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**LA THÈSE A ÉTÉ
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Intercropping of sugar cane with maize

by

J.R. Noël Govindén

A thesis submitted to the School of Graduate Studies
and Research, University of Ottawa
in partial fulfilment of the requirements for
the Degree of Doctor of Philosophy.



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ABSTRACT

Intercropping of sugar cane (Saccharum sp) with maize (Zea mays L.) was investigated in field trials in Mauritius.

Competitive relations were studied at 2 sites. When 3 sequential maize crops were grown in non-additive mixtures with plant sugar cane, the yield of the first was higher and that of the second and the third was lower than expected on the basis of sown proportions. Cane over-yielded in all the mixtures at one site but not at the other. By means of competition functions, it was shown that the cane was the dominant species in the mixtures. Yield advantages were not observed in these non-additive mixtures.

The use of growth factors was studied in a series of 4 trials in which one row of maize was grown in every interrow of plant sugar cane. In one trial in which the crops were fertilized and irrigated, the root systems of the component crops were separated by means of plastic partitions in the soil in order to prevent competition for below-ground factors. At 15 weeks, the number of tillers and the biomass of the cane were reduced by 60 and 51 per cent, respectively. This was attributed to competition for light. Competition for below-ground resources was not observed.

In a second trial one or both of the crops were not fertilized, and no evidence of competition for nutrients was found. Likewise, there was no evidence of competition for water in a trial without irrigation in a dry site, although the intercropped cane may have experienced more water-stress than the sole cane as an indirect consequence of competition for light. With adequate irrigation, on the other hand, excellent maize yields and full cane yields were obtained.

The extent to which maize shaded the cane was measured in a fourth trial by means of tube solarimeters. At 8 weeks, the amount of light reaching the top of the cane canopy was reduced by 28, 39, and 67 per cent by intercropping with maize at densities of 1.56, 3.12, and 6.25 plants/m². Shading led to a reduction in the cane growth as measured by tiller numbers. After the harvest and removal of the maize, tillering of the cane resumed rapidly. Depending on the extent to which the cane growth was affected by the maize, the final cane yield may or may not be reduced.

The effect of maize density and planting pattern was studied in 4 trials with plant and 3 trials with ratoon sugar cane. Maize grain yield increased as plant density was increased from 2.08 to 6.25 plants/m². In some trials, even at the lowest density, intercropping with maize led to a reduction in the yield of sugar. As the maize density increased so did the adverse effect on the yield of sugar. On ratoon sugar cane, the adverse effect was less pronounced. The use of paired cane rows did not improve the

yields of the intercropped cane. On the contrary, pairing of cane rows led to lower sugar yields in some trials.

Yield advantages were measured by an adaptation of the Land Equivalent Ratio in which the difference in crop durations was taken into account. With plant sugar cane, no yield advantages were obtained in the first season (March) plantations but small yield advantages were obtained with some mixtures in the second season (August) plantations. In the second season, there were substantial increases in gross margins of up to 50 % with one row of maize in every inter-row of cane at one site.

This treatment was also the best in ratoon cane. Yield advantages of up to 42 per cent and increases in gross margins of up to 51 percent were obtained with a density of 4.17 plants/m², achieved by growing one row of maize in every interrow of cane.

The implications of the findings of the competition and agronomic studies are discussed in relation to the development of a strategy for maximizing the total productivity and economic returns to land in Mauritius.

RESUME

La culture du maïs (Zea mays L.) en intercalaire de la canne à sucre (Saccharum sp.) a été étudiée dans des essais aux champs à l'île Maurice.

La compétition entre les 2 espèces a fait l'objet d'une étude dans 2 sites. Trois cultures successives de maïs ont été faites en mélanges non-additifs avec la canne vierge. Le rendement de la première culture était supérieur alors que celui de la deuxième et de la troisième culture étaient inférieurs aux rendements escomptés par rapport à la proportion de maïs dans les mélanges. A l'aide de fonctions de compétition on a démontré que des deux espèces, la canne était celle qui dominait. Ces mélanges non-additifs n'ont pas donné de gain en rendements.

Quatre essais ont porté sur l'utilisation des facteurs de croissance par le mélange d'un rang de maïs entre chaque rang de la canne vierge. Dans un premier essai où les espèces étaient fertilisées et irriguées, on a séparé les systèmes racinaires par des cloisons en plastique pour empêcher la compétition pour les facteurs souterrains. A 15 semaines, le nombre de talles et la biomasse de la canne étaient réduits par 60 et 51 pourcent, respectivement. Ces réductions ont été imputées à la compétition pour la lumi-

ère. Par contre, la compétition pour les facteurs endogés n'a pas été observée.

Dans un autre essai, où l'une ou l'autre ou aucune des cultures n'a reçu de fertilisants, on n'a néanmoins pas réussi à mettre en évidence la compétition pour les éléments nutritifs. De même dans un troisième essai dans un endroit sec sans irrigation, on n'a pas observé de compétition pour l'eau. Toutefois, la canne intercalée a peut-être été plus sérieusement affectée par le manque d'eau que la canne non associée, et cela était une conséquence indirecte de la compétition pour la lumière.

Dans un autre essai on a utilisé des solarimètres tubulaires pour mesurer l'atténuation de la lumière par le maïs. Ainsi, à 8 semaines, la quantité de lumière sur la voûte de la canne était réduite par 28, 39 et 67 pourcent par le maïs à des densités de 1.56, 3.12, et 6.25 plants/m², respectivement. L'ombre du maïs sur la canne a eu pour effet une réduction de la croissance de la canne qu'on a détectée par le nombre de talles. Après la récolte du maïs, le tallage de la canne a repris rapidement. En fonction des effets plus ou moins importants sur la pousse de la canne, la récolte finale était plus ou moins affectée.

L'influence de la densité du maïs et de la méthode de culture ont été étudiées dans 4 essais avec la canne vierge et 3 essais avec la canne de repousse. Le rendement du maïs grain augmentait avec la densité de peuplement entre 2.08 et

6.25 plants/m². Dans certains essais, même à la densité inférieure, la culture intercalaire de la canne a mené à des réductions en rendement de sucre. Cette réduction était directement liée à la densité du maïs. La réduction était moins marquée sur les repousses. La plantation de cannes en rangs jumelés n'a pas donné lieu à de meilleurs rendements. Au contraire, dans certains essais, les rendements étaient inférieurs quand les rangs étaient jumelés.

On a mesuré le gain en rendements à l'aide du 'Land Equivalent Ratio' qu'on a amendé pour prendre en compte la différence entre la durée du cycle des deux espèces. Avec la canne vierge, on a obtenu des gains en rendement avec certains mélanges dans la deuxième (août), mais pas dans la première (mars) saison. Il y avait aussi dans la 2^{ème} saison des bénéfices bruts considérables, jusqu'à 50 pourcent avec le mélange d'un rang de maïs entre chaque rang de cannes.)

Ce même mélange était aussi le meilleur avec la canne de repousse. Des gains en rendements de 42 pourcent et en bénéfices bruts de 51 pourcent furent atteints avec une densité de 4.17 plants/m² qu'on a obtenue en plantant un rang de maïs entre chaque rang de cannes.

La portée des résultats des essais de compétition et des essais agronomiques est discutée en relation avec la mise au point d'une stratégie pour maximiser la productivité totale et les bénéfices économiques de l'exploitation de la terre à l'île Maurice.

GLOSSARY

- ATER: Area-time Equivalency Ratio. Definition p. 20.
- C.R.: Competitive Ratio. Definition p.16.
- Complete Fertilizer: 13:13:20:2. Contains 13% of N and of P_2O_5 , 20% of K_2O and 2% of MgO.
- ELER: Effective Land Equivalent Ratio. Explanation p.19.
- I.R.R.I.: International Rice Research Institute. Located at Los Banos, Philippines.
- I.R.S.C.: Industrial Recoverable Sugar Content. Explanation p. 68
- LER: Land Equivalent Ratio. Definition p. 18.
- M.S.I.R.I. Mauritius Sugar Industry Research Institute. Located at Réduit, Mauritius.
- Plant sugar cane: First cycle of crop established from cuttings
- Pol %: Unit of sucrose content as determined by a polarimeter.
- Ratoon sugar cane: Crop obtained from sprouts coming from underground stems of sugar cane after it has been harvested.
- Rattrapage: French term meaning the ability of sugar cane to offset initial setbacks in growth. Discussion pp. 200, 204, 222.

R.C.C.: Relative Crowding Coefficient. Definition p. 14.

Recruit: Fill in gaps in crop stands, in the case of maize, with seeds; in the case of sugar cane, with pre-sprouted cuttings.

SLER: Staple Land Equivalent Ratio. Explanation p.19.

Spindle: The thin, tapered tip of sugar cane shoots consisting of rolled-up leaves.

Stool: A plant with several stems arising together; in the case of sugar cane, originating from one cutting.

Stover: Plant parts left on the field after grain harvest of a crop.

Trash: Dried leaves of sugar cane stripped off during growth.

T.V.D.: Top Visible Dewlap.

Chapter I

INTRODUCTION

1.1 The Regional scene.

1.1.1 Foreword

Two main approaches have been proposed for increasing food production in the world: expanding the area planted and intensifying production on already-cultivated lands (Bradfield, 1970). The use of presently uncultivated lands is not considered to offer much promise because of the excessive costs of opening up the lands, their marginal quality, etc. (Brady, 1970). Moreover, this second approach is not applicable in areas where arable land is already very scarce. In many densely-populated areas, food production may be severely limited by the small size of the individual farmer's plots even though there may be land available elsewhere in the country.

Much effort has been spent on increasing crop production per unit area. It was one of the aims of the "green revolution", a term associated with the success in several developing countries of highly responsive wheat and rice varieties. However, in view of the criticisms levelled at the "green revolution" (see Allaby, 1973; Harwood, 1975;

Harlan, 1977), many research institutions have modified their approach to crop intensification. In particular, emphasis is now placed on a consideration of the farmer within his broad physical, economic and social environment. This approach requires that research at improving traditional cropping systems should be based on a sound understanding of such systems.

Although traditional farming systems in the tropics are very diverse, they do have certain features in common such as, for instance, a predominance of intercropping. This is the practice of growing two or more crops together on the same plot. Although intercropping is an ancient practice, it has not received much attention from the scientific community until recently. In the past decade, however, intercropping has come under increasing scientific scrutiny from researchers, many in tropical countries. This research has indicated that intercropping can be developed into a highly productive agricultural technology based on applied ecological concepts. This thesis reports the results of investigations of the basic principles leading to the technological development of one such intercropping system in a developing country, namely the intercropping of sugar cane with maize in Mauritius.

1.1.2 Mauritius: elements of geography.

Mauritius and its island district, Rodrigues form part of the Mascarene Archipelago in the south west of the Indian Ocean. Mauritius is situated at latitude 20 degrees South and longitude 57 degrees East, about 880 kilometres east of the Malagasy Republic.

The island of Mauritius is volcanic in origin. The land rises from a coastal plain to a central plateau whose altitude varies from 275 to 725 metres.

The climate of Mauritius is maritime, tropical in summer and sub-tropical in winter (Padya, 1984). Temperature is mild throughout the year. The mean maximum temperature in the warmest areas varies from 31.2 ° C in January-February, the warmest months to 25.9 ° C in July-August, the coolest months. Mean minimum temperature in the coolest areas varies from 20.5 ° C in January-February to 14.9 ° C in July-August. Annual rainfall varies from less than 1000 mm in parts of the coast to more than 5000 mm in parts of the central plateau and it is also very variable from year to year. Most of the rains fall in the summer months in the cyclone 'season' from November to April. The frequent occurrence of cyclones characterizes the climate of Mauritius. Cyclones are very damaging to agriculture.

The island of Mauritius covers an area of 1840 square kilometres. Of this, 57 per cent is cultivated. It is generally accepted that very little further land can be put

under cultivation. Indeed, some of the mountain slopes that are presently cropped should probably best be put back under forest. Furthermore, every year the country loses some agricultural land, mainly to urbanization to cater to the needs of a growing population. Already, the population is at one million, making Mauritius one of the most densely populated countries of the world. The need to intensify crop production in the face of land scarcity and a growing population is therefore clear.

1.1.3 Rationale and philosophy of agricultural diversification in Mauritius:

Of the total area presently cropped, 90 per cent is under sugar cane, 6 per cent under tea and the remaining 4 per cent under fruits, vegetables and other crops. The agriculture and the economy is therefore dominated by cane sugar production.

Moreover, Mauritius is presently facing severe economic difficulties. There are increasingly large trade deficits, partly because of the increasing food import bill compared to export earnings. For instance, in 1982, the value of imported food represented 25 per cent of total imports and absorbed about two-thirds of the foreign currency earnings from sugar, the main export (Government of Mauritius, 1983). Hence, there is a general consensus around the need to diversify the agriculture and the economy. Particular emphasis is laid on the policy of "achieving the greatest

autonomy in the control and production of our food supplies" (Boolell, 1980).

Agricultural diversification is not new in Mauritius. The country had a more diversified agriculture and economy until about the middle of nineteenth century when, as a result of a guaranteed market and price, sugar cane became the dominant crop. Periodically ever since, and especially in times of war when supplies were disrupted, efforts have been mounted to produce more food crops. These efforts have usually been short-lived. Nevertheless, new impetus was given to crop diversification with the creation in 1970 of a Food Crop Agronomy Division at the Sugar Industry Research Institute and with the establishment in 1974 of a National Food Production Committee to decide on priorities and targets. However, many obstacles to agricultural diversification still persist (Wiehe et al, 1984), the two main ones being:

A. The climate of Mauritius is characterized by the frequent occurrence of cyclones and droughts resulting in devastating effects on food crop plantations. Over the years, sugar cane has been shown to be the crop that is least affected by these calamities and therefore most adapted to the Mauritian climate.

B. Sugar cane enjoys a relative economic advantage over other crops by virtue of its guaranteed market and negotiated

prices. A large part of the country's sugar production is sold at remunerative prices insulated from the world market. Only about 16 per cent of a potential annual production of 685,000 tonnes is sold on the world market (Wiehe et al, 1984). Besides, this safety margin is required to offset possible shortfalls due to cyclones and drought and hence, to safeguard the country's export quotas.

This situation is translated into an agricultural policy that emphasizes intensification and diversification of agriculture in addition to rather than at the expense of sugar cane (Government of Mauritius, 1983). Based on this policy, a two-pronged strategy for agricultural diversification has been defined:

A. Accelerate the development of agricultural activities which do not require arable land eg. meat, milk, fish production. These represented about 39 per cent of the value of food imports in 1983 (Wiehe et al, 1984).

B. Make maximum use of sugar cane rotational lands and of sugar cane interrows for the production of crops for export and for import-substitution. The last-named category comprised 11 per cent of the value of food imports in 1984. Of the crops that are presently imported and whose production in Mauritius has been shown to be possible, maize and bean are the most important.

1.1.4 Maize in Mauritius: approaches to increasing production

Maize was an important crop grown for food by the early French colonists in the eighteenth century but it was completely displaced by sugar cane by the middle of the nineteenth century. Efforts have been made during the First and the Second World Wars to increase the production of maize but these have met with little success. Production was at its lowest levels of about 200t annually in 1961-1964 (Owadally, 1972). Since then, there has been an increase to about 1500t in 1982-1983. Requirements, on the other hand, have increased from 4300t in 1969-73 to 14,200 t in 1979-83 and are expected to be about 16,000t in 1986 (Govinden and Mauree, 1985).

Numerous constraints limit the production of maize and account for the failures of past attempts to increase production. These have been discussed elsewhere (Pillay and Govinden, 1982; Govinden and Mauree, 1985). Various approaches to increasing maize production have been tried. Presently two approaches are being implemented. The first involves the intensification of cropping by the use of sugar cane rotational lands. It consists of growing a crop of maize on the lands lying fallow for a period of 4-5 months between the harvest of the last sugar cane ratoon crop and the replantation of the field. The area replanted every year is only about 10-12 per cent since the average cane cycle lasts for 8-10 years (ie. one plant and 7-9 ratoons).

This system of producing maize is practiced by sugar estates, and accounted for about 40 per cent of the total production in 1983. The prospects for increasing production by this method is rather limited in view of the competition for sugar cane rotational lands by such crops as tobacco, ginger and turmeric, which for one reason or another, cannot be grown in sugar cane interrows.

The second approach to increasing maize production involves intercropping with sugar cane. This practice is already well-known to Mauritian cane growers, and in 1983, it accounted for 56 per cent of production. It has been very successful with potato, and presently, 77 per cent of the potato produced in Mauritius come from interrows of sugar cane and this is done without reducing the yield of sugar. With maize, however, there have been problems. The main stages in the progress of intercropping sugar cane with maize and the problems will be reviewed in section 1.2. Nevertheless, the practice is seen to offer excellent prospects if it can be made to work and if farmers can be convinced to adopt it. The prospects are good because of the area in plant and especially in ratoon sugar cane that could be put under cultivation. Intercropping would go a long way towards solving the problem of land scarcity.

It must be recognized that land scarcity is but one of the constraints to maize production, even if it is the main one. Others include lack of infrastructure. Fortunately,

the Government seems well disposed to removing other constraints. Seed production has been taken care of, marketing is not presently a problem, shelling and drying facilities are being constructed and an acceptable guaranteed price has been offered (Govinden and Mauree, 1985).

It is in this context that the present research was initiated in 1981. The broad scope was to investigate the system of intercropping of sugar cane with maize in order to gain an insight into the biological basis for the control of productivity in this two-crop system and manipulate it for agronomic purposes. These objectives will be described in section 1.3.

1.2 Literature review

1.2.1 Intercropping: General

1.2.1.1 Terminology and definitions.

Some of the terms used in the growing literature on cropping systems mean slightly different things to different people, hence the need for a uniform terminology. In this thesis, the widely-accepted definitions of Andrews and Kassam(1976) will be used.

Multiple Cropping is the growing of two or more crops on the same field in a year. In essence, it is the intensification of crop production into a third (time) and a fourth (space) dimension; the first dimension is the area of pro-

duction and the second is the yield per unit area (Sanchez, 1976). When the intensification of crop production is into the time dimension only, the system is known as sequential cropping which can be formally defined as the growing of two or more crops in sequence on the same field per year. There is no interaction between the crops and farmers manage one crop at a time. Examples are double and triple cropping.

Intercropping, on the other hand is the growing of two or more crops simultaneously on the same field per year. Crop intensification is in the time as well as the space dimension. There is interaction between the crops during part or all of the crop growth. Farmers manage 2 or more crops at a time. If the crops are together for only a part of their growth cycle, such as in cases where the second crop is planted after the growth of the first is well-advanced, the system is known as relay intercropping. When the crops are arranged in distinct rows, the system is referred to as row intercropping as opposed to mixed intercropping when the crops are not arranged in rows. The practice of growing maize in interrows of sugar cane is an example of row intercropping, but in this thesis, it will be referred to simply as intercropping.

The opposite of intercropping is the growing of one crop alone in pure stands; this is known as sole cropping (synonymous with pure stand cropping and monocropping). The two or more crops that constitute an intercropping system are known as component crops.

1.2.1.2 Importance of intercropping.

Intercropping is a very old practice which is still widespread in tropical areas of Africa (Okigbo and Greenland, 1976), of Asia (Harwood and Price, 1976; Gomez and Gomez, 1983) and America (Pinchinat et al, 1976). The practice has however, almost disappeared from temperate areas, and this may be at the origin of the misconception that intercropping is a primitive practice that must be discarded if agriculture is to progress.

However, there is now growing appreciation for the importance of intercropping whose universal character in the tropics has been reviewed (Dalrymple, 1971; Sanchez, 1976; Andrews and Kassam, 1976; Govinden et al, 1984). It is widely practised under the low input conditions of small peasant farmers (Ruthenberg, 1980) but also on some large plantations of certain cash crops (Chang, 1965; Nelliati et al, 1974).

With such widespread use it is important to determine why farmers are so attracted to intercropping. Indeed in many areas there has been little shift from intercropping to sole cropping in spite of extension efforts (Baker, 1975). Obviously, the farmers must be convinced that there are tangible advantages to growing their crops in mixtures rather than in pure stands. Studies of intercropping are, however, made more difficult because of the wide diversity of crops and cropping patterns. Evidence of advantages of growing mixed crops has been examined in several reviews (Trenbath, 1974;

Sanchez, 1976; Willey, 1979 a & b). They will be discussed in subsequent sections.

1.2.1.3 Competitive relationships

According to Sanchez (1976), an understanding of intercropping should start with the examination of some of the basic concepts of how plants react in mixtures. Unfortunately, different groups have different approaches to the study of plant interactions. Agronomists have traditionally been concerned with the description of effects and the analysis of causes of plant reactions to changes in density in pure stands and of the interaction between species in mixed crops (Harper, 1961). Sanchez (1976) recognized three types of plant interactions: non-competitive, competitive and complementary. Non-competitive interaction occurs when different plants share a growth factor (light, water, nutrients) that is available in sufficient amounts so that it is not limiting. Competitive interaction or simply competition, occurs when one or more growth factors are limiting. Complementary interaction or simply complementarity occurs when one plant helps another, as in the case of legumes supplying nitrogen to grasses via symbiotic fixation.

The present agronomic understanding of plant interactions has developed primarily through the studies of grass-legume mixtures and of varietal mixtures of crop species. They have provided many insights into intercropping (Trenbath, 1974).

The basic experiment on mixtures of two species is the replacement series; that is, a fixed proportion of one species is replaced by an equal proportion of another species. Competitive effects are examined by comparing the actual to the expected yields. Expected yields are those that would be obtained if each species experienced the same degree of competition in mixture as in pure stand; that is, inter-specific competition is equal to intra-specific competition. The 3 possible outcomes of competition in such replacement series are: mutual inhibition, mutual cooperation and compensation (Willey, 1979a). In the case of mutual inhibition, the actual yield of both species is less than expected, whereas in mutual cooperation, the yield of both species is greater than expected. In the third and most common case, compensation, the yield of one species is more and that of the other less, than expected. The more competitive species is known as the dominant or aggressor and the less competitive species, the dominated or repressed species.

Various measures or indices have been proposed to describe the competitive relations of component crops in mixtures. Although these competition functions were developed in plant competition studies, they have also been useful in intercropping situations, and therefore they will be briefly outlined here.

