reported in this thesis every attempt has been made to ensure that a shortage of moisture or nutrients did not restrict growth because these are factors that can be supplemented, although it may not always be economic to do so.

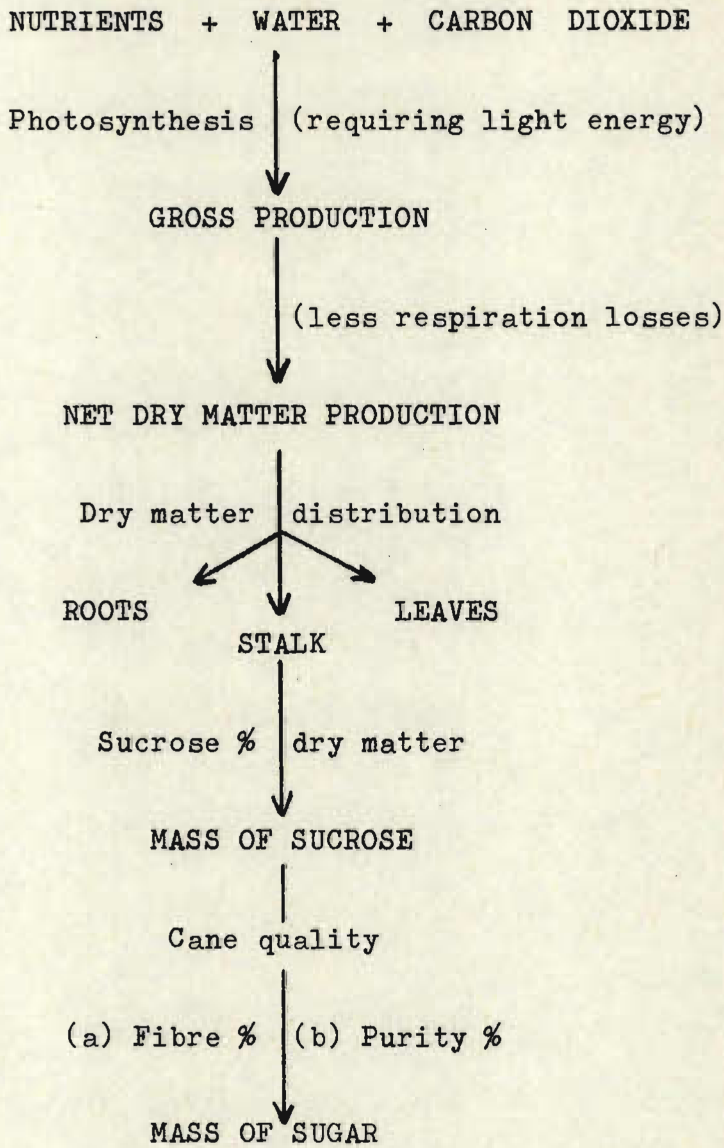


Fig. 1 Diagrammatic representation of the production of sugar

From the simple representation of sugar production in Fig. 1 it can be seen that sugar yield may be improved in any one of the following ways:-

(a) By increasing net dry matter production by the sugarcane plant

(b) By increasing the proportion of this dry matter that is contained in the stalk

(c) By increasing the proportion of sucrose in the stalk

(d) By increasing the proportion of this sucrose that can be recovered from the stalk.

Under favourable growing conditions sugarcane has a high rate of dry matter production and is one of the most efficient crop plants in converting radiant energy into plant material (Burr _et al_, 1957; Westlake, 1963). In other crops, such as lucerne (Pearce _et al_,1969), Soyabean (Dornhoff and Shibles, 1970), and maize (Heichel and Musgrave, 1969; Pendleton _et al_. 1968; and Duncan, 1971) attempts have been made to improve crop yields by selecting for high rates of photosynthesis and an upright leaf growth habit. Results have been generally disappointing (Moss and Musgrave, 1971) and it seems unlikely that such an approach would be any more successful in sugarcane.

Implicit in work of this nature is the assumption that an improvement in the rate of photosynthesis per unit leaf area will result in an increase in the economic yield of the crop. It is possible that this assumption may not be true, and in the case of sugarcane it might also be difficult to improve the rate of photosynthesis beyond the present high rate of commercial varieties, (Hesketh and Moss, 1963; Irvine, 1967; and Bull, 1969). Bull (1971) concluded that rapid rates of growth in sugarcane were related more to rapid rates of canopy development, a tolerance to high temperatures and an extended growing season, than to the occurrence of the efficient C_4 pathway of CO_2 assimilation in this plant (Hatch and Slack, 1966).

Successful South African sugarcane varieties have high populations of stalks per unit area with fairly upright leaves that are steadily replaced at the top of the canopy as older leaves senesce at the bottom. The relatively close row spacing of sugarcane in South Africa, the use of excessive amounts of planting material (Boyce, 1970) and the growth of one sugarcane crop from the stubble of the previous crop should ensure that optimum stalk populations develop naturally when disease is absent and water and nutrients are non-limiting. In the absence of flowering, sugarcane plants have what Blackman (1962) considered the most efficient arrangement of leaves for dry matter production. The upper leaves, which are the most efficient in CO_2 assimilation (Bull, 1971), receive most light but because of the steep angle at which they are subtended from the stalk they also permit light to penetrate easily into the canopy when the sun is high and light saturation of individual leaves most likely to occur (Hesketh and Moss, 1963). Light is then intercepted progressively more efficiently by the horizontal display of leaves in the lower part of the canopy. Under these conditions the dry matter production of varieties with green-leaf area indices sufficiently large to permit complete radiant energy interception, and similar rates of photosynthesis per unit leaf area, will probably vary with the time taken to establish a full canopy of leaves, assuming that at full canopy total plant dry mass and therefore subsequent respiration losses are similar.

The growth of sugarcane, and therefore sugar yield is ultimately controlled by the genetic constitution of the plant, with which soil and weather factors interact to determine the total amount of carbohydrate available for growth and for storage as sucrose. The balance between the plant's requirement of carbohydrate for growth and storage, is controlled by an interplay of plant growth hormones, about which relatively little is known (Glasziou, 1969).

This thesis investigates some of the agronomic aspects of sugar production in relation to weather conditions, the age of the crop at harvest, and the artificial regulation of growth and ripening by the application of chemicals to the crop.

1.2 Scope of the thesis

It was concluded from the literature on the growth of sugarcane and other crops that it might be easier to increase sugar yield per unit of land area by improving the proportion of dry matter converted into sucrose than by increasing the net amount of dry matter produced. A programme of work was undertaken, therefore, in order to confirm this conclusion, to obtain a better understanding of the effects of weather conditions and age of harvest on yields, and to try to determine promising avenues for further research.

The objectives of this work were:-

(a) To study the effect of weather conditions and the age at which the crop was harvested on cane and sugar yield.

(b) To measure the apparent maximum yield of varieties currently grown in South Africa.

(c) To compare the maximum yields of cane obtainable from these varieties with theoretical maximum yields, calculated from the amount of radiant energy available for growth.

(d) To investigate the use of growth regulating compounds to improve cane quality and increase sugar yield.

The results of these investigations have been presented in three separate parts. In the first part, the relationship between the age of the crop at harvest and cane and sugar yields was examined in a series of crops that began to grow at different times of the year. In the second part, the growth and development of three commercial varieties was studied: apparent maximum cane yields were measured, root development was observed and patterns of radiant energy interception by the green leaf canopy of two of the varieties were determined. As a result of the investigations in the first two parts of the thesis a series of experiments was undertaken in which a study was made of the chemical regulation of sucrose production and this is presented in the third part.

CHAPTER 2

THE EFFECTS OF AGE AND TIME OF HARVEST ON THE PRODUCTIVITY OF IRRIGATED SUGARCANE

2.1 Introduction

Sugarcane may be harvested at any time of the year in South Africa because flowering and frost seldom affect the crop sufficiently to restrict harvesting to a specific time. Sugarcane crops can therefore be cut at any age. It is, however, difficult to decide the order in which fields should be cut so that the sucrose concentration of the cane stalks and the yield of sugar per unit area per unit time will be maximised over the whole farm.

The average sucrose percentage of sugarcane for the South African sugar industry varies tremendously with the time of the year (Fig. 2), and the sugar mills usually close during summer when growth

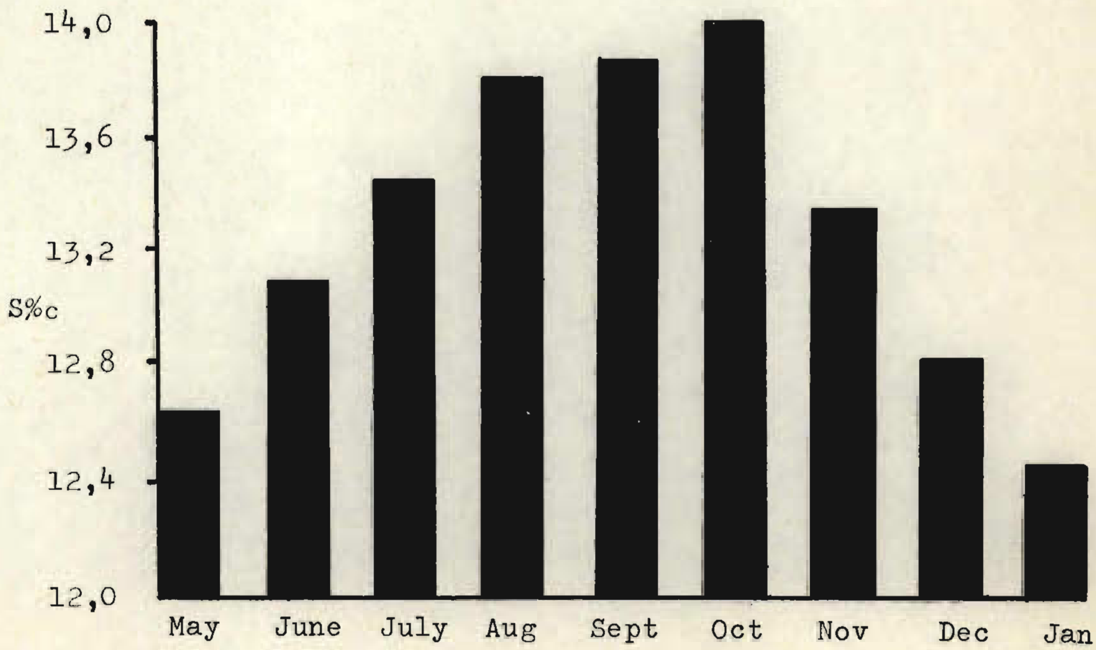


Fig. 2 Mean monthly sucrose percent cane fresh mass for all South African sugar mills, 1963-1972.

is rapid, the sucrose percentage of the stalk is low, and it is difficult to recover the sucrose from the crop.

The age at which crops are harvested usually ranges from 10-17 months in the northern irrigated areas, where growth is rapid, to 16-30 months in the colder midlands area. The productivity of both irrigated and rain-grown crops declines with increasing age (Borden and Denison, 1942; Gosnell, 1967; and May and Middleton, 1972) and a stage is reached in all crops when it is better to cut the existing crop in order to benefit from the faster growth rate of the following ratoon crop.

In many experiments the effects of age and weather conditions on yield are confounded. For example, the higher yields of sugar reported by Pearson (1965) from crops cut every 12 months rather than at 16, 20 or 24 monthly intervals, was in part due to the 16 and 20 month crops ratooning at a less favourable time of year than the 12 month crops. Similarly, Shaw and Innes (1965) found that the highest yields of cane were obtained from 12 month old crops of sugarcane that began to grow at a time of year when radiation intensity and temperatures were highest. Data presented by Clements, Shigeura and Akamine (1952), and Clements, Putman and Yee (1968) demonstrate very clearly the dependence of the growth of sugarcane on both age and weather conditions when moisture and nutrient supplies are adequate. Moberly (1971) found that under irrigated conditions an 18 month cycle alternating between May and November gave higher yields of sugar over a three year period than did the average of 12 month crops ratooned in both May and November.

Thus, it is evident that in attempting to determine the optimum time to harvest a crop of sugarcane, careful attention must be paid to both the age of the crop and the cycle of weather conditions through which it has grown.

Following a detailed study of the growth of a sugarcane crop by Gosnell (1967), which showed that age was an important determinant of a crop's ability to respond to favourable growing conditions, the experiment described in this chapter was designed and planted by staff of the Experiment Station of the South African Sugar Association. Preliminary investigations into the uniformity of ratoon crops of sugarcane by the author when he assumed control of the project, shortly before the first plant crop was harvested, indicated that sub-plots for yield estimates would have to be made larger than initially envisaged. This meant that it was not possible to undertake one of the original objectives of the investigation, which was to try to relate increments of growth throughout the life of a number of crops to weather conditions. The experiment was therefore converted into a time of harvest experiment.

The experiment was established on a fertile soil at the Pongola station of the South African Sugar Association (Lat. 27^{o} 31'S Longt. 31^{o}37'E) and was fully irrigated. The main part of the experiment was carried out on the first ratoon crop of a series of eight plantings made at regular intervals throughout the year. Yield data from the plant crops, which were harvested at similar ages, were also recorded.

2.2 Materials and methods

A randomised block experiment with split plots was established by making eight plantings of variety NCo 376 at intervals of seven weeks between 8 November 1967 (Planting 1) and 16 October 1968 (Planting 8). The main plots (plantings) were sub-divided in the first ratoon crop for harvest at intervals of eight weeks, between 32 and 72 weeks of age.

Each main plot was 404 m^2 in size and at harvest cane yield was recorded from 42 m^2 per plot. The sub-plots comprised three rows, each 5,5 m long and spaced 1,5 m apart (25 m^2). The discard area between plots was sufficient to prevent any shading of one planting by another.

The layout of the experiment is presented in Appendix 1, Fig. 1 and from the dates of planting and harvesting in Table 1 it can be seen that at each sample harvest a series of plots of various ages were harvested. It was possible, therefore, to compare both the patterns of growth of crops that began to grow at different times of the year, and the increments of growth of crops of different ages over the same period of time.

The age at harvest of the successive plant crops was increased by one week in order to increase the interval between the time that ratoon crops began to grow from seven to eight weeks. This meant that the eight crops covered more than one calendar year: the ratoon crops of Plantings 1 and 2 began to grow in December 1968 and February 1969, respectively, whilst Planting 8 began to grow in January 1970.

The experiment was on a deep red loam soil of the Makatini series and details of the chemical and physical analyses are given in Appendix I, Table 1. The plant crops were fertilized with a total of 224 kg N, 93 kg P and 56 kg K per hectare, which is a high rate of application for this soil, and the ratoon crops were top-dressed with 224 kg/ha N, to try to ensure that sufficient nutrients were available for maximum growth.

TABLE 1 Dates of planting, harvesting plant crops and sampling ratoon crops

Planting Number	1	2	3	4	5	6	7	8
PLANT CROP Planted	8/11/67	27/12/67	14/2/68	3/4/68	22/5/68	10/7/68	28/8/68	16/10/68
Harvested	17/12/68	11/2/69	8/4/69	3/6/69	29/7/69	23/9/69	18/11/69	13/1/70
(age in weeks)	(58)	(59)	(60)	(61)	(62)	(63)	(64)	(65)
RATOON CROPS Sample 1	29/7/69 (32)							
2	23/9/69 (40)	23/9/69 (32)						
3	18/11/69 (48)	18/11/69 (40)	18/11/69 (32)					
4	13/1/70 (56)	13/1/70 (48)	13/1/70 (40)	13/1/70 (32)				
5	10/3/70 (64)	10/3/70 (56)	10/3/70 (48)	10/3/70 (40)	10/3/70 (32)			
6	5/5/70 (72)	5/5/70 (64)	5/5/70 (56)	5/5/70 (48)	5/5/70 (40)	5/5/70 (32)		
7		30/6/70 (72)	30/6/70 (64)	30/6/70 (56)	30/6/70 (48)	30/6/70 (40)	30/6/70 (32)	
8			25/8/70 (72)	25/8/70 (64)	25/8/70 (56)	25/8/70 (48)	25/8/70 (40)	25/8/70 (32)
9				20/10/70 (72)	20/10/70 (64)	20/10/70 (56)	20/10/70 (48)	20/10/70 (40)
10					15/12/70 (72)	15/12/70 (64)	15/12/70 (56)	15/12/70 (48)
11						9/2/71 (72)	9/2/71 (64)	9/2/71 (56)
12							6/4/71 (72)	6/4/71 (64)
13								29/5/71 (72)

Irrigation, which was by overhead sprinkler, was more than adequate to replace the evapotranspiration from the crop, estimated from lysimeter studies (Thompson, Pearson and Cleasby, 1963). The crops were not dried off and irrigation was continued until just before harvest. Plant crops were not burnt but all trash was removed from the plots in order to improve the uniformity of germination of the ratoon crops. On a number of occasions the moisture content of sheaths of leaves 3-6 was determined in Plantings 6-8 by taking samples from eight stalks per plot and drying them to constant weight.

At irregular intervals of time until the ratoon crops were 32 weeks old counts were made of the number of shoots per sub-plot. Similarly, stalk height was measured from the top of a fixed peg to the uppermost visible leaf collar (TVD) on 10 stalks in each sub-plot. The development of ground cover was also estimated in Plantings 1-4 with a modified vertical point quadrat (Cackett, 1964).

At harvest, a discard area was removed from each plot and the mass of cane from the net plot area recorded. At the 32 week sample harvest, when most of the sugarcane was short, the stalks were topped by hand by breaking the stalk at the base of the sheath attached to the sixth leaf that was more than half unfurled (node 6). All other samples were topped with a knife in the normal manner. The number of stalks per plot was counted and a sample of one in 20 was measured for length and diameter at the top, middle and bottom. From these a random sample of 10 stalks per plot was removed for analysis.

The samples for analysis were weighed, completely disintegrated with a modified wood planing machine and sub-sampled. Four hundred grammes of the disintegrated material were dried to constant mass and another 500 g were homogenised with 1 l of water in an Ultra-turrax blender for three minutes at 1 000 rpm. The solution was then sub-sampled and the amount of soluble solids (brix) in the filtrate determined with a Zeiss refractometer. The sucrose concentration of the filtrate was estimated by measuring the optical rotation of the sugar solution with a saccharimeter, after the solution had been clarified with lead sub-acetate (Anon, 1971a). Juice purity and an estimate of the recoverable sugar in cane (ers) were calculated using the following formulae. The ers formula was obtained from the South African Sugar Millers Association Report (1968).

$$\text{Juice purity} = \frac{\text{Mass of S in juice}}{\text{Mass of brix in juice}} \times 100$$

$$\text{Ers} = S - 0{,}485\ (\text{brix} - S) - 0{,}056\ \text{fibre}$$

where S is sucrose and

brix is total dissolved solids

Weather data were obtained from a standard meteorological station situated about 50 m from the experiment. Daily radiation was estimated from sunshine records (Glover and McCulloch, 1958 ; Anon, 1964) and periodic checks on the calculated values were made with a Kipp solarimeter.

2.3 Plant crop harvest results

The results of the plant crop harvests are presented in Fig. 3. Cane yields of the crops varied with the cropping cycle. Planting in November and harvesting in December produced the lowest yield of 133 tonnes cane per hectare (tc/ha), and the February planting (harvested in April) gave the highest yield of 244 tc/ha. The October and November plantings were the only ones to produce new, non-millable (bull) shoots, which weighed 15,9 and 5,9 tc/ha, respectively.

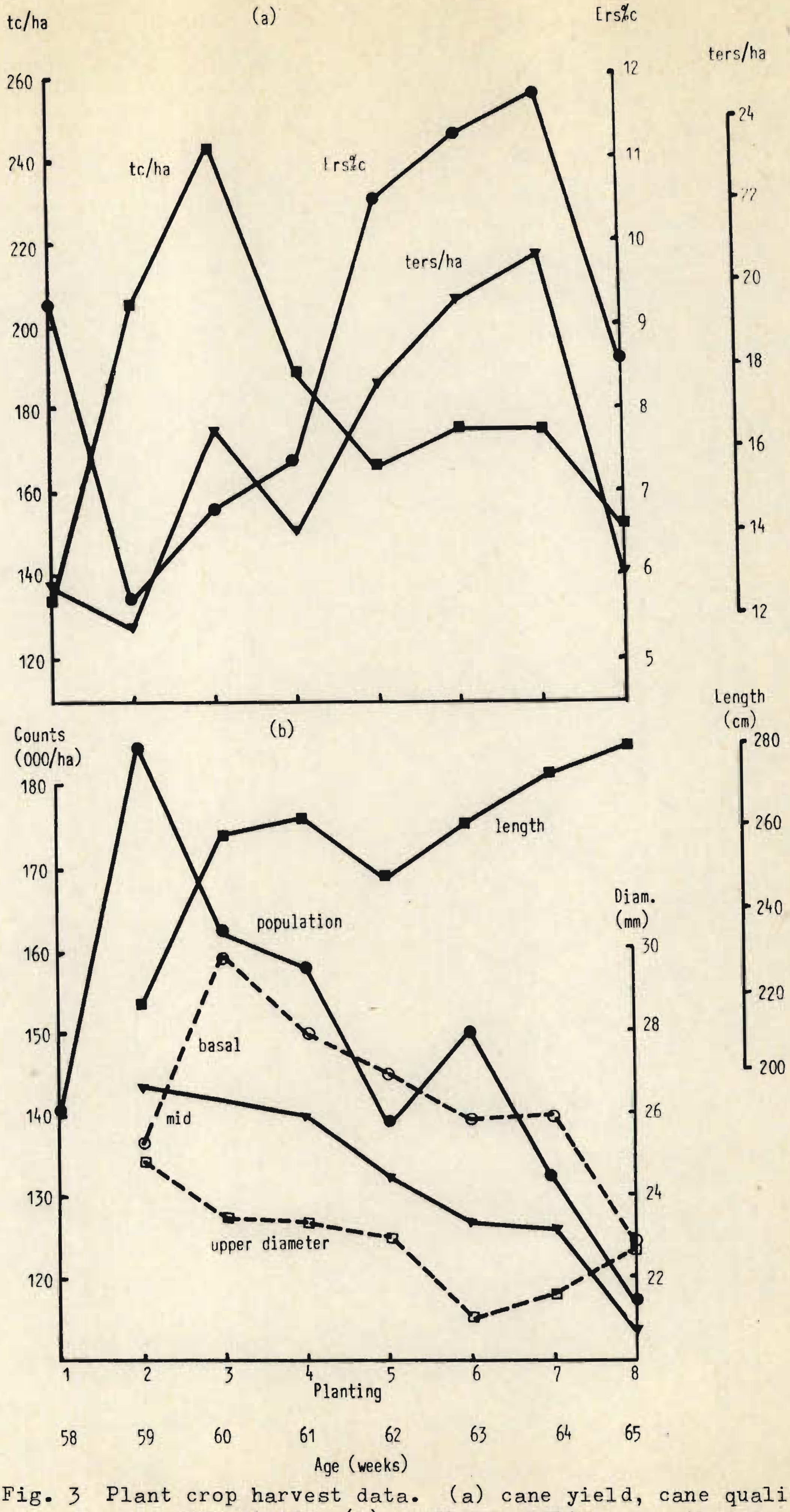


Fig. 3 Plant crop harvest data. (a) cane yield, cane quality and sugar yield. (b) stalk population, length and diameter at upper middle and lower positions.

The percentage estimated recoverable sugar (Ers % c) followed the expected seasonal pattern (Fig. 2) with a gradual change from a minimum value of 5,7% for a crop harvested in February to a maximum of 11,8% for a crop harvested in November (Fig. 3a). For crops harvested between February and June, fluctuations in sugar yield per hectare (ters/ha) resembled fluctuations in cane yield, but at other times of the year ters/ha appeared to be related to Ers % c (Fig. 3a).

The maximum sugar yield of 21 ters/ha was obtained from a crop which was planted in August and harvested in November when it was 64 weeks old. The lowest yield of 12 ters/ha was from a December crop that was harvested in February, when it was 59 weeks old. Measurements of harvested stalks did not correlate well with cane yield, but the crops that had the highest yields of cane, which were those planted between December and April, had high populations of thick stalks (Fig. 3b).

2.4 <u>First ratoon crop results</u>

The presentation and interpretation of these results are not easy because of the large amount of data involved and because it is not possible to separate completely the effects of age and weather conditions on growth and productivity.

Most of the data have been analysed statistically and an example of the analysis of variance for tc/ha is given in Appendix I, Table 2. It should be noted that average values for a planting or for an age at which crops were sample-harvested have little meaning in this experiment because of the diversity of the data contributing to these means.

Following the presentation of weather data (Section 2.4.1) and information about the moisture and nutrient status of the crops

(Section 2.4.2), the main results have been presented in the following order. Details are given in Sections 2.4.3 to 2.4.5 of shoot populations, stalk elongation, stalk dimensions at harvest and lodging of the crops. Cane yields are then presented in Section 2.4.6 and discussed in relation to crop age and crop size (Section 2.4.7) and to weather conditions (Section 2.4.8). Following this, changes in cane quality (Section 2.4.9) lead into yields of estimated recoverable sugar (Section 2.4.10) and finally, the relationships between cane yield, cane quality and sugar yield (Section 2.4.11).

2.4.1 Weather data

Details of the weather during the main part of the experiment, presented in Fig. 4, show that air temperatures and radi-

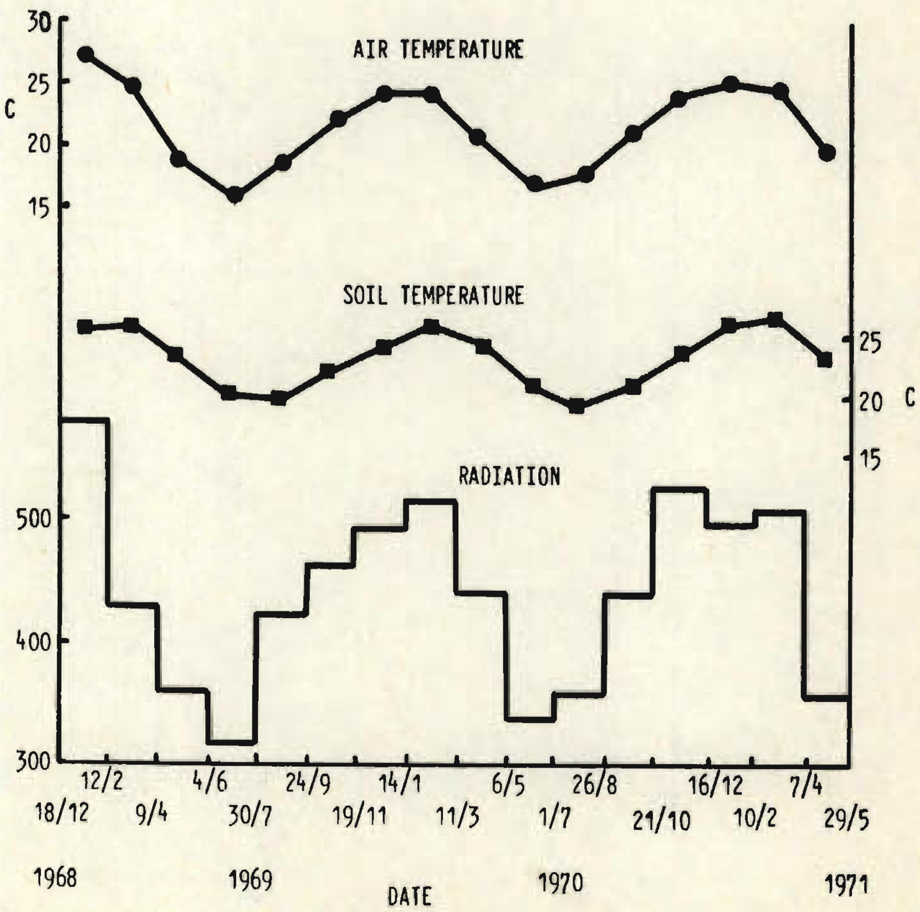


Fig. 4 Variation in mean daily radiation, 8 a.m. soil temperature at 100 cm depth and mean daily air temperature for eight-weekly periods of time during the experiment.

ation were closely correlated and that weather conditions were remarkably similar from one year to the next. Data for weather conditions during the first 32 weeks of ratoon crop growth and the eight-weekly intervals between harvests are given in Appendix I, Table 3. Average weather data for cumulative periods of time are given in Appendix I, Table 4.

2.4.2 Nutrient and moisture status

The nutrient concentration of all laminae samples was either equal to, or higher than those of Planting 8 given in Appendix I, Table 5. There was little change in the concentration of the major nutrients in any planting after 32 weeks of age and there was no indication of a deficiency of nutrients at any stage of growth, when compared with the unpublished standards of the Chemistry Department of the South African Sugar Association Experiment Station. Similarly, soil moisture appeared to be adequate for good growth because sheath moisture content was between 80 and 83% on all sampling occasions, which, as a result of work over a number of years, Clements, Shigeura and Akamine (1952) regard as satisfactory for maximum growth.

2.4.3 Growth measurements

Changes in shoot population and the rate of shoot elongation are presented in Fig. 5. To improve the clarity of Fig. 5a curves for Plantings 5 and 7, which were intermediate between Plantings 4, 6 and 1, have been omitted. Shoot population, shoot elongation and the time taken to reach full ground cover (90% of ground area shaded by leaves) varied with the time of year at which the crops began to grow.

Crops that began to grow between December and February (Plantings 1, 2 and 8), when total radiation and temperatures were

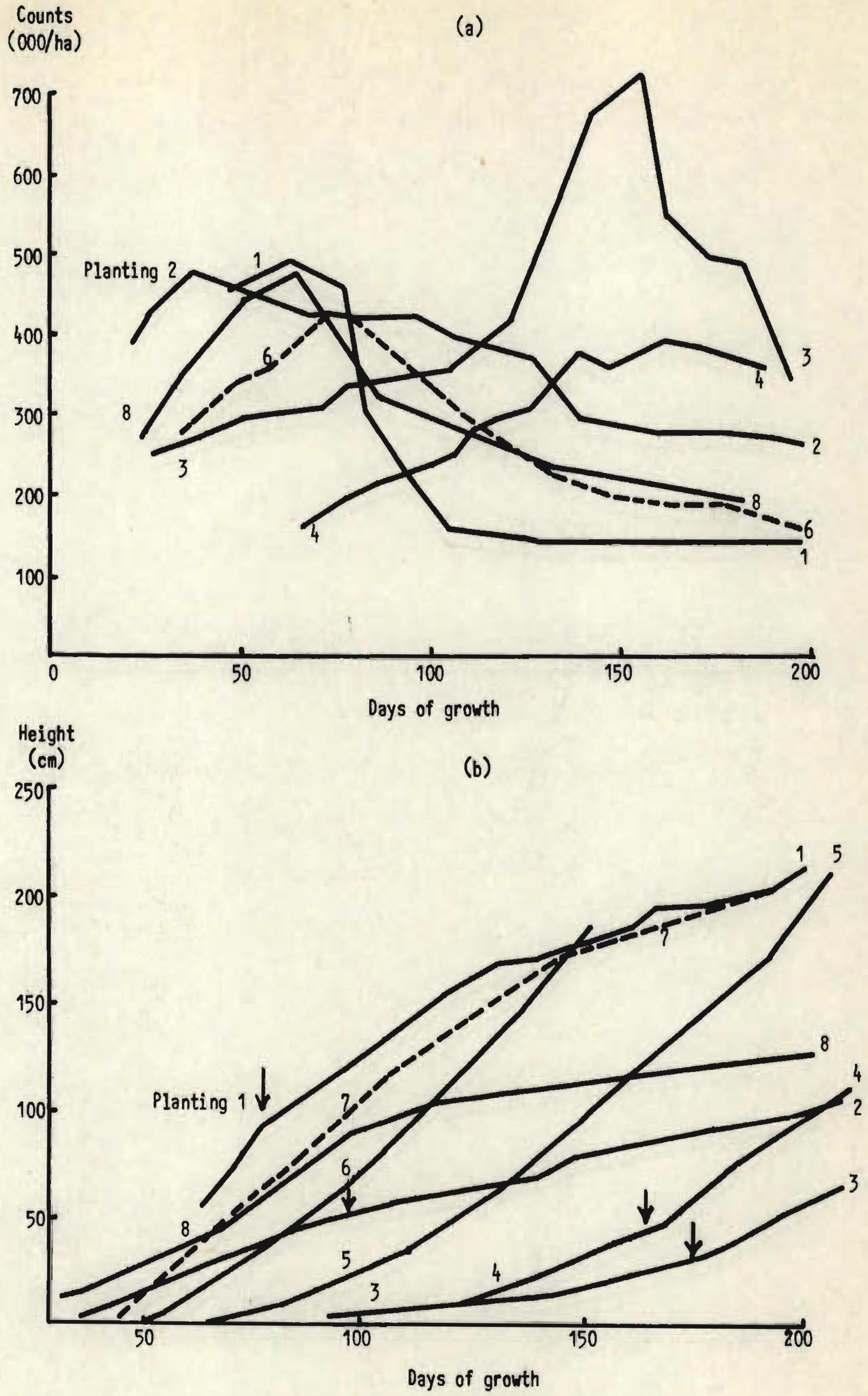


Fig. 5 (a) Shoot counts per hectare (b) Height per shoot of first ratoon crops that began to grow at different times of the year. Plantings 5 and 7 omitted from (a) to improve the clarity of the figure. ↓ Full ground cover reached.

high (Fig. 4) exhibited early peak populations of 480-500 thousand shoots per hectare at 1-2 months of age (Fig. 5a). The population of the December planting fell sharply as surviving shoots elongated rapidly and full ground cover was achieved in 77 days. In the January and February plantings the rate of elongation was much slower than in the December crop, full ground cover was reached relatively later and the decline in shoot population was more gradual. Crops that ratooned in April and June (Plantings 3 and 4) elongated very slowly and reached peak shoot populations and full ground cover at about five months of age.

There was a gradual change in the characteristics of the crops ratooned after June, as the weather became warmer. Rates of shoot elongation increased (from Planting 5 to 6 to 7); peak populations occurred sooner, and the rate of population decline became steeper. The high, late peak population of the crop ratooned in April (Fig. 5a) was not confirmed by check counts done on second ratoon crops that also began to grow in April.

2.4.4 Stalk measurements at harvest

Changes in stalk length, stalk population and mean stalk diameter are shown in Fig. 6 and 7. The data for top, middle and lower stalk diameters, from which the mean values were calculated are given in Appendix I, Table 6.

The population of harvested stalks in all crops fell with increasing age (Fig. 6a). Plantings 1, 2, 7 and 8, which ratooned during summer (November-February), generally had higher populations at all ages than plantings that ratooned during winter. The December, January and February crops had very high populations at 32 weeks of age but these declined rapidly as the stalks elongated during the following summer.

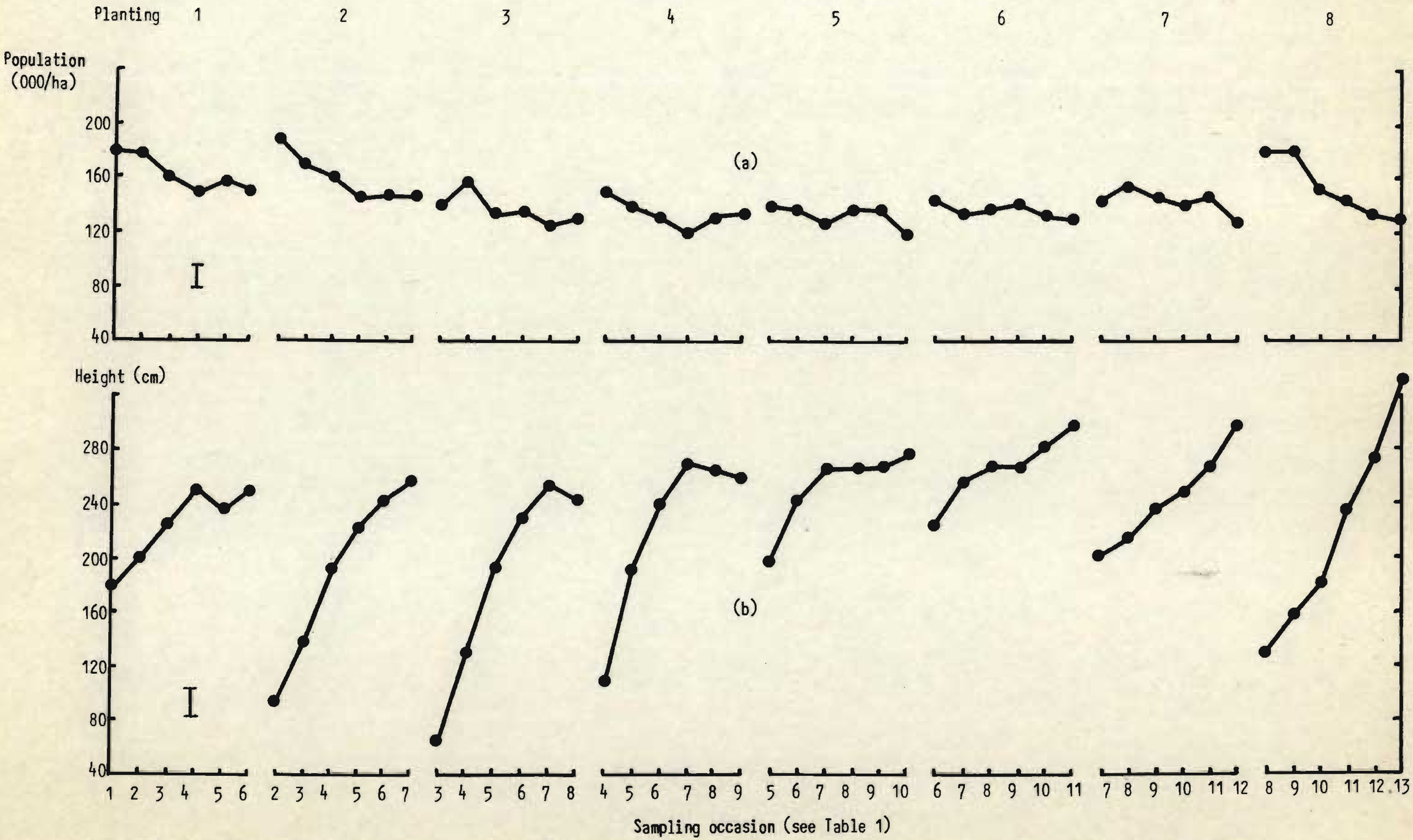


Fig. 6 Ratoon crop harvest data (a) stalk population per hectare (b) average stalk height
L.S.D. (P = 0.05) within plantings I

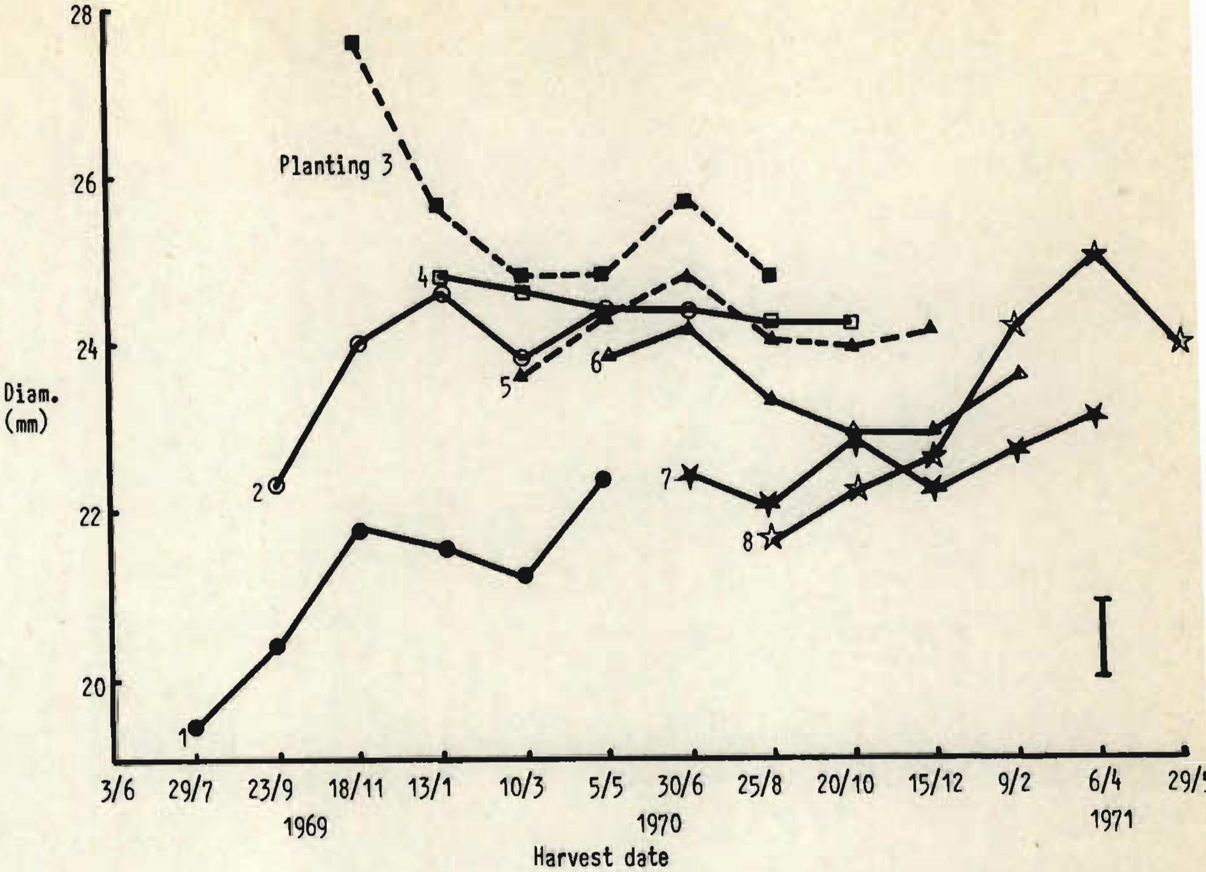


Fig. 7 Ratoon crop harvest data: mean stalk diameter. I = (P=0,05) within plantings.

Stalk length increased rapidly during summer (Fig. 6b) and then generally levelled off at about 260 cm per stalk as the crops aged and winter conditions were experienced. In the case of Plantings 6, 7 and 8, which did not appear to follow this general pattern, there was appreciable death of stalks prior to the later samplings and the death of these, the smaller stalks, would result in an apparent increase in the average length and diameter of the remaining stalks.

There was no further increase in stalk length in Planting 1 after 56 weeks of age, despite favourable weather conditions, and this cessation of stalk growth was associated with lodging and the rapid development of bull shoots. Differences in mean stalk diameter (Fig. 7) on most sampling occasions were inversely related to stalk populations (Fig. 6a) and this relationship was generally maintained throughout the experiment. Planting 1 (December) had the thinnest stalks and planting 3 (April) the thickest.

2.4.5 Lodging

All crops lodged badly, but the age at which lodging occurred and the increase in cane fresh mass yield (tc/ha) after the crops lodged, varied appreciably (Table 2). Lodging was most severe in Planting 1, and Plantings 1 and 7 (December and November) were the only ones to produce bull shoots. The dry mass of bull shoots at 72 weeks of age was 10 tonnes cane dry matter per hectare (tc.dm/ha) in Planting 1, and 2 tc.dm/ha in Planting 7.

TABLE 2 Age and time of year at which first ratoon crops lodged

Planting Date ratooned	1 18/12	2 12/2	3 9/4	4 4/6	5 30/7	6 24/9	7 19/11	8 14/1
Age at lodging (weeks)	40	56	48	56	56	56	52	56
Time of year	Sept.	Mar.	Mar.	June	Aug.	Oct.	Nov.	Feb.
% tc/ha increase after lodging	8	14	10	-4	1	7	14	16

2.4.6 Cane yields

The growth curves for the plantings were similar, whether measured as tc/ha or tc.dm/ha (Fig. 8 and 9), except that the increase in tc.dm/ha in plantings 3-6 between 56 and 72 weeks of age (Fig. 9a) could not be detected in terms of tc/ha (Fig. 8a) because of a simultaneous decline in the moisture content of the cane stalk.

The pattern of increase in cane yield from one planting to the next (Fig. 9a) varied in a systematic manner: from Plantings 2 and 8 (February and January), in which there were linear and statistically significant increases in tc.dm/ha up to 64 weeks of

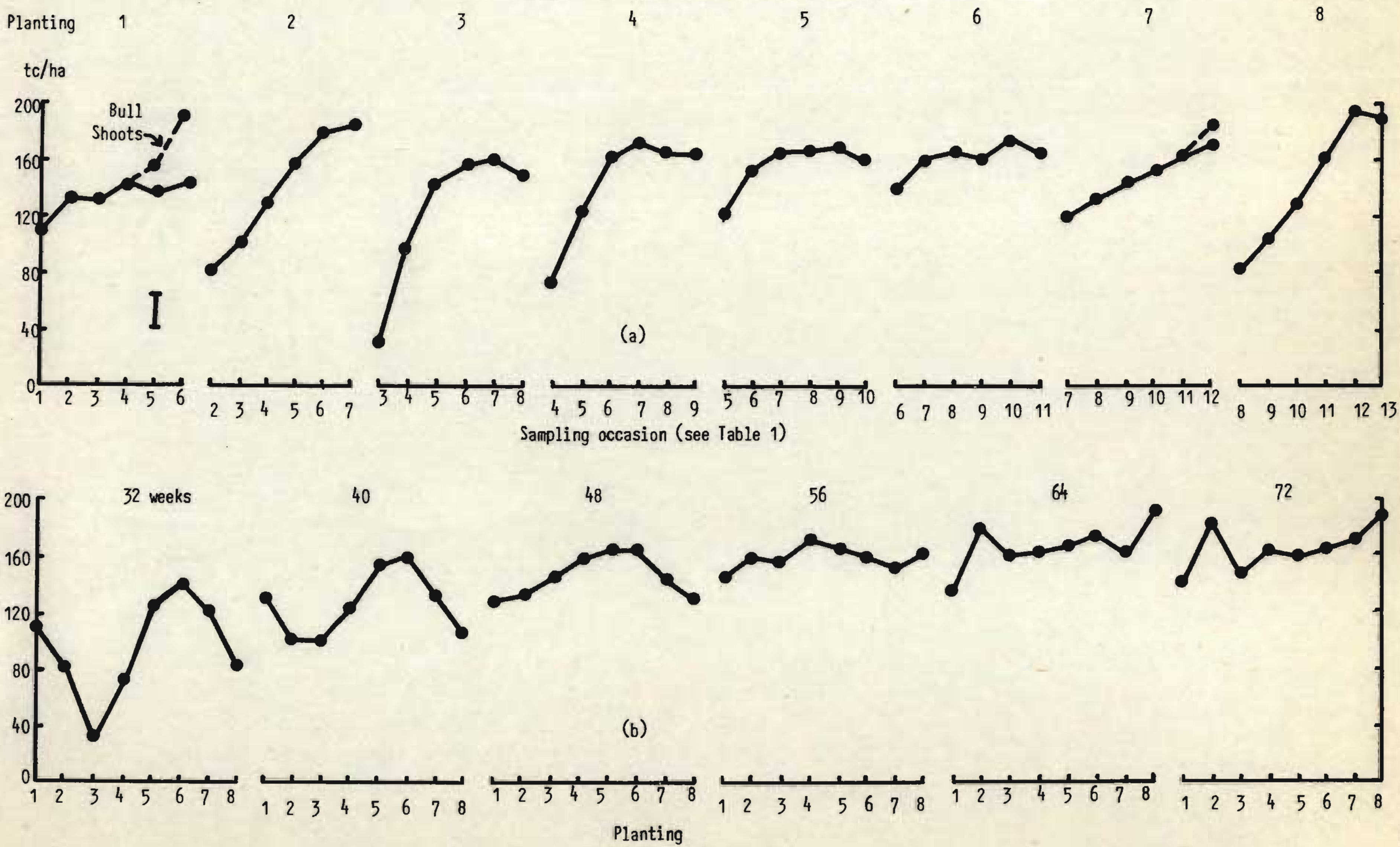


Fig. 8 Cane fresh mass yield. (a) By plantings (b) By ages. L.S.D. (0,05) within plantings I

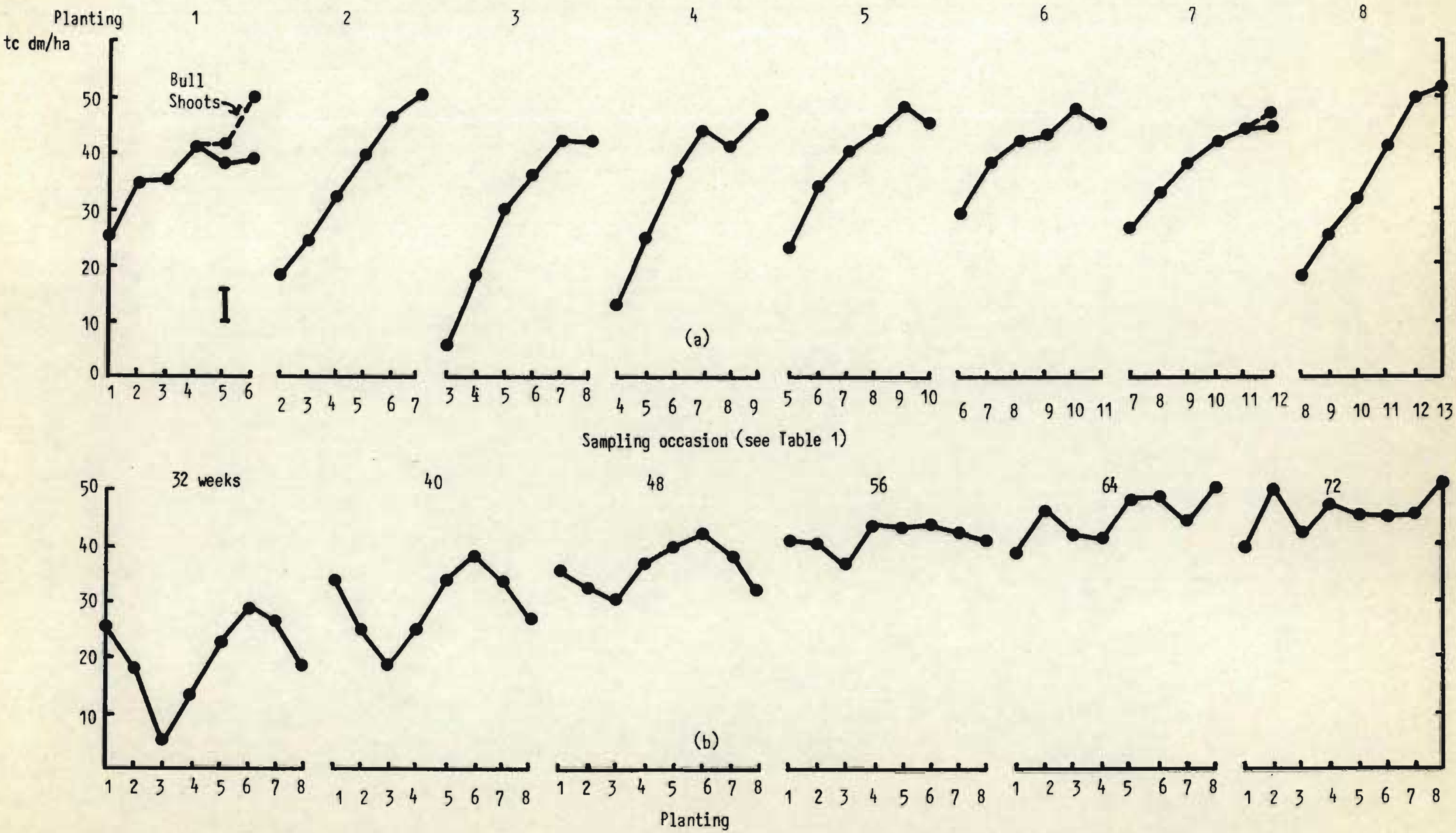


Fig. 9 Cane dry mass yield. (a) By plantings (b) By ages. L.S.D. (0,05) within plantings I

age, to Plantings 3-7 (April to November), in which yield increase was curvilinear, with relatively little increase in tc.dm/ha after 56 weeks of age.

Planting 1 (December) was unique in that the yield curve for the original cane stalks resembled that of Plantings 4-7 (Fig. 9a), but when the mass of bull shoots was included, the increase in mass with time of harvest was linear and approximated that of Plantings 2 and 8. The maximum total stalk yield of 50 tc.dm/ha was also similar to that of these two plantings.

Cane yields at 32, 40 and 48 weeks of age (Fig. 8b and 9b) varied from planting to planting, according to the time of year when they began to grow and therefore whether they had grown through a preponderance of summer or winter conditions. At 52 weeks of age (estimated from the average of 48 and 56 week samples), when all crops had experienced the same weather conditions, the September planting had the highest yield of 43 tc.dm/ha (162 tc/ha). This was followed by the July planting with 42 tc.dm/ha (166 tc/ha) and the June and November plantings with 40 tc.dm/ha (166-148 tc/ha, respectively).

As indicated above, the initial rapid rate of increase in cane yield was not maintained in Plantings 3-7 and the maximum yields in the experiment (excluding bull shoots) of 50-52 tc.dm/ha (184-189 tc/ha) came from the January and February plantings, which had produced only 36 tc.dm/ha (146 tc/ha) at 52 weeks of age.

Examination of cane yield increments (Fig. 10) showed that young sugarcane crops responded more to favourable growing conditions (indicated by higher temperatures) than older crops. It was also observed that as the crops became older, so the maximum increment of growth occurred later in the growing season.

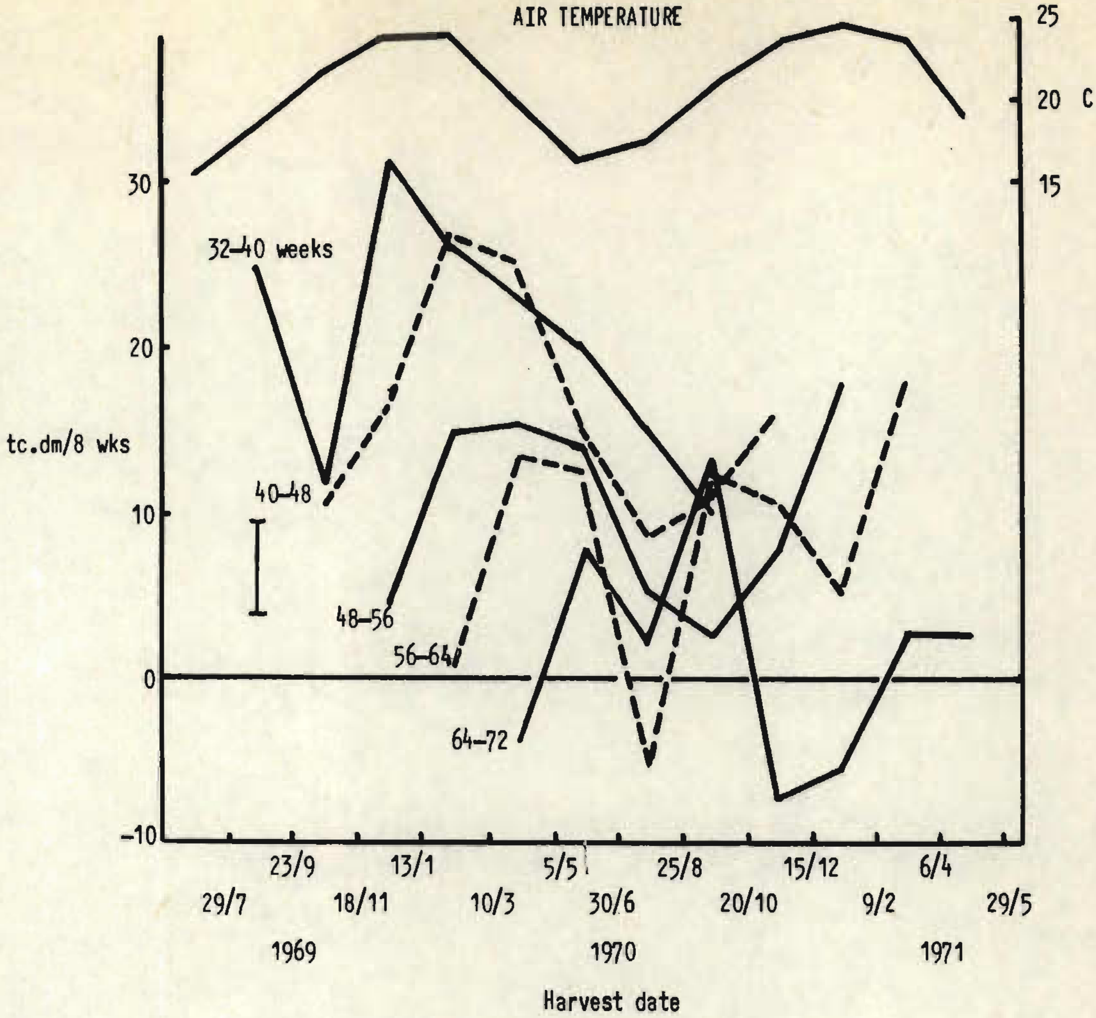


Fig. 10 Mean daily air temperature and eight-weekly cane dry matter increments for sugarcane of different ages. I = L.S.D. (P = 0,05) within plantings.

2.4.7 Cane yield increments, age and crop size

Increments of cane yield declined as crops became older (Fig. 11) or bigger (Fig. 12) at all times of the year except August to October. When all the data were combined, crop size (Fig. 14) was found to be a better indicator of a crop's potential for further growth than crop age (Fig. 13). Nevertheless the quadratic regression equation

$$y = 10{,}776 + 0{,}061x + 0{,}006x^2$$

relating initial cane dry mass yield (x) and subsequent yield increment (y) accounted for only 63% of the total variability

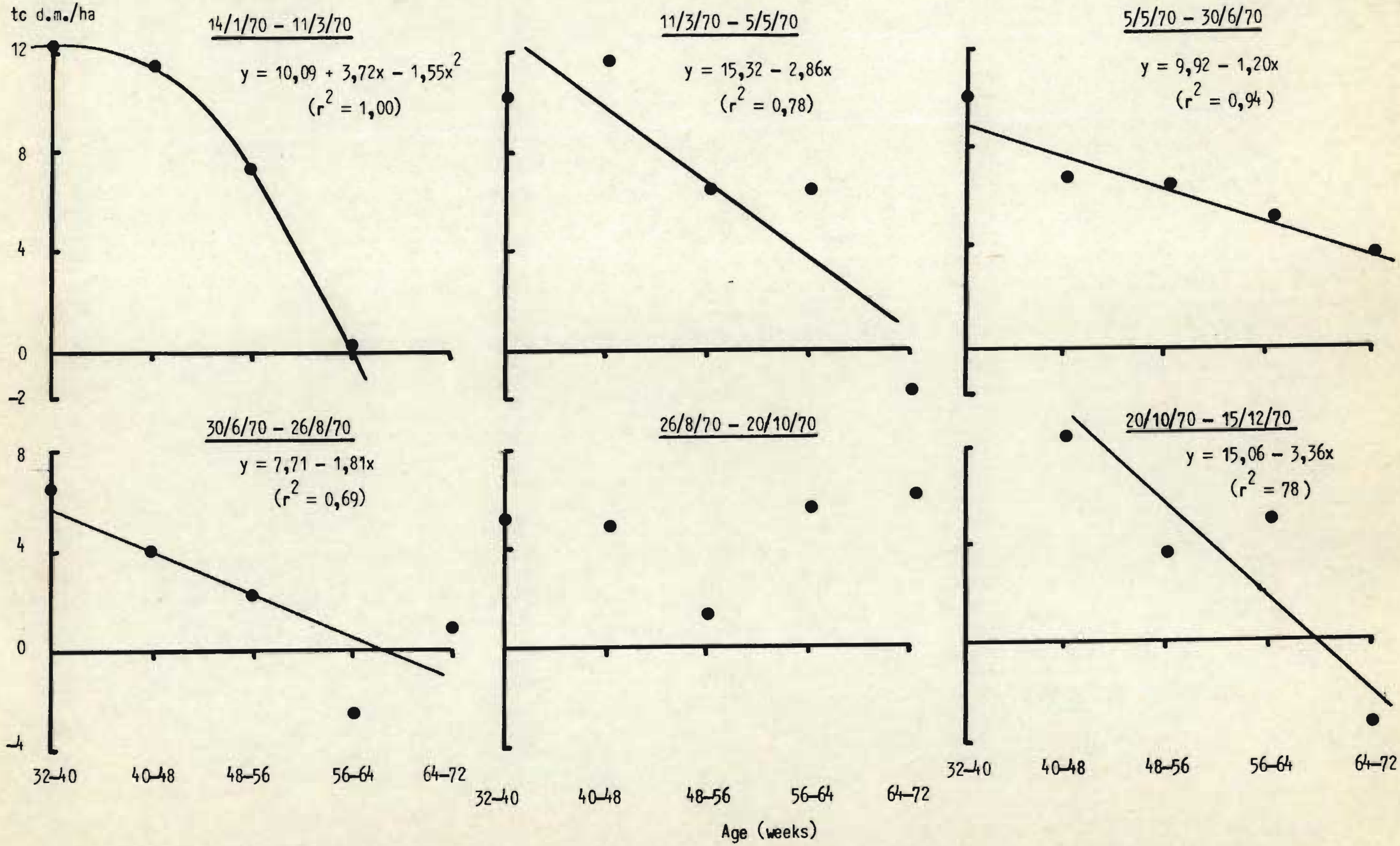


Fig. 11 The relationship between crop age at harvest and cane dry matter increment at different times of the year.

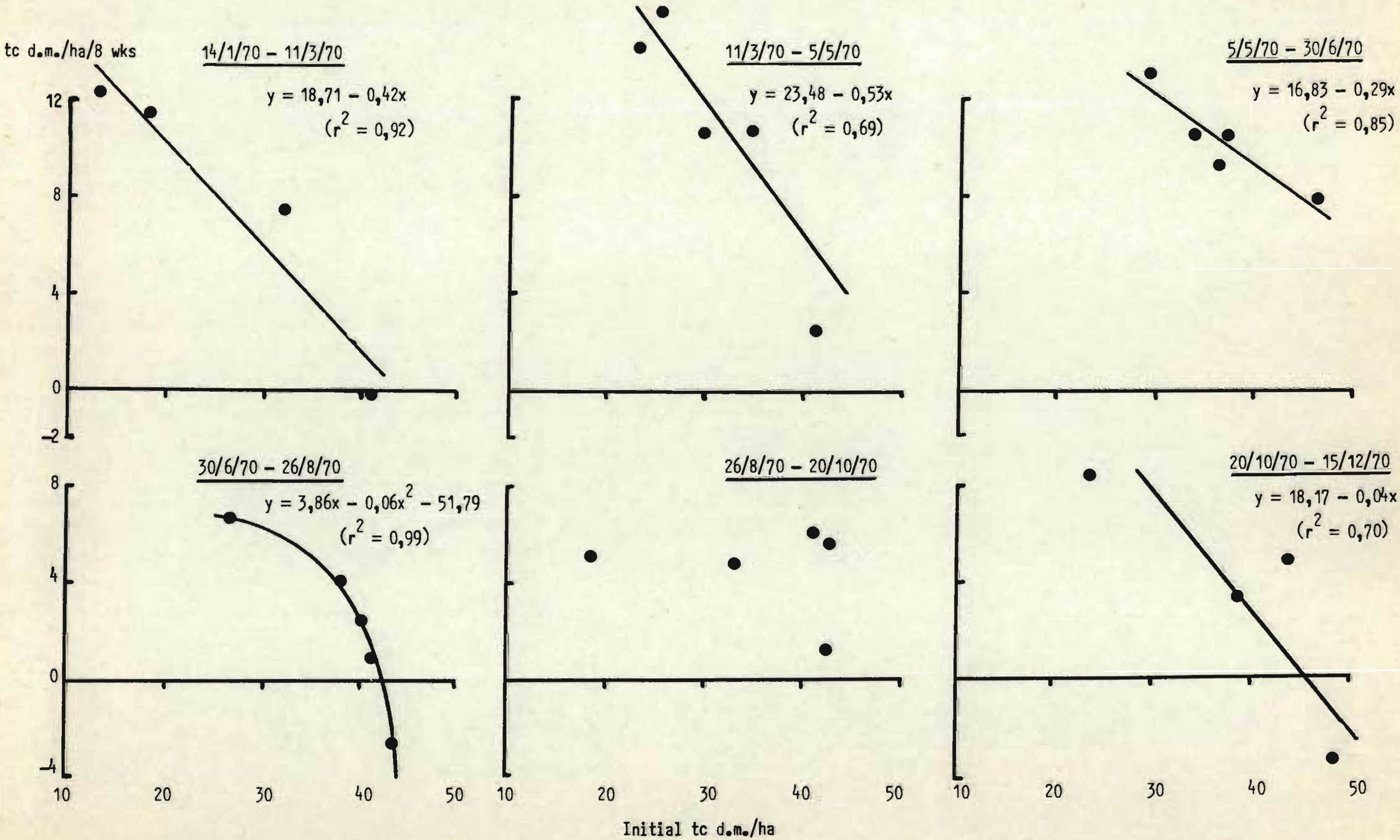


Fig. 12 The relationship between initial canc dry matter yield and cane dry matter increment at different times of the year.