Relative Crowding Coefficient

This concept was developed by de Wit (1961) to describe the spatial relations within populations of one or more species. In replacement series, each species has a Relative Crowding Coefficient, K which measures whether the species has produced more or less yield than expected on the basis of the sown proportion. In the notation of Willey (1979a), the Relative Crowding Coefficient of species a is K_{ab} :

$$K_{ab} = \frac{Y_{ab} \times Z_{ba}}{(Y_{aa} - Y_{ab}) \times Z_{ab}} \quad 1$$

where:

Y_{aa} =Pure stand yield of species a

Y_{bb} =Pure stand yield of species b

Y_{ab} =Mixture yield of species a in combination with b

Y_{ba} =Mixture yield of species b in combination with a

Z_{ab} =Sown proportion of species a in mixture with b

Z_{ba} =Sown proportion of species b in mixture with a

If a species has a Coefficient of less than one, equal to, or greater than one, it means that the species has produced less yield, the same yield, more yield than expected, respectively. The component crop with the higher Coefficient is the dominant one. The product of the Coefficients is a measure of yield advantage. However, as Willey (1979) has shown, the Relative Crowding Coefficients do not give a

direct indication of the magnitude of the yield advantage. Moreover, the value of the Coefficient of one component species can have different meanings depending on the value of the Coefficient of the other component species.

Aggressivity

A second function to measure the competitive ability of components in mixtures was proposed by McGilchrist and Trenbath (1971). It is simply the difference between the relative yields of the component crops. Aggressivity, A of species a in mixture with species b, is given by:

$$A_{ab} = \frac{\text{Mixture yield of a} - \text{Expected yield of a}}{\text{Mixture yield of b} - \text{Expected yield of b}}$$

ie.

$$A_{ab} = \frac{Y_{ab} - Y_{ba}}{Y_{aa} \times Z_{ab} - Y_{bb} \times Z_{ba}} \quad 2$$

and

$$A_{ab} = -A_{ba} \quad 3$$

An Aggressivity value of zero indicates that one species is as competitive as the other. In other cases, the Aggressivity of the dominant species is positive and that of the dominated species is negative. Aggressivity is not a measure of yield advantage.

Competitive Ratio

This alternative to Aggressivity was proposed by Willey and Rao (1980). Whereas Aggressivity is the difference in relative yields, Competitive Ratio is simply the ratio of relative yields. Competitive ratio of species a, CRab is defined as:

$$CRab = \frac{Yab}{Yaa \times Zab} / \frac{Yba}{Ybb \times Zba} \quad 4$$

and

$$CRab = \frac{1}{CRba} \quad 5$$

Competitive Ratio has the advantage over Aggressivity of indicating the exact degree of competition as the number of times one species is more competitive than the other. Competitive Ratio has been found to be useful in identifying characters associated with competitive ability (Faris et al, 1983). It is not, however, an indicator of yield advantage.

1.2.1.4 Assessment of yield advantages

There is increasing evidence that in many intercropping situations there are large yield advantages (Andrews and Kassam, 1976). In view of the importance of this aspect, attention has to be given to the proper assessment of yield advantages. It has been recognized that depending on the

objectives of intercropping, different criteria may have to be applied to different situations. Willey (1979a) has described the three most common situations:

1. Where the combined intercrop yield must exceed the higher sole crop yield. Traditionally, this criterion has been used to assess the yield advantages in mixtures of forage grasses and of genotypes of the same species. It is based on the assumption that unit yields of each component are equally acceptable. In such situations, biomass productions of each of the species are commonly added to form a combined yield. Such situations are rather rare.

2. Where intercropping must give a full yield of a main crop and some yield of a second crop. This has been the primary objective of much of the research work in many tropical countries where the main crop is either a staple cereal or a cash crop. Clearly, the emphasis in such situations is on how to increase the yield of the second crop while maintaining the yield of the main crop.

3. Another common situation is where the combined intercrop yield must exceed a combined sole crop yield. This criterion is based on the assumption that the farmer must grow more than one crop. His choice is between mixing the crops and growing them separately. Yield advantages occur if intercropping gives higher yields than growing the component crops separately. The comparison involves combining the yields of the species.

One method of calculating combined yields involves conversion of yields to some common basis such as protein or calories. This is useful in cases where rather similar crops are grown. The method is however, not of much value in cases where the crops differ widely in 'quality', a characteristic that is difficult to evaluate. One can argue that while protein and carbohydrate can be put on the common basis of energy by means of some equivalence factor, much is lost in the conversion itself. Moreover, farmers may be interested in protein and not in protein equivalent. For the purpose of evaluation, mixed crop yields often have to be standardized or monetarized.

Willey and Osiru (1972) proposed the use of a Land Equivalent Ratio (LER) which can be formally defined as the relative land area required as sole crops to produce the same yields at the same level of management as intercropping. This concept is analogous to the Relative Yield Total of de Wit and Van den Bergh (1965). Using previous notation, Land Equivalent Ratio can be written as:

$$\text{LER} = L_a + L_b$$

$$\text{i.e. LER} = \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}} \quad \dots \dots \dots 6$$

where L_a and L_b are the partial LER's of the two species.

LER is therefore a method of combining the yields of different species. It has been used as a measure of yield advantage and of total productivity but its use is beset with problems

Implicit in the use of LER as a measure of total productivity is the assumption that the yield proportion given by a mixture is exactly that required by the farmer. In the comparison of the LER's of 2 mixtures, these differences in proportions are not considered. For this reason, Mead and Willey(1980) extended the concept of ordinary LER to an Effective Land Equivalent Ratio (ELER) which can be calculated for any proportion of the component crops. It assumes that to achieve a required proportion of the crops, sole crop areas may be mixed with intercropped areas. ELER is always numerically less than LER.

More recently the LER concept has been extended further to cover situations where the yield of a main crop must be maintained at a fixed level. Reddy and Chetty (1984) developed an index which they called Staple Land Equivalent Ratio (SLER). SLER is useful in cases where a farmer's requirement for a main crop is not fully met through intercropping; he would then need to allocate part of his land to pure stands of the main crop.

It must be appreciated that LER has major drawbacks which seriously limit its use as a measure of yield advantage. Firstly, it is a ratio; as such it gives no information on the absolute yields of the mixtures and of their components.

Secondly, the mathematical properties of the ratio are such that they violate the basic assumptions underlying analysis of variance and significance testing. These have been reviewed elsewhere (Mead and Riley, 1981). Moreover, the calculation of the ratio itself is problematic since there are several alternatives in the choice of the sole crop yield to be used as a standardizing factor. On one hand, to use a single divisor as suggested by Mead and Riley (1981) and Oyejola and Mead (1982) may reduce the variability of LER's and make them more normally distributed, but introduces a correlation between the values. On the other hand, the use of different divisors for each block as suggested by Fisher (1977a, 1979), keeps the LER's independent but may decrease the precision of treatment comparisons. The question has not been resolved and much more statistical work is clearly indicated.

Another problem with LER and other related indices arises from the difference in crop durations. In the calculation of LER, it is implicitly assumed that no crop is grown after the harvest of the earlier-maturing sole crop. This inflates the LER values. While it may be true that in certain areas the season is not long enough for a second crop, it is rarely the case in much of the humid tropics where year-round cropping is possible. To solve this problem, Hiebsch (1980) proposed an Area-Time Equivalency Ratio (ATER) which he defined as the sum of the rates of yield

production of the intercrops relative to the sole crops. In the usual notation, ATER is given by the expression:

$$\text{ATER} = \frac{Y_{ab}/t_{ab}}{Y_{aa}/t_{aa}} + \frac{Y_{ba}/t_{ba}}{Y_{bb}/t_{bb}} \quad \text{--- 7}$$

where t_{ab} = time during which the species a is in the mixture

t_{aa} = duration of sole crop a

t_{ba} = time during which the species b is in the mixture

t_{bb} = duration of sole crop b.

ATER has been found to be most useful for comparing complex cropping systems involving relay intercropping and continuous intercropping (Wade and Sanchez, 1984). However, ATER has two shortcomings. Firstly, implicit in the comparison of rates of production is the assumption that such rates can be maintained over the entire year; this discounts the influence of season. Secondly, ATER does not take into account the inevitable delays between the harvest of one crop and the planting of the next.

Thus, it is apparent that none of the indices that have so far been proposed in the literature is universally acceptable as an indicator of yield advantage. Some are more useful than others in particular circumstances but in most cases an adaptation of the basic LER concept may be necessary. Moreover, even if an agronomically-meaningful index may be

derived, its statistical properties are still likely to present difficulties unless it is not a ratio.

In addition to whatever analysis is carried out on yields, some form of economic evaluation is desirable. Willey (1979a) proposed the calculation of an LER on a monetary basis ie. the land area required as sole crops to produce the value of the yields achieved by mixing. This gives exactly the same value as LER based on yields, and has the same shortcomings as well. According to Hildebrand (1976), the only unit that satisfies all the criteria necessary to measure production from multiple cropping systems is the market value. He was of the opinion that its major weakness, that prices change over time, is at the same time an advantage in the sense that it allowed for adjustment to changing conditions. Nevertheless, a shortcoming of expressing results solely in terms of market value is that it does not take into consideration the differences in costs of production. These are important, especially in situations where capital may be scarce. The best approach is to compute net incomes which is the surplus resulting from the deduction of all costs from the market value. In many situations where fixed costs are difficult to estimate, it may be only necessary for the purpose of comparison between treatments to calculate Gross Margins. This is defined as the difference between gross revenue and variable costs. As a final refinement, in order to evaluate the influence of

changing prices on the relative merits of various cropping systems, some form of linear programming may be attempted.

According to Pearce and Gilliver(1978), the combination of crop yields on some common basis such as calorific value, or monetary returns converts an essentially multivariate problem into a univariate one. They argue that there exists a relationship between the yields of the two species in a mixed plot. This relationship can be positive or negative. When a plot is on good soil, the yields of both species may be expected to be good. This would lead to a positive correlation between the 2 yields. On the other hand, because of competition, a good growth and yield of one species may be associated with a poor yield of the other species. They suggested the use of a bivariate analyses of variance which, in the 2-crop mixtures, is much simpler than other multivariate techniques. The bivariate analysis of variance involves the computation of the correlation between the 2 variates after allowing for the effects of treatments etc. according to the model pertinent to the design of the experiment. The variates are then adjusted to allow for this correlation and the comparisons are made on the adjusted variates. Pearce and Gilliver (1979) proposed the use of skewed axes to allow for the correlations and explained how to present the results of the analyses and of significance tests graphically.

The major shortcoming of bivariate analysis is that comparison between the sole crops and the mixed crops is not possible. Moreover, the validity of comparisons between the mixed crops is dependent on certain assumptions such as equality of correlations. In some rare cases, it may be assumed that the correlations between the yields of the 2 crops is similar in all treatments, for example in mixtures of genotypes of species at the same density. In most other cases, the assumption clearly does not hold.

1.2.1.5 Advantages of intercropping

It has already been indicated that intercropping has many advantages over sole cropping. These include increased yield and income, the provision of a more varied diet, more stable production, less problems with pests, diseases and weeds, a better spread of family labour, the control of erosion and a host of other minor benefits, all of which have been reviewed (Sanchez, 1976; Willey, 1979; Govinden et al, 1984). Of particular relevance are the mechanisms underlying some of the advantages and they will be briefly mentioned here.

Yield Advantages

As Donald(1963) has shown and as was later confirmed by Trenbath(1974), yield advantages seldom occur in non-additive two-crop mixtures. This is apparently a result of competition for the same resources. In terms of competitive relationships, it means that the yield of one of the compo-

nent crops is increased at the expense of the other by the phenomenon of compensation previously mentioned. Nevertheless, in a minority of cases, yield advantages, as measured by ordinary LER, have been demonstrated. They are believed to occur as a result of complementarity in resource use. That is, the component crops differ in their use of growth factors in such a way that when grown together, they complement each other rather than compete with one another. Inter-specific competition is less than intra-specific competition. Such complementarity in resource use takes place in space and time.

Temporal complementarity in resource use occurs because different crops make their major demands on growth resources at different times. This explains the large LER's associated with differences in the maturity periods of component crops in mixtures (eg. Krutman, 1968; Osiru and Willey, 1972; Andrews, 1972) As has been pointed out earlier on, in such cases, the yield advantages calculated as LER may be misleading because of the differences in crop durations. This underlines the need in intercropping experiments to separate the effects of differences in crop durations from other effects.

Spatial complementarity in resource use has also been demonstrated. The causal mechanisms include the minimization of competition for light, water and nutrients by virtue of differences in morphological and physiological character-

istics such as leaf area and display, root depth and density, the ability to use different sources of nutrients and to photosynthesize in reduced light intensities etc. (See Reviews by Willey, 1979a; Govinden et al (1984).

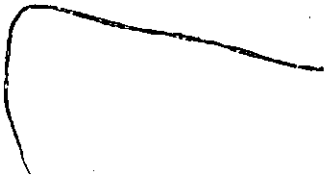
The notion of space is intimately associated with plant density, the size of the area allocated to each plant being the reciprocal of density. De Wit's (1961) Relative Crowding Coefficient, for instance, was developed as much for spacing as for competition studies. In intercropping, further dimensions are of importance: the shape of the area available to the individual plant which is determined by the spatial arrangement, the volume of space, above and below-ground occupied by the plant which is determined by plant height, leaf display, root depth etc., and the time during which this space is occupied. Each of these aspects of spatial relationships has been shown to have bearing on yield advantages (Willey, 1979b).

One of the most important findings which has emerged from recent experimentation on the basis of yield advantages is the association of large yield advantages with increased total population densities in mixtures. It has already been mentioned that yield advantages have seldom been shown to occur in mixtures where the total population was not increased (Donald, 1963; Trenbath, 1974). The grass-legume mixtures are exceptional because of the transfer of N from one species to the other. On the other hand, large yield

advantages have been obtained when the total population densities of the mixed crops were much larger than those of the sole crops (eg. Willey and Osiru, 1972; Baker and Yusuf, 1976). It can be assumed that if one crop complements another in the use of available growth factors, the optimum density of the mixture would be higher than that of the sole crops. Because of the relationships between density and yield, it is important to attempt to separate causal mechanisms. For instance, Fisher (1977b) has shown that much of the yield advantage in maize and bean mixtures in East Africa disappeared if the comparisons were made at equal population densities. He strongly recommended the use of replacement series mixtures in future trials.

Other Advantages

In view of the fact that weeds, pests and diseases are major limiting factors in crop production in the tropics, the reports that intercropping reduces the impact of these biotic factors take on added significance. Many reports have indicated that intercropping controls weeds (Litsinger and Moody, 1976; Burn, 1976). It is not difficult to visualize how low-growing intercrops with a spreading habit can smother weeds in widely-spaced row crops. For example, the Mexican yam bean, (Pachyrrhizus erosus) when intercropped with maize was so effective that weeding was not necessary whereas it is usually essential in sole maize (Moody, 1977).



It is believed that the fact that intercropping has persisted for so long is attributable partly to the existence of certain innate pest control properties (Kayumbo, 1976). Many instances of reduced pest incidence have been reported with intercropping (IRRI, 1973; 1974; 1975). Some of the causal mechanisms have been reviewed (Batra, 1962a; Litsinger and Moody, 1976; Van Emden, 1977). Mention has been made of an intercrop sheltering a host plant (Batra, 1962b), of insects being repelled by volatile substances emitted by intercrops (IRRI, 1973; Trenbath, 1975), and of the reduction of pest numbers in intercropping as a result of the more varied agro-ecosystem leading to higher numbers of predators and parasites (IRRI, 1973; Van Emden, 1977).

Intercropping may reduce the incidence and severity of diseases (Mukiibi, 1976) by virtue of a dilution or barrier effect and the creation of a different microclimate (Trenbath, 1975).

Intercropping is one way to achieve a full canopy cover fast and hence to protect the soil from the erosive hazards of rainstorms. Some combinations that have actually been shown to control soil erosion and water run off are maize and cassava (Aina et al, 1977) and sweet potato and cassava (Okigbo, 1977).

With respect to peasant farmers, many of whom practice intercropping in the tropics, a further appeal of intercropping is believed to rest with the higher yield stability of

intercropping. By this is meant that intercropping reduces the risks of crop failure through the mechanism of compensation. Should one component of a mixture fail because of bad weather, diseases or pests, the yield of the other component may increase. For example, the yield advantages from mixing maize and beans were highest when the maize failed due to hail damage, late planting or diseases (Fisher, 1976). Likewise, rice yields increased when maize was eliminated by diseases from a mixture of rice and maize (IRRI, 1974).

1.2.1.6 Drawbacks

It must be appreciated that in certain circumstances, intercropping may have more drawbacks than advantages. Firstly, yields may be reduced as a result of competition. Some crops cannot be grown together because they compete too strongly for the same resources. There is also the danger of growing together crops which have common pests and diseases. Pest populations and disease inoculum levels may build up on an early-maturing component crop and hence lead to an increase in the damage to a later-maturing component crop in the mixture. This underscores the importance of choosing compatible crops.

Perhaps the most common objection to intercropping is associated with the difficulty of gauging inputs, such as fertilizer, irrigation and biocides on two or more different crops growing together, and with the difficulty of mechanizing cultural operations. This may explain why intercropping

is not common in developed countries where agriculture is more input-intensive and mechanized. With regards to the rates of inputs, it must be pointed out that where the problem has been recognized and addressed by research workers, results have been forthcoming. For instance, successful herbicidal treatments have been found for various crop combinations (Peng and Twu, 1980; MSIRI, 1984). It is definitely more difficult to circulate in intercropped than in sole-cropped fields because of less space, and this does make operations such as top dressing of fertilizer, spraying against pests and diseases and even harvesting more difficult. However, in certain situations, especially in widely-spaced row crops, this difficulty has been overcome, and small animal-drawn and motorized implements can be used. It must be stressed that machinery developed for sole crops must first be adapted for use in intercrops. There is finally the possibility of adapting the cropping pattern to permit mechanization; for example, rows can be paired so as to create more space.

Intercropping is only now beginning to be studied. It has numerous advantages but cannot be used indiscriminately.

1.2.2 Intercropping of sugar cane

1.2.2.1 Importance

Sugarcane is an important cash crop in many tropical and sub-tropical countries where year-round cropping is possible. In several of these countries, sugarcane is intercropped, but statistics on the importance of the practice are difficult to obtain.

Aiyer(1949) surveyed the practice of intercropping in India and reported that intercropping of sugarcane with other crops was widespread. That this is still the case presently is evident from the number of reports from that country. In Taiwan, from 1955 to 1958, 75 and 39 per cent of the fields planted in autumn and spring, respectively, were intercropped(Chang, 1965). The importance of intercropping of sugarcane in Taiwan is also indicated by Yang's(1976) observation that 65 per cent of the cane fields were intercropped. In the Philippines, farmers commonly intercrop sugarcane with mung bean and groundnut (Villarico and Ledesma, 1976). Outside of Asia, sugarcane is intercropped on a commercial scale in Brazil (Lombardi, 1985), in Puerto Rico (Lugo-Lopez et al, 1953) and Colombia (Arboleda et al, 1983). In Africa, there are reports from Egypt where Nour et al (1971) reported that 65 per cent of the cane fields planted in the autumn of 1967 were intercropped with faba beans. Sugarcane is also intercropped with various crops in Reunion island and Mauritius.

Thus, it is clear that intercropping of sugarcane is practised in many countries around the world. In most of these countries, the farms are small, land is scarce and there are no labour constraints. These conditions favour intercropping as a means of intensifying crop production. It is equally clear that intercropping of sugarcane is not practised in many important sugar-producing countries such as Australia, Cuba, South Africa and U.S.A. (Louisiana, Florida, Hawaii). In these countries, the farms are large and heavily mechanized, and land may be less limiting. This suggests that intercropping is not the favoured strategy for increasing crop production in areas where labour, not land is limiting.

1.2.2.2 Rationale and intercropping systems

Row-intercropping of sugarcane is practicable because sugarcane is planted in relatively wide rows and the cane canopy does not close in until 3-6 months. However, there are large variations in the cane row spacings and rates of growth, and these have much bearing on whether intercropping can be undertaken, on the choice of crops, the density that can be planted etc. For instance, row spacing varies from 0.9m in many parts of India to 1.6m in Mauritius and 1.8m in parts of Louisiana (Smith, 1978). Nevertheless, the close planting does not seem to prevent intercropping in India. This may be due to the slow early growth of the cane. In the sub-tropical belt of India, in spite of the climate,

more and more of the cane is planted in autumn since it has been shown that with frost-tolerant cane varieties, autumn planting is more profitable than spring planting (Singh, 1971). However, autumn-planting of cane leads to the loss of a winter crop which used to precede spring sugarcane. Hence intercropping is practised to recoup the loss of this winter crop (Kanwar, 1975). In such cases, the profitability of intercropping should be compared not only to the sole autumn cane but also to the competing rotation of a winter crop followed by spring cane (Kar et al, 1975). For instance, Bhoj and Tandon (1959) found that the net income was 74, 65 and 20 per cent higher with intercropping of autumn sugarcane with chickpea, pea and mustard, respectively, as compared to the rotation of these crops with spring sugarcane. Tiwari and Singh (1981) went further and compared the profitability of autumn cane intercropped with coriander, lentil, wheat and potato to the competing cereal rotation. They found that intercropping of coriander gave 145 per cent higher net income over sole cane, but only 47 per cent higher net income over the competing cereal rotation which consisted of 2 crops of maize and one of wheat.

The reluctance of farmers to forego a spring crop is the basis of intercropping of sugarcane with certain leguminous crops. These used to be grown as green manure in rotation with sugarcane. However, with the advent of inorganic fertilizer, cash crops are now preferred. In order to retain

best of the two alternatives, attempts have been made to intercrop the green manures with sugarcane. Linge-Gowda and Mariakulandai (1972) found no difference between intercropping the legume in situ and bringing it from outside, but there were no beneficial effects on cane yield, either. Bhadauria and Mathur (1973) investigated the benefits of intercropping of sunnhemp (Crotalaria juncea) in 24 trials at 13 sites over 3 years, and found an increase of only 5 per cent in cane yield. In spite of their claims, it is difficult to accept that the practice can be of much economic benefit considering the small yield increase in the face of the costs and trouble involved. In South Africa, sunnhemp is reported to have reduced the yield of intercropped cane (Anon, 1984).

In some parts of India, the cane growth is so slow that a second intercrop may be grown in spring after the harvest of the autumn-planted intercrop (Rathi et al, 1974; Sharma, 1979). In other areas, on the contrary, the growth of cane, especially when planted in narrow rows, is too fast for successful intercropping, and pairing of cane rows has been suggested as a method for creating more space to accommodate intercrops. The use of paired cane rows has given variable results. On one hand, Nadagoudar et al (1978), claimed that growing cane in paired rows with 60cm between the rows in a pair and 120cm between the pairs did not lead to a reduction in cane yield compared to planting in rows uniformly spaced.

at 0.9m. On the other hand, pairing led to a 16 per cent (Sharma, 1979) and 17 per cent reduction (Dhoble and Khuspe, 1983) in cane yield. Nevertheless, the system is seen to offer much promise, particularly in making easier the management of the crops and the mechanization of operations (Singh, 1971).