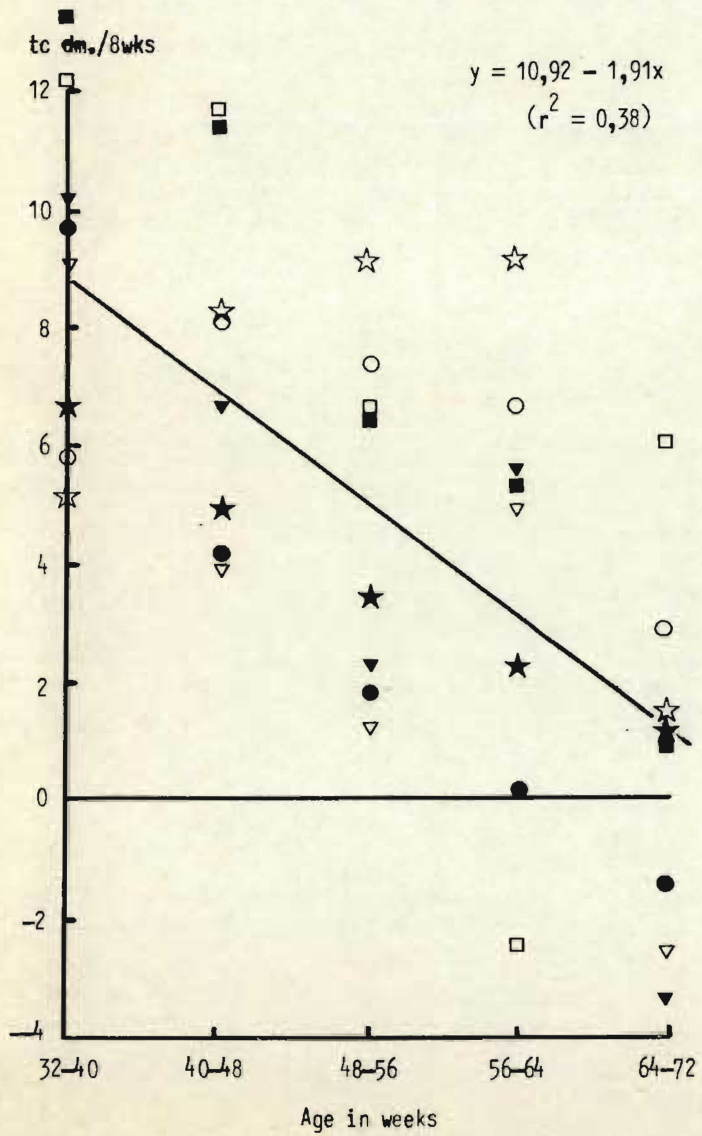


Fig. 13 Combined data: the relationship between crop age and cane yield increment.

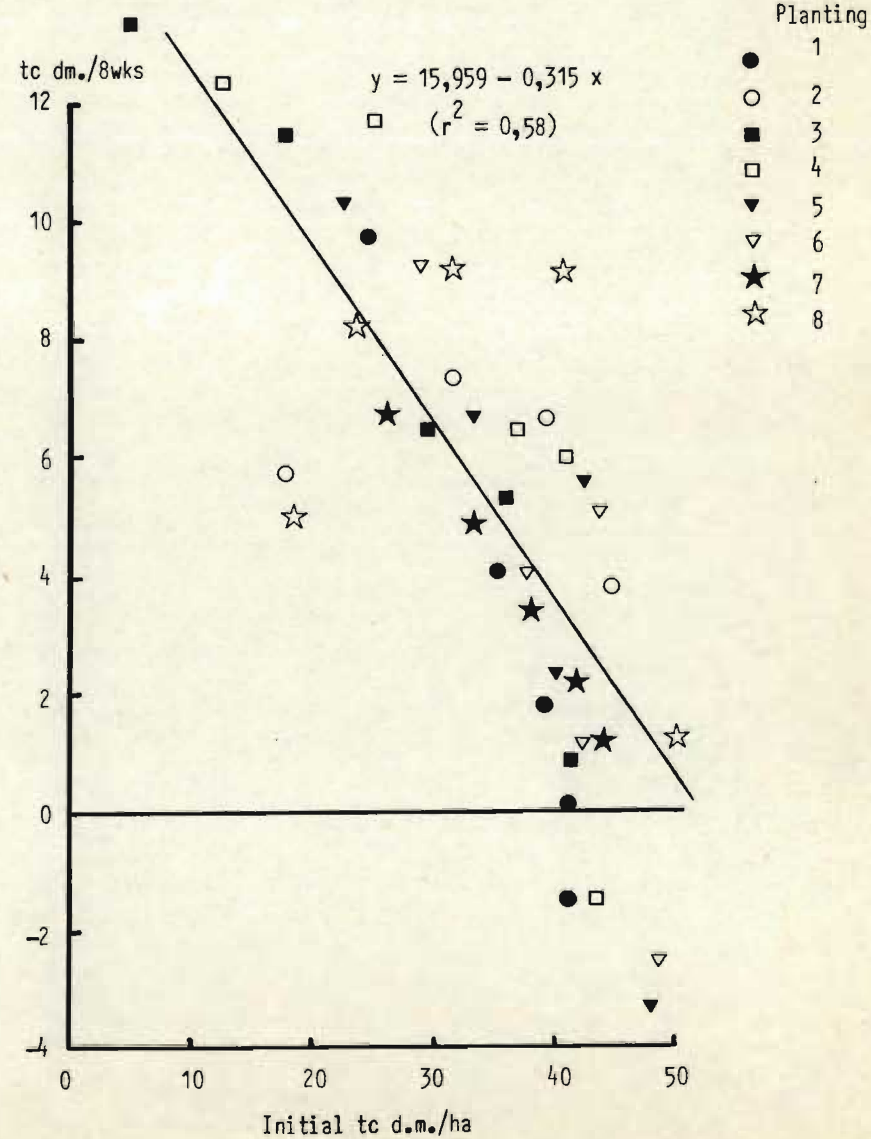


Fig. 14 Combined data: the relationship between initial yield and cane dry matter increment.

(the linear equation accounted for 58%).

Closer examination of the relationship between cane yield and the subsequent increment of growth for each planting (Fig. 15) showed that much of the remaining variability was attributable to Plantings 2 and 8 (February and January). When the results for these plantings were excluded from the combined data, the quadratic equation

$$y = 13{,}237 + 0{,}058x - 0{,}008x^2$$

accounted for 85% of the total variability (linear 79%).

There was a curvilinear relationship between initial size (yield) and yield increment in Plantings 2 and 8 (Fig. 15) and a predominantly linear relationship in all other plantings. This difference was largely due to the relatively small increments in Plantings 2 and 8 during August and October when the crops were young. To try to overcome these differences among plantings, smooth curves were fitted to the sample harvest data before obtaining increments but this did not alter the results appreciably. It was concluded, therefore, that the small increments in Plantings 2 and 8 between August and October were real. Weather data and soil temperatures at these times were carefully examined but no reason for these comparatively small increases in cane mass could be found.

2.4.8 Cane yield and weather conditions

The efficiency of water use varied with both the time of year at which the crop began to grow and the age at which it was harvested (Table 3). The efficiency indices closely followed the pattern of cane yields, with greatest efficiency of water use being shown by Plantings 5 and 6 (July and September) between the ages of 32 and 48 weeks. The lower water use efficiencies when the

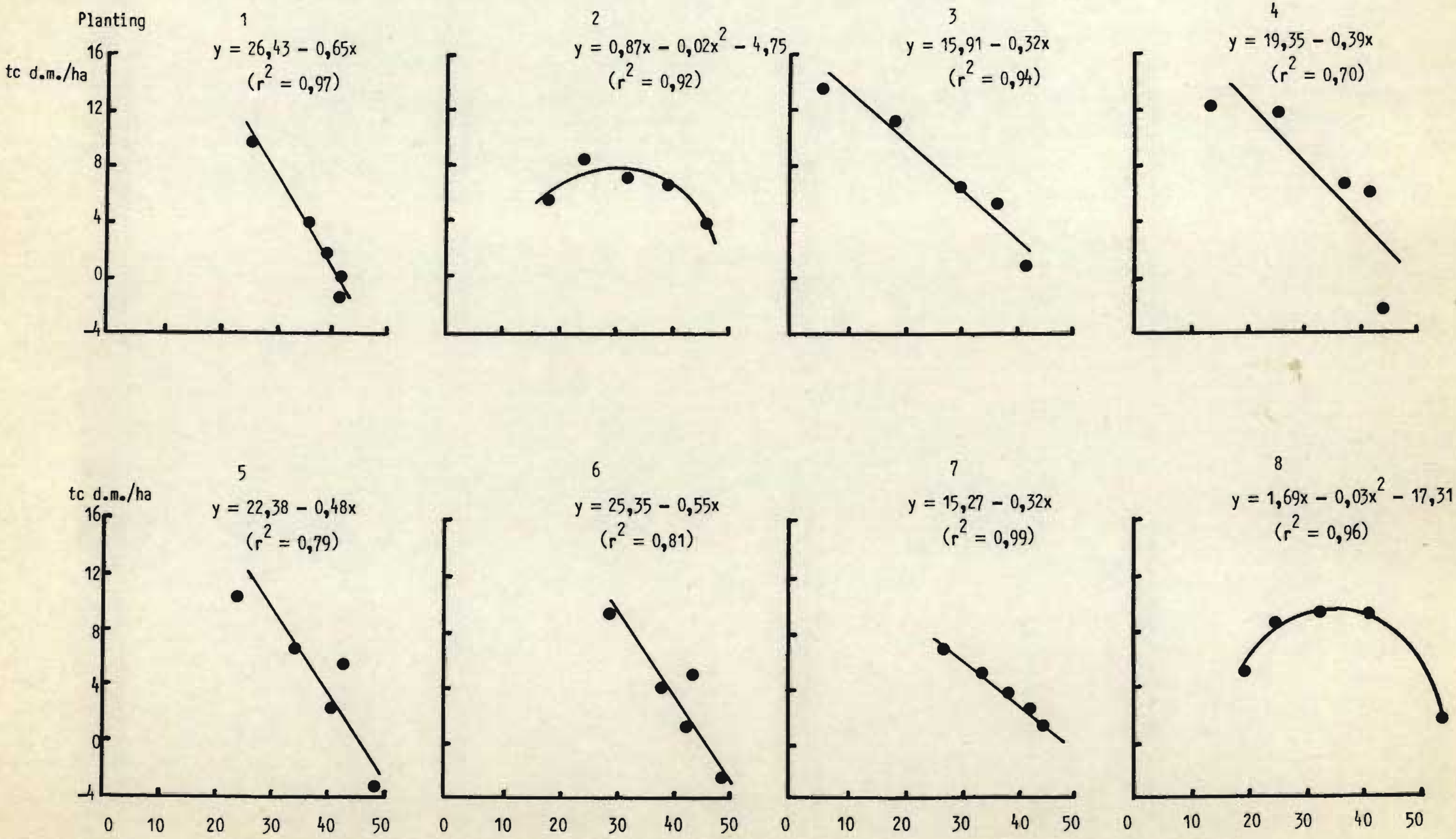


Fig. 15 The relationship between initial cane dry matter yield and cane dry matter increments by plantings

crops were older confirms that water supply was adequate and was unlikely to be the cause of a decline in growth with increasing age.

TABLE 3 The efficiency of cane production per unit of total water received (rainfall + irrigation). Results expressed as tc/100 mm water.

Age at harvest (weeks)	Planting 1	2	3	4	5	6	7	8
32	8,1	7,6	3,2	6,1	8,5	9,6	8,9	7,4
40	8,3	7,3	7,0	7,7	9,0	9,5	8,5	7,3
48	6,7	7,2	7,8	8,5	8,6	8,7	7,5	7,5
56	6,1	7,1	7,4	8,0	7,8	7,2	7,0	7,8
64	4,9	7,1	6,8	7,0	6,8	6,9	6,4	7,8
72	4,7	6,7	5,8	6,1	5,8	5,7	4,9	7,3

Initial cane growth was well correlated with weather conditions (Table 4) and cane yield at 32 weeks of age could be estimated from maximum air temperatures experienced, using the following equations.

Cane fresh mass: $Y = 25{,}488x - 568{,}973$ ($r = 0{,}96$)

Cane dry mass: $Y = 5{,}631x - 130{,}892$ ($r = 0{,}92$)

Where Y = cane mass

x = maximum air temperature.

Similar equations were also obtained for minimum and mean air temperature, and radiation.

The very good correlation between cane yield and weather conditions up to 32 and 40 weeks of age was partly due to the wide spread of the data. To illustrate this, cane yields have been plotted in Fig. 16 against cumulative mean air temperatures, a type of heat unit system (Wang, 1967). The deviations of the 32 week

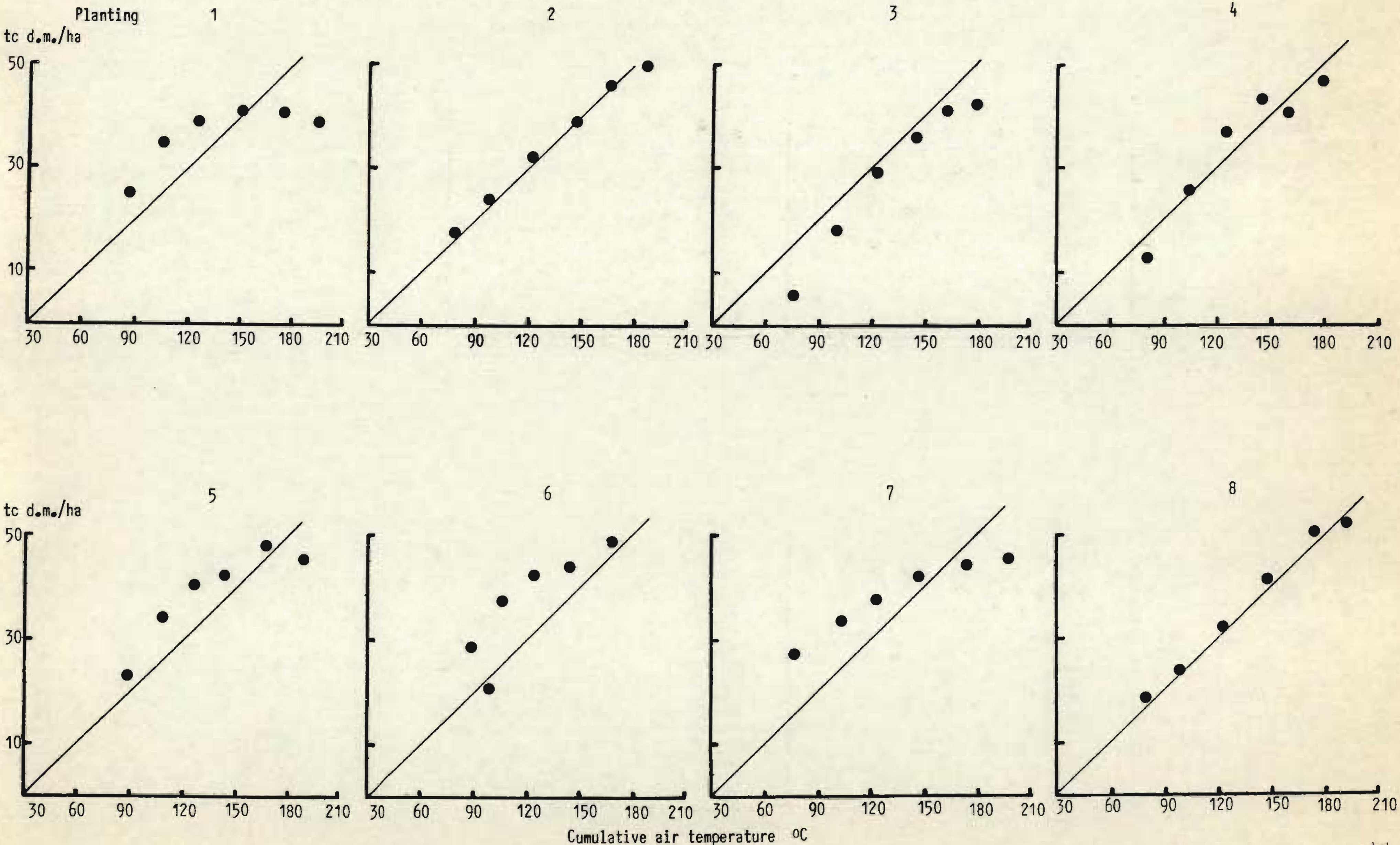


Fig. 16 The relationship between cumulative mean daily air temperature and cane dry matter yield

values for each planting from the 1:1 line can be clearly seen.

TABLE 4 Correlation coefficients (r) between weather data and tc/ha, tc.dm/ha and ters/ha.

Period (weeks)	tc/ha	tc.dm/ha	ters/ha	tc/ha	tc.dm/ha	ters/ha
	RADIATION			MIN. TEMP		
0-32	0,82	0,69	0,37	0,86	0,77	0,52
0-40	0,87	0,61	0,45	0,76	0,62	0,41
0-48	0,75	0,51	0,55	- 0,15	0,07	- 0,22
0-56	- 0,44	0,22	- 0,01	- 0,82	-	- 0,88
	MAX. TEMP			MEAN TEMP		
0-32	0,96	0,92	0,71	0,95	0,89	0,64
0-40	0,93	0,84	0,76	0,94	0,81	0,64
0-48	0,39	0,59	0,74	- 0,82	0,67	0,47
0-56	- 0,41	-	- 0,13	- 0,80	- 0,19	- 0,72

Many of the differences in cane yield at 32 weeks of age among plantings could be explained by the varying lengths of time taken to reach full canopy as this affects the efficiency of utilization of favourable growing conditions by the crop. There was, however, a rapid decline in the correlation between cane yield and weather conditions after 40 weeks of age (Table 4). This was due to the positive correlation between initial cane yield and yield increment (Section 2.4.7) rather than the different weather conditions experienced by the various plantings.

It was not possible to estimate cane yield from weather conditions after 40 weeks of age because of the dominant effect of initial crop size on cane yield increment. The inclusion of either air temperature or radiation as a quadratic component in the equation relating initial crop size and cane yield increment did not improve the estimate of cane yield, even when data for Plantings 2 and 8, which grew differently from other Plantings (Section 2.4.7), were excluded.

2.4.9 Cane quality

Within any one planting changes in juice purity, sucrose percent cane fresh mass (S%c), fibre percent cane fresh mass, and juice purity (%) were similar throughout the experiment (Appendix I, Tables 7-9). It is possible, therefore, to discuss cane quality in terms of changes in the percentage estimated recoverable sugar in the cane stalk (Ers%c), which is derived from juice purity and S%c (Section 2.2), and S%dm.

Ers%c generally increased with age (Fig. 17a) and the younger the crop (up to 64 or 72 weeks of age) at any time of the year, the lower the cane quality. The Ers%c of young crops also varied more from one time of the year to another than the Ers%c of old crops (Fig. 17b). There was a pronounced peak in the seasonal curve of Ers%c for crops of less than 56 weeks of age but not for older crops. Peak Ers%c occurred between June (32 week crop) and August. The Ers%c of all crops harvested at 56 weeks of age was similar between June and December.

Changes in S%dm (Fig. 18) were similar to those in Ers%c, except between July and December, when there was little difference in the S%dm of sugarcane between 48 and 72 weeks of age. Ers%c was therefore affected at these times by changes in cane moisture content rather than changes in sucrose content.

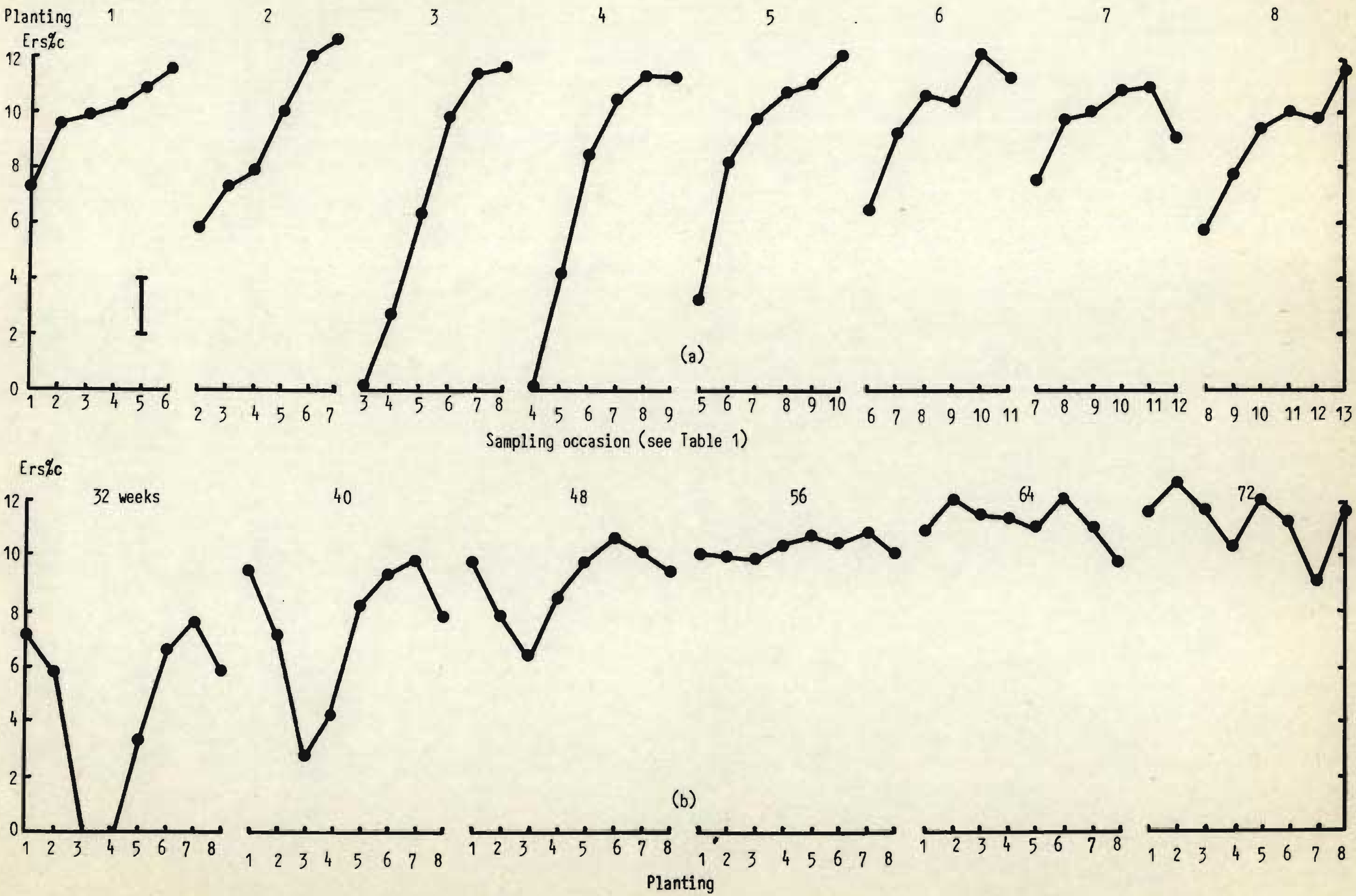


Fig. 17 Estimated recoverable sugar percent cane fresh mass (a) by plantings (b) by ages
L.S.D. (0.05) within plantings I

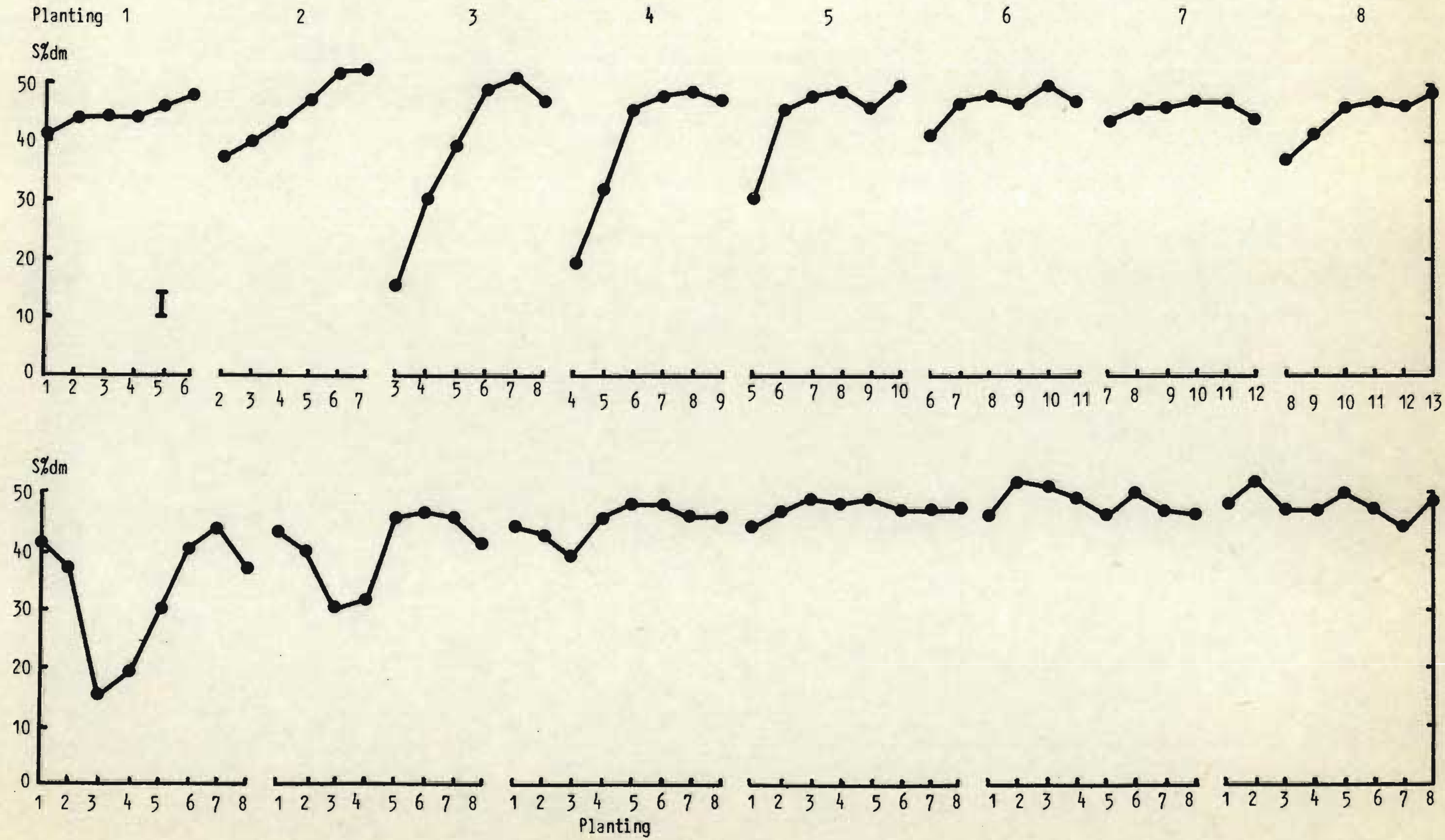


Fig. 18 Sucrose percent cane dry mass (a) by plantings (b) by ages L.S.D. (0,05) within plantings I

2.4.10 Yield of estimated recoverable sugar (ters/ha)

Yields of ters/ha are given in Appendix I, Table 10 and illustrated in Fig. 19. In general, sugar yield increased with age up to 64 weeks of age but there were no consistent differences in ters/ha between crops of 64 and 72 weeks of age (Fig. 19b). The pattern of sugar accumulation in the different plantings varied with the time of year of the previous harvest (Fig. 19a). Crops that began to grow in July and September (Plantings 5 and 6) rapidly achieved high yields of sugar at 48 weeks of age, whilst crops that began to grow in January and February (Plantings 8 and 2) had low yields at 48 weeks of age, but ultimately gave the highest yields in the experiment of 23 ters/ha at 72 weeks of age.

The age at which each ratoon crop produced the maximum amount of sugar per unit area per unit time varied appreciably (Table 5). High yields of 1,4 - 1,6 ters/ha/month were obtained by harvesting Planting 1 (December) in September at 40 weeks of age, Plantings 5 and 6 (July and September) between May and September at 40-56 weeks of age, and Planting 2 (February) in May and June at 64-72 weeks of age. Planting 3 (April) had the lowest ters/ha/month at all ages of harvest.

There was a marked peak in increments of ters/ha/8 weeks for crops of all ages between March and May (Fig. 20).

2.4.11 The relationship between cane yield, cane quality and sugar yield.

Both tc/ha and tc.dm/ha were well correlated with all measures of cane quality and sugar yield but there was a better correlation with tc.dm/ha than with tc/ha (Table 6). There was no correlation between cane yield and fibre % cane.

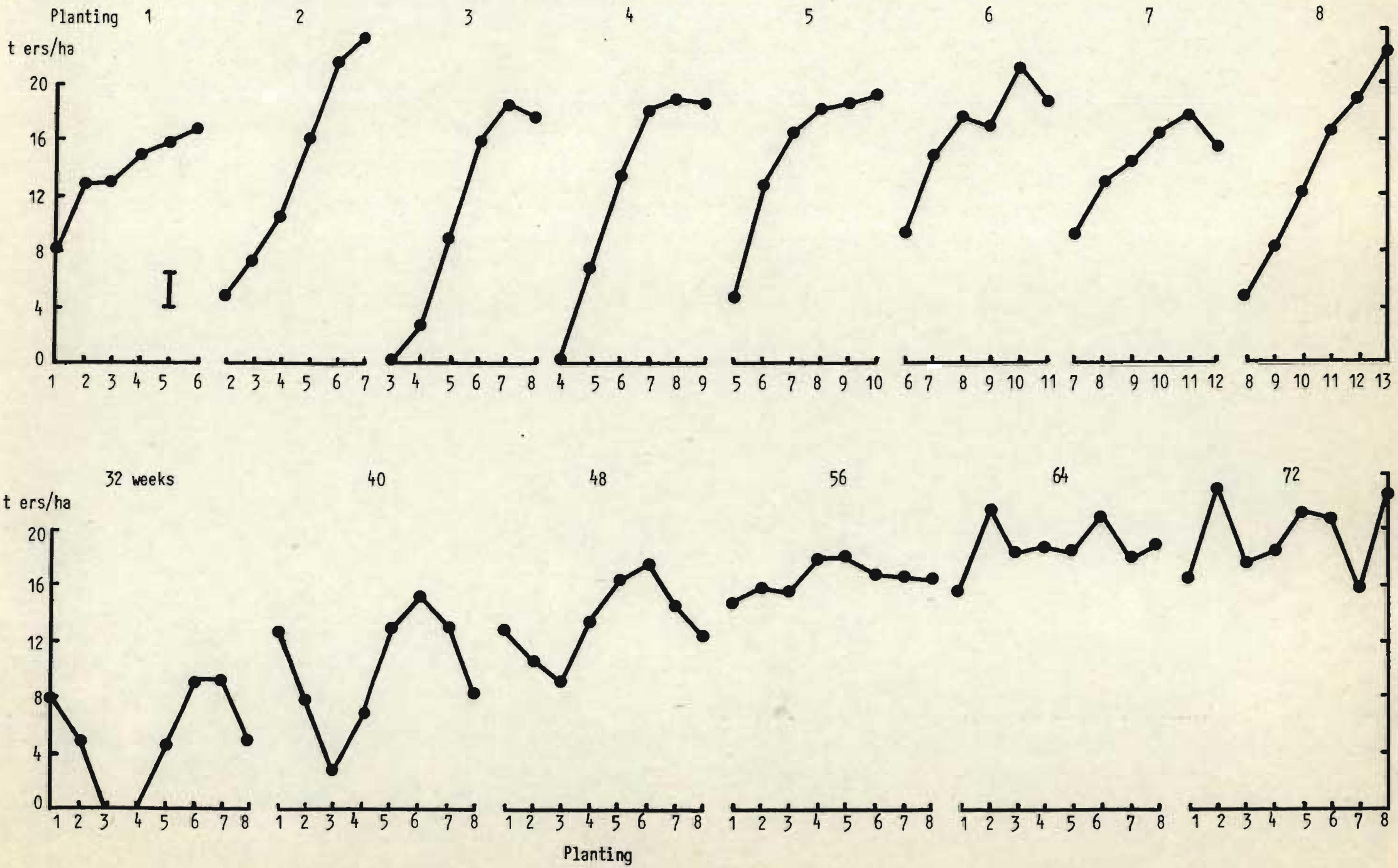


Fig. 19 Estimated yield of recoverable sugar per hectare (a) by plantings (b) by ages.
L.S.D. (0,05) within plantings

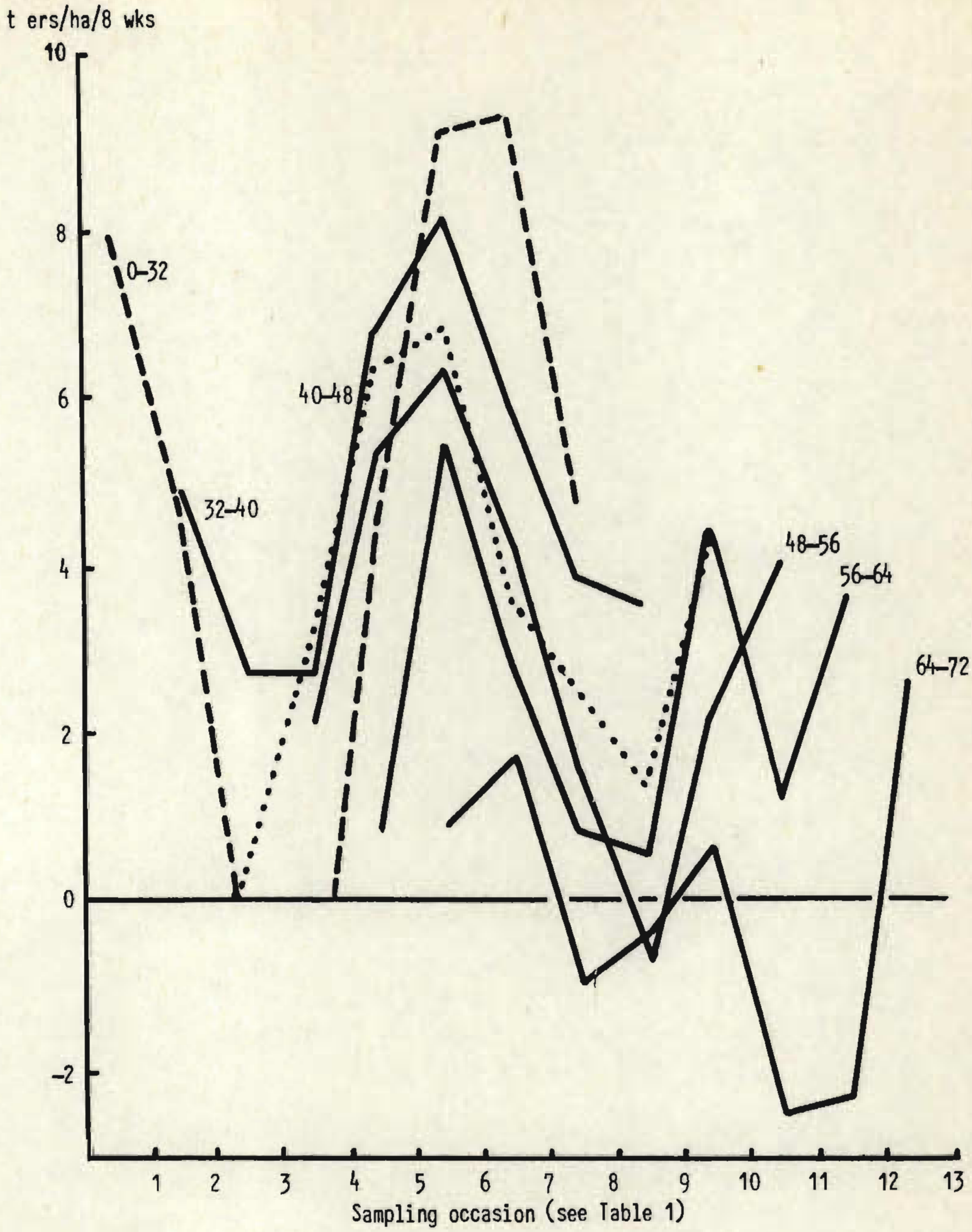


Fig. 20 Eight weekly increments of estimated recoverable sugar per hectare for cane of different ages.

TABLE 5 Sugar production per unit area per unit time (ters/ha/month) for ratoon crops of different ages, harvested at various time of the year

Sample harvest	Planting 1	2	3	4	5	6	7	8
1969								
30/7	1,1 (32)*							
24/9	1,4 (40)	0,6 (32)						
19/11	1,2 (48)	0,8 (40)	- (32)					
1970								
14/1	1,2 (56)	0,9 (48)	0,3 (40)	- (32)				
11/3	0,9 (64)	1,2 (56)	0,6 (48)	0,4 (40)	0,3 (32)			
5/5	1,0 (72)	1,5 (64)	1,2 (56)	1,2 (48)	1,4 (40)	1,2 (32)		
30/6		1,4 (72)	1,2 (64)	1,4 (56)	1,5 (48)	1,6 (40)	1,2 (32)	
26/8			1,0 (72)	1,2 (64)	1,4 (56)	1,5 (48)	1,4 (40)	0,6 (32)
20/10				1,1 (72)	1,2 (64)	1,3 (56)	1,3 (48)	0,9 (40)
15/12					1,2 (72)	1,4 (64)	1,3 (56)	1,1 (48)
1971								
9/2						1,1 (72)	1,2 (64)	1,2 (56)
6/4							1,0 (72)	1,3 (64)
31/5								1,3 (72)

( )* Age in weeks

TABLE 6 Correlation coefficients (r) between tc/ha or tc.dm/ha and measures of cane quality and sugar yield. (Combined data for all harvests)

Variate	tc/ha	tc.dm/ha
tc/ha	-	0,95***
dm % c	0,68***	0,86***
S % c	0,81***	0,91***
S % dm	0,70***	0,75***
Purity	0,76***	0,81***
Ers % c	0,80***	0,90***
ters/ha	0,90***	0,96***
Fibre % c	0,16	0,25

*** Statistically significant at P = 0.001

2.5 Discussion

2.5.1 Reliability of the results

The coefficient of variation for tc/ha was 10,6%, which is rather high, but the following evidence indicates that the experimental results are reliable: the gradual changes from one planting to the next in the development of shoot populations and the rate of stalk elongation, and the correlation between cane yields of all crops at 32 and 40 weeks of age, and weather conditions. There was also a marked similarity in growth, cane yield and cane quality between Planting 2, ratooned in February 1969 and Planting 8, ratooned in January 1970, indicating that the results obtained are reproducible.

Increments of growth were more variable than cumulative data, particularly when the increments were small, but the correlation between dry matter increment at most times of the year and either crop size or age was good (Fig. 13 and 14). The 32-40 week increments of cane dry matter of cane and sugar, were unusually small for the age and size of the crops but there was no obvious reason for this (Section 2.4.7).

The results of this experiment have been presented in terms of cane and sugar yields because these are what are economically important. Stalk mass is, however, only one component of total dry matter yield and it is possible that the correlation of yield increment and weather conditions after 40 weeks of age could be affected by the partitioning of dry matter among plant parts. Total dry matter production (stalk + green and dead leaves + roots) was therefore measured in Planting 8 and full details are given in Chapter 3 (Section 3.2).

It was found that from 32 weeks onwards stalk mass was a large proportion of total plant mass and the proportion of stalk mass to total mass increased as the crop became older (Table 7), confirming results of other workers (Van Dillewijn 1952; Gosnell, 1967). Thus one could expect a better correlation between cane mass (taken as a measure of total crop productivity) and any independent variable when the cane was old, rather than during early growth as reported here. Therefore, the partitioning of total dry matter among plant parts should not affect the results.

2.5.2 Factors affecting cane yield

(a) Weather, age and crop size

Despite the design of the experiment it was not possible to separate the effects of weather and age from one another completely.

The good correlation of cane yields at 32 weeks of age with the weather conditions experienced, confirmed the well-established correlations between weather conditions and such measures of sugarcane growth as stalk elongation (Sun and Chow, 1949; and Glasiou, Bull, Hatch and Whiteman, 1965), cane yield (Borden, 1936; and Shaw and Innes, 1965) and gross photosynthesis (Waldron, Glasziou and Bull, 1967; and Bull, 1971). It was unfortunate that after 32 weeks of age cane yield could not be estimated from weather parameters. For planning ahead this would be of tremendous value both to the sugar farmer and to the sugar industry.

Judged by current standards of sucrose content and stage of maturity, the results of this experiment showed that cane yield became dependent on plant, rather than weather factors, long before the crop was ready for harvest. Future experimental work should therefore attempt to identify and ameliorate the plant factors limiting growth so that favourable growing conditions could be utilized more efficiently.

One way in which better use could be made of favourable weather conditions would be to ripen young crops artificially (see Chapter 4). They could then be harvested at an early age, thus enabling the following crop to begin to grow sooner than it would normally. In this way the decline in growth with increasing age or crop size could be ameliorated to a certain extent.

A decline in sugarcane growth with increasing age is well established (Borden and Denison, 1942; Gosnell, 1967; and Shaw and Innes, 1965), although there is an indication from two experiments in South Africa that age may not be the best criterion to judge a crop's ability to respond to favourable growing conditions. Gosnell (1967) found that the growth of rain-grown sugarcane in the second year of growth was only 20% of that in the first whereas du Toit (1956) in an experiment on a similar site found the same rate of growth in both years. Closer examination of the results of these experiments showed that a possible reason for this apparent contradiction was that at 12 months of age the cane yield in du Toit's experiment was 45 t/ha and 81 t/ha in Gosnell's. These results support the findings reported here that size is a better criterion than age when comparing the growth rate of crops that have grown under different weather conditions over a period of at least 12-18 months.

(b) Time of ratooning

The cycle of weather conditions through which a crop grew determined its pattern of growth and its yield potential (Section 2.4.6). Of particular interest was the linear growth of January and February crops, which ratooned at a time when the mill is normally closed and no cane is cut, compared with the curvilinear growth pattern of the July and September crops. There was a definite interaction between growth cycle and time of harvest for maximum sugar yield per unit area per unit time, with the July and September crops requiring early harvest and the January and February crops a late harvest for maximum productivity (Section 2.4.10).

It is interesting that the decline in growth of Spring ratooned crops at the start of their second growing season occurred at the same time of year when small increments of cane growth (for the crop size) were recorded in Plantings 2 and 8. Taken together, these results indicate that established crops may require time to adapt to, and to begin to make use of gradually improving weather conditions. Gosnell (1967) found that the leaf area index of irrigated sugarcane was low during winter and it is likely that increases in cane and total plant mass would be slow until the leaf area index had returned to its higher summer level.

It may be concluded, therefore, that in early Spring it is advisable to harvest any crop that is big enough, because a new ratoon crop will utilize the improving weather conditions more efficiently than a crop entering its second season.

(c) Lodging

Lodging occurred in all ratoon crops but it was most severe in Planting 1 (December) in which new bull shoots developed at the expense of the growth of existing cane stalks (Fig. 9). Patterns of development of shoot populations and rates of stalk elongation in the various plantings indicated that a combination of high stalk number and rapid stalk elongation in Planting 1, probably as a result of high temperatures and radiation levels (Glasziou et al, 1965), resulted in stalks with a small basal diameter. These were presumably more susceptible to lodging than those of slower growing crops.

The crops planted in October and November, which because of slower establishment are comparable in rate of development to the December ratoon crop, also had small basal diameters, relatively low yields (Fig. 3), and produced bull shoots. Some bull shoots were also produced by the November ratooned crop. The characteristics of these crops therefore appear to be typical of crops becoming established between October and December.

Early lodging and bull shoot development are undesirable because these immature shoots reduce the average quality of the crop if harvest is not delayed until they become mature. It would be advisable, therefore, to try to restrict the growth of these crops during the summer months so that they would approximate more closely the pattern of growth of January and February crops (Plantings 2 and 8). This could be achieved by restricting the amount of irrigation water available to the crops during early growth.

2.5.3 Cane quality

Under the conditions of this experiment changes in cane quality after 32-40 weeks of age were related to crop age or size (Fig. 17 and Table 6), rather than to weather conditions. However, the Ers % c of crops of 32-48 weeks of age, harvested at different times of the year, showed peak values between June and October which were similar to the typical pattern for the South African sugar industry (c.f. Fig. 2 and 17). These results imply that at certain times of the year, when conditions are favourable for growth, the South African sugar industry harvests crops that are either too young, or too small to maintain a high juice purity and a high sucrose content.

Conversely, well grown crops of sugarcane harvested at more than 48 weeks of age had reasonable levels of juice purity and sucrose concentration between December and May, a time of the year when sugar mills normally close because of the poor quality of the sugarcane. By harvesting well-grown crops at this time of the year it would be possible to reduce the period of time when the mills have to close, resulting in a greater annual production of sucrose from a given mill capacity.

2.5.4 Sugar yield and optimum time of harvest

It was not possible to dry off these crops (reduce irrigation prior to harvest) but there is no reason to believe that this would have altered the results to any great extent. Drying off improves juice purity and the sucrose concentration of the crop (Humbert, 1968; Thompson and Boyce, 1968) but there is no conclusive evidence to show that it increases sugar yield per hectare appreciably.

The data for ters/ha and ters/ha/month presented in Fig. 19, and Table 5, may be regarded as standards against which other irrigated crops can be compared. When used as standards the actual figures are less important than the differences between crops that were harvested either at different ages or at different times of the year.

If crops growing under similar conditions do not give yields similar to those reported here it may be concluded that some aspect of management is incorrect. Efforts can then be concentrated on identifying and correcting the factor limiting yield.

High yields of ters/ha/month were obtained from young, well-grown crops harvested early in the milling season (Table 5) but the quality of these crops was poor because of their age and the time of year at which they were harvested. Under these conditions it is difficult to recover the sucrose from the crop at the mill. Drying off to improve cane quality is not easy at this time of the year because of occasional rainfall, and these young crops would benefit most from artificial chemical ripening.

Sugar yields per hectare continued to increase beyond the age of maximum ters/ha/month and for maximum yields of ters/ha at any age, crops should be harvested between August and November, the time of high natural juice purity and sucrose concentration.

2.6 Conclusions

2.6.1 Cane yield could only be estimated from weather parameters until crops were 40 weeks of age. Under conditions of adequate moisture and nutrient supply crop growth was directly correlated with radiation and temperature.

2.6.2 After 40 weeks of age, growth declined in all crops except those ratooned in January and February. Eight-weekly increments of cane growth were better correlated with the amount of growth already made than with crop age.

2.6.3 Maximum yields of cane and sugar of ratoon crops varied with the date of ratooning and the age of the crop at harvest. The highest yields in the experiment were produced by January and February crops harvested in June and August at 64-72 weeks of age. When crops were harvested at about 12 months of age, the maximum yield was produced by a September ratooned crop.

2.6.4 All measures of cane quality were directly correlated with cane yield.

2.6.5 Because young crops were more responsive to favourable growing conditions than older crops, the cane quality of young crops fluctuated more from one time of the year to another than that of older crops.

2.6.6 Maximum increments of sugar yield of crops of all ages were obtained between March and May.

2.6.7 Crops either planted in October/November or ratooned in December produced high populations of thin stalks: lodging was severe and bull-shoots were produced. It is concluded that such crops should be harvested, either as soon as they begin to lodge, or not until the bull-shoots are mature. By restricting irrigation during early growth it may be possible to modify the growth of these crops to approximate the growth and high yield potential of the January and February ratooned crops, without the undesirable effect of severe lodging.

CHAPTER 3

ESTIMATES OF DRY MATTER PRODUCTION AND APPARENT MAXIMUM YIELDS OF IRRIGATED SUGARCANE

3.1 Introduction

Two experiments were undertaken to determine the maximum yields and rates of dry matter production of current sugarcane varieties. By relating these yields to the theoretical maximum yield attainable, calculated from the amount of radiant energy available for growth an estimate can be made of the potential for improving yields. This is of value in assessing sugarcane breeding programmes, a major objective of which is to increase sugar yields beyond their present levels.

Much is known about the physiology and biochemistry of sugarcane but the application of this knowledge to competing stands of plants in the field is not easy. In other crops, differences in yield have been studied in relation to differences in rates of photosynthesis or in leaf area index, leaf angle, and the efficiency of radiant energy interception, but to date there has been little success in increasing yields by selecting plants with apparently desirable physiological and morphological characteristics (Moss and Musgrave, 1971).

Field measurements were made of the yield and dry matter production of variety NCo 376 in Experiment 1, at Pongola, and of varieties NCo 376, NCo 310 and CB 36/14, which differ appreciably in their growth and morphology in Experiment 2, at Mount Edgecombe (Lat. 29°42'E Longt. 31°02'S). Variety NCo 310 is intermediate between NCo 376, which has a high population of thin stalks with upright leaves of medium width, and CB 36/14, which has fewer, thicker stalks with broader, less erect leaves. NCo 376 is also more resistant to drought and does not lodge as easily as the other two varieties. Measurements of radiant energy interception by NCo 376 and CB 36/14 were also made in a first ratoon crop in Experiment 2. Observations of the root growth of the three varieties were made in Experiment 3.

3.2 Experiment 1 January ratooned crop at Pongola

3.2.1 Materials and methods

Yield and dry matter were measured in the first ratoon crop of Planting 8 of the Experiment described in Chapter 2. Between 32 and 64 weeks of age the sugarcane from one row of 5,5 m (area 8,3 m^2) in each of the six plots was divided into stalk, green leaf + top (tops) and dead leaf (trash). The fresh mass of each plant part was determined and representative grab samples were dried to constant mass at 80°C. At 72 weeks of age, plant dry mass and leaf area were determined on an area of 25 m^2 per plot.

The leaf area per plot was estimated from the ratio of leaf area to fresh mass of tops, determined on a random sample of 8 shoots per plot. The leaf area of the sample was measured with a calibrated leaf area photometer in which the deflection of a galvanometer needle gave an accurate measure of leaf area when the leaves were placed between a light source and a photocell (Bunting, 1968). Estimates of root mass were obtained from a 1,5 m length of row (area 2,1 m^2) in each plot by digging out the roots to a depth of 25 cm with a garden fork, washing and drying.

3.2.2 Results

Total dry matter production increased gradually to a maximum of 85,7 t/ha at 64 weeks of age (Table 7) but sampling error was large on this date and this mass may be an overestimate.

TABLE 7 Leaf area, dry matter production and distribution at various ages in a first ratoon crop of NCo 376 at Pongola

Determination	Age at harvest (weeks)					
	32	40	48	56	64	72
Dry mass (t/ha)						
Green leaf and tops	8,6	7,8	8,5	7,9	5,9	5,0
Trash	4,9	7,4	11,4	14,1	17,0	17,5
Stalk	17,2	23,8	33,5	40,5	55,7	51,9
Roots	6,2	6,8	7,6	7,1	7,1	6,7
Total dry mass (t/ha)	36,9	45,8	61,0	69,6	85,7	81,1
S.E. of mean	1,0	1,4	2,4	2,6	5,7	3,3
C of V (%)	6,9	7,4	9,5	9,0	16,2	9,9
D.m. distribution (%)						
Green leaf and tops	23,4	17,1	14,0	11,3	6,8	6,2
Trash	13,2	16,1	18,7	20,2	19,9	21,6
Stalk	46,6	52,0	55,0	58,2	65,0	63,9
Roots	16,9	14,8	12,4	10,2	8,3	8,3
C ($g/m^2/dy$)	16,5	16,4	18,1	17,7	19,1	16,1
Total radiation (ly/dy)	406,5	412,5	431,1	440,2	448,6	438,1
Efficiency (%)*	1,70	1,67	1,76	1,69	1,79	1,54
Leaf area index	3,4	3,5	3,8	3,7	2,8	2,5

* Assuming that the heat of combustion of 1g of carbohydrate is 4200 c

There was little change in the mass of roots and tops up to 64 weeks of age so that the proportion of total dry matter in roots and leaves declined whilst that in trash and stalk increased.

Cumulative crop growth rate (C) ranged from 16,4 to 19,1 $g/m^2/dy$ between 32 and 64 weeks of age, and the efficiency of total incident radiation (r_i) conversion into dry matter ranged from 1,7 to 1,8%. Increments of C, which varied appreciably, did not follow any pattern but there was no indication of a decline in growth rate before 64 weeks of age. Estimated C at 12 months of age was 17,9 g/m^2/dy (mean 48 - 56 weeks), and represented an efficiency of 1,7% of total r_i or 4,1% of visible r_i, assuming that visible r_i is 42% of total r_i. This gave a total dry matter yield of 63,3 t/ha/yr, of which approximately 57% was in the stalk. There was an indication of a decline in leaf area index which ranged from 2,5 to 3,8 between 32 and 72 weeks of age.

3.3 Experiment 2 Plant and ratoon crops of NCo 376, NCo 310 and CB 36/14 at Mount Edgecombe

3.3.1 Materials and methods

(a) Dry matter production

An artificial soil was prepared by excavating a hole 12,6 m x 8,5 m x 1,6 m deep and refilling it in 25 cm layers with a 50 : 50 mixture of washed river sand and the natural clay soil from the site. Details of the chemical and physical properties of the soil are given together with a plan of the experiment in Appendix II Fig 1 and Table 1. To ensure that growth was not restricted by soil-borne pests and diseases each 25 cm layer of soil was fumigated with methyl bromide before the next layer was added.

To try to ensure an adequate supply of nutrients to the crop 385 kg/ha double superphosphate (20% P), 330 kg/ha muriate of potash (50% K) and 55 t/ha chicken manure compost were incorporated into the 0 - 25 cm soil layer before fumigation. The plant crop was topdressed with 330 kg/ha of urea (46% N) at four months of age and the two ratoon crops with 1200 kg/ha of a 4-1-6(31) fertilizer mixture at 3 - 6 weeks of age. These rates of fertilization were higher than the rates recommended on the basis of soil analyses.

Single-eyed setts of the three varieties were heat treated for disease control ($50 \pm 0,5^{o}C$ for 2 hours) and germinated on 16 September 1970. They were then grown for six weeks in small pots containing fumigated artificial soil, selected for uniformity of growth and tillering, and transplanted 25 cm apart in rows spaced 1,4 m apart. There were three rows of 12,5 m of each variety and yields were estimated from the middle 7,2 m of the middle row (area 10,2 m^2).

Irrigation of plant and ratoon crops was by means of perforated pipes laid between the cane rows. The frequency of irrigation was determined from the estimated rate of evapotranspiration and was sufficient to maintain the moisture content in the top 1,25 m of the soil between field capacity, and 50% of field capacity. The plant crop was not dried off (irrigation withheld before harvest) but the first ratoon crop was dried off for 6 - 8 weeks. The plant crop of variety NCo 310 lodged badly, so to prevent further lodging each cane row was supported with poles and strands of wire. This did not affect growth and the development of the crop canopy.

The plant crops were harvested on 14 October 1971, at 393 days of age, and the first ratoon crops were harvested on 12 October 1972, at 362 days of age. The weight of trash and tops from 10 plants per row (2,5 m) was recorded and a small representative sample of each plant part was dried to constant mass. Total dry matter and the leaf area of each variety were also measured in the second ratoon crop on 19 March 1973, at 189 days of age. The fresh mass/area ratio of a random sample of leaves was determined in the plant crops and used to estimate the leaf area of the 10 sample plants. Although the sample taken for leaf area measurements was small there was good agreement among samples taken from the three rows of each variety. Measurements of the leaf area of all stalks in 1 metre length of row in the second ratoon crop indicated that leaf area index in this crop was determined with an accuracy of ± 3%

(b) Measurement of total radiant energy interception

Tube solarimeters (Szeicz, Monteith and Dos Santos, 1965) were installed one above the other on a pole at 4 levels in the canopy of the first ratoon crop of varieties NCo 376 and CB 36/14. The solarimeters were actually thermopiles, 50 cm long and 2,5 cm wide, and comprised 200 copper-constantan junctions. Alternate quarters of the upper surface of the thermopile were painted black and white and it was placed inside a closed glass tube. A continuous stream of air was drawn through each instrument to prevent condensation. The instruments were sited parallel to and mid-way between two cane rows from 29 April until 9 June, when they were re-positioned so that they extended from the centre of the interrow into and at right angles to the row. The two methods gave similar results and data will only be presented for the second period.

The relative positions of the solarimeters in the canopy are illustrated in Appendix II, Fig. 2. The lowest solarimeter (number 4) was placed so that it was level with the uppermost part of the lowest green leaf, which on 11 June was 150 cm from ground level in NCo 376 and 200 cm in CB 36/14. The remaining solarimeters were then placed at 50 cm intervals above the first, and the uppermost solarimeter (number 1) was approximately level with the uppermost visible leaf collar. On 29 April this was 90 cm below the tip of the uppermost leaf in NCo 376 and 102 cm in CB 36/14. When the last measurement was taken on 17 September the distances to the tip of the uppermost leaf were 106 cm and 130 cm for NCo 376 and CB 36/14, respectively. The lowest green leaf of NCo 376 was mid-way between solarimeters 3 and 4 at this time and the same leaf of CB 36/14 was just below solarimeter 3.

The energy output from each solarimeter was recorded at 6 minute intervals throughout the experiment on a 12 point Kent recorder. Potentiometers were used to standardise the output of each solarimeter against a calibrated Lintronic solarimeter, which was placed on a stand above the crop canopy during the experiment. All instruments were checked every 3 - 4 days to ensure that they were level and that the glass was clean. Care was taken not to disturb the crop canopy around the solarimeters. Curves for each solarimeter on cloudless days were integrated with a planimeter and the area for the period between sunrise and sunset was expressed as a percentage of the area obtained from the Lintronic solarimeter.

3.3.2 Results

(a) Dry matter production

Details of the dry matter yields and the efficiency of conversion of total r_i into dry matter for the plant and ratoon crops are given in Table 8. Data for the plant crop of NCo 310 have been excluded from the average figures given below because of the lodging that occurred.

There was good agreement among the varieties in the total amount of dry matter produced and in the distribution of this dry matter among the plant parts (Table 8). The average crop growth rate over a period of 365 days for plant and first ratoon crops of the varieties was 17,0 g/m^2/dy. This represented a conversion of 1,9% of total r_i or 4,3% of visible r_i into plant dry matter to give an average total dry matter yield of 65,3 t/ha/yr. In the second ratoon crop, harvested at six months of age, C ranged from

17,9 to 20,3 $g/m^2/dy$ for the three varieties and the efficiency of total r_i conversion was 2,0 - 2,3%.

TABLE 8 Dry matter production and distribution amongst plant parts, adjusted to 365 days, leaf area, and the efficiency of incident radiation utilization in plant and first ratoon crops at Mount Edgecombe

	Plant Crop			First ratoon crop		
	NCo 376	CB36/14	NCo 310*	NCo 376	CB36/14	NCo 31
Dry mass (t/ha)						
Green leaf and tops	5,2	5,3	4,2	7,7	8,6	9,8
Trash	12,6	14,5	12,2	12,1	14,5	12,2
Stalk	39,7	39,9	27,8	35,9	40,8	35,2
Roots (estimated)	6,4	6,6	4,9	6,2	7,1	6,4
Total dry mass	63,9	66,3	49,1	61,9	71,0	63,6
D.m. distribution %						
Green leaf and tops	8,1	8,0	8,5	12,4	12,1	15,4
Trash	19,8	21,8	24,8	19,6	20,5	19,2
Stalk	62,1	60,2	56,7	58,0	57,4	55,4
Roots (estimated)	10,0	10,0	10,0	10,0	10,0	10,0
C ($g/m^2/dy$)	17,5	18,2	13,4	17,0	19,5	17,4
Efficiency (%)**	2,04	2,11	1,56	1,91	2,19	1,95
Leaf area index	2,4	2,9	3,3	-	-	-

* Crop badly lodged

** Assuming 1g carbohydrate = 4200 cal.

Mean radiation: Plant crop 360 ly/dy
Ratoon crop 374 ly/dy

Harvested stalk populations were similar in the plant and first ratoon crops of each variety and ranged from 172 thousand per hectare for NCo 376 to 112 thousand per hectare for CB 36/14 (Table 9

TABLE 9 The yield and quality of harvested stalks in plant and first ratoon crops at Mount Edgecombe. Cane yield adjusted to 365 days.

	NCo 376		CB36/14		NCo 310	
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
tc/ha	157,5	146,0	151,0	158,7	132,6	137,0
ters/ha	17,2	15,5	16,5	18,6	11,9	16,9
Ers % c	10,9	10,6	10,9	11,7	9,0	12,3
Purity (%)	82,8	87,2	84,3	89,2	81,2	89,7
D.m. % cane	25,2	24,4	26,4	25,5	21,0	25,5
S % dm	49,8	50,1	47,5	52,1	50,2	54,3
Stalk no.(000/ha)	172	160	116	112	122	123

Leaf area indices varied from 2,4 to 3,3 in the plant crop. Leaf areas were not measured in the first ratoon crop. The stalk populations in the second ratoon crop at six months of age of 256, 167 and 151 thousand per hectare for NCo 376, NCo 310 and CB 36/14, respectively, and leaf area indices of 5,9, 6,2 and 5,8 were higher than in the plant crop.

Of the net amount of dry matter produced in the plant and first ratoon crops between 55 and 62% was in the stalk, representing a cane fresh mass yield of 150 (137-159) t/ha/yr (Table 9), with a dry matter content of 25,4%. The sucrose content of the stalk expressed on a dry matter basis was between 47,5 and 54,3%, giving an average yield of estimated recoverable sugar of 16,9 (15,5 - 18,6) ters/ha/yr.