Another approach to deal with the problem of too fast cane growth and early canopy closure is the practice of relay intercropping of sugarcane. In Taiwan, sugarcane is commonly relay-intercropped with paddy rice, the cane being planted at one to two months before the rice harvest (Chang, 1965; Yang, 1976). This practice has the advantages of minimizing the effect of cane on rice and of permitting the plantation of cane earlier than would be possible with rotation. Relay intercropping of sugarcane with rice is also practised in Indonesia (Karthohadikoesoemo, 1982). Relay intercropping may also be resorted to in order to minimize the effects of the intercrops on cane. For example, when sugarcane is relay-intercropped with cotton, the sugar cane is planted 3 months after the cotton and the crops interact for 2 months only (Hsiung et al., 1963). Finally, relay-intercropping may also be necessary when the best planting times for sugarcane and the intercrops do not coincide. For instance, at New Dehli, India, it was reported that the optimum planting time for sugarcane is at the end of February whereas that of onion is in early January. The inter-

crop should therefore be planted before the cane for best results (Ramdhawa, 1975).

1.2.2.3 Competitive effects

A main concern of research workers has been to compare the effects of various crops on the yield of intercropped sugarcane and on the profitability of intercropping. For instance, Lugo-Lopez et al. (1953) working in Puerto Rico, reported that in one trial, soybean and kidney bean had no effect on cane yield whereas maize reduced cane yield by 14 per cent. In a second trial, they observed no effect of cucumber, cowpea and melon on cane yield but a 64 per cent reduction with maize. Behl and Narwal (1977) found in India, reductions in cane yield of 4, 25 and 32 per cent on intercropping with onion, wheat and chickpea, respectively. Intercropping with onion increased the net profit by 98 per cent, and with wheat by 9 per cent, whereas with chickpea, there was a loss of 54 per cent. Although such comparisons are common, they do not serve much purpose beyond the particular concern of the research worker. The comparison of the competitive ability of various crops is not valid unless the various crops are grown at standard and comparable densities. Unfortunately, it has not been possible to find a single such comparison in the literature.

The response of sugarcane growth and yield to intercropping has been examined in many trials. Effects on the following will be briefly reviewed : germination, tillering, yield and yield components.

It is well established that the germination of sugarcane is not affected by intercropping (Bose and Ashraf, 1972; Bhadauria and Mathur, 1973; Kar et al, 1975, Gawhane and Patil, 1976). This is not unexpected in view of the fact that germination starts within 2-3 weeks after planting, and this does not give the intercrops sufficient time to affect the environmental processes that influence germination.

Tiller formation, on the other hand, has been systematically observed to be seriously affected by intercropping. Tillering is reduced to variable extents depending on the species and/or the densities of the intercrops (Kar et al, 1975; Gawhane and Patil, 1976; Srinives et al, 1976). The duration of the effect is also variable. For instance, Misra (1964) presented 3 years' tillering data for autumn-planted sugarcane intercropped with pea, mustard and chick-pea in India. Peak tiller numbers occurred one month later in the intercropped cane. Moreover, mustard and pea reduced peak tiller numbers by 50 and 25 per cent, respectively. Tiller mortality started earlier in the sole cane, and the tillering period of the intercropped cane was extended. The difference in tiller numbers between the intercropped and the sole cane tended to disappear with time. Similar results have been found whenever tillering has been followed (e.g. Tang, 1963; Leclezio et al, 1985).

Even though the effects of intercrops disappear well before the cane is harvested, nevertheless the intercrops

may have adverse effects on the cane yields. The effects of several intercrops on cane yields are summarized in table 1. The cereals, wheat and maize systematically reduced cane yield. So did sugar beet, mustard and pea. Onion, groundnut and potato had variable effects. The effects of mung bean were generally positive.

The effects of intercrops on the yield components of sugarcane have been examined in several trials. In general, there have been small reductions in the number of millable canes (Bose and Ashraf, 1972; Deshpande and Nankar, 1977; Narwal and Malik, 1981). The reductions in cane yield were usually associated with a reduction in millable cane and in peak tiller number, although the nature of the association has not been determined (Narwal and Behl, 1978).

Intercrops have been found not to affect the sucrose content of intercropped cane. Gill (1963) reviewed 16 trials involving 39 comparisons of cane intercropped with several crops. He found an average increase of 4 per cent in sucrose content of the cane juice as a result of intercropping. This increase may not have been significant. Misra (1964) also compiled comparisons on the effect of mustard, pea and chick pea on the sucrose content of cane juice and found a negligible increase of less than one half of a per cent in 5 trials with mustard, and no increase in 14 trials with pea and 13 trials with chick pea. Mathur (1975) found an average reduction in sucrose content of 3 per cent in 19 trials

Table 1: Survey of the effect of selected intercrops on the yield and net income of sugar cane.

Crop	Country	Change in cane yield (%)	Change in net income (%)	Remarks	Reference
Maize	Puerto Rico	-14	-102	plant cane + ratoon	Lugo-Lopez et al.(1953)
	Puerto Rico	-64	N.A.	plant cane	Lugo-Lopez et al.(1953)
	Puerto Rico	-14	N.A.	ratoon cane	Lugo-Lopez et al.(1953)
	Puerto Rico	-9	-8	plant cane	Lugo-Lopez et al.(1953)
	Taiwan	-13	-12	2 years	Tse & Shiue (1966)
	India	-13	+22	2 years	Bhoj & Kapoor (1970)
	India	-30	+3	-	Bose & Ashraf (1972)
	Thailand	-4	N.A.	6 cane treatments	Srinives et al. (1976)
	India	-10	+35	8 maize treatments x 3 years	Gawhane & Patil (1976)
	India	-25	-25	fodder maize	Deshpande & Nankar(1977)
	Mauritius	-3	N.A.	12 maize treatments x 4 sites	Pillay & Mameet (1978)
	India	-31	+12	high maize density x 3 years	Patil et al (1978)
	India	-5	+9	low maize density x 3 years	Patil et al (1978)
	India	-10	-17	fodder maize, 2 years	Dhoble & Khuspe(1983)
	Colombia	-3	N.A.	14. maize treatments	Arboleda et al. (1983)
	Brazil	-13	+40	Santa Catarina	Lombardi (1985)
Brazil	-4	-6	Rio de Janeiro	Lombardi (1985)	
Wheat	India	-38	+20	8 maize treatments	Bose & Ashrat (1972)
	India	-24	+13	3 years	Singh & Singh (1974)
	Pakistan	-28	-16	3 trials	Kar et al. (1975)
	India	-12	N.A.	19 trials	Fasihi & Hussain (1975)
	India	-18	+29	-	Mathur (1975)
	India	-25	+9	tall wheat cultivar	Behl & Narwal (1977)
	India	-36	-15	-	Narwal & Behl (1978)
	India	-16	+38	short wheat cultivar	Narwal & Behl (1978)
	Bangladesh	-6	N.A.	-	Rassaque et al. (1978)
	India	-20	+22	21 trials (review)	Rathi & Singh (1979a)
	India	-10	+5	6 treatments x 2 years	Joshi et al (1980).

Table 1. continued

Crop	Locality	Change in Cane Yield (%)	Change in Net Income (%)	Remarks	Reference
Potato	Mauritius India India India India India	+4 +7 +11 -12 -5 -13 +3	N.A. +55 +38 +6 +39 N.A. +41	8 trials - 3 years plant cane ratoon cane - 16 trials (review)	Rouillard (1968) Bose & Asraf (1972) Kar et al. (1975) Chatterjee et al (1978) Chatterjee et al (1978) Parashar et al (1979) Rathi & Singh (1979b)
Sugar Beet	India India India India India	-20 -27 -41 -24 -27	N.A. +24 -59 +26 N.A.	- - 2 cane spacings 10 trials (review) 9 beet treatments x 3 years	Parashar et al. (1979) Behl & Narwal (1977) Sharma (1979) Rathi & Singh (1980a) Chauhan et al (1981)
Groundnut	Taiwan India Philippines Philippines India India India Brazil	+5 -11 +4 +2 -8 -18 -13 -8	N.A. N.A. +55 +26 +5 N.A. -8 +6	- 2 years plant cane, 4 trials ratoon cane, 2 trials - - 2 years Alagoas	Chang (1965) Prasadarao & Rao (1969) Villarico & Ledesma (1976) Villarico & Ledesma (1976) Deshpande & Nankar (1977) Nadagoudar et al. (1978) Dhoble & Khuspe (1983) Lombardi (19857)
Onion	India India India India India India India	-5 -34 -5 -5 +1 -14 -13	+19 +295 +98 N.A. +109 +39 +13	4 onion treatments x 2 years - - - 2 cane spacings ratoon cane 2 years	Kar et al (1972) Ramdhawa (1975) Behl & Narwal (1977) Parashar et al (1979) Sharma (1979) Bhutada & Parashar (1981) Dhoble & Khuspe (1983)

Table 1. continued.

Crop	Locality	Change in Cane Yield (%)	Change in Net Income (%)	Remarks	Reference
Mung bean	Thailand	-1	N.A.	6 cane treatments	Srinives et al (1976)
	India	+1	+28	3 cane spacings	Narwal & Behl (1978a)
	India	+12	+36	8 bean treatments x 2 years	Parashar et al (1978)
	India	-3	+8	ratoon cane	Bhutada & Parashar (1981)
	India	+11	+170	3 cane varieties	Narwal & Malik (1981)
Pea	India	-6	+18	4 bean treatments	Sethi & Parashar (1981)
	India	-11	N.A.	14 trials(review)	Misra (1964)
	India	-16	N.A.	-	Parashar et al (1979)
	India	0	+6	6 treatments x 2 years	Joshi et al (1980)
Mustard	India	-12	+3	13 trials(review)	Rathi & Singh (1980b)
	India	-17	N.A.	-	Singha (1961)
	India	-33	+5	-	Bose & Ashraf (1972)
	India	-13	+41	24 trials (review)	Rathi & Singh (1979c)

with wheat in 3 years. In many instances, the intercrops had no effect on sucrose content although the reduction in cane yield was quite marked (Bhoj and Tandon, 1959; Patil et al, 1978).

In spite of the many trials in which yield reductions were observed, (table 1), causal mechanisms have not been given much attention. In most of the Indian reports, causal mechanisms are not mentioned at all. When they are mentioned, the statements are mere speculations that are not even supported by field observations. Nevertheless, a few observations relating to possible causal mechanisms have been found in the literature. Tang (1963) attributed the adverse effects of sweet potato on cane yield to shading and to competition for water. He had observed that the sweet potato grew into the cane rows and assumed that competition occurred. Chang (1965) mentioned that because of its profuse branching habit, cotton undoubtedly caused heavy shading of young canes, thus reducing tillering. He suggested that the cane be allowed to tiller first before the cotton was interplanted or that the cotton be defoliated early. Tse and Shiue (1966) noticed that when cane was intercropped with several crops, some cast more shade on the cane than others. They measured the resulting etiolation which lasted until soon after the removal of the intercrops. In one trial, groundnut had no effect on the length of cane stalk from the time it was planted to harvest. Maize, on the con-

trary, increased cane stalk length by 40 per cent at 7 weeks, but at harvest there was a slight reduction of 5 per cent only. In an attempt to minimize the effect of maize on cane, Cheng (1979) tried planting 2 rows of maize in alternate interrows of cane instead of one row in every interrow. He obtained a 3 per cent increase in cane and a 6 per cent increase in sugar yield with the new system of planting, but he did not quote the yield of the sole cane. The improvement was attributed to less shading of cane in the new system.

Thus, in a number of instances, competition for light has been suggested as being responsible for the observed reductions in tiller number and in cane yield. However, other mechanisms may also be operative. For instance, the results of Srinives et al., (1976) show that sunflower and sorghum may have more adverse effects than could be explained on the basis of competition for light. In a trial in Thailand, sunflower and sorghum occupied the land for less time than maize and were at the same density as maize, but they reduced cane yield by 33 and 38 per cent, respectively, whereas maize reduced it by less than 5 per cent. In a trial on intercropping of beans with sugarcane in South Africa, one of the rare ones from that country, Leclezio et al. (1985) determined that the number of tillers at 3 months, i.e. at bean harvest, was correlated with the available water content at 30cm depth, but the correlation was quite

low ($r = 0.38$). Thus the reduction in tillering which they observed with intercropping was related to competition for soil water. Whether competition for water or competition for light was the main cause of the reduction in tiller was not established.

1.2.2.4 Resource use

Theoretically, there is more transpiration in intercropped than in sole cropped fields. Hence, the consumption of water is higher too. In order to manage water - a limiting resource in many situations - with maximum efficiency, the difference in consumption use of sole and of intercropped cane should be known. In one trial under controlled conditions, Chang et al (1968) determined that the peak water requirements of soybean, sweet potato and groundnut occurred at 2, 3 and 3 months, respectively, whereas that of sugarcane does not occur until several months later. This indicates a degree of complementarity in water use between sugarcane and its intercrops. They further calculated that for the first 4 months, the water requirement of sugarcane intercropped with soybean, sweet potato or groundnut is respectively 40, 24 and 40 per cent higher than that of sole cane. In their trials, water was supplied at rates to maintain optimum soil moisture levels and to allow maximum growth rates. Nevertheless, the intercrops caused marked decreases in cane tiller number which the authors attributed to shading of the cane.

Tracer studies have yielded important information on the absorption of nutrients by sugarcane and its intercrops and on competition for nutrients. When tagged fertilizers were placed in between cane and groundnut rows, the cane controlled more of the label than the groundnut, especially as the depth of placement was increased. (Chang and Lai, 1963). The cane was slightly more successful, especially after 3 months, at 'stealing' fertilizer P placed under the groundnut row than the reverse. Sweet potato was more competitive. When placement of P was midway between the rows, the sweet potato accumulated much P. Even when the fertilizer was placed under the cane row, the sweet potato obtained some. This may be related to the ability of sweet potato to strike roots at each node. Similar studies with labelled Rb in lieu of K yielded much the same pattern of absorption (Chang et al, 1969).

The literature search has not yielded any information on the interception and use of light by intercropped cane.

1.2.2.5 Agronomy

Possibly because much of the research work on intercropping of sugar cane has been carried out at sugar cane research institutes, more emphasis has been placed on investigating agronomic aspects leading to formal recommendations to growers. The links between such empirical recommendations and the more fundamental issues of competition and resource use have seldom been made. For this reason, the

findings about optimum practices are seldom relevant outside of the areas and the situations for which they were developed. Nevertheless, a few examples of the type of information to be found in the literature will be given.

A number of investigations have focused on the comparison between cultivars of selected intercrops. For example, Narwai and Behl (1978) reported that a tall and a dwarf wheat cultivar reduced cane tiller number at 31 weeks by 75 and 55 per cent, respectively, reduced the number of millable cane by 23 and 13 per cent, respectively and reduced cane yield by 36 and 16 per cent, respectively. Similar trends were obtained by Rathi et al (1974). Fu et al (1964) tested 4 varieties of rice which differed in plant height and length of the crop cycle. They calculated by means of partial regressions that there was a decrease in yield of sugar amounting to 100kg for every one day increase in the growing period of rice. Plant height was not an important factor determining the yield of sugar.

Time of planting has been examined in a number of studies. For instance, Tang (1963) observed that when planted at the same time as cane, sweet potato reduced cane yield by 11 per cent whereas with a delay of 1 month, there was no reduction. On the other hand, a delay of 2 weeks in time of planting of maize did not improve the yield of intercropped cane (Gawhane and Patil, 1976).

Plant density and planting pattern have received much attention.. Consistent with the observations that the reductions in cane yield (table I) may be attributed to competition for growth resources, are the findings that in general, cane yield decreased as the density of the intercrops was increased (Gawhane and Patil, 1976; Patil et al, 1978). In several instances, there were large increases in the yields of the intercrops and rather small additional reductions in cane yields, such that the profitability increased (Hsiung et al, 1963; Kwong and Chen, 1973).

Many of the fertilizer trials in intercropped cane were not conclusive, often because of inadequate controls. Moreover, the results of such empirical studies conducted at one site are not necessarily applicable at another. Several investigations have focused on the possibility of reducing the adverse effect of intercrops on cane yields by giving the cane an additional dose of fertilizer N. The results have not always been consistent. In a trial over 2 years, Bhoj. and Kapoor (1970) were able to bring up the yield of cane intercropped with maize close to that of sole cane by an application of 112 kg N per hectare. On the other hand, an addition of up to 120 kg N per hectare to sugarbeet in a sugarbeet and cane intercrop did not significantly alter beet yields suggesting that nutrients may not have been limiting the productivity of beet (Chauhan et al, 1981).

Likewise, field trials on irrigation have not always been successful. In spite of 3 to 4 extra irrigations to the cane, its yield was still reduced by 13% by a maize intercrop (Bhoj and Kapoor, 1970). As there was no second control, it was not possible to know what would have happened if the cane had not been given the extra irrigation. Similarly results were obtained in another trial over 2 years in which Kar et al (1972) gave 6 extra irrigations to an onion-cane intercrop. Nevertheless, in one trial, onion reduced cane yield by 18 per cent. In a trial of cane intercropped with garlic, wheat or pea, neither the sole nor the intercropped cane responded to the irrigation treatment. The reduction in cane yield due to wheat was not offset by irrigation (Joshi et al, 1980). Similar results were obtained by Parashar et al, (1978) who found that irrigation of sugar cane intercropped with mung bean had no effect on mung bean and significantly increased cane yield in one out of 2 trials.

The responses of plant and of ratoon sugarcane to intercropping have not been compared. There is only indirect evidence from trials in different years and in which there could have been year x intercropping interactions to indicate that ratoon cane is more competitive than plant cane. For instance, Lugo-Lopez (1953) observed a 66 per cent reduction of plant cane on intercropping with maize but only a 14 per cent reduction of ratoon cane in another year.

Likewise, potato reduced the yield of intercropped plant sugarcane by 12 per cent and that of ratoon cane by 5 per cent. The yield of the potato itself was reduced by 6 per cent by the plant and by 28 per cent by the ratoon cane (Chatterjee et al, 1978). It has also been reported that sunnhemp reduced the yield of plant cane by 20 per cent but had no significant effect on ratoon cane (Anon , 1984).

The effects of intercropping on pests and diseases have not received much attention, although there are a number of passing references to them in the literature.

Sugarcane and maize have several important diseases in common. Of these, downy mildew has been mentioned as being such a problem in South East Asia that intercropping of sugarcane with maize is dependent on the use of resistant cultivars (Ledesma and Villarico, 1977) and is not recommended without them (Cheng, 1979).

Rege and Patwardhan (1953) reported that when sugarcane was intercropped with maize, the difference in borer infestation was negligible. However, they observed that besides Argyria, another species of borer, Chinazonellus which is specific to maize was also observed on cane. This observation has not been confirmed. Singha (1961) observed that when sugarcane was intercropped with coriander, it was free of pests. Batra (1962) expressed the opinion that berseem clover "hid" sugarcane from attack by borers. Ramdhawa (1975) also observed that when cane was intercropped with

onions, it was free of borers. This may be related to volatile substances emitted by the onion. On the other hand, there is one report from Bangladesh (Razzaque et al, 1978) in which pink borer (Sesamia inferens) infestation was actually measured in sole and intercropped cane. It was found that infestation was significantly increased by intercropping with wheat but not with watermelon, mustard, tomato, potato, lentil, chickpea, sesame and cabbage. This report underscores the need to exercise caution in the choice of intercrops.

With respect to weeds, Kanwar (1975) stated that there were less weeds in cane plots intercropped with rapeseed and wheat in India. Similarly, in the Philippines, Villarico and Ledesma (1976) noted a marked depression in weeds, especially Cyperus rotundus, in sugarcane intercropped with mung bean, soybean and groundnut. This is contrary to the author's personal observation in Mauritius. The nutgrass, Cyperus rotundus is one of the most noxious weeds in sugarcane fields intercropped with potato, groundnut and even maize in Mauritius. Weed control with such herbicides as 2, 4-D in post-emergence is possible in cane intercropped with maize but not with the others (MSIRI, 1984). In the Philippines, recommendations have been issued too; atrazine is recommended in pre-emergence, and 2, 4-D and MCPA in post-emergence (Ledesma and Villarico, 1977). Screening of herbicides for use in intercropped cane fields is also routinely carried out in Taiwan (Peng and Twu, 1980).

1.2.2.6 Overview of intercropping of sugar cane with maize in Mauritius.

Maize was an important crop in Mauritius until the middle of the nineteenth century when sugar cane became the main crop and maize production diminished. At the end of the nineteenth century, maize was intercropped with sugar cane and a keen observer reported on the influence of maize density:

... "si le maïs est clairsemé, il n'aura aucune influence nuisible sur les jeunes cannes."
(Bonâme, 1900?)

Bonâme (1910) drew the attention of cane growers to the advantages of intercropping sugar cane with food crops. He underlined the monetary advantages and the complementarity in labour use. In particular, he exhorted cane growers to take up maize production (Bonâme, 1911) but apparently without success, judging from the large amounts of maize that were being imported at that time (De Sornay, 1926). Among the causes of this lack of interest, mention is made of storage pests (D'Emmerez de Charmoy, 1915; Moutia, 1940) and of the devastating effects of cyclones (Bodkin and Craig, 1941). It appears however, that it was generally accepted that maize had no adverse effect on intercropped cane (Lefebure, 1937).

During the Second World War, cane planters were forced by law to put a portion of their lands under food crops including maize. Although intercropping was practised (Anon, 1942), it was probably on a limited scale. Moreover, the crop was not economically attractive and planters tended to neglect the maize in favour of sugar cane, and weeds became a serious problem (Craig, 1944). The influence of a remunerative price on production was clearly demonstrated after the end of the war; production rose sharply in response to a guaranteed and remunerative price and dropped to very low levels as sharply when subsidies were removed in 1949 (North-Coombes and d'Emmerez de Charmoy, 1960).

Agronomic trials on intercropping were initiated in 1948 to compare the effects on plant sugar cane of intercropping with several food crops including maize. Slight to severe reductions of cane yield were reported with intercropping with maize (Rochecouste, 1950). Potato did not have any adverse effects whereas the adverse effects of sweet potato were substantial. In the next years, large adverse effects of maize on ratoon cane were found in 2 out of 4 sites (De Sornay, 1952). Further trials at various sites showed that when grown as one row in alternate interrows of ratoon sugar cane, maize did not reduce cane yield (Nundloll, 1952; Rochecouste, 1953). Nevertheless, maize production in interrows was not adopted by cane growers. In fact, production decreased from about 2000 tonnes in 1955 to only 180 tonnes in 1961 (Owadally, 1972).