(b) Radiant energy interception

These results are illustrated in Fig. 21. The amount of radiant energy intercepted by the canopy above each solarimeter has been presented as the difference between the energy recorded by the

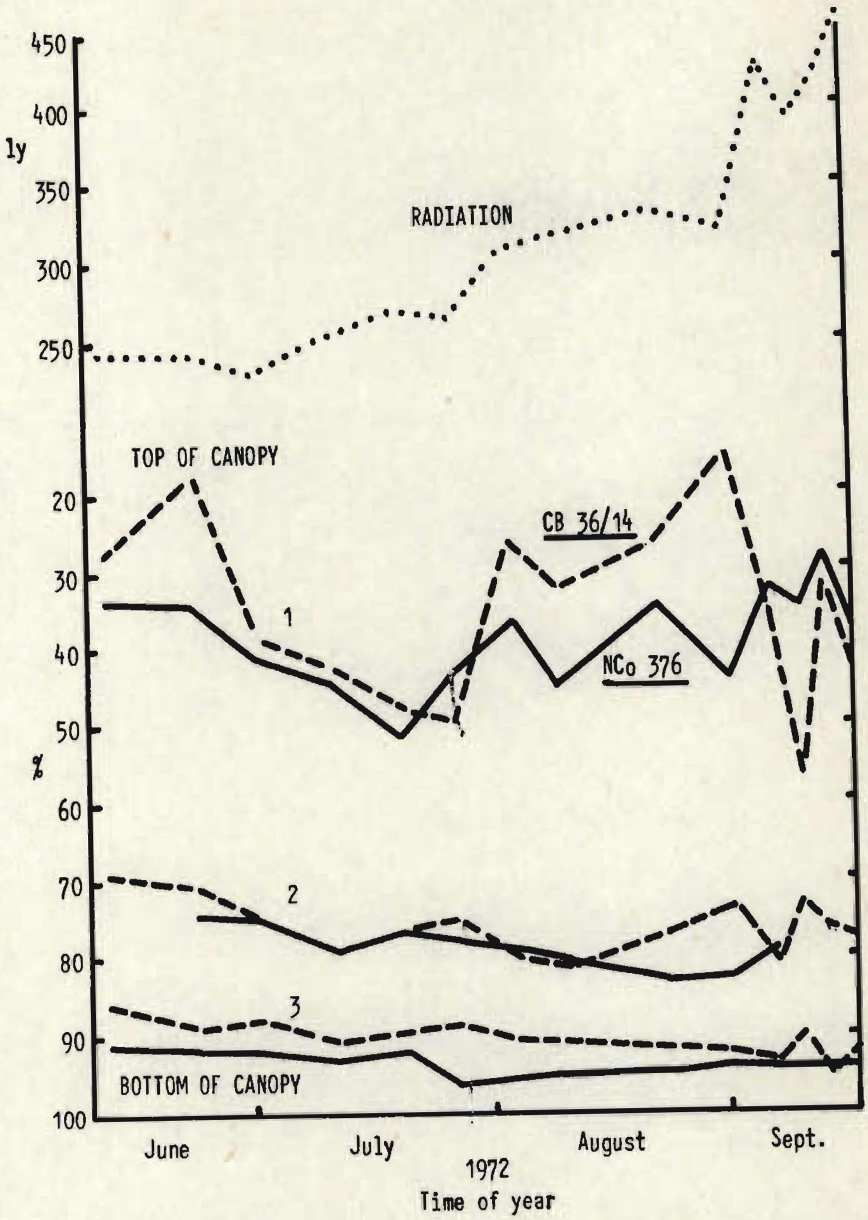


Fig. 21 Total daily radiation and the proportion of this total intercepted above solarimeters placed at three positions in the canopy of varieties NCo 376 and CB 36/14.

Lintronic solarimeter and that recorded by each tube solarimeter. Readings of the lowest solarimeter could not be easily distinguished from zero, indicating almost complete energy interception above this point, and they have been omitted from Fig. 21. There was little difference in energy interception between the varieties and the amount of energy intercepted by each solarimeter was similar between 11 June and 17 September, despite a gradual increase in radiation during this period from 292 ly/dy to 508 ly/dy. Average figures for energy interception between these dates, starting with the uppermost solarimeter, were 39%, 79% and 94% for NCo 376, and 35%, 76% and 91% for CB 36/14.

3.4 Experiment 3 - Observations of root growth

3.4.1 Methods

Selected, single-bud setts of varieties NCo 376, NCo 310 and CB 36/14 were planted on 21 September 1970 into a disturbed Table Mountain Sandstone soil at the Mount Edgecombe root laboratory (Glover, 1967). This is an underground tunnel with glass walls through which roots may be observed. The soil was fumigated with ethylene dibromide to a depth of 30 cm and fertilized with 800 kg/ha of a 2-3-2(22) fertilizer mixture. The varieties were topdressed at four months of age with 1 t/ha of dolomitic limestone (40% Ca, 40% Mg) and 600 kg/ha of a 1-0-1(47) compound fertilizer.

There were two separate root laboratory windows for each variety and the first row of sugarcane was planted adjacent to and along the windows. Observations of root growth were made until the varieties were ploughed out 10 months after planting. Soil samples were taken to a depth of 0,8 m on 22 January 1971 and examined for nematodes (Jenkins, 1964). Root samples were incubated in glass flasks and also examined for nematodes on 2 April 1971.

Growth was poor in this first plant crop, especially of variety CB 36/14, and to avoid a possible variety/fumigation interaction the crop was removed and the soil on the experimental site excavated to a depth of 1,5 m for a distance of 2 m from the windows. Each 25 cm soil layer was kept separate and fumigated with methyl bromide before replacing in its' original position. The varieties were then replanted on 26 January 1972 in rows at right angles to the windows. The soil was fertilized before planting with 3 000 kg/ha dolomitic limestone, 150 kg/ha double superphosphate and 150 kg/ha muriate of potash, and the crop was topdressed two months after planting with 500 kg/ha of 1-0-1(47) fertilizer mixture. Crop establishment was assisted by irrigating on one occasion.

3.4.2 Results

In the first crop, in which only the topsoil was fumigated, none of the varieties grew well, but the root and top growth of NCo 376 was much better than that of NCo 310 and CB 36/14. Analysis of soil samples showed that the soil was low in K, Ca and Mg, and this may have contributed to the results observed. Once the setts had germinated roots of NCo 376 grew faster, were more abundant and penetrated the soil faster than those of both NCo 310 and CB 36/14

Roots of NCo 376 were active at a depth of 100 cm within 2 months of planting, but NCo 310 and CB 36/14 had few roots below 50 cm depth even when the experiment ended. NCo 376 had many fine, branched roots at all times, but the roots of CB 36/14 tended to be short, thick and stubby. Roots of NCo 310 appeared similar to those of NCo 376 but there were fewer of them. Examination of soil and root samples for nematodes did not give a clear picture as there were slightly more Trichodorus spp. in soil from plots of CB 36/14 but roots of NCo 376 contained more Pratylenchus spp.

Following methyl bromide fumigation to 1,5 m depth, root growth and development, and the appearance of the tops of the plants of both NCo 310 and CB 36/14 were comparable with those of NCo 376, although NCo 376 developed its root system quicker and seemed to have slightly more roots per unit volume of soil.

3.5 Discussion

3.5.1 Crop growth rate and radiant energy utilization

The maximum rates of C at Mount Edgecombe of 19,5 $g/m^2/dy$ over a period of one year (Table 8) and 20,3 $g/m^2/dy$ over a six month period (Section 3.3.2a) appear to be low, compared with maximum values quoted for other crops. This was probably because the rates reported here were measured over a longer period than in the work with other crops discussed in the following paragraph. Mean values of C will also be affected by the proportion of the time over which measurements were made when the crop canopy was incomplete.

Some maximum rates of C recorded in the literature are, sugarcane 38 $g/m^2/dy$ for a 3 month period (Borden, 1942, quoted by Blackman and Black, 1959); green maize in Israel (period not specified), 42 $g/m^2/dy$ (Westlake, 1963); Maize and Sorghum in California, 51 and 52 $g/m^2/dy$ for periods of 12 and 35 days (Loomis and Williams, 1963; and Williams, Loomis and Lepley, 1965) and Bulrush millet in Australia, 54 $g/m^2/dy$ for a 14 day period (Begg, 1965). However, the average crop growth rates for longer periods of time for sugarcane were 18 $g/m^2/dy$ over one year (Borden, 1942) and 18 $g/m^2/dy$ (tops only) for maize over a period of 160 days (Loomis and Williams, 1963). The crop growth rates reported here therefore confirm the high rate of dry matter production by sugarcane.

The annual productivity of sugarcane in South Africa has been compared in Table 10 with that of Hawaii, which is reputed to produce the highest yields of sugarcane per hectare in the world (Burr et al, 1957). The data show that when allowance is made for differences in solar radiation, productivity in South Africa is equivalent to that in Hawaii. They also show that the efficiency of r_i utilization by sugarcane declines as the level of r_i increases.

TABLE 10 The efficiency of conversion of incident total radiation into dry matter by field crops (including estimates of root dry mass)

Source	Age (days)	Cane f. mass (t/ha)	Total r_i (ly/dy)	C (g/m²/dy)	Effic* (%)
South Africa					
Pongola (Exp. 1)	365	146	436	17,9	1,72
Mount Edgecombe (Exp. 2)	365	150	368	17,0	1,94
C.F.S. (May, unpublished)	365	148	377	14,9	1,66
Chaka's Kraal (Gosnell, 1967)**	365	105	367	13,1	1,48
Ottawa (Thompson & de Robillard, 1968)***	426	150	-	-	1,80
Hawaii					
Plant crop trmt D (Borden, 1942)	348	191	489	18,1	1,58
Plant crop trmt C (Borden, 1945)	365	194	524	19,9	1,58
Ratoon crop trmt C (Borden, 1948)	365	214	630	21,1	1,40

* Assuming that 1 g carbohydrate ≡ 4 200 cal.

** Soil conditions restricted growth and there was evidence of nutrient deficiency in this crop.

*** Estimated from cane yields by the authors; 10% has been added for root mass.

The reasons for differences in r_i utilization by variety NCo 376 between Experiment 1 at Pongola and Experiment 2 at Mount Edgecombe are not known, but the lower efficiency at Pongola may be attributable in part to the crop beginning to grow in January. The Mount Edgecombe crop began to grow in September and the results in Section 2.4.6 show that crops ratooned in January had lower yields of cane at 12 months of age than crops that began to grow in September. Other reasons for the lower efficiency of r_i utilization at Pongola could be the higher radiation level at Pongola and the possible beneficial effects of soil disturbance and fumigation on growth at Mount Edgecombe.

3.5.2 <u>Apparent maximum cane yields</u>

In Experiment 1 at Mount Edgecombe the crops that began to grow in September and October, were harvested at just over 12 months of age and everything possible was done to ensure that the growth of the crops was as rapid as possible. A comparison of the efficiencies of r_i utilization with those of other well grown crops (Table 10) also confirm that growth in this experiment was good. It may be concluded, therefore, that for practical purposes the apparent maximum yields of cane that can be obtained from current South African varieties at Mount Edgecombe are at least 145-160 tc/ha/yr at a dry matter content of 25%. This is higher than the actual maximum yield of 142 tc/ha obtained at C.F.S. (Table 10), near Mount Edgecombe, and quoted by Glover (1972).

The theoretical maximum cane yield obtainable at Mount Edgecombe was estimated by Glover (1972) to be 198 tc/ha/yr at a dry matter content of 29%, calculated from actual maximum recorded rates of photosynthesis, actual whole plant respiration data and average meteorological data, allowing for periods of incomplete canopy. The cane yields of 145-160 tc/ha/yr recorded in this thesis are 63-70% of this theoretical maximum yield, allowing for differences in cane moisture content. There would therefore appear to be considerable scope for breeding varieties with a higher cane yield potential.

3.5.3 Radiant energy interception and yields of NCo 376 and CB 36/14

Under the good growing conditions of Experiment 2 both varieties had similar cane yields, despite large differences in stalk population (Section 3.3.2a). There were, however, large differences in growth in Experiment 3 when the growth of CB 36/14 may have been affected by poor soil fertility (Section 3.4.2). It is possible, therefore, that the popularity of NCo 376, which was over 50% of the sugarcane milled in South Africa in 1972/73 season (Morgan, 1973) is due to its better adaptability to varied soil, weather and management conditions, compared with varieties such as CB 36/14 (and NCo 310).

The similarity between NCo 376 and CB 36/14 in leaf area indices and patterns of radiant energy interception is interesting because their differences in leaf width and leaf angle are as extreme as can be found among commercial South African varieties. Measurements of radiant energy interception were not well replicated but the similarity of the results at two completely different situations in the crop canopy and the continued agreement between the varieties when radiation intensity increased, indicate that the data are reliable. The results show that differences in leaf width and leaf angle were not large enough to affect apparent maximum cane yields in these varieties. From this it may be concluded either that rates of photosynthesis per unit leaf area were similar in the two varieties, or that any differences in photosynthesis have no effect on net dry matter production and cane yield.

It is concluded that it may not be an easy task to increase cane yields beyond the level obtainable with variety NCo 376, despite the apparent discrepancy between the maximum yields recorded in this thesis and the theoretical yields calculated by Glover (1972). The limited growth measurements recorded here do not indicate any promising lines of further research.

3.5.4 Increasing sugar yield by improving sucrose concentration

There are appreciable differences in sucrose concentration among varieties and there was an indication in the first ratoon crop at Mount Edgecombe (Table 9) that under some conditions CB 36/14 may have a higher sucrose concentration than NCo 376, which is known to have only a moderate sucrose content. It was also shown in Section 2.4.11 that there was a positive correlation of cane yield and Ers%, and there is evidence that selection for stalk sucrose content in breeding programmes should not have an adverse effect on cane yields (Hogarth 1971). If this is correct for varieties with high cane yields, then improving sucrose concentration may be an easier way of increasing sugar yield than trying to raise the potential maximum cane yield.

Inheritance of the most important characters in sugarcane, including cane yield and juice quality, are controlled by multiple genes (Stevenson, 1965) and this linking of the genes concerned with the inheritance of yield and quality makes it difficult in breeding programmes to eliminate undesirable genes whilst retaining desirable ones. It is therefore unlikely that the maximum degree of favourable combinations of many genes will ever be attained. A further difficulty in sugarcane breeding is to identify a desirable genotype when it occurs from the many less desirable combinations.

An alternative approach to the improvement of sugar yield and, more especially cane quality, which bypasses the difficulties involved in cane breeding, is to increase sugar yields artificially by means of growth regulators. This approach is examined in detail in the following chapter.

CHAPTER 4

THE CHEMICAL RIPENING OF SUGARCANE

4.1 Introduction

The study of the optimum age of harvest of irrigated sugarcane, described in Chapter 2, showed that high rates of sugar production per unit area per unit time were obtained from young crops harvested in Autumn at the beginning of the milling season. However, the natural sucrose concentration of the stalk and the purity of the juice (quality) of such crops are poor, making it difficult to recover the sucrose from the crop. A number of pot and field experiments were undertaken, therefore, to determine whether the yield and quality of these crops could be improved by the application of growth regulating chemicals just before harvest.

Experiments were also carried out at the end of the milling season because any means of improving the quality of the cane, and increasing sugar yields at the beginning and at the end of the milling season would be of tremendous value to the South African sugar industry. It should improve the efficiency of sugar recovery at the mill and it could lead to an extension of the milling season into what is at present an unfavourable time of the year.

Many chemicals have been screened as sugarcane ripeners since Beauchamp (1950) reported that applications of 2,4-D improved cane quality and sugar yield. The early work on chemical ripening has been reviewed by Vlitos and Lawrie (1967), Fewkes (1971) and Alexander (1973). Much of the screening of chemicals for ripening ability has been done at the Experiment Station of the Hawaiian Sugar Planters Association (Nickell and Tanimoto, 1965 and 1967;

Nickell and Takahashi, 1972). From this work one chemical, Polaris (N,N-bis(phosphonomethyl)glycine), formerly coded CP41845 and Mon 845, has shown particular promise in many parts of the world (Tianco and Escober, 1970; Anon, 1971b; Nickell and Takahashi, 1971; Alexander and Montalvo-Zapata, 1972). Nevertheless, Bieske (1970) found that Polaris reduced cane yield to such an extent in some experiments that improvements in juice purity and pol (sucrose) percent cane did not result in higher yields of sucrose. Similarly in some of the trials reported by Nickell and Takahashi (1972) there was either no response or a negative response to Polaris.

It is probable that several plant and weather factors influence the response of sugarcane to chemical ripeners, but these have seldom been taken into account when assessing the results of field trials, possibly because consistent results had not been obtained prior to the work with Polaris. Before this it was difficult to decide whether negative results were due to a lack of activity by the chemical under test or to the crop being unable to respond

The response of sugarcane to a proven ripener may vary with the rate of application of the chemical, the variety, the physiological stage of the crop at the time of spraying, and growing conditions before and after spraying. In order to ensure that any decline in growth would not restrict the response to chemical ripeners, many of the experiments reported here were on young, irrigated sugarcane at the beginning of the milling season.

Because of the wide range of chemicals reported to ripen sugarcane and the conflicting results obtained in some sugarcane growing areas, six promising chemicals were compared in an initial field experiment. From this experiment it was concluded that Polaris and Ethrel (2-chloroethyl-phosphonic acid) were the most promising ripeners and further work was concentrated on these two chemicals.

Polaris has been developed solely as a sugarcane ripener but Ethrel is an ethylene releasing compound that has shown considerable promise in regulating the growth and ripening of a wide range of crops (de Wilde, 1971). Experiments with Ethrel on sugarcane have given variable results and the reasons for this are not yet known. Results from glasshouse trials were sufficiently encouraging for field trials to be undertaken in Puerto Rico and the West Indies (Yates, 1972) but both formulations of Ethrel tested (66-329 and 68-250) stimulated growth and reduced quality in the field. Similar results have also been reported by Alexander and Montalvo-Zapata (1973a) with another variety.

In this Chapter results are presented of two pot experiments (numbered 1 and 2) and nine field experiments (numbered 3 to 11), which covered a period of two years. For convenience, the experiments are presented in appropriate categories rather than in chronological order. The pot experiments were designed to investigate the effects of Ethrel and Polaris on the growth and photosynthesis of variety NCo 376 in more detail than was possible in field experiments.

Variety NCo 376 was used for Experiments 1-10, and variety N55/805 was used in Experiment 11. The field experiments with NCo 376 have been divided into two categories on the basis of their response to Ethrel and Polaris:-

(a) Good response: early season experiments (3-7)

(b) Poor response: early season experiment in the Midlands area of Natal (8), and late season experiments (9 and 10).

4.2 Materials and methods

Relevant details of the experiments, including the rates of Ethrel and Polaris applied, are given in Table 11. The following chemical treatments were also applied: in Experiment 3, Pesco 1815 (a mixture of 15% 2-methyl-4-chlorophenoxyacetic acid and 4,8% 2.3.6 - trichlorobenzoic acid) at 44 l/ha; Hydrothol 191 (Mono N,N dimethyl alkylamine) salt of 3,6 endoxohexahydrophtholic acid) at 3,7 kg a.i./ha; DA at 3,4 kg a.i./ha and CGA 11610 at 3,9 kg a.i./ha. The composition of DA5 and CGA 11610 is not known.

In Experiment 4, which was on the same site as Experiment 3, Pesco 1815 was applied at 47 l/ha and the residual effects of Polaris and Hydrothol were determined by measuring the yield from plots that had received these chemicals in the previous crop. All other treatments in Experiment 4 were randomized so that the results would not be affected by residual effects. Experiment 5 was on the same field as Experiments 3 and 4 but not on the same sugarcane. Experiments 6, 7 and 10 were also on the same site (Table 11).

All experiments were randomized blocks, except number 7, for which an incomplete latin square design was used.

4.2.1 Pot experiments

Selected, disease free, single-bud setts were germinated in vermiculite, selected for uniformity of germination and grown in the artificial soil described in Section 3.3.1 in 15 cm deep, 8,5 cm diameter, plastic sleeves. They were then selected for uniformity of tillering and re-potted into 5 l plastic pots. The plants in Experiment 1 remained in these pots until harvest, but in Experiment 2 the plants were transplanted at 3 months of age into 80 l plastic dustbins. All pots were free draining and the plants were watered at least twice daily and received a complete nutrient solution

TABLE 11 Details of the experiments, including yield and purity data for untreated sugarcane

Expt.	Site	Date sprayed	Rate (kg a.i./ha)		No. reps	Crop	Age (months)	tc/ha		Purity (%)	
			Ethrel	Polaris				Initial*	Final	Initial	Final
1 a	Pots	26.10.72	-	1,7 3,5 7,0	6	Plant	3	-	-	-	-
2 a	Pots	25. 4.73	0,5 1,0 2,0	2,8 3,8 4,8	6	Plant	9	-	-	71	82
EARLY SEASON EXPERIMENTS											
3 b	Chaka's	29. 4.71	1,2	3,3	4	Plant	9	80	104	61	75
4 b	Kraal	5. 4.72	1,2	2,5 3,2 4,8 5,2	4	1R	10	50	92	67	87
5 b	C. Kraal	11. 4.73	0,5 0,9 2,0	2,8 3,4 4,8	4	2R	8	64	-	72	77
6 a	Ubombo	21. 3.72	-	3,7	7	3R	10	101	137	65	81
7 a	Ranches	8. 3.73	1,2	4,5	7	4R	9	70	95	66	85
EARLY SEASON EXPERIMENT IN MIDLANDS											
8 a	Sevenoaks	29. 3.72	-	4,9	7	2R	18	100	115	85	89
LATE SEASON EXPERIMENTS											
9 b	Flanders Est.	30.12.71	1,2	3,8	5	Plant	14	110	-	86	85
10 a	U. Ranches	20. 9.72	-	3,7	6	3R	10	100	110	87	85
11 b	Ottawa Estate	26.10.72	0,5 1,0 1,8	2,7 3,1 4,5 5,2	4	1R	12	105	-	88	89

Experiment 11 Variety N55/805; All others variety NCo 376

* Estimated from sample mass

a Sprayed with knapsack sprayer; spray volume about 320 l/ha; plot size 92-100 m^2

b Sprayed by aeroplane; spray volume about 56 l/ha; plot size 0,2 - 0,3 ha three times a week (Arnon, 1938).

In Experiment 1, the treatments were applied when the plants were 12 weeks old and harvested 8 weeks later. Shoot number, leaf area, and the fresh and dry mass of each plant were determined.

In Experiment 2, half the plants were 9 months old at the time of spraying and the remainder of the plants were 11 months old. All plants, except selected ones used for photosynthesis measurements were harvested 9 weeks after spraying. Stalks were topped at node 6 and analyzed for sucrose, brix and dry matter content, as described in Section 2.2.

Measurements of apparent photosynthesis were made between 8 and 10 weeks after spraying, in Experiment 2 on individual plants placed inside a perspex box (Plate 1) that was 5 m high, 1,8 m wide and 1,8 m deep (16 m^3). One plant of each age group from the control, Ethrel 2,0 kg a.i./ha and the Polaris 4,8 kg a.i./ha treatments were used. The method of photosynthesis measurement has been fully described by Glover (1974) and will only be outlined briefly.

The depletion in the CO_2 concentration of air drawn through the box at a rate of 2,0 - 2,5 m^3/min was measured with an infra red gas analyser, for 2 minute periods, 10 times an hour during daylight hours. There was a 100 mm diameter inlet pipe close to the top of one side of the box and a 75 mm diameter outlet pipe at the base of the opposite side. A fan rated at over 5 m^3/min operated continuously inside the box to ensure adequate mixing of the air.

The CO_2 concentration within the box did not fall below 260 ppm during the measurements and the air temperature within and immediately above the canopy was approximately 2^{o}C above ambient temperature. Radiation intensity was measured inside the box with a calibrated Middleton solarimeter. Plants were put into the box

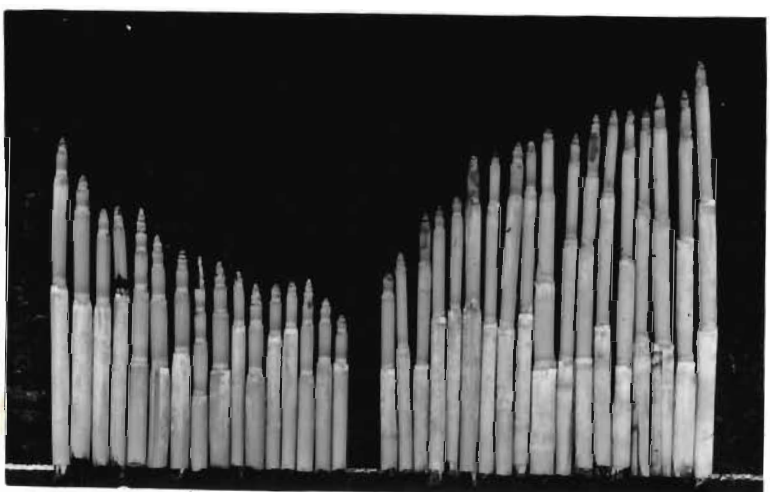
PLATE 1

Photosynthesis chamber with guard plants removed.

A B

PLATE 2

The tops of two sticks of variety NCo 376 taken from the same plot 13 weeks after spraying with Polaris at the rate of 3,6 kg/ha. A. Severe stunting and side shooting of the upper buds. B. Only leaves that were small at the time of spraying were stunted and subsequent shoot growth was normal.



A B

PLATE 3

Representative stalk samples taken 6 weeks after spraying, showing the effect of Polaris applied at a rate of 4,4 kg/ha on the length of internodes above the point of topping.
A. Control B. Polaris

in rotation and treated plants were not tested until control plants had shown the normal pattern of CO_2 uptake. After the last photosynthesis measurement, total dry mass of the plants was determined and total lamina area was measured.

4.2.2 Field experiments

These were either small scale trials in which the chemicals were applied with a hand-operated knapsack sprayer, or large scale trials in commercial fields of sugarcane where the chemicals were applied by aeroplane (Table 11). Spraying was done early in the morning to ensure that spray drift was eliminated.

All experiments, except Experiment 8, were irrigated, but there was some moisture stress for the first 4 weeks after spraying in Experiments 5 and 9. A drying off treatment was included in Experiment 10, and Experiments 5 and 8 were uniformly dried off. Drying off was rather more severe than intended in Experiment 8 and there was some senescence of lower leaves in all plots. Details of the amount of rainfall and irrigation during each experiment are given in Appendix III, Table 1.

Samples of 20 stalks per plot (16 in Experiment 1) were taken before spraying and at regular intervals until harvest. At harvest the cane from measured areas of each plot in Experiments 3, 6, 7, 8 and 10 was weighed. There was sufficient cane in Experiments 6, 7, 8 and 10 for it to be cut and topped in the normal estate manner and sent to the mill, plot by plot. The cane was weighed and crushed at the mill and the brix and sucrose concentration of the first expressed juice determined. The sucrose percentage of the cane was estimated by means of the Java ratio, which is the ratio of the average sucrose content of the first expressed juice and the sucrose in the cane stalk. In Experiment 6, the concentration of reducing sugars in the juice was also determined in the mill laboratory by the Clerget method (Spencer Meade, 1963). An estimate of cane yield was obtained at the last sampling in Experiments 5 and 11 by determining the mass per stalk on a larger sample of 48 stalks per plot and relating this to the total number of stalks in the plot. In Experiment 5, these 48 stalks were divided by eye into thick and thin sub-samples, and assessed for the degree of lateral bud development (side-shooting).

Topped stalk samples were divided for analysis into the top six internodes (6-11) and the remainder of the stalk. Wherever possible measurements were made of the length and the mass of these upper internodes and of the internodes discarded with the tops (1-5). The effect of treatments on lamina mass and area was also measured in some trials.

4.3 Results

A large amount of data has been collected from these experiments, much of it confirming the results of other workers and of other experiments. Therefore only selected, representative data will be given in detail.

Changes in sucrose percent cane fresh mass (S%c), sucrose percent dry mass (S%dm), and juice purity, normally follow one another very closely and for most experiments the results will be presented in terms of the estimate of recoverable sucrose (Ers %c). For brevity this will be referred to as cane quality. Summaries of the initial and final sample data for all experiments are given in Appendix III, Table 2. The final samples were taken at the following times after spraying: 8 weeks in Experiments 3 and 11, 10 weeks in Experiments 7 and 10, 12 weeks in Experiments 4, 5, 6 and 8, and

$13\frac{1}{2}$ weeks in Experiment 9.

4.3.1 Growth effects

(a) Pot experiments

Polaris, at all rates of application, reduced the leaf area and the fresh and dry mass of all parts of the plant in Experiment 1 (Fig. 22). The 7,0 kg a.i./ha treatment reduced total plant dry mass by 52% but there was only a 15% reduction at both lower rates of application. The number of shoots per plant was significantly reduced by 1,7 kg a.i./ha Polaris.

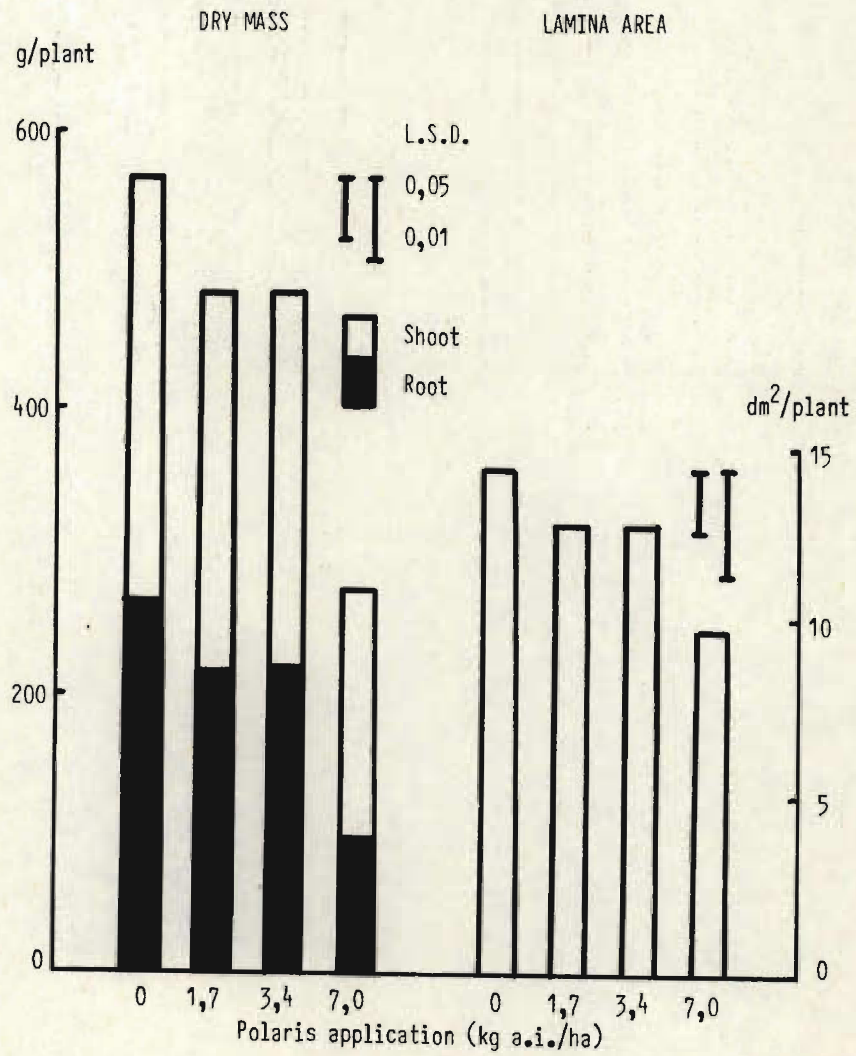


Fig. 22 The effect of Polaris on total plant dry mass and lamina area per plant in Experiment 1.

Both Ethrel and Polaris had only small statistically non significant effects on growth at all rates of application in Experiment 2. Ethrel reduced foliage fresh mass and lamina area at all rates of application and the effect was very marked at the 2,0 kg a.i./ha rate of application. Polaris only reduced foliage mass and lamina area at the 4,8 kg a.i./ha rate

(b) <u>All Field Experiments</u>

Hydrothol, Ethrel and Polaris were the only chemicals to have any appreciable effect on growth but Pesco 1815 caused some leaves to break away from the stalks easily in the later samplings of Experiment 3. Hydrothol scorched the leaves severely within one week of spraying and caused a reduction in cane yield and quality. Ethrel and Polaris had less obvious effects on growth than Hydrothol and these effects varied with the variety, the stage of maturity of the cane at the time of spraying, and the rate of chemical application

Variety N55/805 appeared to be more sensitive to the chemicals than NCo 376, and young, vigorously growing NCo 376 sugarcane was affected more than older, more mature cane. This meant that there was a bigger ripening response to the chemicals at the beginning of the milling season than at the end. There was also a small response at the beginning of the season in the colder, slower growing midlands area (Experiment 8) but there was no visual effect on either the foliage or the cane stalks.

Polaris at the higher rates of application produced white spots on a few leaves of NCo 376 in some experiments, and caused bleaching of the young unfurled leaves of some stalks in Experiment 3. There was also side-shooting of some stalks in Experiments 3, 5 and 6. It was also observed in Experiment 3, and confirmed in Experiment 5, that there was more side-shooting in the thicker stalks in a plot (Table 12) The higher the rate of Polaris application the greater the amount of side shooting, and 19% of all the stalks treated with 4,8 kg a.i./ha Polaris showed some sign of sideshooting.

TABLE 12 Total number of stalks per treatment with small sideshoots 12 weeks after spraying in Experiment 5

Type of stalk *	Control	Ethrel		Polaris	
		Rate applied	Number	Rate applied	Number
Thin	0	0,5	0	2,8	1
Thick	0		0		3
Thin		0,9	0	3,6	2
Thick			1		10
Thin		2,0	0	4,8	10
Thick			3		27

* 48 stalks per plot divided by eye into two categories

Ethrel only affected the foliage in Experiment 7, in which it caused slight burn of the leaf tips. In general, Ethrel had no effect on lateral bud development but there was an indication of sideshooting at the higher rates of application in Experiment 5 (Table 12). Occasionally the development of root primordia was observed in the lower internodes of stalks in Ethrel treated plots. Neither Ethrel nor Polaris caused side shooting in variety N55/805.

Neither chemical had any effect on leaf senescence but both chemicals reduced the size and the mass of some, or all, young leaves and sheaths of shoots of both NCo 376 and N55/805 (Table 13). In experiments where the response to the chemicals was small, leaf

TABLE 13 The effect of Ethrel and Polaris on foliage fresh mass expressed as a percentage of control

Treatment (kg a.i./ha)	Top 5 laminae					All tops	
	Experiment						
	5		7		11*	5	
	weeks						
	6	12	6	8	8	10	12
Control	100	100	100	100	100	100	100
(g/stalk)	(56)	(56)	(63)	(54)	(78)	(166)	(151)
Ethrel							
0,5	96	85			72	100	100
0,9-1,2	87	72	84	80	66	92	88
1,8-2,0	92	69			49	94	83
Polaris							
2,7-2,8	90	83			83	104	98
3,1-3,6	96	85			71	102	103
4,5-4,8	91	80	92	101	46	95	98
5,2	-	-	-	-	45	-	-
L.S.D. (0,05)	10	9			10		13
(0,01)	14	12			14		18
C of V (%)	7	7			9		9

* Variety N55/805

and sheath stunting was variable within plots (Plate 2) : it was severe in some stalks whilst in others only 3-4 leaves were affected and subsequent leaf growth was normal.

The length and dry mass of internodes 1-5 were increased in all experiments, except number 8, by both chemicals, at all but the lowest rates of Polaris application (Plate 3 and Appendix III, Tables 3 and 4). The mass of other sections of the stalk was generally equal to, or higher than those of control plants

(Table 14), indicating that the increase in mass at the top of the stalk was real and not due to an alteration in the pattern of internode development following treatment. This was confirmed in all experiments by the fact that the chemicals appeared to have no effect on total cane mass (Appendix III, Table 2).

TABLE 14 The effect of Ethrel and Polaris on stalk dry mass 12 weeks after spraying in Experiment 5 (g/stalk)

Treatment	Internodes			Whole stalk	
(kg a.i./ha)	1-5	6-11	Remainder	Mass	%
Control	2,4	51,2	136,1	189,7	100
Ethrel					
0,5	4,2	52,4	130,3	186,9	98
0,9	4,8	52,1	130,3	187,2	99
2,0	5,2	50,5	144,2	199,9	105
Polaris					
2,8	5,1	57,3	129,4	191,9	101
3,6	5,7	61,1	134,4	201,2	106
4,8	5,1	68,2	123,8	197,1	104
Mean	4,6	56,1	132,6	193,4	102
L.S.D. (0,05)	1,1			NS	
(0,01)	1,5				
C of V (%)	15,9			8,4	

In most experiments with NCo 376 there was a reduction in apparent stalk length measured to the uppermost visible collar because of a shortening of the upper leaf sheaths but there was little reduction in the length of internodes 6-8 and 9-11 (Appendix III, Table 3). In variety N55/805 the elongation of internodes 1-5 was less marked than in NCo 376, and Ethrel, but not

Polaris, stimulated internode elongation lower down the stalk. The higher the rate of application, the greater the number of nodes affected (i.e. down to number 11).

4.3.2 Effects on apparent photosynthesis

There was a good correlation between the curves of radiation and the apparent photosynthesis of unsprayed plants, and the results have been presented in Fig. 23, in which the scale of the graphs has been adjusted so that the curves of control plants would fall together to give a ratio of 1,0 when the area beneath the curves was planimetered (Table 15). On the assumption that the photosynthesis of unsprayed plants would have been correlated in a similar manner on the days when the photosynthesis of treated plants was monitored, the difference between the radiation and photosynthesis curves represent the effect of the chemicals.

TABLE 15 Harvest data and daily CO_2 uptake per plant in Experiment 1

Treatment (kg a.i./ha)	Plant dry mass (kg)	Lamina dry mass (g)	Lamina area (dm^2)	Lamina area (%)	Total CO_2 uptake* (%)	CO_2 uptake / lamina area
9 month plant						
Control	2,8	382	306	100	97	1,0
Ethrel 2,0	2,0	217	195	64	74	1,2
Polaris 4,8	3,1	335	264	86	67	0,8
11 month plant						
Control	3,6	334	281	100	98	1,0
Ethrel 2,0	2,8	224	200	71	44-57	0,6-0,8
Polaris 4,8	2,2	194	201	72	38-50	0,5-0,7

* Area below radiation and CO_2 curves planimetered and "CO_2 area" expressed as a percentage of "radiation area"

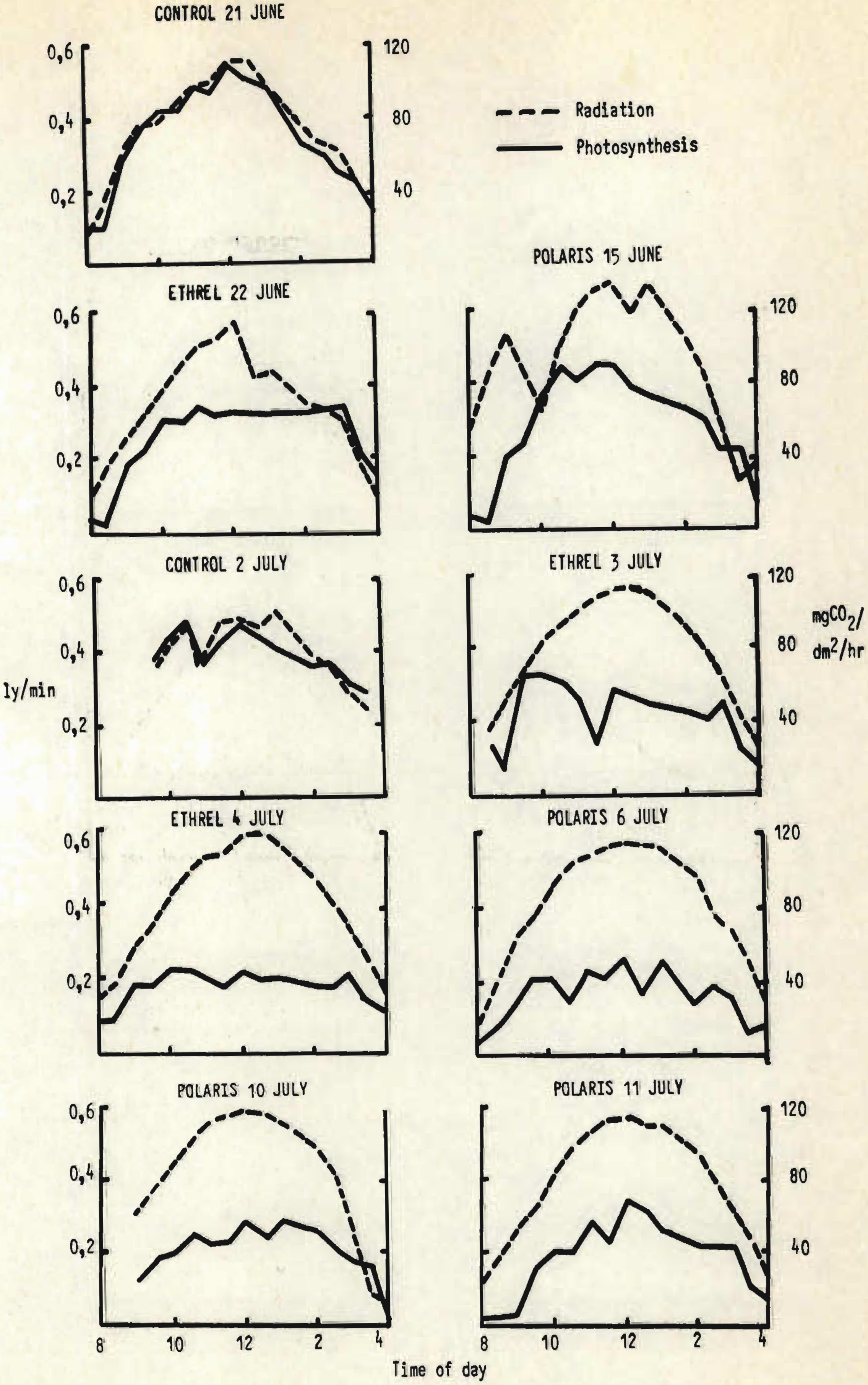


Fig. 23 Radiation and photosynthesis curves for individual plants in Experiment 2.

Both Ethrel at 2,0 kg a.i./ha and Polaris at 4,8 kg a.i./ha reduced CO_2 uptake below what would have been expected on the days in question and there was a marked plateau in the photosynthesis curve of treated plants at high levels of radiation (Fig. 23), indicating that the depression in CO_2 uptake was not entirely due to a reduction in leaf area (Table 15). If the results had been due to the smaller leaf area of treated plants the photosynthesis curve would have been similar to, but displaced from the radiation curve. An interesting feature of the results was the gradual change in the CO_2 uptake curve of the Polaris treated plant, which became more dome-shaped between 6 and 11 July, indicating a recovery from the effects of the chemicals as new leaves expanded.

4.3.3 Early season field experiments, numbers 3-7

(a) Cane quality

A summary of the main results of the initial and final sample data is given in Appendix III, Table 2. The initial sucrose percentage of the whole stalk ranged from 6-8 S%c or 32-37 S%dm and the juice purity was 61-72%. There were rapid improvements in cane quality during the course of these experiments and comparison with data for other experiments showed that the largest responses to Ethrel and Polaris were obtained in Experiments 3-7. The chemicals had their biggest effect on the upper internodes of the stalk and this is illustrated in Fig. 24 with data from Experiments 4 and 6.

In Experiments 3 and 4, Pesco 1815 and DA5 produced small and consistent improvements in cane quality but the results were not statistically significant.

Ethrel and Polaris produced large, and in general statistically significant improvements in all measures of quality from 4 weeks after spraying in Experiments 3, 4, 6 and 7 (Fig. 25).

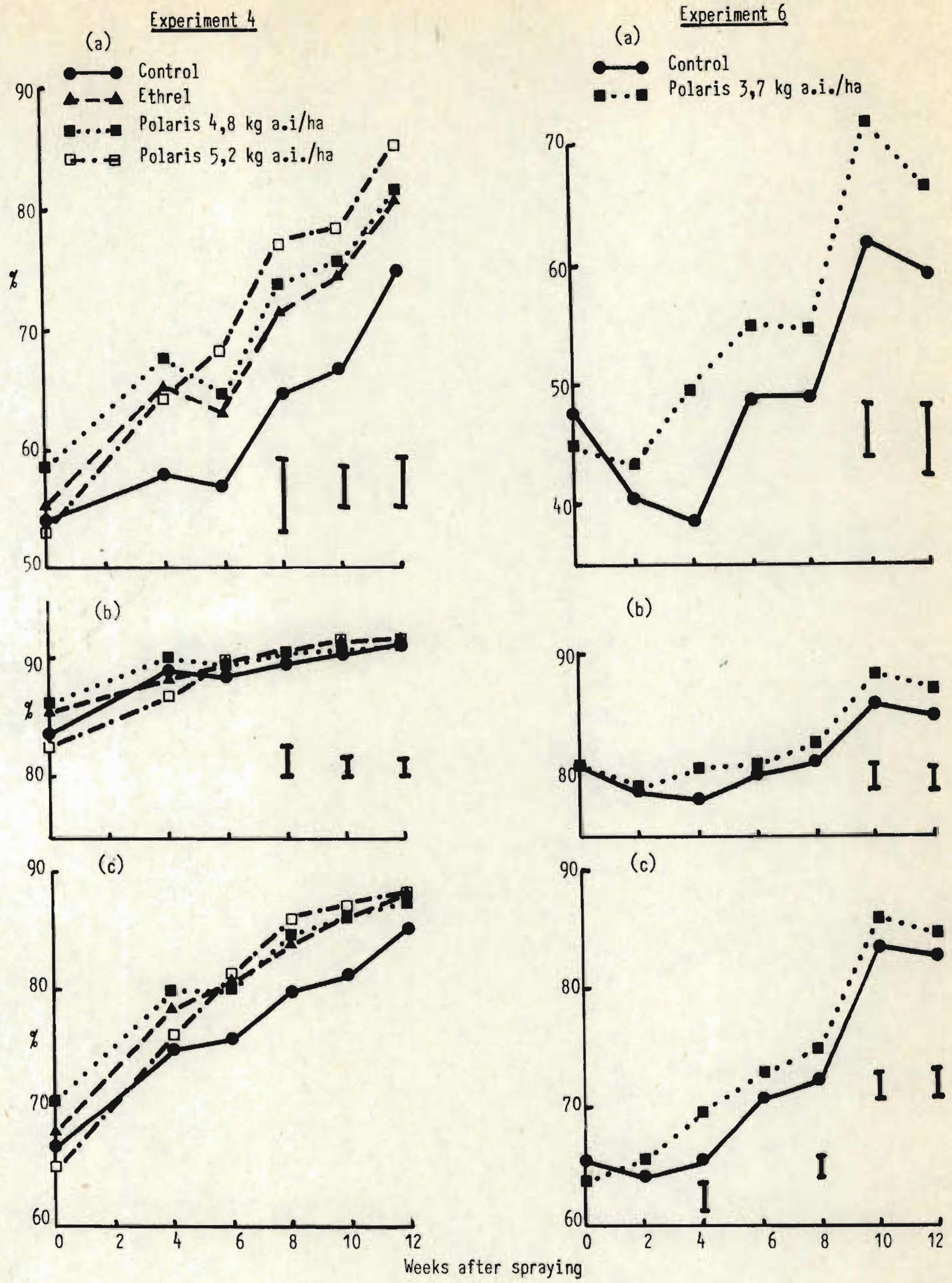


Fig. 24 The effect of Ethrel and Polaris on the juice purity % of (a) top six internodes (b) remainder of the stalk, and (c) whole stalk in Experiments 4 and 6. L.S.D. (P=0,05) I

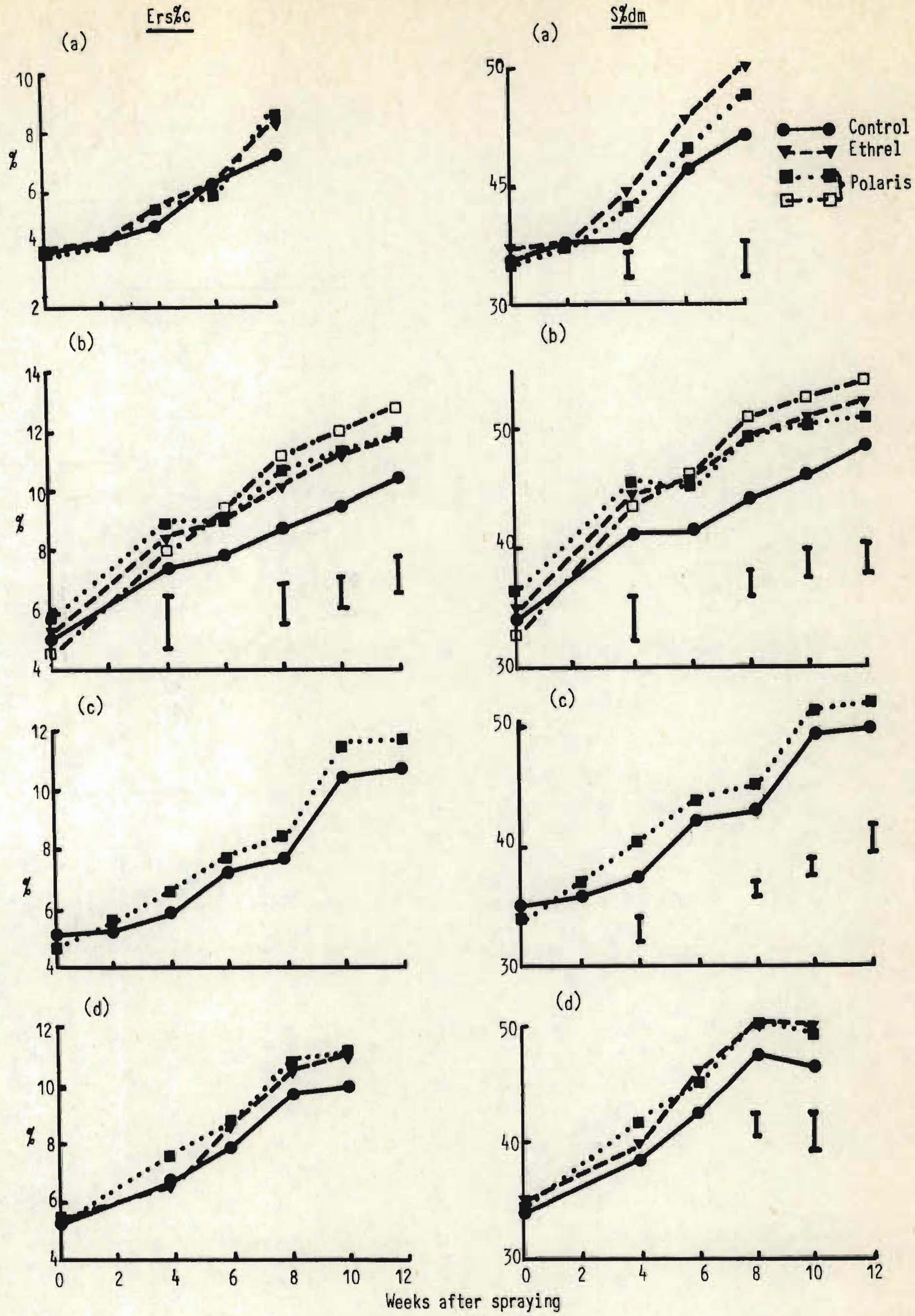


Fig. 25 The effect of Ethrel and Polaris on Ers%c and S%dm in (a) Experiment 3 (b) Experiment 4 (c) Experiment 6, and (d) Experiment 7. L.S.D. (P = 0,05) I

The response was only apparent from 6 weeks after spraying in Experiment 5 (Fig. 26), in which there was no irrigation and only 9 mm of rainfall in the first 4 weeks after spraying.

Once the response to Ethrel and Polaris had been obtained it was maintained until 12 weeks after spraying but there was no further increase after the initial response. Severe drying off in Experiment 7 did not eliminate the response although there was an apparent loss of sucrose from the upper internodes of the stalk. Increasing the rate of either Ethrel or Polaris applied in Experiment 5 increased the size of the response (Fig. 26), which was linear for Polaris up to the highest rate of application (4,8 kg a.i./ha) and curvilinear for Ethrel up to 2,0 kg a.i./ha.

(b) Cane mass and cane moisture content

Neither chemical had any appreciable effect on cane dry mass in any experiment. During the course of these experiments there were appreciable increases in cane dry mass in all treatments, but this was not always obvious from fresh mass measurements because of a steady increase in cane dry matter percentage. Polaris generally increased cane dry matter percentage and the effect was greater the higher rate of application. Ethrel had little effect on dry matter content.

(c) Mass of estimated recoverable sugar

Ethrel and Polaris consistently increased the mass of Ers on most sampling occasions in all experiments (Table 16) and the biggest response was in the upper part of the stalk. Too much reliance should not be placed on the size of the response on any one occasion, because the data are only from samples of 20 stalks

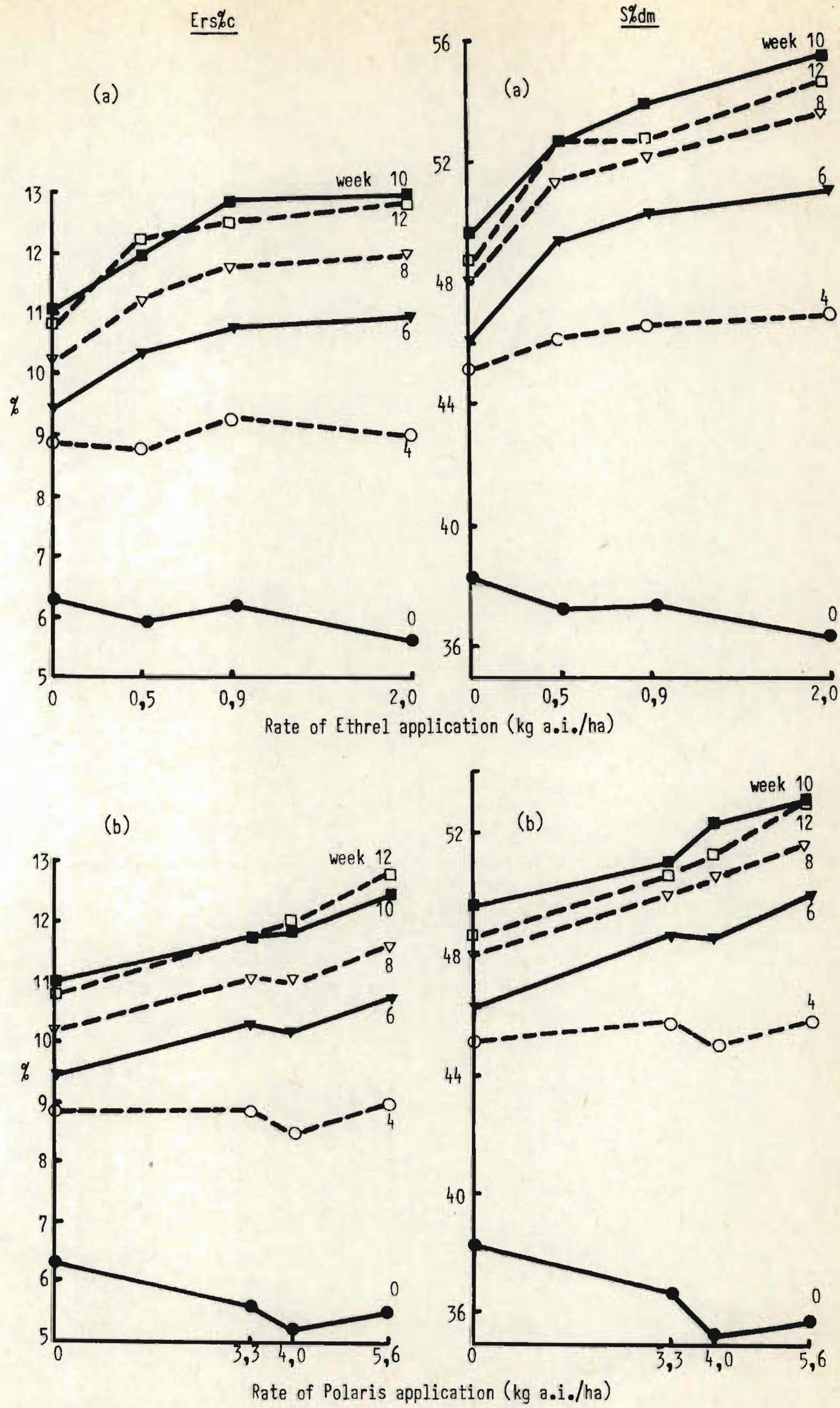


Fig. 26 The effect of rates of (a) Ethrel (b) Polaris on Ers%c and S%dm of variety NCo 376 Experiment 5.

per plot. Nevertheless, the consistency of the results from one date to the next and the statistical significances attained for such criteria as juice purity and sucrose percentage indicate that the average increases in sugar yield of between 6,5% and 12,8% over the 6-12 week period after spraying are real. The results show that both chemicals had a similar effect on sugar yield and that once an increase in yield had been obtained it was maintained for at least 12 weeks after spraying.

TABLE 16 Mass of Ers at various times after spraying in early season experiments, results expressed as percentage change from control

Weeks after spraying	Ethrel (0,9-1,2 kg a.i./ha)				Polaris (3,3-4,8 kg a.i./ha)				
	Experiment								
	3	4	5	7	3	4	5	6	7
	INTERNODES 6-11								
0	-16	-11	-12	14	-41	20	-30	-29	0
4	330	53**	15	6	289	91**	24	581**	55
6		26	30**	19		48**	56**	58	31
8	38	18	22	14	57	30	51	50*	43*
10		10	28**	8		9	61**		26
12		13	31*			32**	81**		
Mean 6-12		16,8	27,8	13,7		29,8	62,2	54,0	33,
	WHOLE STALK								
0	3	- 4	- 5	- 3	4	5	- 5	- 8	- 5
4	3	3	-13	3	13	15	- 5	11	18
6		16	0	14		12	15**	1	6
8	20	15	6	8	32	7	8	7	1
10		14	12*	12		9	12*	27*	8
12		6	8			4	14	13**	
Mean 6-12		12,8	6,5	11,6		8,0	12,2	12,0	8,

Statistically significant at * P = 0,05

** P = 0,01

Ethrel was more active than Polaris in increasing sugar yield (Table 16) and this effect was apparent over the whole range of application rates tested (Table 17). Polaris increased the mass of Ers linearly from 5% above the control at 2,8 kg a.i./ha to 12% at 4,8 kg a.i./ha but Ethrel at 0,5 kg a.i./ha increased ters/ha by 10%. There was a smaller average response to 1,0 kg a.i./ha, largely due to the apparent lack of response at 6 weeks. The large average increase of 19% ters/ha at 2,0 kg a.i./ha Ethrel was associated with a slight decrease in cane dm% and some side-shooting, indicating a possible resumption of growth in this treatment.

TABLE 17 Mass of estimated recoverable sugar when NCo 376 was sprayed with various rates of Ethrel and Polaris in Experiment 5, results expressed as percentage change from control

Treatment	Weeks after spraying						Mean
(kg a.i./ha)	0	4	6	8	10	12	6-12
Ethrel							
0,5	- 2	- 8	13	8	14	8	10
0,9	- 5	-13	0	6	12	8	6
2,0	- 9	- 5	24	16	18	20	19
Polaris							
2,8	- 9	- 8	2	5	9	5	5
3,6	-20	-10	12	3	12	12	9
4,8	- 5	- 5	15	8	12	14	12
L.S.D. (0,05)					14	16	
(0,01)					18	21	
C of V (%)					8	10	

(d) Harvest data

The agreement between results obtained from samples of 20 stalks per plot and results from harvesting whole plots was good, confirming the reliability of sample data (Table 18). Ethrel and Polaris produced large, and statistically significant improvements in S%c, S%dm, Ers%c and ters/ha in Experiments 3 and 6 (Appendix III, Tables 5 and 6) but in Experiment 7 the ripening response was smaller and statistically non-significant (Appendix III, Table 7).

TABLE 18 Comparison of the percentage response to the chemicals at harvest, determined from sample and whole plot data

Experiment	Treatment	Ers %		ters/ha	
		Sample	Whole plot	Sample	Whole plot
3	Ethrel	18	-	20	22
	Polaris	20	-	32	22
6	Polaris	12	16	13	15
7	Ethrel	11	8	12	8
	Polaris	12	8	8	6
8	Polaris	5	5	-3	-5
10	Polaris	2	1	2	1

4.3.4 Early season field experiment in the Midlands (Experiment 8) and late season experiments 9 and 10

(a) Cane quality

The initial quality (Ers%c) of the cane in these experiments was much higher than that of the cane dealt with in Section 4.3.3 (Appendix III, Table 2) and the changes in cane yield and quality during the course of the experiment, as well as the response to the Chemical, was smaller than in other experiments (cf Fig. 25 and Fig. 27). Polaris improved Ers%c from 4 weeks after spraying

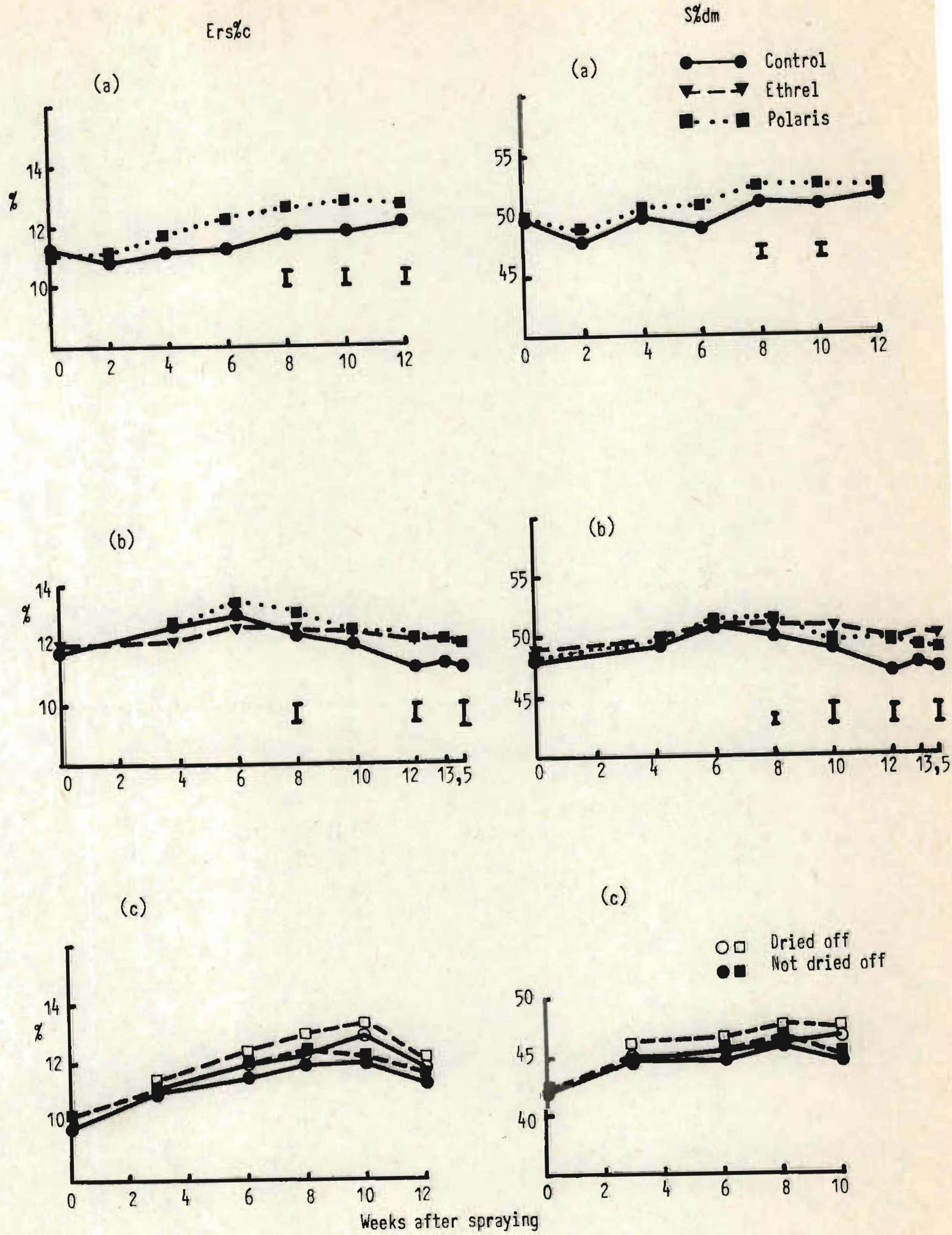


Fig. 27 The effect of Ethrel and Polaris on Ers%c and S%dm in (a) Experiment 8 (b) Experiment 9 (c) Experiment 10. L.S.D. (P = 0,05) I

in Experiment 8 (Fig. 27) but only from 8 weeks in Experiment 9, in which drought soon after spraying delayed the response to both Polaris and Ethrel. In this experiment the first statistically significant response to Ethrel occurred at 10 weeks for S%dm and at 12 weeks for S%c.