Prompted by the success of potato in interrows of sugar cane, the Mauritius Sugar Industry Research Institute initiated new trials in 1968. Results of 12 trials on intercropping of ratoon sugar cane with maize did not confirm the previous findings of Nundloll (1952) and Rochecouste (1953) and showed that the reductions in cane were enough to offset the gains in maize (Rouillard, 1971). For the first time, it was postulated that the local maize variety- the only type grown in the country until that time- may be too tall and late-maturing for use in sugar cane interrows. This led naturally to the importation and testing of short, early-maturing varieties. These were found not to reduce cane yields (MSIRI, 1975a) and were therefore recommended for use in ratoon sugar cane interrows. (Pillay and Mamet, 1978). However, yields of intercropped maize were rather low, probably because of a low plant density (19,000 plants/hectare). Moreover, neither total productivity nor costs of production seemed to have been taken into account in the recommendations.

The new early-maturing hybrids were also tried in interrows of plant sugar cane. It was found that, as with ratoon cane, one row of maize in alternate interrows of plant cane had no effect on cane yield. However, when grown in every interrow of plant cane, the maize reduced cane yield, and the magnitude of the reduction increased as maize density increased (MSIRI, 1977). At the density at which the effect

on cane was negligible, the maize yields were still rather low. Perhaps for this reason, sugar cane planters did not adopt the practice and there was no increase in maize production from 1975 to 1983 (Govinden and Mauree, 1985).

At the beginning of the 1970's, there was much interest in the mechanization of cane and of maize. It was feared that with industrialization, there might be a shortage of labour. Moreover, costs of labour were rising. This explains the interest in what has become known as 'differential cane spacing'. The idea is to pair the cane rows so that 2 rows can be harvested simultaneously. Trials with 2 cane varieties at 4 sites showed that there was no loss in sugar with the change from the traditional uniform 5ft (1.62m) rows to paired rows either at 6ft/4ft(1.94/1.30m) or 7ft/3ft(2.27/0.97m) (MSIRI, 1975b). With paired cane rows there is more space for intercropping, and it was postulated that it may be possible to increase the maize density without detriment to the cane. Moreover, mechanization of maize planting and harvesting may be simpler. Problems had been encountered with the development of a corn-picker for use in sugar cane interrows; but eventually, it was made to work (MSIRI, 1979). Trials were therefore started on the growing of maize in interrows of differentially-spaced cane. With 2 cane varieties, it was reported that pairing of cane rows was associated with an average reduction of 14 per cent in cane yield, significant at $P=0.2$; doubling of the number of

maize rows led to doubling of the yield of maize without increasing the adverse effects on cane. (Pillay, 1980). The increase in maize yields as a result of the doubling of the number of rows in differentially-spaced cane was confirmed in another trial. Additionally, it was observed that when the within-row spacing in the 2 maize rows was 15 cm, giving a density of 41,600 plants per hectare, there was a significant loss of cane and sugar. At a density of 25,000 plants per hectare, the maize had no significant effect on cane yield (MSIRI, 1981). Unfortunately, in this trial there was no proper control; the sole cane was planted in paired rows but not in uniformly-spaced rows. It was therefore not possible to evaluate the effects of differential spacing per se.

By 1981 when the present project was initiated, much had been accomplished but there were still a number of problems to be resolved. At the prevailing prices, growers were not convinced of the benefits to be derived from the intercropping of cane with maize. A new approach was clearly necessary.

1.2.3 Conclusions

The review of literature has revealed the following main points :-

- (i) Intercropping of sugarcane is widely practised in some countries but is completely absent in others.

(ii) Sugarcane is intercropped mainly to increase the productivity of land and the profitability of the enterprise. The increased productivity of land has not properly been assessed because of major shortcomings in the indices that have been proposed. Increased profitability assessed as net profit or net income is well established for a number of crop combinations and situations.

(iii) Competition has been studied with respect to the effects of intercrops on sugarcane. However, comparisons between the competitive abilities of different intercrops are probably invalidated by the variations in plant densities. The quantification of competition between sugarcane and its intercrops by means of competition functions has not been attempted.

(iv) Many intercrops reduce the number of cane tillers, the number of millable cane and the final cane yield, but the mechanisms of competition are not known. Shading has often been implicated. Germination and sucrose content are not affected by intercropping.

(v) The literature on fundamental aspects of resource use is scanty. The relationships between resource use under controlled environments and in the field have not been established for any of the growth factors, light, water, nutrients.

(vi) Several aspects of the agronomy of intercropping of sugarcane with other crops have been studied and recommendations have been made. Because of the variations in cropping systems and climate et.c, the recommendations are usually specific to the conditions for which they were developed.

(vii) In Mauritius itself, there is still much to be done, particularly on increasing our understanding of the fundamental aspects of intercropping of sugarcane. The total biological productivity and economic profitability of cane-maize mixtures have to be calculated.

1.3 The Research project and its objectives.

The research project consisted of 4 parts.

Part 1 : Competitive relations.

The competitive relations of plant sugar cane and maize were studied in 2 replacement series trials. The main objective was to determine, with the help of competition functions, which of the 2 species was more competitive in 2 contrasting environments.

Part 2 : Resource use.

The objective of a series of 4 trials was to study the nature of the interaction between plant sugar cane and maize in one mixture. In particular, it was proposed to assess to what extent the 2 crops competed for, or were complementary

in their use of, the major growth resources, light, water, nutrients.

Part 3 : Temporal relations .

The influence of time was studied in 2 trials. The hypothesis to be tested was that the competitive relationships of the 2 crops and the productivity of the mixture could be altered by varying the relative times of planting of the 2 component crops. Of particular interest, was the possibility of reducing adverse effects of the maize on the plant cane yields by delaying the planting of the maize.

Part 4 : Spatial relations and productivity.

In a series of 4 trials in plant sugarcane and 3 trials in ratoon sugarcane, the effects of maize density and planting pattern were studied in several contrasting environments. The objectives were :

(a) to evaluate the relative agronomic and economic merits of 5 combinations of 3 maize densities and 2 planting patterns in several contrasting environments.

(b) to attempt to relate the observed responses of sugarcane to previous findings on competitive relations in space and time.

Chapter II

MATERIALS AND METHODS

2.1 Description of sites.

The 15 field experiments reported in this thesis were conducted at 6 localities in 3 climatic zones of Mauritius (figure 1):

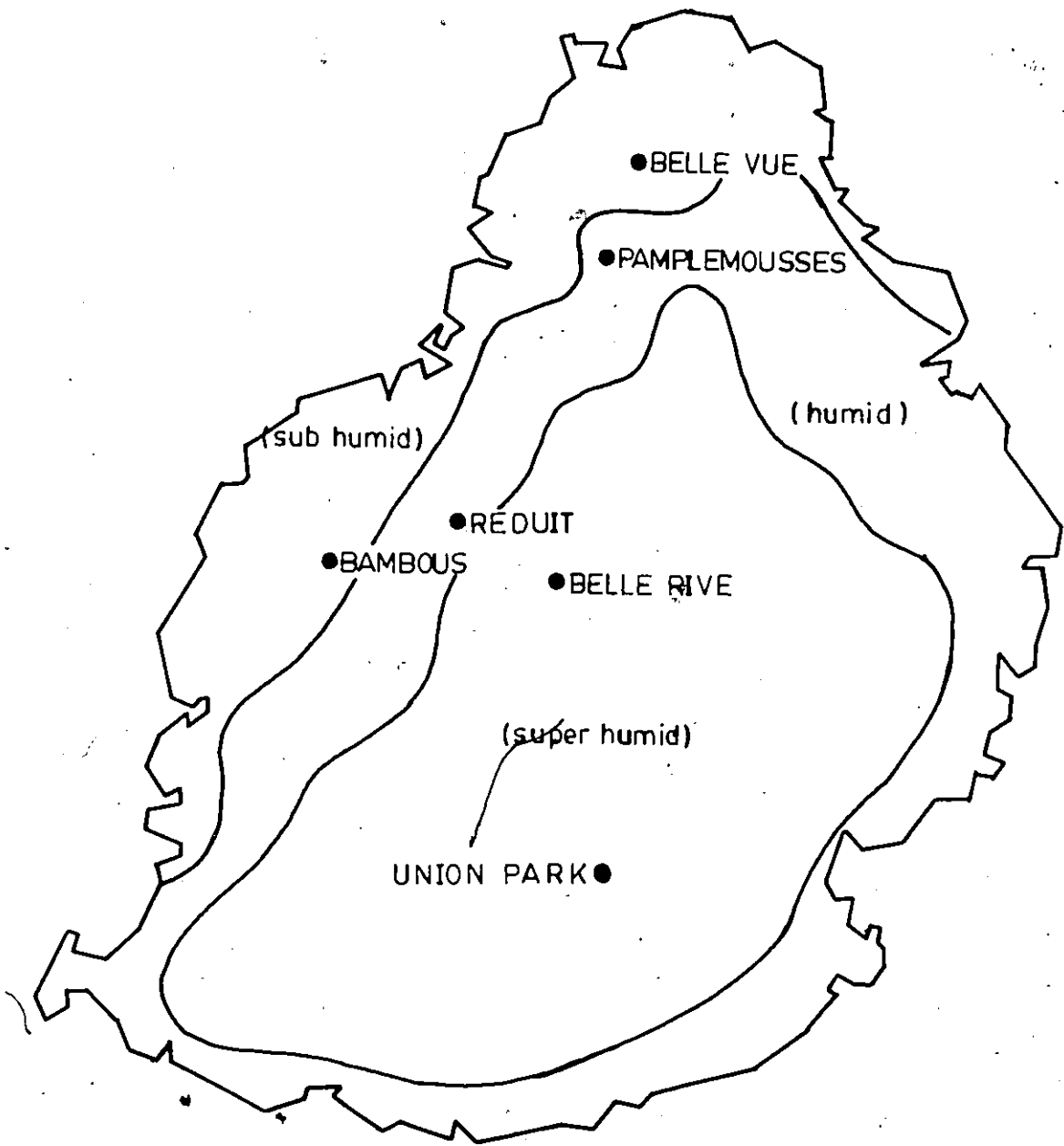
Belle Rive and Union Park: Super-humid
 Réduit and Pamplémousses : Humid (irrigated)
 Bambous and Belle Vue : Sub-humid (irrigated)

At Réduit, Belle Rive, Pamplémousses and Union Park, the trials were located on Sugar Experiment Stations belonging to the Mauritius Sugar Industry Research Institute. The trials at Bambous were on a newly-opened Experiment Station now managed by the Ministry of Agriculture. At Belle Vue, the trial was on a section of the Belle Vue Mauricia Sugar Estate.

The main characteristics of the sites are summarized in table 2. All Mauritian soils are volcanic derived. At Réduit, Pamplémousses and Bambous, the soil is a deep silty clay with a moderately fine granular structure. At Belle Vue, the soil is a moderately-shallow silty clay loam in which gravels are common and the crumbs weakly developed. The soil at Belle Rive is a deep silty clay loam. It has a

Figure 1 : Location of Study Sites

Map of Mauritius showing the location of study sites and the three main climatic zones, super-humid, humid and sub-humid.



● BELLE VUE

● PAMPLEMOUSSES

(sub humid)

(humid)

● REDUIT

● BAMBOUS

● BELLE RIVE

(super humid)

UNION PARK ●

weak coarse granular structure, and its clay type differs from that of the 4 preceding sites in being predominantly gibbsite instead of kaolinite. The soil at Union Park is a shallow silty clay loam with numerous gravels. It has a weak medium crumb structure and its clay type has not been determined.

The agricultural suitability ratings (F.A.O. and MSIRI, 1973) of the soil at the sites are given as:

Bambous, Réduit,

Belle Vue

and Pamplemousses Highly suitable for sugar cane and for
maize (with irrigation) ;

Belle Rive Moderately suitable for sugar cane and
for maize ;

Union Park Marginally suitable for sugar cane, and
not suitable for maize.

2.2 General field and laboratory techniques.

Standard agronomic and laboratory practices in force at the Mauritius Sugar Industry Research Institute were followed. The general field and laboratory techniques will be reported first. Specific techniques and departures from the general methods will later be given for each trial (section 2.3).

10 Table 2: Climate and soil characteristics of sites in Mauritius where field trials were conducted.

Site	Trial no	Elevation (m)	Climate						Soil Types*3	
			Zone	Rain-fall (mm)*	Temperature-(° C)*2				A	B
					July		January			
Redit	3,6,8,9	305	Humid	1600	Max. 22.5 Min. 15.1	Max. 28.0 Min. 21.0	Low Humic Latosols	Tropeptic Haplustox (Oxisols)		
Pamplemousses	12,15	80	Humid	1575	25.8 16.0	30.6 22.0	Low Humic Latosols	Tropeptic Haplustox (Oxisols)		
Bambous	1,4,7,10	140	Sub-Humid	1025	25.8 16.9	31.1 22.8	Low Humic Latosols	Tropeptic Haplustox (Oxisols)		
Belle Vue	5	95	Sub-Humid	1400	24.1 16.9	29.5 22.2	Latosolic Red Prairie*4	Ustic Eutropepts (Inceptisols)		
Belle Rive	2,13	480	Super Humid	3350	21.9 13.9	26.8 19.1	Humic Ferruginous Latosols	Dystropeptic Gibbsiorthox (Oxisols)		
Union Park	11,14	80	Super Humid	3525	21.6 15.7	27.1 20.7	Latosolic Brown Forest	Lithic Humitropepts (Inceptisols)		

* Thirty year (1951-1980) normal annual rainfall (Padya, 1984).

*2 Mean maximum and mean minimum temperatures for the coolest and the warmest months (Padya, 1984)

*3 A: Mauritius Great Soil Group; B: Tentative equivalent in U.S.D.A. Soil Taxonomy.

*4 Transitional between Latosolic Red Prairie and Low Humic Latosols.

2.2.1 Plant sugar cane

2.2.1.1 Plant establishment, and field plot technique

Land under fallow was cleared of old sugar cane stools by means of a shallow sub-soiler to a depth of 30-40 cm. This was followed by the passage of a disc plough to a depth of 30 cm, in two directions at right angles. The soil was levelled either with a disc harrow or a rotovator (Redit and Pamplémousses, only). Cane furrows were dug either by a tractor-drawn furrow-opener and corrected with garden hoes or entirely with garden hoes. The cane furrows were 20-30 cm wide and 20-30 cm deep, and were at a distance, centre to centre, of 1.6m, except in trials where cane spacing or density was varied.

Fertilizers were applied at the recommended commercial rates (section 2.3). The P was given as triple super phosphate, all of which was applied in the furrows at planting. The K was in the form of muriate of potash (potassium chloride) and was also given in one dose in the furrows at planting. Nitrogen was supplied as sulphate of ammonia or calcium ammonium nitrate and was given in one dose as a top-dressing on the cane rows at 4-8 weeks.

Plant cane was established from 3-bud cuttings at the rate of 31,250 cuttings per hectare. The cuttings were obtained from commercial nurseries and were treated at source with a fungicide, aretan (5 g/litre of the 6% formulation) or benlate (0.5 g/litre). The fertilizers in the

bottom of the furrows were covered with 5-10 cm of soil. The cuttings were placed diagonally in the furrows at intervals of 20 cm and were covered with 5-10 cm of soil.

The field was sprayed with a pre-emergence herbicide, atrazine (2.5 kg a.i./ha) after the cane and maize plantation. The fields were kept free of weeds by hoe-weeding. In some trials, a second application of a commercial herbicide was made before the cane canopy closed. It was applied as the amine salt of 2,4-D (2 kg a.e./ha) at 1 to 2 weeks before the maize was harvested.

Cane was recruited with pre-germinated cuttings at 6-8 weeks; gaps of 20 cm or more were filled in.

In the irrigated trials, 30-50 mm of water were given every 7-15 days depending on rainfall. About 20-30 mm of water were applied per hour by means of an over-head sprinkler system. Irrigation was stopped 2 months before cane harvest to allow the cane to ripen.

The plots were trashed once or twice during growth and at 1-2 weeks before harvest in order to facilitate harvesting.

Pests and diseases were not observed to be of much importance in the trials. Rust (Puccinia melanocephala) was prevalent on young canes in some trials but the disease disappeared with no apparent adverse effect when the cane canopy closed.

2.2.1.2 Field data collection

Plots varied in size (section 2.3), and usually consisted of a minimum of 4 rows of cane 6m long. The central 5m portions of the 2 middle rows constituted the experimental plot of 16m² from which data were recorded and plot yield obtained.

Tiller density was determined by counting all live tillers in the experimental plot.

Stalk height was measured from ground surface to the top visible dewlap (T.V.D). At the start of measurement, all the cane stalks that were likely to survive to harvest were measured and the average height of the stalks in the plot was calculated. A representative sample of 20 stalks was taken such that the average height of the sample was equal (to + or - 5 per cent) to that of the plot. These 20 stalks were tagged and their growth was followed over the cycle until cane harvest or until the cane flowered.

Number of millable canes was counted at harvest either on the standing canes or as the individual canes were being weighed.

Unit stalk weight was recorded on individual canes with a laboratory balance to + or - 25g. Bulk plot weight was measured with a field scale to + or - 500 g.

2.2.2 Ratoon sugar cane

At Belle Rive (trial no.13) and Union Park (trial no.14), the trials were in first ratoon sugar cane. The plant cane was established one year before maize planting as described in the previous section (2.2.1.1). No intercrops were, however, grown in the interrows of the plant cane. After the harvest of the plant cane, the trash was lined in the cane interrows in which maize was not to be grown. The cane was recruited with whole cane stools, gaps of 30 cm or more being closed.

At Pamplémousses (trial no.15), the trial was in second ratoon. The plant cane crop had borne a maize intercrop, but the first ratoon was not intercropped. The yield of the first ratoon was measured for each plot, and as there was no difference in cane yield of the plots, the field was deemed uniform enough for a trial in second ratoon.

In all 3 trials with ratoon cane, fertilizers were applied as a top-dressing on the cane row immediately after cane harvest and trash lining, prior to maize plantation. The complex fertilizer 17:8:25 was used at rates that varied from site to site (section 2.3)

Cultural practices and data collection were as for plant cane (section 2.2.1)

2.2.3 Determination of the yield of sugar

2.2.3.1 Sampling

Thirty canes were randomly cut from experimental plots. They were topped and separated into 3 sub-samples of 10 canes each. All canes were cut into 3 approximately equal parts, the top portion in the first sub-sample, the middle portion in the second sub-sample and the bottom portion in the third sub-sample being retained. The 3 sub-samples of 10 cane portions were then placed in a sampling bag such that 5 distal ends and 5 proximal ends in each sub-sample were at the bottom of the bag. This ensured that both extremities of each portion of cane were equally represented in the crushed bulk.

2.2.3.2 Analysis

Sucrose content of cane was determined by standard procedures as described by Saint Antoine (1968). About two-thirds of each portion of cane in the sample were chipped into pieces approximately 0.5 mm thick by means of a locally-made cane chipper (Jeffco, Forges Tardieu, Port-Louis, Mauritius). The chipped material was thoroughly mixed manually and a sample of 329g was removed. To this sample, one litre of water containing 10ml of a 5 per cent solution of sodium carbonate was added to prevent the inversion of sucrose. The mixture was disintegrated for 8 minutes in a wet disintegrator (Jeffres Model 291, Jeffres

Bros., Brisbane, Australia). The contents of the wet disintegrator were filtered over calico cloth, the filtrate was saved for sucrose content determination. The filtrate was clarified with lead acetate and filtered. The pol of the clarified juice extract was determined using an automatic pol reader (Saccharomat III, Schmidt and Haensch, Federal Republic of Germany), the reading of which gives the pol per cent cane directly.

2.2.3.3 Calculation of sugar yield

Sugar yield is the product of cane yield and the Industrial Recoverable Sucrose Content (I.R.S.C.). This parameter was obtained from the equation of Saint Antoine and Halais (1961):

$$\text{IRSC} = 0.9 \text{ Pol}\% - 1.8$$

The first coefficient, 0.9 relates the sugar content obtained by the laboratory procedure to that of industrial mills in Mauritius. The laboratory wet milling procedure was found to give values higher than those of industrial operations, and the canes from experimental plots were also generally much cleaner than canes sent to factories for processing. The correction factor, -1.8 relates sugar content to recoverable sugar content. On average, the sugar losses during factory operations in Mauritius were found to be about 1.8 pol % cane irrespective of juice purity and fibre content.

2.2.4 Maize

2.2.4.1 Plant establishment and field plot technique

Maize furrows were about 10-15 cm wide and 10-15 cm deep and were dug with a garden hoe. The complete fertilizer, 13:13:20:2 was applied at recommended rates (section 3.3) to the bottom of the furrows and were covered with about 5 cm of soil. An additional dose of nitrogen was given as a top-dressing at 4-5 weeks after sowing. In intercropped plots, the fertilization of maize was pro-rata of its density.

At planting, a granular insecticide, Carbofuran (Furadan 10G) was applied in the furrows at the rate of 1.5kg active ingredients per hectare as a preventive measure against web worms, Angustalius malacellus (Lepidoptera, Pyralidae, Crambinae) which reduce plant stands unless controlled.

Unless otherwise specified, sole maize was planted at a density of 62,500 plants per hectare achieved with an inter-row spacing of 0.8m and an intra-row spacing of 0.2 m. Two seeds of the locally-developed 3-way cross hybrid, U-R14 were sown per hill. The trials were recruited after 7-10 days and the plant stands were thinned down to one plant per hill after 20-25 days.

Although leaf diseases, especially leaf blights (Helminthosporium turcicum) and leaf rusts (Puccinia polysora and P. sorghii) were prevalent in the trials and may have reduced yields in the first season trials, no control measures were employed. Pests were of minor importance and were

reasonably well controlled. Cutworms, Agrotis ipsilon (Lepidoptera, Noctuidae) and field mice damaged germinating seeds and were controlled with poisoned baits. The trials were fenced to keep hares from damaging young maize and cane seedlings. In spite of a watchman, birds nevertheless reduced maize plant stands by uprooting the germinating seedlings, hence the need for recruiting.

2.2.4.2 Field data collection

Maize was harvested at one week after physiological maturity when the moisture content of the grain was 25-35 per cent. All plants in the experimental plot were counted, and the ears were removed, dehusked and weighed to + and - 50 g. The ears from each plot were separately stored in a crib for 7-15 days. The maize plants were cut at ground level and the weight of the fresh stover was recorded. A sample of 15-20 plants from each plot was milled. The rest was placed in the cane interrows. The milled material was mixed thoroughly and a sub-sample of 500g was dried in an oven at 95 ° C for moisture content determination.

The air-dried ears were shelled and the weights of cob and grain recorded. After mixing, samples of 500 g of grain and of cobs from each plot were used for moisture content determination at 95 ° C for 24 hours.

Dry weights of stover, cob and grain add up to the total above-ground biomass, oven dry basis. Grain yield was expressed at 12 per cent moisture content (12% m.c.), the level considered safe for storage in Mauritius.

2.3 Materials and methods specific to each trial

2.3.1 Trials 1&2: Replacement series trials to study competitive relation of plant cane and maize

The trials were conducted at Bambous (sub-humid, irrigated) and Belle Rivè (super-humid) with plant sugar cane. Non-additive mixtures of maize and plant sugar cane were used; that is, the total plant population densities of all the mixtures were equivalent to 100 per cent. But the proportions of the two crops in the mixtures were varied in order to give the crops a range of competition opportunities.

The mixtures were constituted on the basis that the optimum densities of the sole crops were equivalent. One cane 'plant' was taken to be equivalent to 2 maize plants since their optimum densities are respectively 31,250 cane cuttings per hectare and 62,500 maize plants per hectare. Alternatively, one row of cane was taken to be equivalent to 2 maize rows since sole cane is normally planted in rows 1.6m apart while sole maize is normally planted in rows 0.8m apart. In both sole cane and sole maize, the intra-row spacing was 0.2m. Thus in a 1:1 cane:maize mixture, one row of maize alternated with 2 rows of maize and in a 2:1 cane:maize mixture, two rows of cane alternated with 2 rows of maize (figure 2). In all cases the distances were 1.6m between 2 sole cane rows, 0.8m between 2 sole maize rows and 1.2m between a cane and a maize row. There were 3 mixtures

which together with the sole crops constituted a replacement series.

There were two plots of each mixture; in half of the plots maize was planted only once, a few days after cane plantation (table 3). In the other half, maize was planted three times, one crop being replanted as soon as the preceding crop was harvested. The 8 treatments in the trial were:

1. Sole Cane (100%)
2. 67% Cane + 33% Maize (1 crop)
3. 50% Cane + 50% Maize (1 crop)
4. 33% Cane + 67% Maize (1 crop)
5. Sole Maize (100%)
6. 67% Cane + 33% Maize (3 crops)
7. 50% Cane + 50% Maize (3 crops)
8. 33% Cane + 67% Maize (3 crops)

The treatments were arranged in randomized complete blocks with 4 replicates.

The crops were fertilized separately at the commercially-recommended rates (table 3). Details of plot size and of dates of planting and harvesting are also given in table 3.

Figure 2 : Replacement series mixtures of plant sugar cane and maize.

Top: sole cane in rows at 1.6 m;

Center: 2:1 cane: maize mixture showing 2 rows of cane alternating with 2 rows of maize;

Bottom: 1:2 cane: maize mixture showing one row of cane alternating with 4 rows of maize.

Photograph taken at Bamboos 9 weeks after planting of cane and of maize.



Table 3: Details of methods in replacements series trials at 2 sites.

Trial no	Trial no 1	Trial No 2
Site Climatic Zone	Bambous Sub-humid irrigated	Belle Rive Super-humid
Cane Variety Maize Variety	M 13/56 U-R14	M 574/62 U-R14
Date of planting plant cane maize(1st crop) maize(2nd crop) maize(3rd crop)	Aug 13, 1982 Aug 19, 1982 Dec 12, 1982 Apr 11, 1983	Aug 11, 1982 Aug 13, 1982 Jan 4, 1983 Apr 19, 1983
Date of harvest plant cane maize(1st crop) maize(2nd crop) maize(3rd crop)	Sept 1, 1983 Dec 16, 1982 Apr 7, 1983 Jul 25, 1983	Sept 14, 1983 Dec 24, 1982 Apr 12, 1983 Aug 15, 1983
Total Plot size (m ²) Experimental plot size (m ²) Design No. of replicates	8x6-48 3.2x5-16 RCBD 4	8x6-48 3.2x5-16 RCBD 4
Sole cane fertilization N(kg.ha ⁻¹) P ₂ O ₅ (kg.ha ⁻¹) K ₂ O(kg.ha ⁻¹) Sole maize fertilization N(kg.ha ⁻¹) P ₂ O ₅ (kg.ha ⁻¹) K ₂ O(kg.ha ⁻¹)	145 295 220 115+110 115 180	145 325 210 75+100 75 120
Irrigation	35 mm/week	N11

2.3.2 Trial 3 : Soil partitioning trial to study the relative importance of above and below-ground interactions.

In a trial with plant sugar cane under irrigation at Redit, the root systems of the maize and of the cane were separated by means of vertical plastic partitions in the soil following the technique described by Willey and Reddy (1981).

After the land had been ploughed and levelled as described in section 2.2.1.1, six plots were allocated at random to each of 4 replicates according to a randomized complete block design. There were 2 plots each of 3 cropping systems, one with and one without, soil partitions:-

- Sole Cane in rows spaced at 1.6m, without partition;
- Sole Cane in rows spaced at 1.6m, with partition;
- Sole Maize in rows spaced at 1.6m, without partition;
- Sole Maize in rows spaced at 1.6m, with partition;
- Intercropped Maize and Cane, without partition;
- Intercropped Maize and Cane, with partition;

In the plots bearing the soil partitions, trenches 30 cm wide, 60 cm deep and 9m long were dug at 0.4m from the locations of the cane and maize rows. Sheets of thick polythene plastic (thickness 0.02 mm) were laid vertically in the trenches which were filled with soil. The soil was compressed and allowed to settle for 2 months, after which the cane and maize furrows were dug for planting. In the intercropped plots, one row of maize was grown in every cane

interrow. In the sole maize at 1.6m, and in the intercropped maize, the intra-row spacing was 0.15m, so that the plant densities were identical.

Plots were 9.6m wide and 9m long. In sole cane, one metre borders were kept at the ends of each cane row, and the 5m portions of 2 middle rows out of 6 cane rows constituted the experimental plot (16 m²). In maize, the experimental plot consisted of the 60 plants in the central maize row (14.4 m²).

Sugar cane variety M 21/73 was planted on September 7, 1983 and harvested after 57 weeks on October 10, 1984. Maize variety U-R14 was sown on September 12, 1983 and harvested at 15 weeks on December 27, 1983. Maize harvest was one week before the scheduled date because a cyclone had caused all the maize to lodge on December 25, 1983.

At planting, cane was given 385 kg P₂O₅ and 210 kg K₂O, and at 6 weeks, 130 kg N per hectare. Maize was supplied with 155 kg N, 155 kg P₂O₅ and 240 kg K₂O at planting and an additional 275kg N per hectare at 4 weeks as a top dressing. In the intercropped plots, maize fertilization per plant was the same as in sole cane.

Cane canopy height was measured from ground level to the tip of the tallest leaf at 5 sampling points at intervals along each of the two experimental rows. Maize canopy height was measured from ground level to the tip of the tassel at silking. There were also 10 measurements per plot.

At maize harvest at 15 weeks, cane biomass was estimated from 2 one-metre samples (3.2 m^2), located at 1m from the end of each experimental row. The samples were milled and dried in an oven at 95°C for 24 hours. At cane harvest, the weights of cane trash, tops and stalks were recorded separately. Samples were milled and dried. Cane above-ground biomass was calculated as the sum of trash, cane tops and cane stalks.

Root density was examined by the trench profile method (Böhm, 1979). A trench 1m wide and 70cm deep was dug perpendicular to the cane rows from the centre of one row to the next. The two vertical planes across the cane rows were smoothed with a sharp knife. All roots were cut with a pair of scissors and the soil was washed to a depth of 5 mm with a jet of water under pressure. A metallic frame on which was marked a grid of squares 10cm by 10cm, was then fixed to the sides of the trench, and the number of root ends in each square grid was recorded. There were 4 observations in each of 2 replicates. The root counts were averaged for 3 soil depths, 0-20 cm, 20-50cm and 50-70cm from the soil surface, and for 2 locations across the rows, 0-40 cm (within row) and 40-80 cm (interrow) from the centre of the cane row. In the first location, 0-40cm (within row) were found the roots that were bounded by the partitions whereas in the 40-80cm (interrow), were found the roots that had crossed the partitions.

2.3.3 Trial no 4. Role of nutrients

The trial was planted at Bamboos on virgin soil. The land had been under fallow probably since the late 1940's. The land was cleared with a crawler tractor and derocked. Land preparation and planting techniques were as previously described (Section 2.2), except for rates of fertilizer which varied.

The treatments were:

Factor A: Cropping pattern

- A1: Sole cane at 1.6m
- A2: Sole maize at 1.6m
- A3: Intercropped maize and cane

Factor B: Fertilizer rate to maize and/or cane.

- B1: "Unfertilized" :No fertilizer was added
- B2: "Fertilizer" :at 100 kg N/ha.
150 kg P₂O₅/ha.
200 kg K₂O/ha
- B3: "Over-fertilized":at 300 kg N/ha
450 kg P₂O₅/ha
600 kg K₂O /ha

There were 15 treatments in all: 3A1, 3A2 and 9A3. The 9A3 treatments consisted of all combinations of 3 levels of NPK applied to maize with 3 levels of NPK applied to cane. The 15 treatments were allocated at random to 3 replicates as per a randomized complete block design.

One row of maize was planted in every interrow of sugar cane. In both the sole and the intercropped maize, the intra-row spacing was 0.2m.

Nitrogen was supplied as sulphate of ammonia, phosphorus as single super phosphate and potassium as muriate of potash. All fertilizers were applied in the furrows at planting.

The plots consisted of 4 rows 9m long. The 2 middle rows made up the experimental rows from which samples were obtained for biomass, NPK and yield determinations (figure 3). The experimental rows consisted of 2 parts, a 5m section for samples and a 2m section for harvest data. The sections were separated from one another and from the inter-block paths by 1m borders. The maize sample consisted of 2 sub-samples of 0.5m, obtained at random, one from each experimental row. Likewise, the cane samples consisted of 2 sub-samples of 0.5m, one from each row.

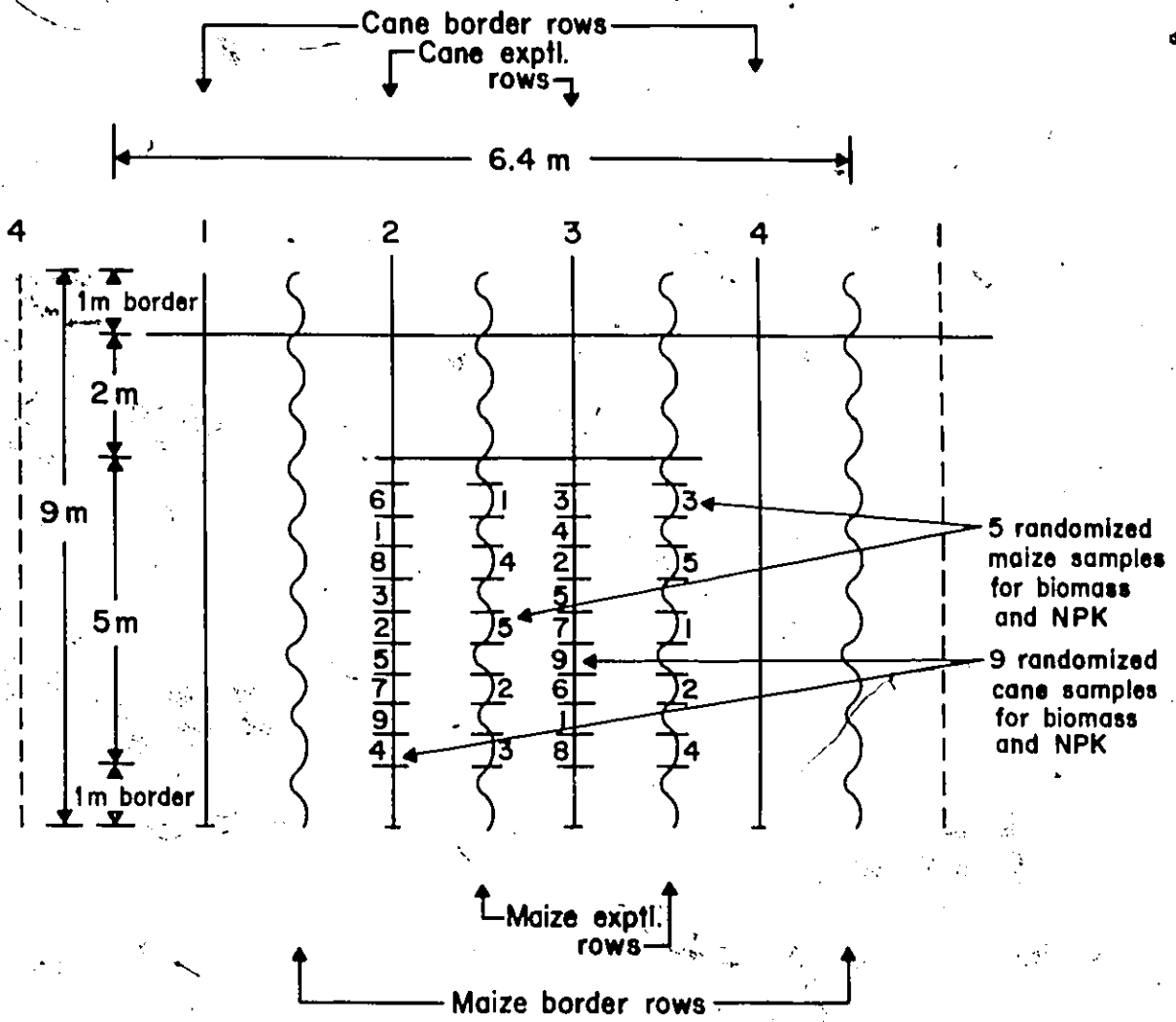
Sugar cane variety, Triton was planted on April 1, 1983 and harvested on August 23, 1984 after 71 weeks. Maize variety, U-R14 was sown on April 6, 1983 and harvested on July 22, 1983 after 16 weeks.

Maize and cane samples were cut at 3 week intervals. The plant material was dried in an oven at 70 ° C for 48 hours

Figure 3 : Diagram showing the arrangement of experimental and border rows in trial number 4.

The role of nutrients in the intercropping of plant sugar cane with maize.

Two central cane and 2 central maize rows were harvested.



and weighed to give the above-ground biomass. The dry mass was then shredded in a coarse mill, and a sample was pulverized in a fine mill. NPK were determined by standard procedures.

The trial was sprinkler irrigated regularly until the 25th week. Because of drought in the country no water was available for irrigation. In an attempt to save the crop, surface irrigation was provided irregularly as from the 34th week.

2.3.4. Trial No. 5: Role of water

A 3x3 factorial experiment was laid out at Belle Vue in the sub-humid zone to study the role of water in intercropping of plant sugar cane with maize. There were 3 levels of 2 factors:

Factor A: Water regime

A1: No irrigation

A2: Mild water stress

A3: No water stress

Factor B: Cropping pattern

B1: Sole sugar cane in 1.6m rows

B2: Sole maize in 1.6m rows.

B3: Cane intercropped with maize; with one row of maize planted in every interrow of cane in 1.6m rows.

The plots were arranged in a split-plot design with 4 replicates. Water regimes were on main plots and cropping pattern on sub-plots. Cane and maize sole crop plots consisted of 6 rows 14m long. The middle 3 rows constituted the experimental rows from which data were recorded and samples taken (figure 4).

Land preparation and cultural practices were as described in section 2.2. Cane variety, S17 was planted on March 27, 1984 and harvested on July 5, 1985 after 66 weeks. Maize variety U-R14 was sown on March 30, 1984 and harvested at 16 weeks on July 16, 1984.

After planting, the trial was sprinkler-irrigated twice at 4 day intervals in order to promote germination. Then, the water regimes were applied.

A drip-irrigation system was used to irrigate treatments A2 and A3. Dripper lines were placed at 0.8m intervals on the soil surface and distributed water equally to the cane and maize rows. In the sole crop plots, there were therefore dripper lines also in the middle of the interrows. In the intercropped plots, there was one dripper line for each crop row.

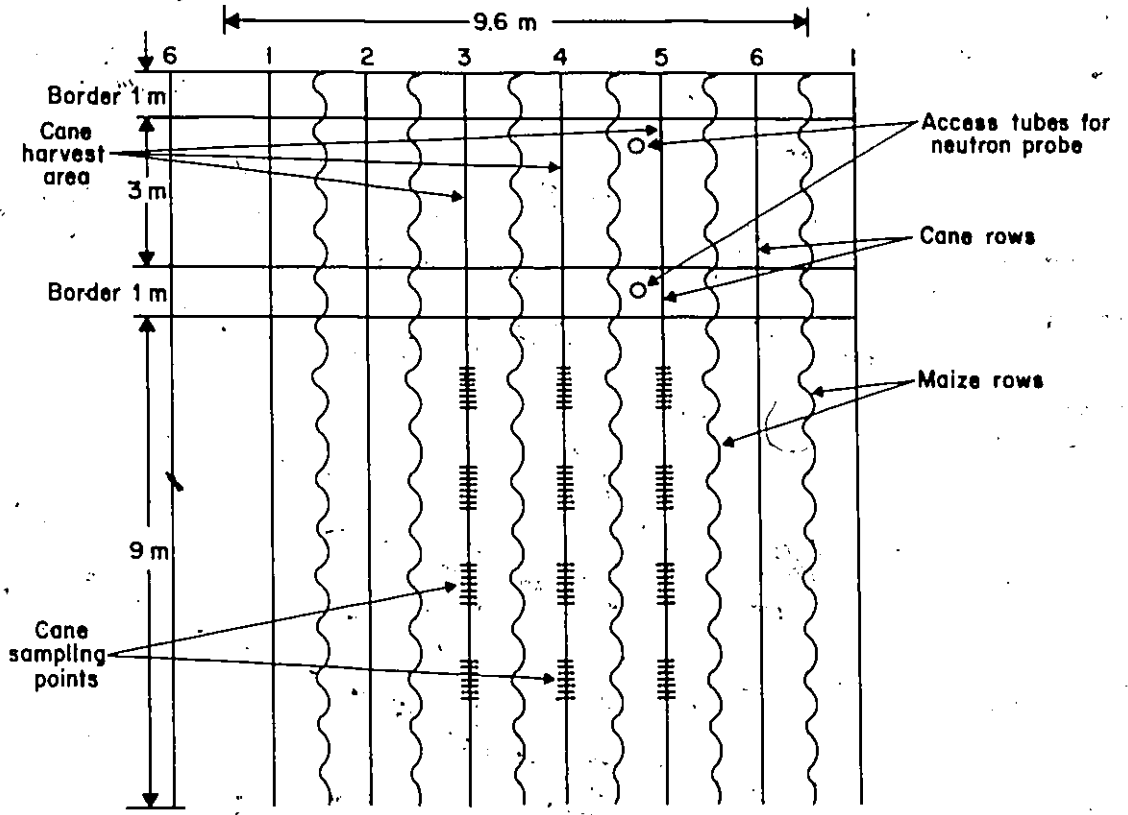
The amount of water to be applied was estimated by a method adapted from Doorenbos and Pruitt (1977). It consisted of the following steps:

- a. Calculation of a reference crop evapotranspiration E_{To} from climatic data by means of the modified Penman's

Figure 4 : Diagram showing the arrangement of experimental and border rows in trial number 5.

The role of water in the intercropping of plant sugar cane with maize. Neutron probe access tubes were placed at 0.4 m from the cane and maize rows. Cane rows number 3,4 and 5 were experimental rows; two central maize rows were harvested.





equation which relates daily evapotranspiration, ETo to temperature, net radiation, wind speed and vapour pressure of the ambient air. At Belle Vue, daily ETo values were computed automatically from climatic data obtained from meteorological instruments located on the site itself.

b. The crop evapotranspiration Etc was obtained by multiplying ETo by a crop factor, Kc that depended on the stage of development, particularly of the ground cover, of the crop. For maize, Kc varies roughly from 0.3 for the initial 3 weeks to 1.2 at mid-season. For sugar cane, Kc increases from 0.5 for the first 7 weeks to 1.2 at full canopy and decreases to 0.6 during the final ripening stage (Doorenbos, and Pruitt, 1977)

c. The amount of water to be applied per day was estimated by keeping a balance sheet. At the end of each week, the daily Etc 's for the week were added. From the total, were deducted the balance of the previous week if any, the amount of water given during the week, and the effective rainfall. Effective rainfall was estimated as the actual amount of rainfall in each shower minus 2mm in each case; this was to take into account the fact that rainfall of 2mm or less wets the leaves and does not reach the soil. The weekly balance was divided by 6 to obtain the amount of water to be applied per day in the next week, since irrigation was given daily except on Sundays.

In the "no stress" regime (A3), the amount of water applied was meant to cover all of the calculated requirements of the crops. In the 'mild-stress' regime (A2), only part of the crops requirements was given; this proportion of the crops' requirements given as irrigation varied with the crops and with time (Appendix I). Because of relatively good rainfall during the first part of the season, very little water was in fact given in A2 (table 4). For the first part of the season, the A2 regime was therefore rather similar to the A1 regime (rainfed). In order to increase the difference between the two regimes and also because of practical difficulties encountered in controlling irrigation in the field, the A2 regime was changed to A3 after maize harvest.

Cane tiller numbers were recorded from the 3m portions reserved for harvest in the 3 middle rows (figure 4.). Cane biomass was estimated at intervals during growth from samples removed from the 3 middle rows. Each sample consisted of two 1-m sub-samples (3.2 m²) taken at random from 12 sampling points. Biomass was transformed to the natural logarithm before analysis.

During growth, the development of internal water stress in the cane plant was estimated from spindle elongation, a sensitive indicator of water stress (Imam-Bamber, Personal Communications, 1984). Ten tillers having spindles of about 5 to 10 cm were chosen from the experimental row. The tillers were tagged and the

Table 4: Actual amounts of water received by sole and mixed crops on three water regimes at Belle Vue during the first 16 weeks.

Week	Amount of water (mm)						
	Rain-fall	A1: Rainfed		A2: Mild Water Stress		A3: No Water Stress	
		Irriga-tion	Total	Irriga-tion	Total	Irriga-tion	Total
1-2	37	40*	77	40	77	40	77
3-4	51	-	51	-	51	-	51
5-6	29	-	29	5	34	41	70
7-8	20	-	20	10	30	59	79
9-10	48	-	48	4	52	39	87
11-12	12	-	12	-	12	19	31
13-14	36	-	36	10	46	29	65
15-16	22	-	22	16	38	23	45
Total			295		340		505

* Applied at the rate of 20 mm at planting and 4 days later in order to promote crop germination.

height of the tip of the spindles from ground level was recorded on the morning of day one and again on day three. The average spindle elongation per day was computed as half of the difference between the 2 readings.