There was no statistically significant response to Polaris in Experiment 10 but there were small and consistent improvements in quality, especially in the upper internodes, which indicated that treatment with Polaris had a similar effect to drying off. The effects of Polaris and drying off treatments appeared to be additive.

(b) Cane mass and cane moisture content

None of the treatments had any appreciable effect on cane dry mass in Experiments 8, 9 and 10. Polaris caused a statistically significant reduction in tc/ha in Experiment 8 (Appendix III, Table 8), but this was partly due to a small, consistent reduction in cane moisture content from 4 weeks after planting. There was also a similar reduction in cane moisture content from 6 weeks after spraying in Experiments 9 and 10. Ethrel had no effect on cane moisture content.

(c) Mass of estimated recoverable sugar

There were only small, and mainly non-statistically significant increases in the mass of whole stalk Ers following Ethrel and Polaris application in Experiments 8 and 10 (Table 19) but examination of the upper internode data indicated that the responses to the chemicals were probably real. At harvest the relatively low cane yield of Polaris plots in Experiment 8 more than offset the improvements in cane sucrose concentration, resulting in a lower yield of Ers (Appendix III, Table 8). Similarly in Experiment 9 (Table 19) the beneficial effects of the chemicals on mass of Ers of the whole stalk were lost if harvest was delayed beyond 12 weeks, although the mass of Ers in internodes 6-11 of treated stalks was still higher than in control plots.

TABLE 19 Mass of Ers at various times after spraying in Experiments 8-10, expressed as percentage change from control

Weeks after spraying	Ethrel 1,2	Polaris (3,7 - 3,8 kg a.i./ha)		
		Experiment		
	9	8	9	10
		INTERNODES 6-11		
0	-4	0	- 12	
2		3		
4	5	15	7	5
6	-20	11	5	4
8	-12	15	- 15	10
10	12	13*	- 21	2
12	21	11**	25	
13,5	9		27	
Mean 6-12	1,6	12,5	-4,0	5,3
		WHOLE STALK		
0	-1	-2	- 1	
2		-3		
4	-8	1	- 14	-1
6	-10	7	4	2
8	2	5	- 1	4
10	5	14**	2	2
12	14	-3	11	
13,5	-3		- 14	
Mean 6-12	2,8	5,8	1,9	2,7

Statistically significant at * P = 0,05
** P = 0,01

4.3.5 Experiment 11 on variety N55/805

Ethrel at all rates of application reduced the quality of the whole stalk from 4 weeks after spraying (Fig. 28). Polaris, which had a smaller effect, reduced quality at 8 weeks at rates of application above 3,2 kg a.i./ha. These reductions in Ers%c were due to the lower dry matter percentage of treated stalks (Fig. 29).

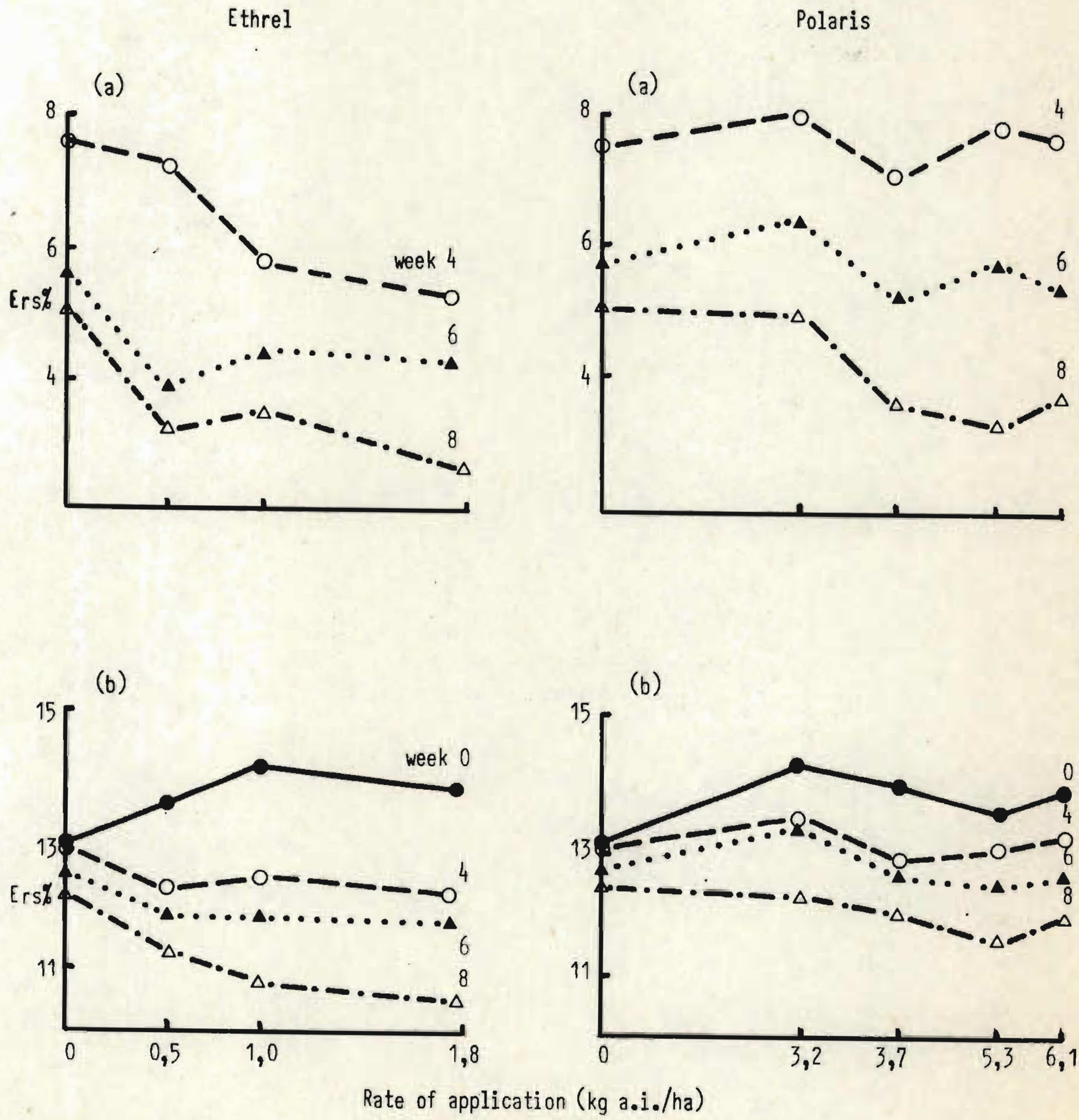


Fig. 28 The effect of various rates of Ethrel and Polaris on Ers%c of (a) top six internodes (b) whole stalk of variety N55/805 at various times after spraying.

Cane dry matter yield was not affected and there was apparently no effect on the mass of Ers (Fig. 29).

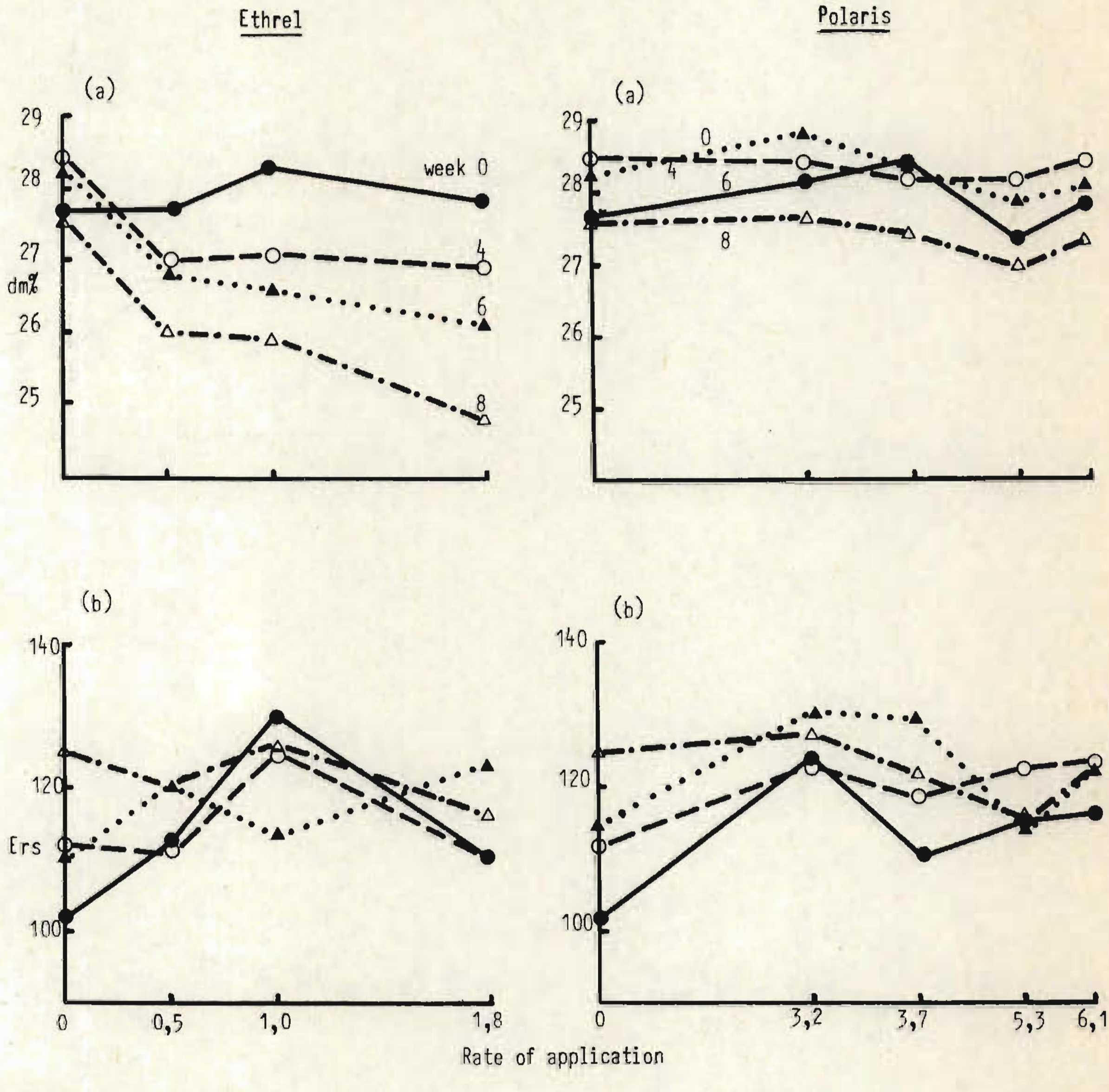


Fig. 29 The effect of Ethrel and Polaris on whole stalk (a) cane dry matter % (b) mass of Ers of variety N55/805 at various times after spraying.

4.3.6 Residual effects of Polaris and Hydrothol following Experiment 3

Polaris applied to this plant crop at the rate of 3,3 kg a.i./ha caused chlorosis and purpling of a few shoots as they emerged in the following ratoon crop. The shoots soon outgrew this and the chemical had no effect on either shoot population at 3 months of age or on final yield and stalk number per plot. Hydrothol had no residual effect on either growth or yield.

4.4 Discussion

When sugarcane matures either naturally or after artificial inducement, there are improvements in sucrose percent fresh mass and juice purity (i.e. cane quality) but if these improvements are only due to changes in cane moisture content they will not result in a higher yield of sugar. This can be seen in the later samplings of Experiment 9 (Table 19) and from harvest data of Experiment 8 (Appendix III, Table 8), where improvements in cane quality were more than offset by a reduction in cane moisture content, and sugar yield was not increased. Similarly in Experiment 11 with variety N55/805, both Ethrel and Polaris reduced Ers%c, but there was no change in the total amount of sugar produced (Section 4.3.5). These results emphasise the need to consider both cane quality and sugar yield when assessing the merits of chemical ripeners.

Improvements in sucrose percent cane fresh mass will reduce farmers' transport costs per ton of sucrose sent to the mill and improve the ease with which the sucrose can be recovered from the cane stalk. But, it is unlikely that these changes alone will be sufficient to cover the cost of the aerial application of expensive chemicals to sugarcane. To be of economic value, chemical ripeners must improve both cane quality and sugar yield.

4.4.1 Ripening effects of Ethrel and Polaris on variety NCo 376

Ethrel and Polaris had similar beneficial effects on both the quality of the cane and the sugar yield of variety NCo 376 but the response to the chemicals varied with the condition of the cane at the time of spraying, the amount of chemical applied, and growing conditions after spraying. The results obtained with Polaris on variety NCo 376 agree with results obtained in many parts of the world. It is interesting to note, however, that like variety N55/805 (Section 4.3.5), some varieties did not respond to Polaris in Mauritius (Anon, 1971b), Hawaii (Nickell and Takahashi, 1972), and Louisiana and Florida (Selleck et al 1974). The positive ripening response of NCo 376 to Ethrel is contrary to results obtained by other workers, who found that Ethrel reduced quality, as it did in variety N55/805. This aspect of the results is discussed in Section 4.4.4.

There was a bigger response to Ethrel and Polaris in early season experiments (Section 4.3.3) conducted under favourable growing conditions than in either late season experiments or the early season experiment in the Midlands (Section 4.3.4), when plant or weather conditions were less favourable for growth. Chemical ripening was most successful when the natural juice purity and the sucrose percentage of the cane stalks were low and increased rapidly in both treated and control plots during the course of the experiment. Conversely, when initial cane quality was high and cane growth after spraying relatively poor, there was a poorer ripening response to the chemicals. This is illustrated in Fig. 30, in which the average increase in sugar yield following the application of either Ethrel or Polaris is plotted against initial juice purity, taken as a measure of the maturity of the crop.

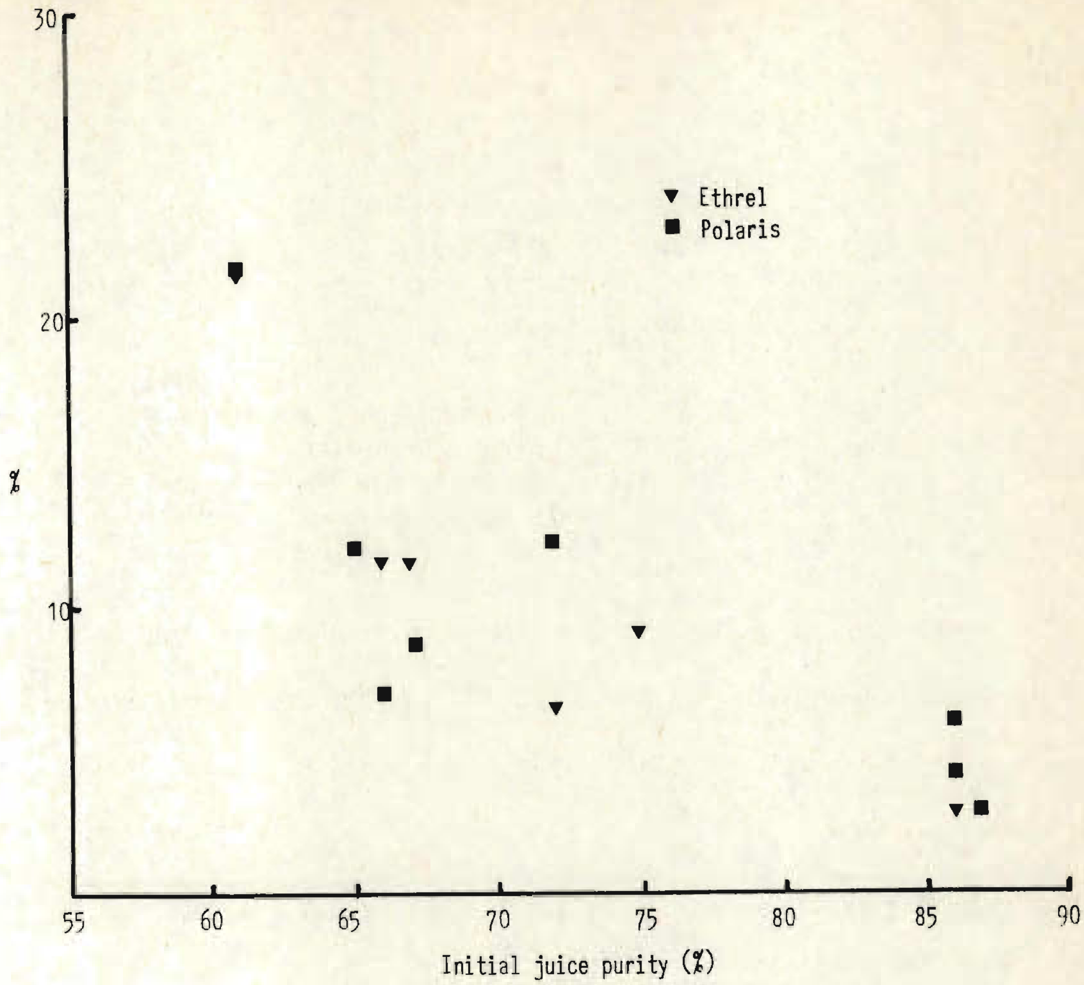


Fig. 30 The relationship between the juice purity of the whole stalk at the initial (0 weeks) sampling and the average increase in mass of ers between 6 and 12 weeks after sampling. Data for all field experiments.

Under favourable growing conditions the ripening response to the chemicals occurred within 4-6 weeks of spraying and was then maintained for at least four weeks (Section 4.3.3a). Because of this 'once only' effect of the chemicals it is possible that when conditions are favourable for growth there may be a further response to a second application of ripener, say one month after the first. Such an effect would be of value under conditions similar to those experienced in Experiments 3 and 6, where final juice purity of chemically treated sugarcane was still low.

The similarity between Ethrel and Polaris in their effects on the growth and ripening of variety NCo 376 under a wide range of conditions suggests that their mode of action within the plant may be similar. Ethrel is generally regarded as a plant growth inhibitor (Pratt and Goeschl, 1969; Burg,1973) but there have been reports of Ethrel stimulating stalk elongation in Callitriche (Musgrave, Jackson and Ling, 1972) and Poa pratensis L. cv. Sydsport (Poovaiah and Leopold, 1973). The increase in stalk length in Poa pratensis was accompanied by a marked reduction in leaf length, as in some of the experiments reported here.

Both chemicals consistently reduced the size and the mass of the sheaths and laminae of young leaves, and the limited number of photosynthesis measurements in Experiment 2 showed that CO_2 uptake was restricted at high light intensities. There was a resultant reduction in total plant dry mass in both small and large pot plants, confirming results of Alexander and Montalvo-Zapata (1972) and Yates (1972), but stalk dry mass was not affected in either pot or field experiments. The increase in the mass of sucrose stored in the stalk apparently resulted from a modification of the pattern of dry matter distribution within the plant.

This ripening effect was associated with an induced moisture stress within the plant, which was analogous to natural ripening: lamina, sheath and cane dry matter content increased, particularly in the upper part of the stalk, and the length of internodes below the point of topping was reduced. The plateaux observed in the daily patterns of CO_2 uptake by treated plants were similar to the effects of moisture stress observed by Glover (1974), and the gradual assumption of a more dome-shaped CO_2 uptake curve, observed in Polaris-treated plants, was similar to the pattern of recovery from moisture stress.

4.4.2 The response of variety NCo 376 to increasing rates of Ethrel and Polaris application

It was to a certain extent fortuitous that the single rate of Polaris application chosen in many experiments gave a positive ripening response. There were large responses to 3,3 and 3,7 kg a.i./ha in Experiments 3 and 6, respectively, but there were further increases in Ers%c at higher rates of application in Experiments 4 and 5 (Appendix III, Table 2). There was little response in Experiments 8, 9 and 10, although 4,9 kg a.i./ha Polaris was applied in Experiment 8 (Appendix III, Table 2).

No conclusions can be reached, therefore, about the optimum rate of either Polaris, or Ethrel application for maximum ripening response. It is evident that more work will be necessary to define the conditions, both plant and weather, under which optimum rates of chemical application can be determined. There is a vast literature on the response of other plants to Ethrel (de Wilde, 1971), which releases ethylene, a hormone essential for many growth processes (Pratt and Goeschl, 1969).

Sucrose biosynthesis, transport and storage is a complex of biochemical processes and it is unlikely that the optimum conditions for maximum response to given rates of ripener application can be determined without some knowledge of the physiological and biochemical composition of the variety under test. Alexander and Montalvo-Zapata (1972, 1973a and 1973b) working with small plants in the glasshouse have shown that ripening chemicals, and Polaris in particular, affect the enzyme systems of sugarcane before growth effects are evident. However, the direct translation of results from the glasshouse into the field is often unreliable and Samuels et al (1972) found that Cycocel, which had shown promise in the glasshouse (Alexander and Montalvo-Zapata, 1973a) did not ripen field grown sugarcane. Similar conflicting results between glasshouse and field experiments were also reported by Yates (1972) in work with Ethrel. In the absence of data to describe adequately the biochemical and physiological condition of the sugarcane in the two situations, the reasons for these anomalous results cannot be determined. Similarly, in the work reported here the data are insufficient to explain why different responses were obtained to similar rates of chemical ripener applied under different plant and weather conditions.

It is concluded that for further meaningful advances to be made on the artificial ripening of sugarcane detailed biochemical information is required about material from field experiments. Without this knowledge of the biochemical composition of the plants under test and the effect on this of chemical ripeners, the chemical ripening of sugarcane is likely to remain a 'hit and miss' investigation. Under such haphazard conditions it is unlikely that the conditions necessary for maximum ripening response can be defined. Similarly, it will not be easy to identify chemicals that have a better ripening effect than Ethrel and Polaris.

4.4.3 The effect of moisture stress on the response of variety NCo 376 to Ethrel and Polaris

Active growth was necessary for chemical ripening to occur but severe drying off in Experiment 7 (Section 4.3.3a) did not alter the ripening response once it had occurred. When irrigation was withheld after spraying in Experiments 5 and 9 the response to the ripeners was delayed. It is therefore probable that the success of chemical ripeners under rain-grown conditions will depend on the amount of rainfall before, and immediately after spraying.

4.4.4 Varietal response to Ethrel and Polaris

The consistent improvements in cane quality and sugar yield following the application of Ethrel to variety NCo 376 are contrary to the results obtained by other workers with other varieties, but the reduction in cane quality and the side shooting caused by Ethrel (and to a lesser extent Polaris) in Experiment 11 with variety N55/805 were similar to the effects of Ethrel reported by Yates (1972) and Alexander and Montalvo-Zapata (1973a).

Measurements of internode length (Appendix III, Table 3) showed that there was little difference between the growth response of NCo 376 and N55/805 to Ethrel: only the length of internodes 1-5 was increased in NCo 376 but in N55/805 the elongation of these internodes was less marked and growth stimulation extended further down the stalk to internodes 6-11. Also, the higher the rate of Ethrel application, the greater the number of internodes affected in variety N55/805.

These results suggest that some varieties may be more responsive to Ethrel than others, and so may require much smaller amounts of chemical to achieve a ripening effect similar to that obtained with NCo 376. It is interesting to note that Polaris, even at the highest rate of application, did not reduce the Ers%c of the whole stalk of N55/805 as much as Ethrel did. Similarly in experiments with NCo 376, more Polaris was required to achieve the ripening effect of Ethrel (Table 17). These results further confirm that both chemicals have a similar effect on the growth and ripening of sugarcane and that Ethrel is more active than Polaris.

CHAPTER 5

GENERAL DISCUSSION AND CONCLUSIONS

The results presented in this thesis, and the conclusions drawn from them, are applicable to fully irrigated areas of Southern Africa, which at present comprise about 15% of the area planted to sugarcane. Care will be required, however, in extrapolating these results to crops grown under rain-fed conditions and therefore subject to moisture stress. This thesis may provide a guide to what can be achieved in rain-fed areas, given an adequate supply of water, but further work will be necessary to determine optimum cropping cycles and to evaluate the response to chemical ripeners when growth is restricted by moisture stress.

At present such investigations should not receive high priority in any programme of research work on sugarcane because they are unlikely to improve our ability to predict or modify crop growth appreciably. The apparent random occurrence of periods of drought, even during the growing (rainy) season, makes it doubtful whether accurate predictions of crop growth and the optimum age of harvest for maximum sugar production per unit area per unit time are possible for non-irrigated sugarcane.

The comparison made of apparent maximum stalk yields of sugarcane with calculated theoretical maximum yields (Section 3.5.2) indicated that when moisture and nutrient supplies were adequate, stalk, and therefore sugar yields could be increased above the level of existing varieties. It may be difficult to improve maximum stalk yields of current commercial varieties, however, because it was confirmed that sugarcane uses radiant energy efficiently compared with other plants. It was also found that differences in stalk population, leaf width and leaf angle between two extreme varieties, NCo 376 and CB 36/14, were insufficient to affect growth and yield appreciably.

The differences in growth and morphology between these two varieties are as extreme as can be found among commercial varieties in South Africa, and this suggests that there may be no easy way in which sugarcane yield can be improved by modifying the morphology of successful varieties. This conclusion requires further confirmation, which will probably necessitate fundamental studies of differences of light interception, the efficiency of carbon dioxide assimilation and the distribution of assimilate within the plants among varieties, in order to determine how to obtain higher yields of sugar. Such studies will not be easy and they should not be undertaken lightly because they will probably require a multi-disciplinary team approach to the problem and the use of sophisticated equipment.

It was found that the yield of sugar per unit area per unit time of well-grown, irrigated, sugarcane crops could be increased by modifying management practices in either of two ways. Firstly, by deciding when to harvest a crop according to the cycle of weather conditions that it had experienced, and secondly, by the use of artificial growth regulators.

Age at harvest was important in determining sugar yield because the decline in crop growth and the potential maximum yield of the crop appeared to be related to the initial growth of the crop, which varied with the time of year at which it began to grow. Lodging was an important factor reducing the growth and the yield of a crop ratooned in December, but it was less important in other crops, particularly those ratooned in January and February, where yield increased linearly even after lodging had occurred. The increasing proportion of respiring, non-photosynthesising stalk material as a crop ages should contribute to a decline in growth, but in crops ratooned in January and February growth was still linear when the yield of stalk material was higher than that of crops in which there was a marked decline in growth. This indicates that the accumulated weight of stalk material *per se* was not the only factor causing a reduction in the growth rate of older crops.

High yields of sugar per unit area per unit time were obtained in young immature crops when the quality of the stalk was low. It was fortunate, therefore, that it was these crops that responded best to chemical ripening. The ripening properties of Polaris were confirmed with variety NCo 376 but the success of Ethrel, which was found to be more active than Polaris, was contrary to findings in other parts of the world.

Because of the complexity of sugarcane breeding, due to polygenic inheritance, and the difficulty of identifying desirable physiological characteristics, it seems probable that it will be easier to obtain higher yields of sugar by artificially regulating plant growth than by breeding new varieties. Many sugarcane varieties grow rapidly and produce high yields of cane stalks, but are undesirable because they have only a low sucrose content, and it has been suggested by Vlitos and Fewkes (1969) that it might be possible to ripen these varieties chemically. This may require more than one application of a chemical because the ripening effect of both Ethrel and Polaris was mainly in the upper part of the stalk, which may be only a small proportion of the total stalk weight.

Sucrose yield increased following ripener application, despite reductions in leaf area, apparent photosynthesis and total plant weight. This indicates, either that under some circumstances the foliage area of the crop was larger than was necessary for maximum sugar yields, or that translocation out of senescing leaves was more than sufficient to compensate for any reduction in net photosynthesis. The reduction in the growth of treated plants ultimately resulted in lower sugar yields than those of control plants when conditions favoured natural ripening, or when harvest was delayed (Section 4.3.4), but there was no reduction in yield when the crops were growing rapidly.

There is a complex relationship between leaf photosynthesis rate and the accumulation of assimilate, which is not fully understood (Neales and Incoll, 1968). Nevertheless, when the leaf area of apples was artificially reduced there was a compensating increase in the rate of photosynthesis of the remaining leaves (Maggs, 1964). Further investigations (Maggs, 1965) also showed that stalk growth was maintained at the expense of root growth if young leaves were removed at a time when growing conditions were favourable. Chemical ripening of sugarcane with both Ethrel and Polaris caused similar reductions in leaf area and, under certain conditions, a similar gain in sucrose content. If this modification of growth in favour of sucrose storage does not prejudice further growth of the crop, multiple applications of a ripener could result in large increases in sugar yield.

In South Africa, as in all sugarcane producing countries, the mills close when cane quality is low during the period of maximum crop growth. The use of chemical ripeners at this time of the year could lead to an extension of the present milling season.

Such a move would permit increased sugar production without extending milling capacity, resulting in lower average costs per ton of cane processed.

It is concluded that efforts to increase the sugar yield of well-managed crops of sugarcane receiving adequate amounts of water and nutrients should concentrate on improving the proportion of photosynthate stored as sucrose. Chemical ripening appears to offer a novel and effective way of achieving this objective but further detailed investigations are required. There are many problems concerning varieties and rate and time of ripener application, and it is unlikely that these will be resolved satisfactorily without a better understanding of the biochemical aspects of sugarcane growth and ripening.

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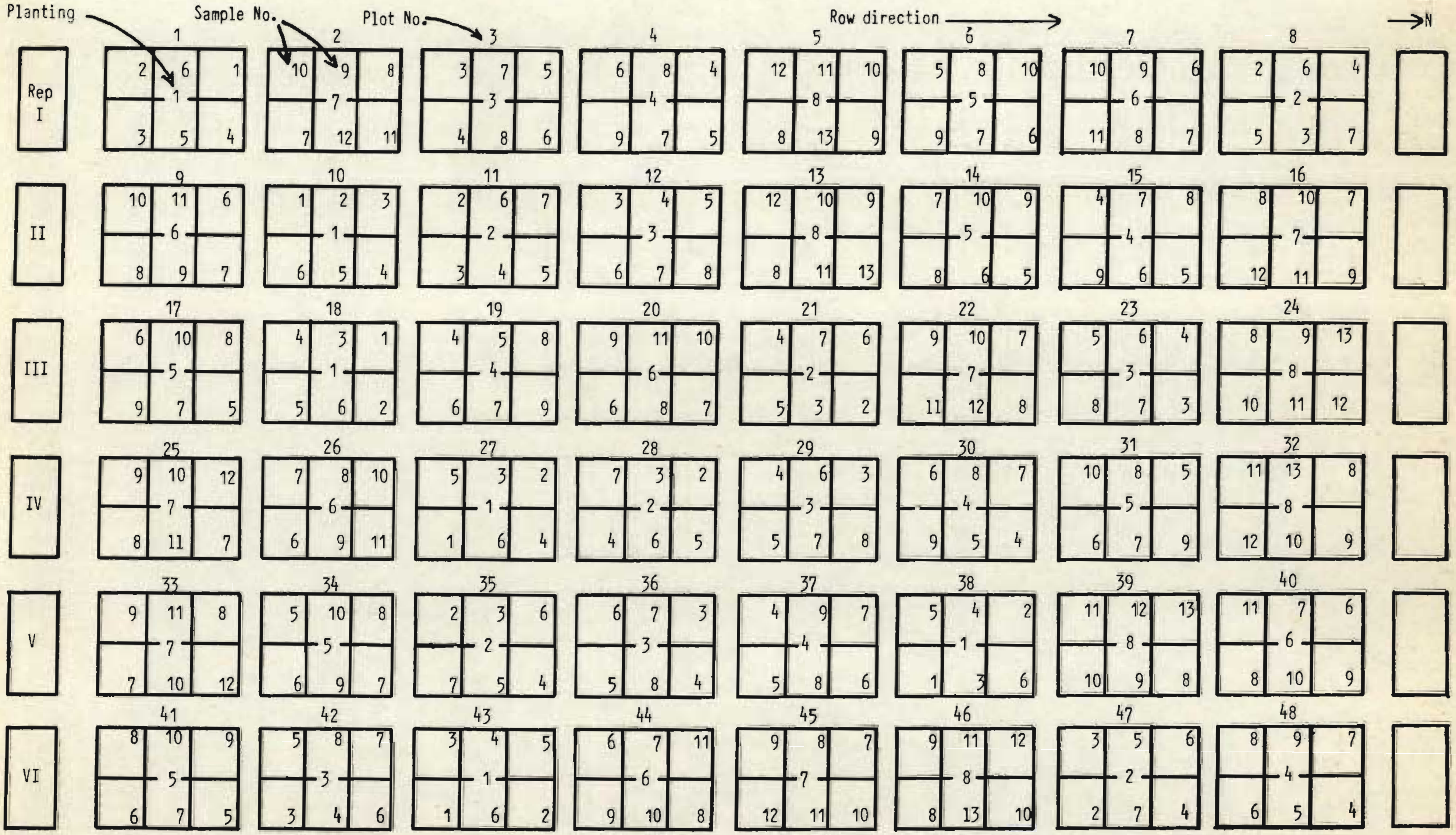
ACKNOWLEDGEMENTS

I am grateful to the Director, Mr. J. Wilson and the Committee of the Experiment Station of the South African Sugar Association for the opportunity to undertake this research work.