Depletion of water in the root zone was estimated by neutron probing. Two access tubes were installed in each plot in 3 replicates. The tubes were located at 40cm from a cane or maize row (figure 4). Neutron counts were recorded for 3 depths: 20, 35, and 50 cm. Water content was obtained from the calibration of neutron counts against soil water content. After maize harvest, root ends were counted by the method previously described (section 2.3.2).

2.3.5 Trial No. 6 : Role of light.

The trial to measure the extent to which maize shades cane was laid down at Reduit in the humid irrigated zone. Three maize densities were planted in order to vary the extent of shading. There were 4 treatments in the trial; they were arranged in a randomized complete block design and replicated 6 times. The treatments were:

1. Sole cane at 1.6m;
2. Cane intercropped with maize at a density of 15,625 plants per hectare achieved by planting one row of maize in alternate cane interrows;
3. Cane intercropped with maize at a density of 31,250 plants per hectare achieved by planting one row of maize in every cane interrow.

4. Cane intercropped with maize at a density of 62,500 plants per hectare obtained by planting two rows of maize in every cane interrow.

Cane variety, Triton was planted on April 11, 1985 and will be harvested in August 1986. Maize variety, U-R14 was planted on April 12, 1985 and harvested on August 15, 1985.

Planting techniques and cultural practices were as described in section 2.2.

Plots consisted of 7 cane rows 8 m long (89.6 m²). Each plot was sub-divided into 2 to give 2 subplots 4 m long, one for sampling and one for data recording and harvest.

Solar radiation in the crops was measured by means of 97cm long tube solarimeter (Delta-T Devices Ltd., Cambridge, England), according to the method described by Szeicz et al (1964). The tubes measure average irradiance (rate at which solar energy is received by unit area of a horizontal surface) in situations where the distribution of radiant energy is not uniform. A copper-constantan thermopile under black and white painted areas measures the temperature difference caused by the incident energy flux. The difference is recorded as an electric potential. The tubes were calibrated to give an output of 15 millivolt per kilowatt per square metre (15mv per kWm⁻²). The thermopile is enclosed in a pyrex glass tube which limits the response to visible and infra-red radiation in the waveband 350-2500 nm. Outputs from tubes within the crop were therefore always referenced

to that of a tube above the crop in order to get the proportion of radiation transmitted into the crop (per cent transmission).

In treatments 1, 3, and 4, two tubes were used per plot. They were mounted horizontally with the help of the leveling platform present at the end of each tube. One tube was placed at the bottom of the canopy on a ruler resting on the soil surface, and the second tube was mounted on top of the cane canopy on the arms of thin iron stands (figure 5). In treatment 2, there were 4 tubes per plot, two at the bottom and 2 at the top, one of each in 2 adjacent cane rows. The tubes were placed diagonally across the 20-cm wide rows and were all parallel to one another and to the tube on top of the canopy of the sole cane which served as the reference.

On day 1, the tubes were placed in the plots. The millivolt recorders were set to zero at 09h00. The next day (day 2), the cumulative readings were taken at 09h00, after 24 hours. The tubes were left in place while the maize plants were cut at ground level. The integrators were re-set to zero. Readings were taken again after 24 hours on day 3. All readings were expressed as per cent of the control. This gives the per cent transmission at each sampling point i.e. bottom or top of canopy from which were computed a mean for the 2 points for a given time and a cumulative mean over time.

Figure 5 : Placement of tube solarimeters in trial number 6.

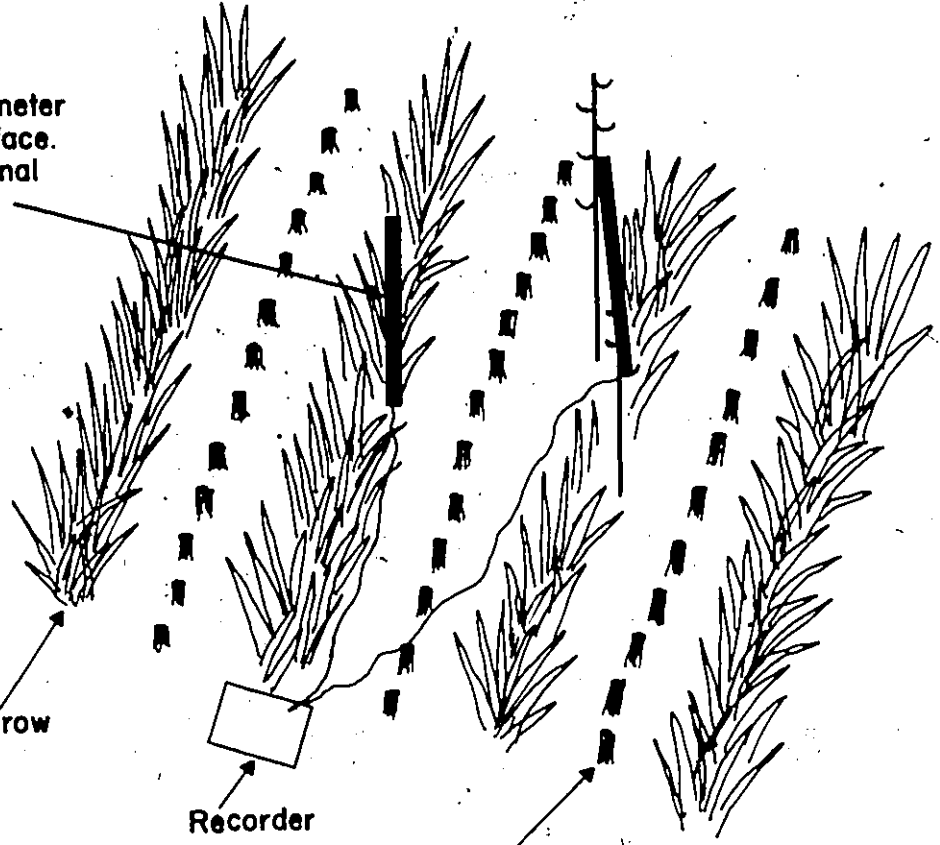
The role of light in the intercropping of plant sugar cane with maize. Maize plants have been removed. Solarimeter on the left was on the soil surface; the one on the right was supported by a stand and was located at the top of the cane canopy. Both tubes were placed diagonally across the cane rows and were parallel.

Tube solarimeter
on soil surface.
Note diagonal
placement.

Cane row

Recorder

Maize stumps



2.3.6 Trials 7 & 8 : Effect of time of planting maize.

The trial to investigate temporal effects in intercropping of plant sugar cane and maize was first laid down at Bambous in the sub-humid irrigated zone and then repeated at Redit in the humid irrigated zone.

There were 3 cropping patterns:

1. Sole cane at 1.6 m;
2. Sole maize at 1.6 m (at Bambous); or at 0.8 m (at Redit);
3. Cane intercropped with maize; one row of maize was grown in every interrow of cane.

Sugar cane variety Triton was planted at Bambous on April 26, 1983 and harvested on 24 August 1984 after 69 months. The same variety was planted at Redit on July 27, 1984 and harvested on August 17, 1985 after 55 weeks. Maize variety U-R14 was sown at different dates and these constituted the treatments. Time of planting was 8 weeks and 4 weeks before cane, at the same time as cane, 4 weeks and 8 weeks after cane.

Planting techniques and cultural practices for cane and for maize were as described earlier in section 2.2. The trials were irrigated, but at Bambous, irrigation was stopped as from the 20th week because of lack of water. Irrigation was resumed on an irregular basis as from the 34th week.

2.3.7 Trials 9,10,11, & 12: Effect of Maize density and planting pattern on plant sugar cane.

There were 4 trials, two in the first season (March plantation) at Reduit and Bambous, and two in the second season (August plantation) at Union Park and Pamplemousses. The treatments were:

1. Sole Cane in rows 1.6m apart;
2. Cane as in 1; one row of maize in alternate interrows of cane giving a maize density of 20,800 plants per hectare (33% of density of sole maize)
3. Cane as in 1; one row of maize in every cane interrow giving a Maize density of 41,600 plants per hectare (67% of density of sole maize);
4. Sole cane in rows alternately 2.25 and 0.95 m apart;
5. Cane as in 4; one row of maize in the wide interrows of cane, giving a maize density of 20,800 plants per hectare. (33% of density of sole maize, as in 2)
6. Cane as in 4; two rows of maize in the wide interrows of cane giving a maize density of 41,600 plants per hectare. (67% of density of sole maize, as in 3)
7. Cane as in 4; three rows of maize in the wide interrows of cane giving a maize density of 62,500 plants per hectare (density equal to that of sole maize).
8. Sole maize planted at a distance of 0.2m within rows spaced at 0.8m to give a plant density of 62,500 plants per hectare.

Cane and maize planting techniques and cultural practices were as described previously in section 2.2. Details of practices are summarized in table 5.

2.3.8 Trials 13,14,15 :Effect of maize density and planting pattern on ratoon sugar cane

The three trials were in the second season (August plantation) and were planted at Belle Rive and Union Park in first ratoon sugar cane and at Pamplémousses in second ratoon sugar cane. The treatments were identical to those in trials 9-12 (section 2.3.7), viz

1. Sole Cane at 1.6m;
2. Cane as in 1 + Maize at density of 20,800 plants per hectare (33%);
3. Cane as in 1 + Maize at density of 41,600 plants per hectare(67%);
4. Sole Cane at 2.25/0.95 m.
5. Cane as in 4 + Maize at density of 20,800 plants per hectare(33%);
6. Cane as in 4 + Maize at density of 41,600 plants per hectare(67%)
7. Cane as in 4 + Maize at density of 62,500 plants per hectare(100%)
8. Sole Maize in 0.8m rows at density of 62,500 plants per hectare.

Cane and maize planting techniques and cultural operations were as described in section 2.2. Further details of methods are given in Table 6.

Table 5: Details of practices followed in 4 trials on the effect of planting pattern on plant sugar cane.

Trial No.	Trial No.9	Trial No.10	Trial No.11	Trial No.12
Site Climatic zone	Reduit Humid irrigated	Bambous Sub-humid irrigated	Union Park Super-humid	Pamplemousses Humid irrigated
Cane variety Maize variety	M 13/56 U-R14	M 13/56 U-R14	M 574/62 U-R14	M 13/56 U-R14
Date of planting: Cane Maize Date of harvest: Cane Maize	Mar 27,1981 Mar 27,1981 July 16,1982 July 13,1981	Mar 22,1982 Mar 25,1982 July 18,1983 July 8, 1982	Aug 26,1981 Aug 27,1981 ^a Dec 12,1982 Dec 29,1981	Aug. 20,1981 Aug. 21,1981 Nov 24,1982 Dec 12,1981
Total plot size (m ²) Experimental plot size (m ²)	7x8-56 3.2x7-22.4	16x6-96 3.2x5-16	9.6x6-57.6 3.2x5-16	9.6x6-57.6 3.2x5-16
Design No. of replicates	RCBD 4	RCBD 3	RCBD 4	RCBD 4
Cane fertilization N(kg.ha ⁻¹) P ₂ O ₅ (kg.ha ⁻¹) K ₂ O(kg.ha ⁻¹) Sole Maize fertilization. N(kg.ha ⁻¹) P ₂ O ₅ (kg.ha ⁻¹) K ₂ O(kg.ha ⁻¹)	145 220 210 115+85 115 180	145 335 220 115+85 115 180	145 225 180 115+85 115 180	145 335 220 100+180 100 160
Irrigation	25 mm/week	35 mm/week	Nil	45 mm/week

Table 6: Details of trials on the effect of maize density and planting pattern on ratoon sugar cane at 3 sites.

Trial No.	Trial No.13	Trial No.14	Trial No.15
Site Climatic Zone	Belle Rive Super humid	Union Park Super-humid	Pamplémousses Humid Irrigated
Cane variety Maize variety	M 574/62 U-R14	M574/62 U-R14	M 13/56 U-R14
Date of harvest: previous cane: Date of planting: maize. Date of harvest: experimental cane Date of harvest: maize.	Aug 4, 1983 Aug 8, 1983 Aug 22, 1984 Dec 29, 1983	Aug 19, 1983 Sept 2, 1983 Aug 28, 1984 Dec 30, 1983	Aug. 24, 1983 Sept. 6, 1983 Aug 21, 1984 Dec 27, 1983
Total plot size (m ²) Experimental plot size (m ²) Design No. of replicates	57.6 19.2 RCBD 4	57.6 19.2 RCBD 4	57.6 16 RCBD 4
Cane fertilization N(kg.ha ⁻¹) P ₂ O ₅ (kg.ha ⁻¹) K ₂ O(kg.ha ⁻¹) Sole maize fertilization: N(kg.ha ⁻¹) P ₂ O ₅ (kg.ha ⁻¹) K ₂ O(kg.ha ⁻¹)	120 55 175 100+180 100 160	85 40 125 90+125 90 140	120 55 175 100+150 100 160
Irrigation	Nil	Nil	45 mm/week

Chapter III

RESULTS

3.1 Competitive relations

3.1.1 Maize responses

In the two replacement series trials, (trials no 1 & 2) the first maize crop gave higher yields than expected on the basis of sown proportions. Above-ground biomass and grain yield per plant were higher in the mixtures than in the sole crops, the differences being significant at the 5 per cent level at Bambous (table 7) and at the 10 per cent level at Belle Rive (table 8). Between the mixtures themselves, there were no significant differences in yield per plant. At both sites, the harvest index of the intercropped maize was not significantly different from that of the sole maize.

In contrast to the observations on the first maize crop, the yields of the second maize crop were, with one exception, lower than expected on the basis of sown proportions. (tables 9 and 10). The exception was the 2:1 maize:cane mixture at Belle Rive whose actual yield was equal to the expected yield (table 10).

In both trials, the third maize crop was deemed a failure in the mixtures because yields were exceptionally low (tables 9 and 10).

Table 7: Response of the first maize crop to intercropping with plant sugar cane in a replacement series trial at Bamboos.

Treatment	Above-ground biomass		Grain yield at 12% m.c.		Harvest index %
	t.ha ⁻¹	g.plant ⁻¹	t.ha ⁻¹	g.plant ⁻¹	
Sole maize	12.20 (100)	205(100)	6.64(100)	111(100)	47.9
2/3 Maize +1/3cane	8.84(73)	223(109)	5.05(76)	126(113)	50.2
1/2 Maize +1/2cane	7.76(64)	260(127)	4.24(64)	142(127)	48.8
1/3 Maize +2/3cane	5.10(42)	245(120)	2.71(41)	131(117)	46.8
C.V.(%)	10.2	11.5	9.5	9.6	10.9
S.E.	0.40	13.6	0.21	6.2	2.6
L.S.D. (P=0.05)	1.19	40	0.61	18	7.8

Figures in brackets are responses as per cent of sole maize

Table 8: Response of the first maize crop to intercropping with plant sugar cane in a replacement series trial at Belle Rive.

Treatment	Above-ground biomass		Grain yield at 12% m.c.		Harvest index
	t.ha ⁻¹	g.plant ⁻¹	t.ha ⁻¹	g.plant ⁻¹	%
Sole maize	5.96(100)	136(100)	2.41(100)	54.5(100)	35.6
2/3 Maize + 1/3cane	4.56(77)	147(108)	2.00(83)	64.3(118)	38.7
1/2 Maize + 1/2cane	3.55(60)	153(113)	1.42(59)	61.5(113)	35.3
1/3 Maize + 2/3cane	2.33(39)	153(113)	0.91(38)	59.9(110)	34.8
C.V.(%)	9.6	9.2	13.6	12.5	10.9
S.E.	0.19	6.8	0.11	3.9	2.0
L.S.D. (P=0.05)	0.54	20	0.32	11.2	5.8

Figures in brackets are responses as per cent of sole maize

Table 9: Yield of 3 successive maize intercrops in a replacement series trial with plant sugar cane at Bamboos.

Treatment	Grain yield at 12% m.c. (t.ha ⁻¹)			
	1st Crop	2nd Crop	3rd Crop	Total
Sole maize	6.64(100)	6.71(100)	6.79(100)	20.14(100)
2/3 Maize + 1/3cane	5.05(76)	3.36(50)	1.49(22)	9.89(49)
1/2 Maize + 1/2cane	4.24(64)	0.88(13)	0.49(7)	5.61(28)
1/3 Maize + 2/3cane	2.71(41)	1.06(16)	0.10(2)	3.87(19)
C.V.(%)	9.5	23.5	26.9	12.0
S.E.	0.21	0.35	0.30	0.59
L.S.D. (P=0.05)	0.61	1.13	0.96	1.90

Figures in brackets are responses as per cent of each sole maize crop yield.

Table 10: Yield of 3 successive maize intercrops in a replacement series with plant sugar cane at Belle Rive.

Treatment	Grain Yield at 12% m.c. (t.ha ⁻¹)			
	1st Crop	2nd Crop	3rd Crop	Total
Sole maize	2.41(100)	4.32(100)	5.08(100)	11.81(100)
2/3 maize + 1/3cane	2.00(83)	2.84(66)	1.45(29)	6.28(53)
1/2 maize + 1/2cane	1.42(59)	1.85(43)	0.85(17)	4.13(35)
1/3 maize + 2/3cane	0.91(38)	1.11(26)	0.54(11)	2.56(22)
C.V.(%)	13.6	11.3	21.0	9.4
S.E.	0.11	0.14	0.21	0.29
L.S.D. (P=0.05)	0.32	0.46	0.66	0.94

Figures in brackets are responses as per cent of each sole maize crop yield.

Intercropping with cane had, therefore, different effects on the three successive maize crops; relative maize yields declined with each successive cropping pattern.

The overall response of maize over the entire plant cane crop cycle was given by the sum of the yields of the 3 maize crops. In both trials, the intercropped maize under-yielded in all 3 mixtures. For instance, at Bambous where under-yielding was more pronounced, the overall maize yields in the 1:1 and 1:2 maize:cane mixtures were respectively 56 and 58 per cent of the yields expected on the basis of sown proportions (table 9).

Thus, the maize was found to over-yield or under-yield, depending on the number of maize crops under consideration. When only the first maize crop was considered, it over-yielded; when the response of the 3 maize crops was considered, maize under-yielded.

3.1.2 Cane responses

During cane growth, the cane response was assessed from tiller density. The effect of the first maize crop on number of tillers per metre changed with time. Three phases were recognized at Belle Rive and two at Bambous where counting started too late to observe the first. In the first phase which lasted to the 16th week at Belle Rive, there were significantly ($P=0.05$) less tillers per square metre in the intercropped cane than in the sole cane (figure 6), but there were no differences in number of tillers per

metre, indicating an effect of cane density but not of intercropping. In the second phase which lasted to the 27th week at Belle Rive and to the 23rd week at Bambous (figure 7), the intercropped cane had fewer tillers per square metre as well as per metre, indicating effects of cane density as well as of intercropping. At Belle Rive, the proportion of maize in the mixture had little effect on the number of tillers per metre but at Bambous, number of tillers per metre decreased as maize density was increased. In the third and final phase, compared to the sole cane, the intercropped cane had more tillers per metre but fewer tillers per square metre, indicating that the increase associated with intercropping was not adequate to compensate for the reduction in cane density.

In the two trials, there was little difference in the effects on number of tillers per metre of intercropping with one compared to three maize crops, indicating that the second and third maize crops had little effect on tillering.

The existence of the above-mentioned 3 phases indicate that, on the basis of number of tillers per metre, the competitive ability of cane changed with time. At first, the cane was as competitive as the maize; then, it was less competitive than the maize; and finally, it became more competitive than the maize.

At harvest, the competitive ability of cane was assessed from sugar yield and its components. At both sites, the

Figure 6 : Tillering of sole and intercropped plant sugar cane in a replacement series trial at Belle Rive.

Top: tillers per square metre (1 maize crop)

Centre: tillers per metre (1 maize crop)

Bottom: tillers per metre (3 sequential maize crops)

○: sole cane

×: 2/3 cane + 1/3 maize

◻: 1/2 cane + 1/2 maize

△: 1/3 cane + 2/3 maize

Vertical bars are LSD (P=0.05)

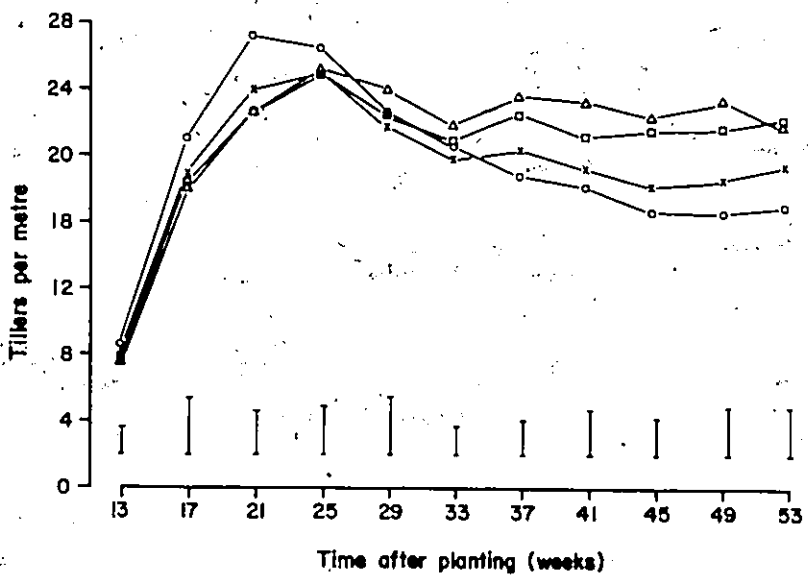
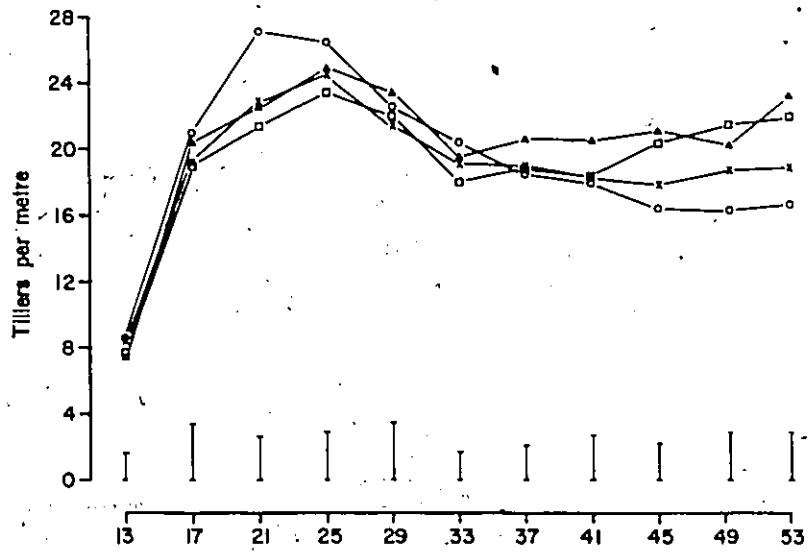
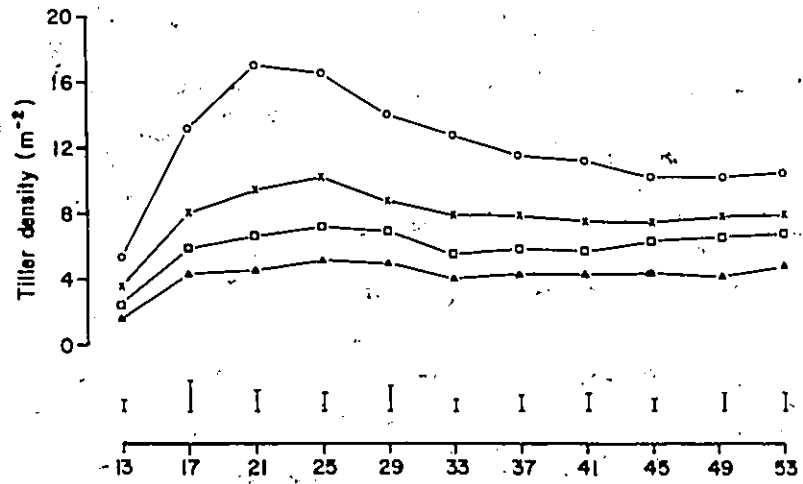


Figure 7 : Tillering of sole and intercropped plant sugar cane in a replacement series trial at Bambous.

Top : tillers per square metre (1 maize crop)

Center : tillers per metre (1 maize crop)

Bottom : tillers per metre (3 sequential maize crops)

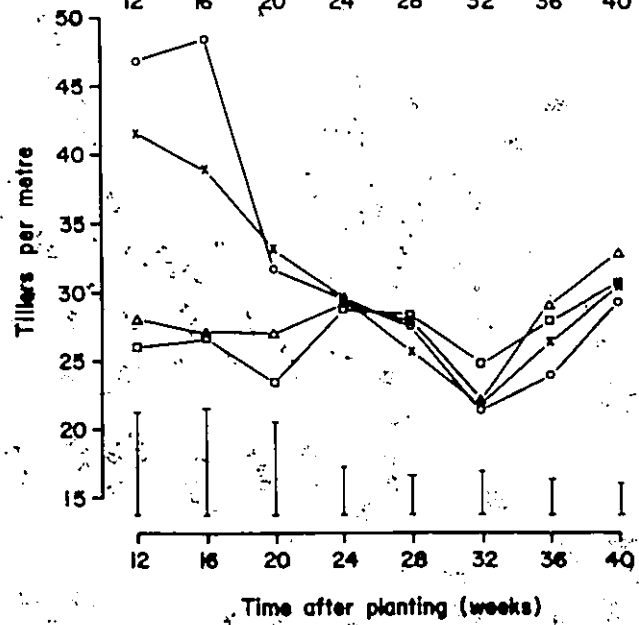
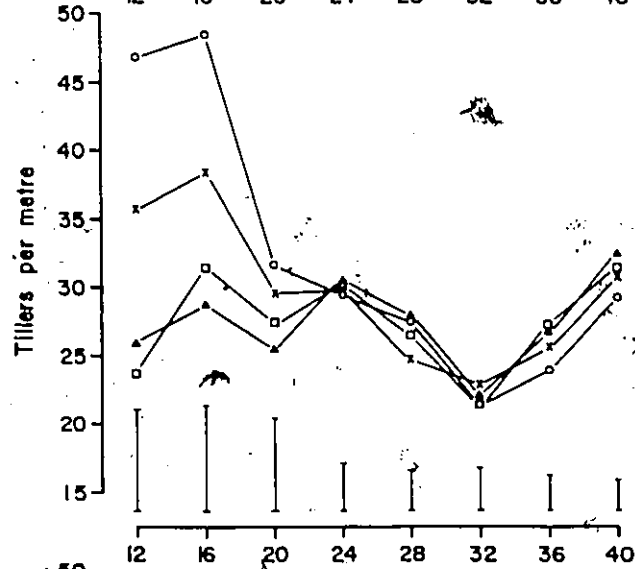
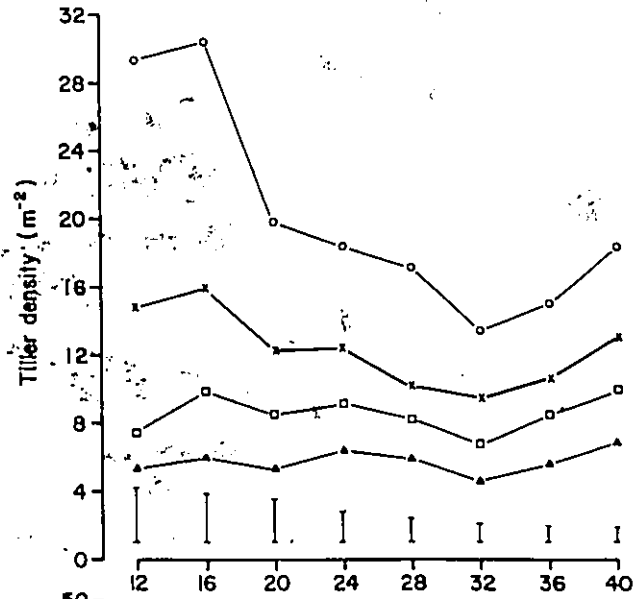
○ : sole cane

× : 2/3 cane + 1/3 maize

□ : 1/2 cane + 1/2 maize

△ : 1/3 cane + 2/3 maize

Vertical bars are LSD (P=0.05).



response to treatment of the three yield functions, cane above-ground biomass, cane stalk yield and sugar yield, were quite similar. In general, cane yield decreased slightly as the number of intercropped maize crops increased. (tables 11 and 12). At Bambous, cane over-yielded in most mixtures, particularly those with only one maize crop, regardless of whether yield per metre was measured as above-ground biomass, stalk-yield or sugar yield. The general trend was for yield per metre to increase as the proportion of cane in the mixture decreased (table 11). At Belle Rive, on the other hand, cane over-yielded in the 1:1 and 1:2 cane:maize mixtures only (table 12).

At both sites, there was little difference in the sucrose content and in the unit stalk weight of cane in the various mixtures (tables 13 and 14), showing that the response of these two yield components could not account for the differences in sugar yields. On the other hand, there were significant differences ($P=0.05$) in the number of millable canes. The response of millable cane paralleled that of yield. At Bambous, for instance, with one maize crop, the number of millable canes per metre increased as the proportion of cane in the mixture decreased. (table 11).

Thus, on the basis of sugar yield the cane was more competitive than the maize in the 6 mixtures at Bambous where the competitive ability of cane increased as the proportion of cane in the mixture decreased. At Belle Rive, on the

Table 11: Yield and yield components per metre of intercropped plant sugar cane in a replacement series trial at Bambous.

Treatment	Cane biomass	Millable cane	Cane stalk yield	Sugar yield
	(kg m ⁻¹)	(m ⁻¹)	(kg m ⁻¹)	(kg m ⁻¹)
Sole cane	7.66(100)	18.70(100)	22.7(100)	2.10(100)
2/3 cane+1/3 maize(1 crop)	7.89(103)	17.80(95)	23.9(105)	2.45(117)
2/3 cane+1/3 maize(3 crops)	8.10(106)	18.78(100)	24.8(109)	2.45(117)
1/2 cane+1/2 maize(1 crop)	10.03(131)	20.55(110)	30.6(135)	2.92(139)
1/2 cane+1/2 maize(3 crops)	8.82(115)	18.35(98)	26.6(117)	2.69(128)
1/3 cane+2/3 maize(1 crop)	10.45(136)	23.90(128)	32.5(143)	3.31(159)
1/3 cane+2/3 maize(3 crops)	8.77(115)	22.30(119)	25.9(114)	2.78(133)
C.V.(%)	13.9	9.5	15.4	13.9
S.E.	0.61	0.95	2.1	0.19
LSD (P=0.05)	1.82	2.83	6.1	0.55

Figures in brackets are responses expressed as per cent of sole cane.

Table-12: Yield and yield components per metre of intercropped plant sugar cane in a replacement series trial at Belle Rive.

Treatment	Cane biomass	Millable cane	Cane Stalk yield	Sugar yield
	(kg m ⁻¹)	(m ⁻¹)	(kg m ⁻¹)	(kg m ⁻²)
Sole cane	4.56(100)	10.90(100)	11.8(100)	1.29(100)
2/3 cane+1/3 maize(1 crop)	4.19(92)	11.42(105)	11.3(96)	1.17(91)
2/3 cane+1/3 maize(3 crops)	4.11(90)	11.35(104)	11.0(93)	1.13(88)
1/2 cane+1/2 maize(1 crop)	5.55(122)	13.10(120)	14.9(126)	1.55(120)
1/2 cane+1/2 maize(3 crops)	4.44(97)	12.30(113)	11.8(100)	1.20(93)
1/3 cane+2/3 maize(1 crop)	5.27(116)	12.95(119)	14.3(121)	1.46(113)
1/3 cane+2/3 maize(3 crops)	5.13(113)	12.35(113)	13.4(114)	1.36(105)
C.V.(%)	17.0	9.4	19.1	18.7
S.E.	0.40	0.57	1.2	0.12
LSD (P=0.05)	1.20	1.68	3.6	0.36

Figures in brackets are responses expressed as per cent of sole cane.

other hand, the cane was more competitive than the maize in only two of the 6 mixtures.

At both sites, the increases in sugar yield per metre were not enough to compensate for the reduction in cane density (tables 13 and 14). Hence, sugar yields per hectare of even the 2:1 cane:maize mixtures, were much less than that of the sole cane.

3.1.3 Joint responses

The joint responses of the two crops have been examined, first through bivariate analysis of variance and then, through the use of several indices.

Bivariate analysis of variance revealed that the residual correlations between sugar and maize yields of the mixtures were -0.42 at Bambous and -0.09 at Belle Rive, indicating that the background relationship between the yields of sugar and of maize was negligible at Belle Rive but not at Bambous. After the treatment comparisons had been adjusted for the background relationships, it was observed that at the two sites treatment effects were more predominant on maize yields (figure 8).

Indices of competition and of yield advantage have been calculated for three hypothetical situations defined as:

1. Only one maize crop is grown in association with cane, and only one maize crop can be grown as a sole crop over the entire plant cane crop cycle.

Table 13: Yield per hectare and yield components of intercropped plant sugar in a replacement series trial at Bambous.

Treatment	Unit Stalk Weight	Sucrose Content	Sugar Yield
	(kg)	(Pol% Cane)	(t.ha ⁻¹)
Sole Cane	1.33(100)	12.25(100)	13.15(100)
2/3 Cane+1/3 Maize(1 c)	1.56(118)	13.43(110)	10.2(78)
2/3 Cane+1/3 Maize(3 c)	1.51(113)	13.03(106)	10.2(78)
1/2 Cane+1/2 Maize(1 c)	1.60(120)	12.70(104)	9.53(72)
1/2 Cane+1/2 Maize(3 c)	1.54(116)	13.23(108)	8.40(64)
1/3 Cane+2/3 Maize(1 c)	1.50(113)	13.28(108)	6.93(53)
1/3 Cane+2/3 Maize(3 c)	1.46(110)	13.95(114)	5.80(44)
C.V.(%)	9.7	4.0	11.8
S.E.	0.07	0.26	0.54
LSD (P=0.05)	0.21	0.78	1.62

Figures in brackets are responses expressed as per cent of sole cane.

(1 c) and (3 c) are the short form of 1 crop and 3 crops respectively.

Table 14: Yield per hectare and yield components of intercropped plant sugar in a replacement series trial at Belle Rive.

Treatment	Unit stalk weight	Sucrose content	Sugar yield
	(kg)	(Pol% cane)	(t.ha ⁻¹)
Sole cane	0.93(100)	14.15(100)	8.05(100)
2/3 Cane+1/3 maize(1 c)	0.84(91)	13.48(95)	4.89(61)
2/3 Cane+1/3 maize(3 c)	0.89(96)	13.48(95)	4.72(59)
1/2 Cane+1/2 maize(1 c)	0.95(103)	13.50(95)	4.83(60)
1/2 Cane+1/2 maize(3 c)	0.88(95)	13.33(94)	3.75(47)
1/3 Cane+2/3 maize(1 c)	0.91(98)	13.33(94)	3.03(38)
1/3 Cane+2/3 maize(3 c)	0.99(107)	13.33(94)	2.82(35)
C.V.(%)	12.0	3.4	18.8
S.E.	0.06	0.23	0.43
LSD (P=0.05)	0.18	0.68	1.28

Figures in brackets are responses expressed as per cent of sole cane.

(1 c) and (3 c) are the short form of 1 crop and 3 crops respectively.

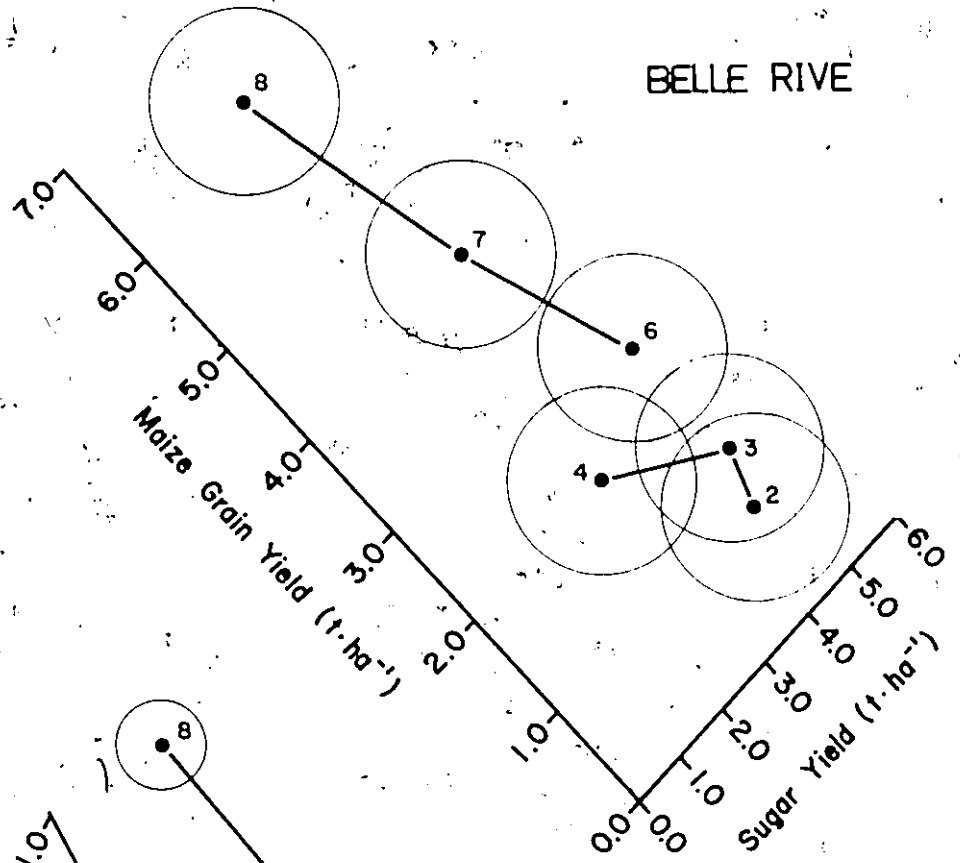
Figure 8 : Joint sugar and maize grain yields of mixtures of plant sugar cane and maize in replacement series trials at 2 sites.

The sites were: Belle Rive (top) and Bambous (bottom). Adjustment for correlations between the yields of the 2 crops was by means of skewed axes. Circles represent confidence zones at $P=0.05$.

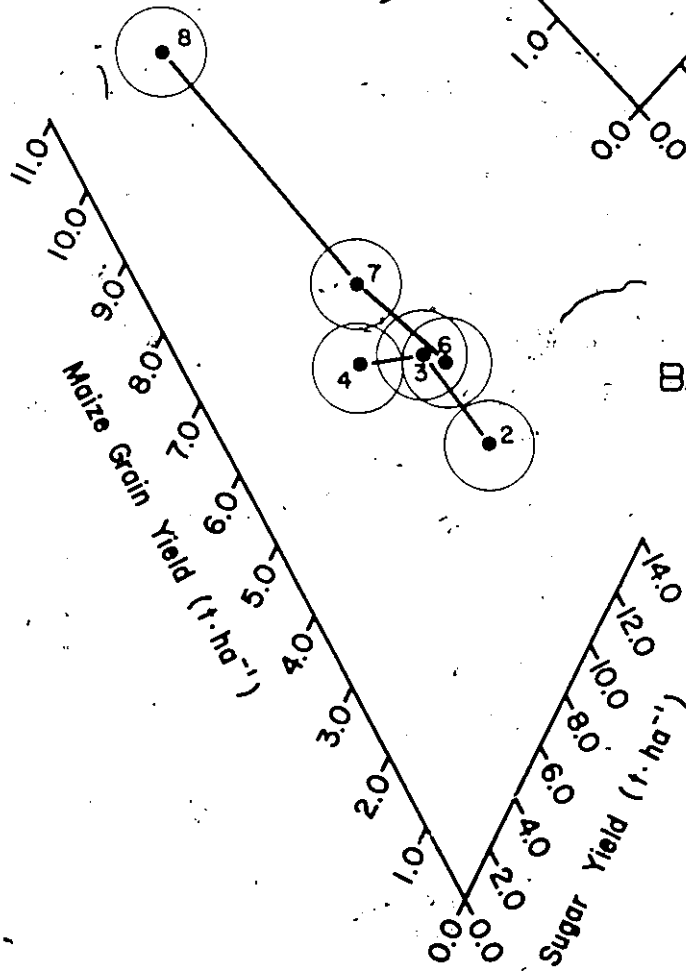
Treatments were:

- 2 : $2/3$ cane + $1/3$ maize (1 crop)
- 3 : $1/2$ cane + $1/2$ maize (1 crop)
- 4 : $1/3$ cane + $2/3$ maize (1 crop)
- 6 : $2/3$ cane + $1/3$ maize (3 crops)
- 7 : $1/2$ cane + $1/2$ maize (3 crops)
- 8 : $1/3$ cane + $1/3$ maize (3 crops)

BELLE RIVE



BAMBOUS



2. Only one maize crop is grown in association with cane but 3 maize crops can be grown sequentially as sole crops over the plant cane crop cycle.
3. Three maize crops are grown sequentially in association with cane and 3 maize crops can also be grown as sole crops over the plant cane crop cycle.

Two indices were used to determine which of the two component crops was more competitive: the Aggressivity (A) and the Competitive Ratio (C.R). Both indices show clearly (table 15) that under situations 2 and 3, cane was always the dominant crop but that under situation 1, this was not always the case. Both indices were successful in indicating that under situation 1, cane was not dominant in the 2:1 cane:maize mixture at Bambous, and that cane was not repressed in the 1:1 cane:maize mixture at Belle Rive. Thus, the indices were consistent with one another.

Three indices of combined yields were calculated: Relative Crowding Coefficient (RCC), Area-Time Equivalency Ratio (ATER) and Land Equivalent Ratio (LER). All three indices show clearly (table 16), that under situations 2 and 3, there was no yield advantage at Belle Rive with the 2:1 cane:maize mixture, and that at Bambous, the 1:1 cane:maize mixture gave the highest yield advantage. ATER values were not calculated for situation 1 because with ATER, in effect, it is assumed that several sole maize crops would be grown over the cane crop cycle whereas one of the conditions of situation 1 is that only one sole maize crop can be grown.

The various analyses and indices of combined yields underlined one important result, namely that the competitive abilities of the crops and yield advantages of the mixtures depended on the situation under consideration. As shown in the LER diagrams yield advantages occurred under situation 1 but not situation 3, (figures 9 & 10).

3.2. Resource use

3.2.1 Relative importance of above and below-ground interactions as determined by soil partitioning.

3.2.1.1 Maize responses

At the time of maize harvest, the soil partitions were observed to have been totally effective in keeping the root systems of the two crops separate. No roots had passed through the partitions but a few maize roots had reached the partitions and had grown parallel to them.

The treatments had no effect on either the final canopy height or the harvest index of maize (table 17). However, the partitions reduced above-ground biomass and grain yield by approximately 11 per cent in each case. The effects of intercropping and also of the interaction between partitioning and intercropping were not significant on any of the response variables.

Table 15: Relative competitive ability of maize and plant sugar cane in replacement series mixtures at 2 sites and under 3 hypothetical situations.

Treatment	Aggressivity		Competitive Ratio	
	Cane	Maize	Cane	Maize
<u>Situation 1.</u>				
Bambous				
2/3 Cane+1/3 maize	-0.06	0.06	0.95	1.05
1/2 Cane+1/2 maize	0.17	-0.17	1.14	0.88
1/3 Cane+2/3 maize	0.44	-0.44	1.39	0.72
Belle Rive				
2/3 Cane+1/3 maize	-0.22	0.22	0.80	1.25
1/2 Cane+1/2 maize	0.02	-0.02	1.02	0.98
1/3 Cane+2/3 maize	-0.11	0.11	0.91	1.10
<u>Situation 2.</u>				
Bambous				
2/3 Cane+1/3 maize	0.76	-0.76	2.89	0.35
1/2 Cane+1/2 maize	1.03	-1.03	3.44	0.29
1/3 Cane+2/3 maize	1.20	-1.20	4.20	0.24
Belle Rive				
2/3 Cane+1/3 maize	0.68	-0.68	3.93	0.25
1/2 Cane+1/2 maize	0.96	-0.96	4.98	0.20
1/3 Cane+2/3 maize	0.88	-0.88	4.45	0.22
<u>Situation 3.</u>				
Bambous				
2/3 Cane+1/3 maize	0.59	-0.59	2.02	0.50
1/2 Cane+1/2 maize	0.72	-0.72	2.29	0.44
1/3 Cane+2/3 maize	0.59	-0.59	1.80	0.56
Belle Rive				
2/3 Cane+1/3 maize	0.23	-0.23	1.35	0.74
1/2 Cane+1/2 maize	0.23	-0.23	1.33	0.75
1/3 Cane+2/3 maize	0.25	-0.25	1.32	0.76

-The Aggressivity of the dominant species is positive and that of the dominated species is negative.