The advice and criticism offered by Professor K. Nathanson and Dr. G.D. Thompson during the course of these studies is sincerely appreciated.

I also wish to thank my colleagues at the Experiment Station for their assistance in supervising experiments and for their continued encouragement. I am particularly grateful to Mr. M.G. Murdoch for advice on biometrical problems, Mr. S. Kanniappen for technical assistance, Mr. P C. Finlay for construction of solarimeters, and staff of the Biometry and Chemistry Departments for advice and routine analyses.

Thanks are also due to staff of Ubombo Ranches, Noodsberg Sugar Company and Natal Estates for providing experimental sites and for assistance in harvesting experiments.



APPENDIX I. Fig. 1 Layout and randomisation of the age at harvest experiment

APPENDIX I, TABLE 1

(a)

Percentage physical analysis of the 0-40 cm layer of the Makatini series soil

O.M.	Clay	Silt	Fine sand	Medium sand	Coarse sand
2,9	48,0	9,5	4,0	9,5	26,5

(b)

Chemical composition (ppm) of the 0-25 cm layer of the Makatini series soil

P	K	pH	Mg	Ca	Na
6	245	6,0	330	640	34

APPENDIX I, TABLE 2

Typical analysis of variance and summary of results, tc/ha

Sample	Planting 1	2	3	4	5	6	7	8	Mean
1	109	80	32	74	122	140	121	82	95
2	133	102	101	125	154	160	133	106	127
3	130	132	144	160	166	164	143	130	146
4	145	159	156	171	166	161	153	162	159
5	136	179	161	164	168	174	162	194	167
6	143	184	149	163	159	164	171	189	153
Mean	133	139	124	143	156	160	147	144	143

	Within plantings	Sample mean	Planting mean
S.E. Treatment mean	6,17	2,18	2,88
S.E. Diff. of 2 means	8,72	3,08	4,07
L.S.D. (0,05)	17,3	6,1	8,3
(0,01)	22,8	8,1	11,1

	Sub plots	Whole plots
S.E. (single plot)	15,11	17,27
C. of V(%)	10,6	12,0

ANALYSIS OF VARIANCE

Source	DF	SS	MS	F
Replications	5	2050,40	490,08	1,64
Plantings	7	35386,44	5055,21	16,96
Error (a)	35	10433,27	298,09	
Whole plots	47	48270,11	1027,02	4,50
Samples	5	187441,49	37488,30	164,01
Planting x Sampling	35	71985,85	2056,74	9,01
Error (b)	197	45437,66	228,33	
Sub plots	284	353135,11		

Correction factor = 5905338,8888

APPENDIX I, TABLE 3

(a) Weather data for the first 32 weeks of ratoon crop growth

Pltg.	Dates	Rain mm	Irrig. mm	R + I mm	Radn. ly/day	Air Temp. °C Max.	Min.	Mean
1	18/12-29/ 7/69	490	853	1343	419	27,2	16,0	21,6
2	12/2 -23/ 9/69	327	732	1059	381	25,4	13,7	19,6
3	9/4 -18/11/69	266	732	998	390	24,8	12,9	18,8
4	4/6 -13/ 1/70	301	914	1215	423	25,9	14,3	20,1
5	30/7 -10/ 3/70	395	1036	1431	473	27,9	16,3	22,1
6	24/9 - 5/ 5/70	416	1036	1452	477	28,5	16,7	22,6
7	19/11-30/ 6/70	322	1036	1358	440	27,8	14,9	21,4
8	14/1 -25/ 8/70	197	914	1111	406	26,6	12,8	19,7

(b) Weather data for successive 8 weekly periods after the first sampling date

Period	Dates	Rain mm	Irrig. mm	R + I mm	Radn. ly/day	Air Temp. °C Max.	Min.	Mean
1	30/7 -23/ 9/69	6	244	250	425	25,2	11,9	18,6
2	24/9 -18/11/69	150	183	333	462	27,0	16,6	21,8
3	19/11-13/ 1/70	140	305	445	492	28,9	19,1	24,0
4	14/1 -10/ 3/70	99	305	404	514	30,4	17,6	24,0
5	11/3 - 5/ 5/70	27	244	271	440	27,9	13,5	20,7
6	6/5 -30/ 6/70	56	183	239	338	23,9	9,3	16,6
7	1/7 -25/ 8/70	15	183	198	358	24,4	10,7	17,6
8	26/8 -20/10/70	100	244	344	437	26,8	14,7	20,8
9	21/10-15/12/70	97	183	280	524	29,9	18,3	24,1
10	16/12- 9/ 2/71	120	244	364	494	29,7	20,0	24,8
11	10/2 - 6/ 4/71	211	183	394	507	29,7	18,8	24,2
12	7/4 -29/ 5/71	50	61	111	354	25,3	13,3	19,3

APPENDIX I, TABLE 4

Average weather data for cumulative periods of time

Weeks	Planting 1	2	3	4	5	6	7	8
				RADIATION (ly/dy)				
0-32	419,4	381,1	389,9	423,4	473,3	477,2	440,1	406,5
0-40	420,4	397,3	410,3	441,6	466,7	449,4	423,6	412,5
0-48	427,4	413,1	427,7	441,4	445,3	434,1	425,8	431,1
0-56	436,6	427,5	429,5	426,7	432,8	434,4	439,8	440,2
0-64	446,3	429,2	418,1	418,0	433,2	445,6	446,6	448,6
0-72	445,7	419,1	411,4	420,1	443,3	451,1	453,4	438,1
				MAX. TEMP. °C				
0-32	27,2	25,4	24,8	25,9	27,9	28,5	27,8	26,6
0-40	26,8	25,7	25,6	26,8	27,9	27,6	27,1	26,6
0-48	26,8	26,2	26,4	27,0	27,2	27,0	27,1	27,2
0-56	27,1	26,8	26,6	26,5	26,8	27,0	27,5	27,5
0-64	27,5	27,0	26,3	26,3	26,8	27,4	27,8	27,8
0-72	27,6	26,6	26,1	26,3	27,2	27,6	28,0	27,5
				MIN. TEMP. °C				
0-32	16,0	13,7	12,9	14,3	16,3	16,7	14,9	12,8
0-40	15,2	14,3	14,1	15,0	15,7	15,2	14,1	13,2
0-48	15,4	15,1	14,7	14,7	14,7	14,5	14,2	14,0
0-56	15,9	15,4	14,5	13,9	14,1	14,5	14,8	14,9
0-64	16,2	15,2	13,9	13,5	14,2	15,0	15,4	15,4
0-72	15,9	14,5	13,5	13,7	14,6	15,5	15,8	15,1
				MEAN TEMP. (max + min ÷ 2) °C				
0-32	21,6	19,6	18,8	20,1	22,1	22,6	21,4	19,7
0-40	21,0	20,0	19,8	20,9	21,8	21,4	20,6	19,7
0-48	21,1	20,6	20,6	20,8	21,0	20,8	20,6	20,6
0-56	21,5	21,1	20,6	20,2	20,4	20,8	21,2	21,2
0-64	21,8	21,1	20,1	19,9	20,5	21,2	21,6	21,6
0-72	21,8	20,6	19,8	20,0	20,9	21,6	21,9	21,3
				RAIN AND IRRIGATION (mm)				
0-32	1344	1059	998	1215	1431	1452	1358	1112
0-40	1594	1392	1442	1619	1703	1691	1556	1455
0-48	1927	1836	1846	1890	1941	1889	1900	1735
0-56	2372	2240	2117	2129	2139	2233	2180	2099
0-64	2775	2511	2355	2327	2483	2513	2544	2493
0-72	3046	2750	2554	2671	2763	2876	2938	2605

APPENDIX I, TABLE 5

Percentage composition of the laminae of the third leaves of the ratoon crop of Planting 8 that began to grow on 14 January 1970

	Age in weeks							
Element	16	24	32	40	48	56	64	72
Nitrogen	2,44	2,10	1,96	1,69	1,65	1,66	1,49	1,59
Phosphorus	0,24	0,23	0,20	0,19	0,21	0,21	0,21	0,22
Potassium	1,86	1,90	1,76	1,60	1,72	1,88	1,82	1,68
Calcium	0,28	0,29	0,28	0,24	0,19	0,20	0,16	0,20
Magnesium	0,26	0,24	0,20	0,19	0,23	0,20	0,14	0,14

APPENDIX I, TABLE 6

Stalk diameters measured at harvest at three positions on the stalk (mm

Age at harvest (weeks)	Planting 1	2	3	4	5	6	7	8
				UPPER DIAMETER				
32	19,0	23,5	25,2	23,2	22,1	22,7	21,8	21,8
40	20,6	26,1	23,2	23,4	22,6	23,0	21,6	23,3
48	23,2	25,7	23,1	23,0	23,0	22,0	22,6	24,3
56	23,3	24,4	22,7	22,7	22,5	22,1	22,5	25,6
64	22,6	24,5	23,5	22,4	22,3	21,9	23,0	25,6
72	24,0	24,6	22,6	22,7	23,0	23,0	23,8	23,1
				MIDDLE DIAMETER				
32	19,3	22,4	28,1	24,9	23,4	23,4	22,0	21,6
40	20,0	25,1	25,2	23,8	24,0	23,7	21,4	21,8
48	20,7	25,8	23,8	24,0	24,3	22,8	22,6	22,1
56	20,4	25,4	23,7	24,0	23,3	22,3	21,3	24,6
64	20,1	26,1	24,8	23,5	23,4	22,4	22,1	26,4
72	21,4	26,0	23,7	23,7	23,4	23,3	22,8	25,7
				LOWER DIAMETER				
32	19,8	21,1	29,4	26,4	25,4	25,4	23,3	21,6
40	20,5	20,9	28,4	26,4	26,3	26,0	22,9	21,6
48	21,6	22,2	27,4	26,2	27,0	25,1	23,2	21,5
56	21,1	21,6	27,8	26,4	26,3	24,4	22,7	22,4
64	20,8	22,8	28,8	26,7	26,1	24,3	23,0	22,9
72	21,9	22,8	28,0	26,2	25,9	24,4	22,7	22,7

APPENDIX I, TABLE 7

S % c

Sample (weeks)	Planting 1	2	3	4	5	6	7	8
32	9,3	8,2	2,2	3,4	4,7	8,6	9,7	8,4
40	11,3	9,5	5,4	5,8	10,1	11,3	11,6	9,9
48	11,8	10,3	7,4	10,5	11,6	12,5	12,2	11,4
56	12,3	11,2	11,6	12,3	12,5	12,6	13,0	11,9
64	11,2	13,3	13,2	13,0	13,2	14,0	12,7	12,1
72	13,1	14,3	13,7	13,4	14,0	12,9	11,6	13,5

APPENDIX I, TABLE 8

Juice purity (%)

Sample (weeks)	Planting 1	2	3	4	5	6	7	8
32	78	72	31	38	52	76	75	68
40	86	77	56	60	80	82	84	76
48	84	76	69	78	83	84	80	82
56	84	82	83	83	85	80	82	84
64	84	91	86	85	82	86	87	77
72	89	88	87	82	85	88	74	88

APPENDIX I, TABLE 9

Fibre % c

Sample (weeks)	Planting 1	2	3	4	5	6	7	8
32	10,8	10,8	7,6	8,4	-	9,4	9,0	10,4
40	12,8	11,0	8,3	-	9,2	10,1	11,2	11,2
48	12,7	10,3	8,8	9,4	10,3	11,1	11,5	10,7
56	13,4	10,8	9,5	10,7	11,1	11,2	11,6	11,3
64	-	11,2	10,5	10,6	12,7	11,6	12,5	10,4
72	12,8	11,0	13,0	12,5	11,5	12,8	10,9	-

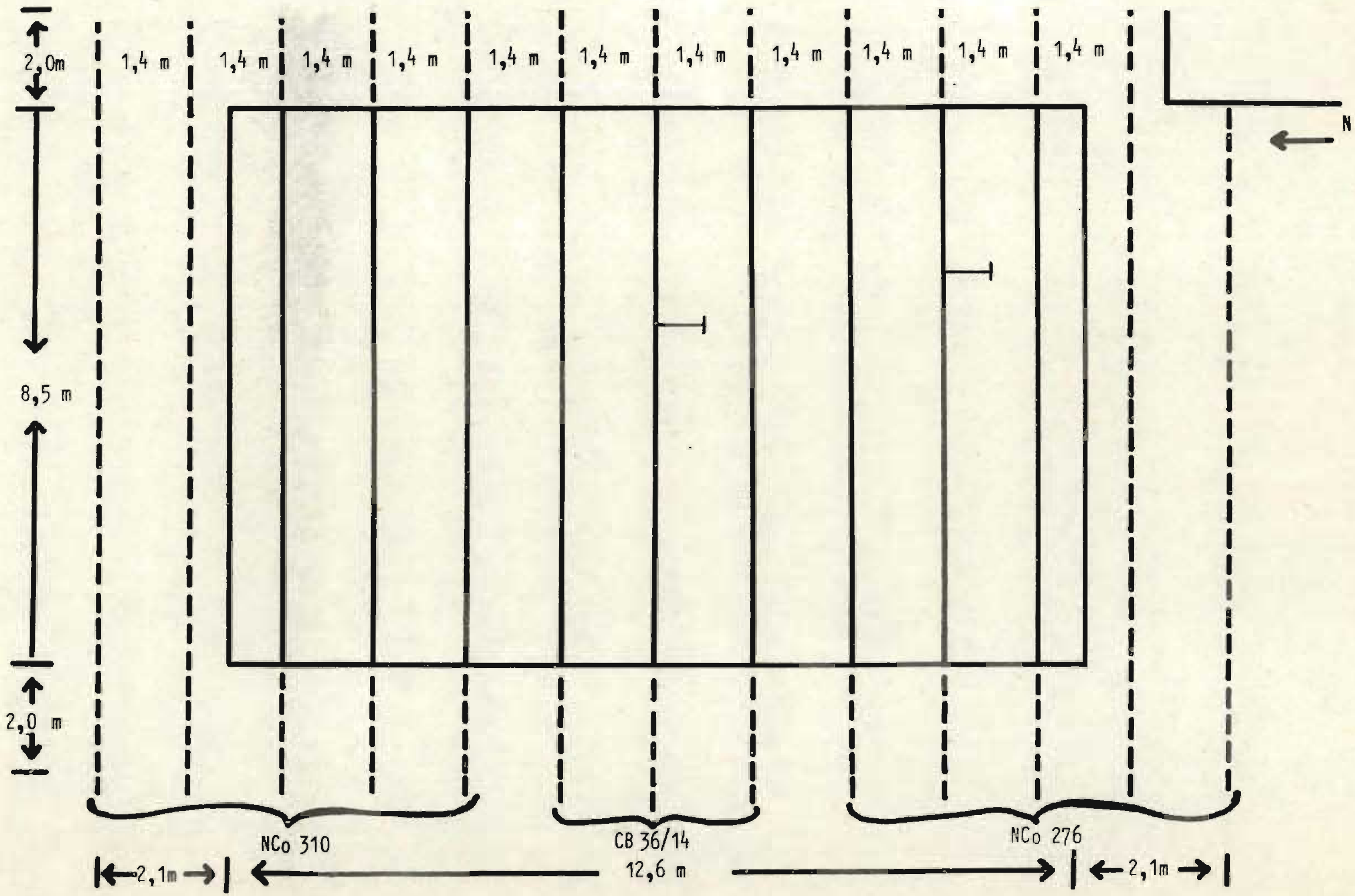
APPENDIX I, TABLE 10

ters/ha

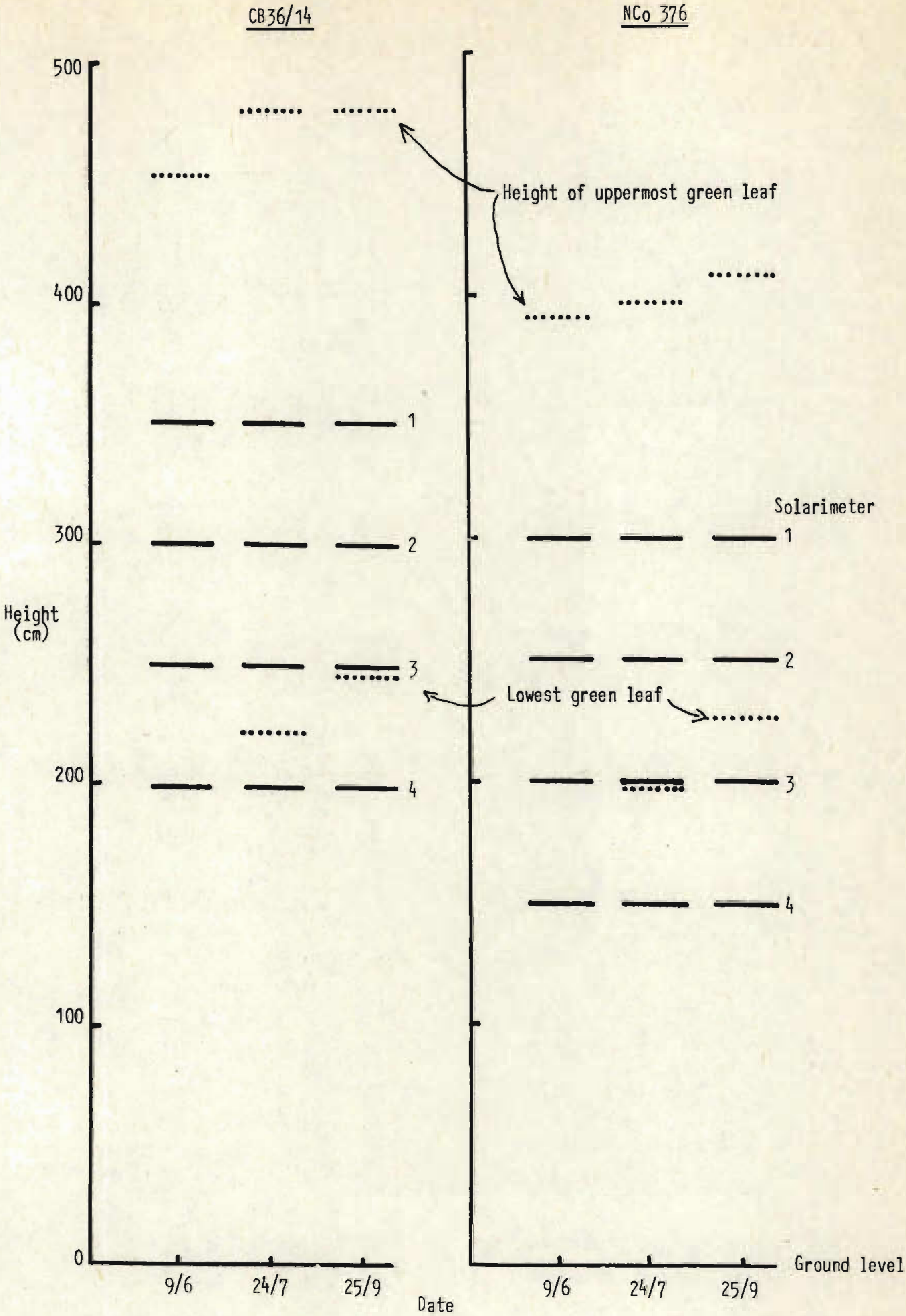
Sample	Planting								
(weeks)	1	2	3	4	5	6	7	8	Mean
32	7,9	4,7	0,02	0,02	4,6	9,2	9,2	4,7	5,1
40	12,8	7,4	2,7	6,8	12,8	15,1	13,1	8,2	9,9
48	12,8	10,7	9,1	13,6	16,4	17,5	14,4	12,4	13,4
56	14,9	16,0	15,6	18,0	18,0	16,8	16,7	16,4	16,5
64	15,7	21,6	18,4	17,4	18,5	21,2	17,9	19,0	18,7
72	16,6	23,3	17,4	18,4	19,2	18,7	15,6	22,6	19,0
Mean	13,4	14,0	10,5	12,4	14,9	16,4	14,5	13,9	13,8

	Within plantings	Sample mean	Planting mean
S.E. Treatment mean	1,00	0,35	0,40
S.E. Diff. of 2 means	1,41	0,50	0,57
L.S.D. (0,05)	2,80	0,99	1,15
(0,01)	3,70	1,31	1,55

	Sub plots	Whole plots
S.E. (single plot)	2,45	2,41
C. of V (%)	17,8	17,4



APPENDIX II, Fig.1 Plan of the maximum yield plot. Solid lines represent cane rows within the excavated area; broken lines are guard rows.
——┤ Position of solarimeter



APPENDIX II, Fig. 2 Position of the four solarimeters in the canopy of varieties CB36/14 and NCo 376, relative to the uppermost and lowest green leaf in June and September.

APPENDIX II, TABLE 1

(a) Physical analysis of the artificial soil, % (average of the) 0-125 cm depths

O.M.	Clay	Silt	Fine sand	Medium sand	Coarse sand
3,8	12,0	5,5	14,0	22,5	42,2

(b) Chemical composition (ppm) of the 0-25 cm layer of the artificial soil

	P	K	pH	Mg	Ca	Na
Initial composition	6	63	6,18	>80	518	64
After fertilization	119	277	7,35	>80	500	102
After plant crop	51	115	5,60	>80	640	35
After first ratoon crop	43	64	6,30	>80	620	46

Note: 1200 kg/ha of a 4-1-6(31) fertilizer mixture was applied to the ratoon crop

APPENDIX III, TABLE 1

Total rainfall and irrigation (mm) during the course of the ripening experiments

	Weeks after spraying				
Experiment	0-4	4-8	8-10	10-12	Total
3	161	54	-	-	215
4	111	114	←53→		278
5	9	100	←53→		162
6	66	121	←71→		258
7 (a)	134	29	1	-	164
8	59	93	←33→		185
9	31	142	←78→		251
10 (a)	137	62	43	-	242
	137	186	43		366
11	79	97	-	-	176

(a) Dried off - others not dried off

APPENDIX III, TABLE 2

Summary of sample results from experiments with Ethrel and Polaris. Data for cane fresh mass and mass Ers expressed as kg/20 stalks

Expt.	Trmt. (kg a.i./ha)		Initial						Final					
			Ethrel			Polaris			Ethrel			Polaris		
	Ethrel	Polaris	Cane mass	Ers %	Ers mass	Cane mass	Ers %	Ers mass	Cane mass	Ers %	Ers mass	Cane mass	Ers %	Ers mass
							EARLY SEASON	EXPERIMENTS						
3	0	0	14,6	4,0	0,6	14,6	4,0	0,6	16,7	7,2	1,2	16,7	7,2	1,2
	1,2	3,3	15,2	3,9	0,6	15,7	3,9	0,6	16,9	8,6**	1,4**	18,2	8,6**	1,6**
4	0	0	8,7	5,0	0,4	8,7	5,0	0,4	13,1	10,6	1,4	13,1	10,6	1,4
	1,2	2,5	8,1	5,2	0,4	8,5	4,6	0,4	12,3	11,9*	1,5	13,5	9,7	1,2
		3,2				8,7	4,9	0,4				13,9	10,6	1,5
		4,8				7,8	5,7	0,5				12,2	11,8*	1,5
		5,2				8,1	4,4	0,4				11,4	13,0**	1,5
5	0	0	11,8	6,3	0,7	11,8	6,3	0,7	14,8	10,8	1,6	14,8	10,8	1,6
	0,5	2,8	12,2	5,9	0,7	12,0	5,6	0,7	14,1	12,2**	1,7	14,3	11,8*	1,7
	0,9	3,4	11,3	6,2	0,7	11,4	5,2	0,6	13,8	12,5**	1,7	14,9	12,0*	1,8
	2,0	4,8	12,0	5,6	0,7	12,7	5,5	0,7	15,0	12,8**	1,9*	14,2	12,9**	1,8
6	-	0				16,7	5,1	0,9				22,6	9,8	2,2
	-	3,7				16,7	4,8	0,8				22,8	11,0*	2,5**
7	0	0	13,6	5,2	0,7	13,6	5,2	0,7	15,0	10,0	1,5	15,0	10,0	1,5
	1,2	4,5	13,0	5,3	0,7	13,2	5,2	0,7	15,2	11,1	1,7	14,8	11,1	1,6

APPENDIX III, TABLE 2 (continued)

Summary of sample results from experiments with Ethrel and Polaris

Expt.	Trmt. (kg a.i./ha)		Initial						Final					
			Ethrel			Polaris			Ethrel			Polaris		
	Ethrel	Polaris	Cane mass	Ers %	Ers mass	Cane mass	Ers %	Ers mass	Cane mass	Ers %	Ers mass	Cane mass	Ers %	Ers mass
						EARLY SEASON MIDLANDS AND LATE SEASON EXPERIMENTS								
8	-	0				11,3	11,2	1,3				13,3	12,1	1,6
	-	4,9				11,3	11,0	1,3				12,4	12,7*	1,6
9	0	0	15,2	11,8	1,8	15,2	11,8	1,8	22,0	11,2	2,5	22,0	11,2	2,5
	1,2	3,8	15,0	12,0	1,8	15,2	11,8	1,8	21,2	11,9*	2,5	19,4	12,1*	2,3
10	-	0				14,0	9,8	1,4				15,1	11,6	1,9
	-	3,7				14,0	10,2	1,4				14,9	11,8	1,9
						VARIETY N55/805								
11	0	0	16,0	12,9	2,0	16,0	12,9	2,0	20,1	12,2	2,5	20,1	12,2	2,5
	0,5	2,7	16,3	13,6	2,2	17,4	14,2	2,3	21,0	11,3*	2,4	20,7	12,2	2,6
	1,0	3,1	18,4	14,2	2,6	16,0	13,9	2,2	23,0	10,8**	2,6	20,0	11,9	2,4
	1,8	4,5	16,0	13,8	2,2	17,0	13,5	2,3	21,7	10,5**	2,3	20,0	11,5	2,3
		5,2				17,0	13,8	2,3				20,2	11,9	2,4

Statistically significant * P = 0,05
** P = 0,01

APPENDIX III, TABLE 3

The effect of Ethrel and Polaris on the length of upper internodes, expressed as a percentage of control

Treatment (kg a.i./ha)	Internodes 1-5						Internodes 6-8					Internodes 9-11		
Experiment	4			5		11*	4		5		11*	4	5	11*
Weeks	6	12	14	6	12	8	6	14	6	12	8	14	12	8
Control	100	100	100	100	100	100	100	100	100	100	100	100	100	100
(mm/stalk)	(10)	(10)	(11)	(12)	(12)	(10)	(36)	(31)	(35)	(28)	(16)	(41)	(37)	(17)
Ethrel														
0,5				130	143	107			99	98	126		100	94
0,9 - 1,2	120	121	103	128	144	109	87	90	95	89	134	90	95	104
1,8 - 2,0				138	153	118			99	89	136		97	118
Polaris														
2,7 - 2,8	116	98	91	137	148	109	99	102	106	102	99	96	102	104
3,1 - 3,4	127	119	72	130	153	122	98	91	107	106	98	88	101	93
4,5 - 4,8	137	147	148	115	129	118	96	99	106	115	103	89	101	86
5,2	112	166	100			130	81	89			103	90		90
Mean	116	121	102	126	139	114	93	95	102	100	112	92	99	99
L.S.D. (0,05)	24	21		15	19	18	9			8	12			10
(0,01)	33	30		21	26	25	12			11	16			14
C of V (%)	12	10		8	9	11	6			5	7			7

* Variety N55/805

APPENDIX III, TABLE 4

The effect of Ethrel and Polaris on the dry mass of upper internodes, expressed as a percentage of control

Treatment (kg a.i./ha)	Internodes 1-5					Internodes 6-11	
	Experiment 4			Experiment 5		Experiment 4	Experiment 5
	Weeks 6	12	14	6	12	14	12
Control (g/stalk)	100 (1)	100 (2)	100 (1)	100 (2)	100 (2)	100 (26)	100 (51)
Ethrel							
0,5				153	177		102
0,9 - 1,2	141	132	117	149	200	82	102
1,8 - 2,0				182	217		99
Polaris							
2,7 - 2,8	146	97	95	150	214	90	112
3,1 - 3,4	154	132	69	168	237	92	119
4,5 - 4,8	174	204	186	174	213	92	133
5,2	143	253	98				
Mean	143	153	111	154	194	92	110

APPENDIX III, TABLE 5

Harvest data for Experiment 3

Treatment	tc/ha	S%c	S%dm	Purity	tc/ha	t ers/ha
Control	104	9,2	44,2	74,5	9,6	7,5
DA5	107	9,9	48,0	75,3	10,6	8,5
Ethrel 1,2	113	10,4	49,9	78,5	11,7	9,7
Hydrothol 191	105	8,6	45,1	73,2	9,0	7,0
Polaris 3,3	109	10,5	48,0	78,3	11,4	9,4
Pesco 1815	107	9,8	48,7	76,0	10,5	8,5
CGA 11610	106	9,4	44,1	75,0	10,0	7,9
Mean	108	9,7	46,9	76,0	10,4	8,4
L.S.D. (0,05)	10	0,7	3,0	3,3	1,2	1,1
(0,01)	14	1,0	4,1	4,5	1,6	1,5
C of V (%)	7,6	5,8	5,1	3,5	9,0	10,5

APPENDIX III, TABLE 6

Mill harvest data for Experiment 6

Treatment	tc/ha	S%c	Purity	ers%c	t ers/ha	Red Sug. % Juice	Red sug. / sucrose
Control	137	10,6	77,2	7,9	10,8	1,14	8,9
Polaris	135	11,7	82,0	9,2	12,4	0,91	6,4
% change	-1,5	+10,4	+6,2	+16,5	+14,8	-20,2	-28,1
L.S.D. (0,05)	NS			0,7	0,8		
(0,01)				1,1	1,3		
C of V (%)	6,9			6,1	5,1		

APPENDIX III, TABLE 7

Mill harvest data for Experiment 7

Treatment (kg a.i./ha)	tc/ha	S%c	Purity	ers%c	t ers/ha
Control	95	11,6	77,5	9,1	8,6
Ethrel 1,2	98	12,1	77,8	9,8	9,3
Polaris 4,5	92	12,2	78,1	9,8	9,1
Mean	95	11,9	77,8	9,6	9,0
L.S.D. (0,05)	5,3			1,3	1,5
C of V (%)	4,4			10,7	12,8

In this incomplete latin square design each variate was analysed independently

APPENDIX III, TABLE 8

Mill harvest data for Experiment 8

Treatment	tc/ha	S%c	Purity	t ers/ha
Control	115	12,2	84,6	12,0
Polaris 4,9 kg a.i./ha	104	12,8	86,1	11,4
% change	-9,6	+4,9	+1,8	-5,0
L.S.D. (0,05)	7,1	0,6	2,3	0,8
(0,01)	11,2	1,0	3,7	1,2
C of V (%)	4,4	3,3	1,8	4,4