-Competitive Ratio gives the number of times one species is more competitive than the other.

Table 16: Total Productivity and Yield Advantage of mixtures of Maize and plant Sugar Cane in Replacement Series at 2 sites and under 3 situations.

Treatment	Relative Crowding Coefficient			Area Time Equivalency Ratio			Land Equivalent Ratio		
	Cane	Maize	Total	Cane	Maize	Total	Cane	Maize	Total
Situation 1.									
Bambous									
2/3 Cane+1/3 Maize	1.73	1.38	2.38	—	—	—	0.78	0.41	1.18
1/2 Cane+1/2 Maize	2.63	1.76	4.63	—	—	—	0.72	0.64	1.36
1/3 Cane+2/3 Maize	2.23	1.58	3.52	—	—	—	0.53	0.76	1.29
Belle Rive									
2/3 Cane+1/3 Maize	0.77	1.22	0.94	—	—	—	0.61	0.38	0.99
1/2 Cane+1/2 Maize	1.50	1.44	2.16	—	—	—	0.60	0.59	1.19
1/3 Cane+2/3 Maize	1.21	2.42	2.92	—	—	—	0.38	0.83	1.21
Situation 2.									
Bambous									
2/3 Cane+1/3 Maize	1.73	0.31	0.54	0.78	0.10	0.88	0.78	0.13	0.91
1/2 Cane+1/2 Maize	2.63	0.27	0.70	0.72	0.16	0.89	0.72	0.21	0.93
1/3 Cane+2/3 Maize	2.23	0.17	0.37	0.53	0.19	0.72	0.53	0.25	0.78
Belle Rive									
2/3 Cane+1/3 Maize	0.77	0.17	0.13	0.61	0.12	0.73	0.61	0.08	0.69
1/2 Cane+1/2 Maize	1.50	0.14	0.21	0.60	0.19	0.79	0.60	0.12	0.72
1/3 Cane+2/3 Maize	1.21	0.10	0.12	0.38	0.26	0.64	0.38	0.17	0.55
Situation 3.									
Bambous									
2/3 Cane+1/3 Maize	1.73	0.48	0.82	0.78	0.15	0.93	0.78	0.19	0.97
1/2 Cane+1/2 Maize	1.77	0.39	0.68	0.64	0.22	0.86	0.64	0.28	0.92
1/3 Cane+2/3 Maize	1.58	0.48	0.76	0.44	0.38	0.83	0.44	0.49	0.93
Belle Rive									
2/3 Cane+1/3 Maize	0.71	0.55	0.39	0.59	0.19	0.78	0.59	0.22	0.80
1/2 Cane+1/2 Maize	0.87	0.54	0.47	0.47	0.31	0.78	0.47	0.35	0.82
1/3 Cane+2/3 Maize	1.08	0.57	0.61	0.35	0.48	0.83	0.35	0.53	0.88

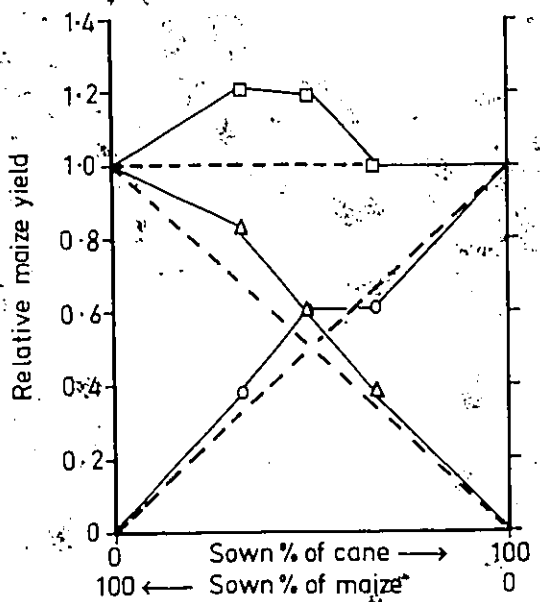
The component crop with the higher Relative Crowding Coefficient is the dominant crop.

Figure 9 : LER diagrams for replacement series mixtures of plant sugarcane and maize at Bellè Rive.

Left : one maize crop grown in mixtures; one sole maize crop.

Right : three sequential maize crops grown in mixtures and three sequential sole maize crops.

1 Maize Crop



3 Maize Crops

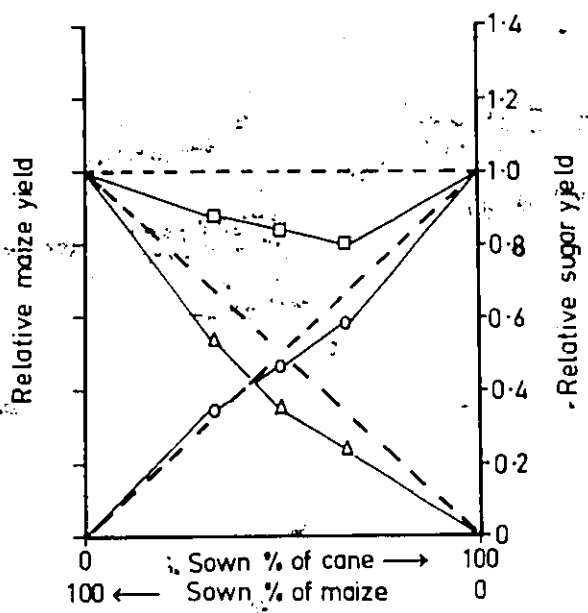
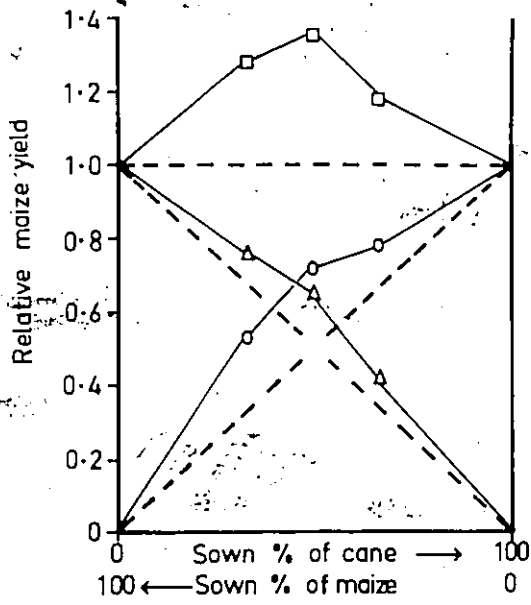


Figure 10 : LER diagrams for replacement series mixtures of plant sugar cane and maize at Bambous.

Left : one maize crop in mixtures; one sole maize crop.

Right : three sequential maize crops in mixtures and three sequential sole maize crops.

1 Maize Crop



3 Maize Crops

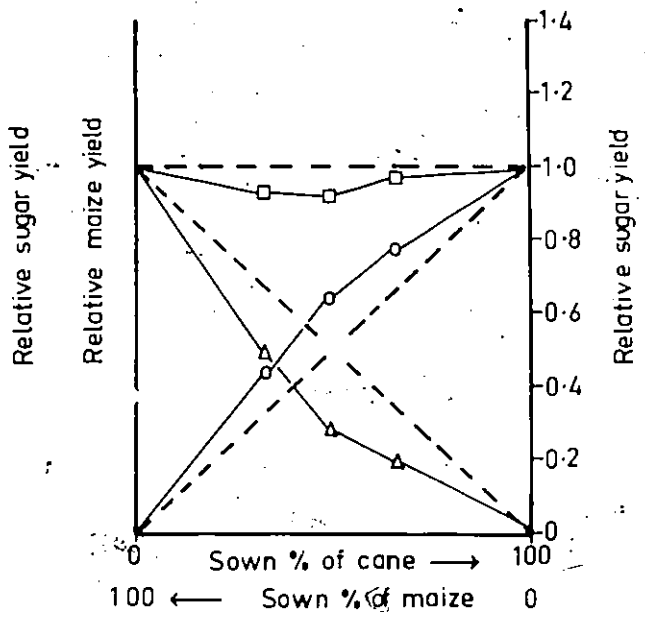


Table 17: Effects of an underground partition on maize intercropped with plant sugar cane at Redit.

Treatment	Final canopy height	Biomass	Harvest index	Grain yield @12% m.c.
	(cm)	(t.ha ⁻¹)	(%)	(t.ha ⁻¹)
<u>Sole maize</u>				
Without partition	256.4(100)	10.90(100)	45.5(100)	5.64(100)
With partition	257.3(100)	9.54(88)	44.5(98)	4.81(85)
Mean	256.8	10.22	45.0	5.23
<u>Intercropped Maize</u>				
Without partition	258.1(101)	10.42(96)	44.6(98)	5.27(93)
With partition	257.1(100)	9.54(88)	45.0(99)	4.88(87)
Mean	257.6	9.98	44.8	5.07
C.V.(%)	1.8	6.7	4.2	7.7
F. Test:				
Partitioning	N.S.	**	N.S.	*
Cropping system	N.S.	N.S.	N.S.	N.S.
Interaction	N.S.	N.S.	N.S.	N.S.
S.E.	2.3	0.34	1.0	0.20

Figures in brackets are responses expressed as per cent of sole maize without partition.

3.2.1.2 Cane responses

The partitions had no significant effect on tiller density of either the sole or the intercropped cane, whereas intercropping with maize caused a marked reduction in tiller density between the 8th and the 24th weeks (figure 11). Thereafter, there was no difference in tiller density of any of the treatments.

The partitions had no effect on cane canopy height (figure 12), whereas intercropping led to an increase in canopy height as from the 7th to the 15th week, thus confirming the visual observation that the intercropped cane was etiolated.

In spite of the etiolation observed earlier in the season, the stalk height of the intercropped cane was less than that of the sole cane (figure 12). The difference observed at 20 weeks was maintained to the end of the season, indicating identical stalk elongation rates. Here again, the partition had no effect on canopy or stalk height.

In parallel with the reductions in tiller density and with etiolation, intercropping severely reduced cane biomass at 15 weeks (table 18). However, with time, the intercropped cane caught up, as shown by the fact that, at harvest, the adverse effect on biomass was much less, although it was highly significant ($P=0.01$).

In contrast to the observation at 15 weeks that the partitions had been totally effective in preventing the cane roots from penetrating into the interrow, it was observed at

Figure 11 : Effect of soil partition and intercropping with maize on the tillering of plant sugar cane.

Vertical bars are LSD(P=0.05).

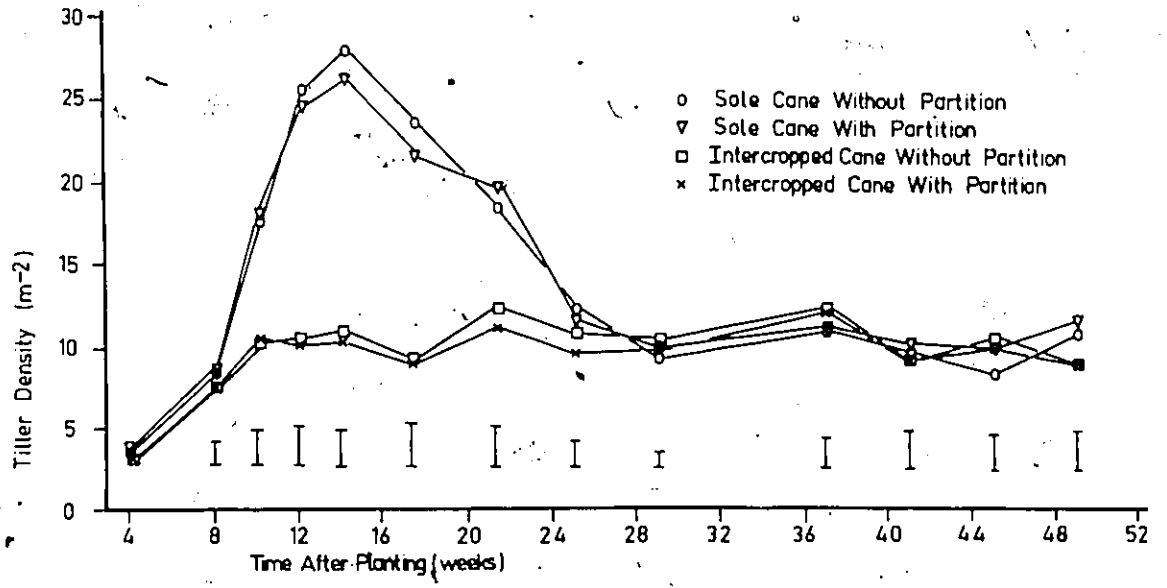


Figure 12 : Effect of soil partition and intercropping with maize on plant sugar cane canopy height and stalk height.

Top : Cane canopy height measured from ground level to the tip of tallest leaf.

Bottom : Cane stalk height measured from ground level to the top visible dewlap.

Vertical bars are LSD(P=0.05)

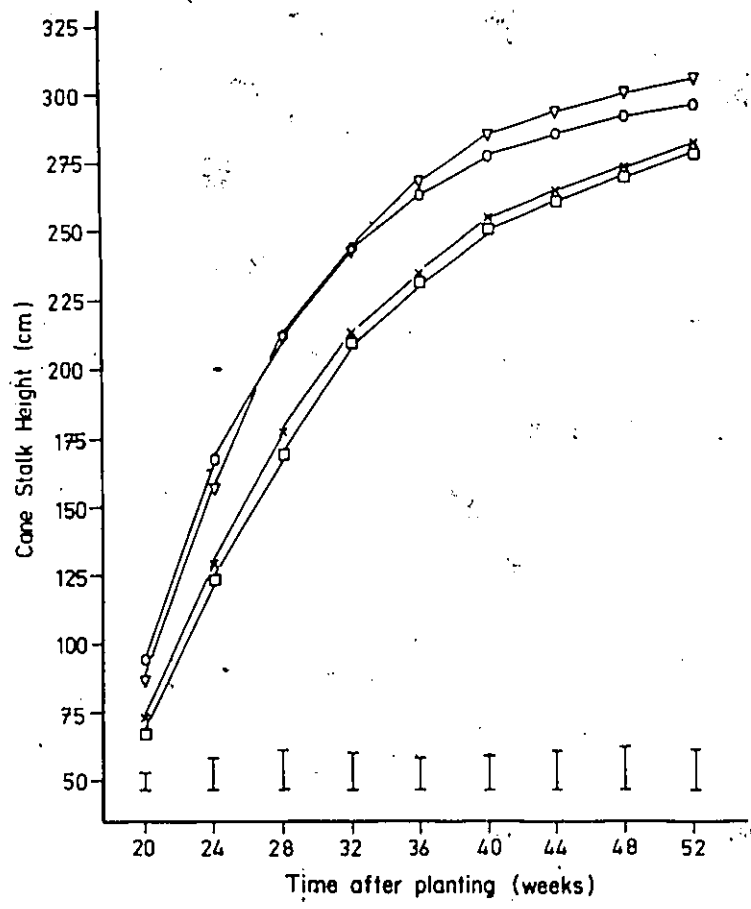
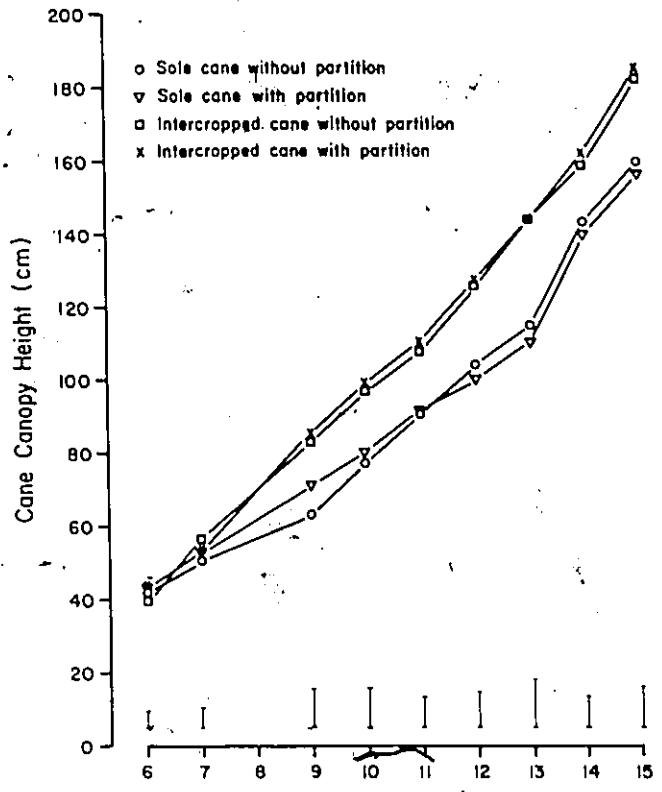


Table 18: Biomass at 15 weeks and at harvest of plant sugar cane as influenced by an underground partition and intercropping with maize.

Treatment	Cane biomass (t.ha ⁻¹)	
	At 15 weeks	At harvest
<u>Sole cane</u>		
Without partition	6.86(100)	79.8(100)
With partition	7.07(103)	80.2(101)
Mean	6.96	80.0
<u>Intercropped cane</u>		
Without partition	3.97(58)	69.5(87)
With partition	3.48(51)	64.4(81)
Mean	3.72	67.0
C.V.(%)	18.4	9.7
F. Test:		
Partitioning	N.S.	N.S.
Cropping system.	***	**
Interaction	N.S.	N.S.
S.E.	0.49	3.6

Figures in brackets are responses expressed as per cent. of sole maize without partition.
N.S.=Not significant at P=0.05.

harvest that the cane roots had nevertheless crossed into the interrow by passing above and below the partition. By themselves, the partition did not affect the root density as measured by the total number of root ends in the profile but they did alter the distribution of roots (table 19). Root density was reduced in the shallow layer (0-20cm) of the interrow but it was increased in the intermediate (20-50cm) and the deep (50-70 cm) soil layers within the cane row. By itself, intercropping reduced the total number of root ends, the effect being located in the shallow and intermediate layers. Surprisingly, the effects of intercropping and of the partition were not additive. Indeed, the intercropped cane had more roots in the presence of the partitions than in their absence!

As was observed on the growth parameters, the partition had no significant effect on yield and yield components of sugar. (table 20). On the other hand, intercropping caused a severe and highly significant ($P=0.01$) reduction in sugar yield even though the intercropped cane had caught up partially in biomass (table 18). The reduction in sugar yield was through slight but significant reductions in all the yield components.

The results obtained in this trial demonstrated conclusively that sugarcane growth and yield were profoundly affected by intercropping with maize even under conditions where competition for below-ground resources was not allowed

Table 19: Influence of an underground partition and of intercropping with maize on the density of plant sugar cane roots in 3 soil horizons and at 2 positions across the rows.

Treatment	Number of root ends (Mean of 4 observations in each of 2 replicates \pm standard errors)						
	soil		horizon				Total
	0-20 cm		20-50 cm		50-70 cm		
Within row	Inter-row	Within row	Inter-row	Within row	Inter-row		
<u>Sole cane</u> Without partition (control)	107 \pm 9	70 \pm 4	102 \pm 9	63 \pm 5	16 \pm 4	13 \pm 3	368 \pm 11
With partition	102 \pm 7	24 \pm 6 **	123 \pm 17	54 \pm 8	45 \pm 10 *	21 \pm 8	366 \pm 36
<u>Inter-cropped Cane</u> Without partition	103 \pm 7	50 \pm 6 *	72 \pm 4 *	46 \pm 4 *	12 \pm 2	12 \pm 5	296 \pm 12 *
With partition	110 \pm 12	53 \pm 9	138 \pm 7 *	63 \pm 10	26 \pm 7	12 \pm 5	403 \pm 31

-The 2 positions across the rows were: within row, 0-40cm and interrow, 40-80 cm from the centre of the cane row.

*,**: Significantly different from the control at the 5 per cent and the 1 per cent levels of significance, respectively.

All other differences are not significant at $P=0.05$.

Table 20: The effect of soil partition and of intercropping with maize on the yield and yield components of plant sugar cane.

Treatment	Millable cane	Unit stalk weight	Cane stalk yield	Sucrose content	Sugar yield
	m ⁻²	kg	t.ha ⁻¹	Pol% cane	t.ha ⁻¹
<u>Sole Cane</u>					
Without partition	7.92 (100)	1.89 (100)	150. (100)	15.53 (100)	18.24 (100)
With partition	7.44 (94)	1.94 (103)	144 (96)	15.15 (98)	17.05 (93)
Mean	7.68	1.92	147	15.34	17.65
<u>Intercropped Cane</u>					
Without partition	6.91 (87)	1.80 (95)	124 (83)	14.40 (93)	13.93 (76)
With partition	6.72 (85)	1.79 (95)	120 (80)	14.38 (93)	13.34 (73)
Mean	6.81	1.80	122	14.39	13.64
C.V.(%)	10.7	4.2	11.4	3.8	13.7
F. Test					
Partitioning	N.S.	N.S.	N.S.	N.S.	N.S.
Cropping system	*	*	*	**	**
Interaction	N.S.	N.S.	N.S.	N.S.	N.S.
S.E.	0.39	0.04	7.7	0.28	1.07

Figures in parenthesis are responses expressed as per cent of sole cane without partition.

to take place. The adverse effect was very marked at about the time of maize harvest and became less important with time as the cane caught up. However, the catching up was not complete.

3.2.2 Role of nutrients

In the preceding section (section 3.2.1) were reported the results of a trial to study the relative importance of above and below-ground competition under conditions where nutrient and water supply were very good, if not non-limiting. Evidence was presented that under such conditions maize competed for above-ground, not below-ground resources. It is also necessary, however, to examine competition under a range of fertility situations. The results of a trial laid out at Bambous on the role of nutrients are reported below. First, the maize responses and then, the cane responses will be examined for evidence of competition for nutrients.

3.2.2.1 Maize responses

At no time in the crop cycle was the maize above-ground biomass significantly affected by intercropping with cane (figure 13). Of particular interest is the fact that biomass of unfertilized maize intercropped with over-fertilized cane was not higher than that of unfertilized maize intercropped with unfertilized cane. This implies that the maize did not benefit from the excess nutrients present under the cane rows.

Figure 13 : Effect of NPK and intercropping with plant sugar cane on the biomass and N content of maize.

Top : Maize biomass(g/m^2), oven dry basis.

Bottom : N content(%)

Left : Unfertilized maize.

Right : Fertilized maize, i.e. given the recommended NPK rate.

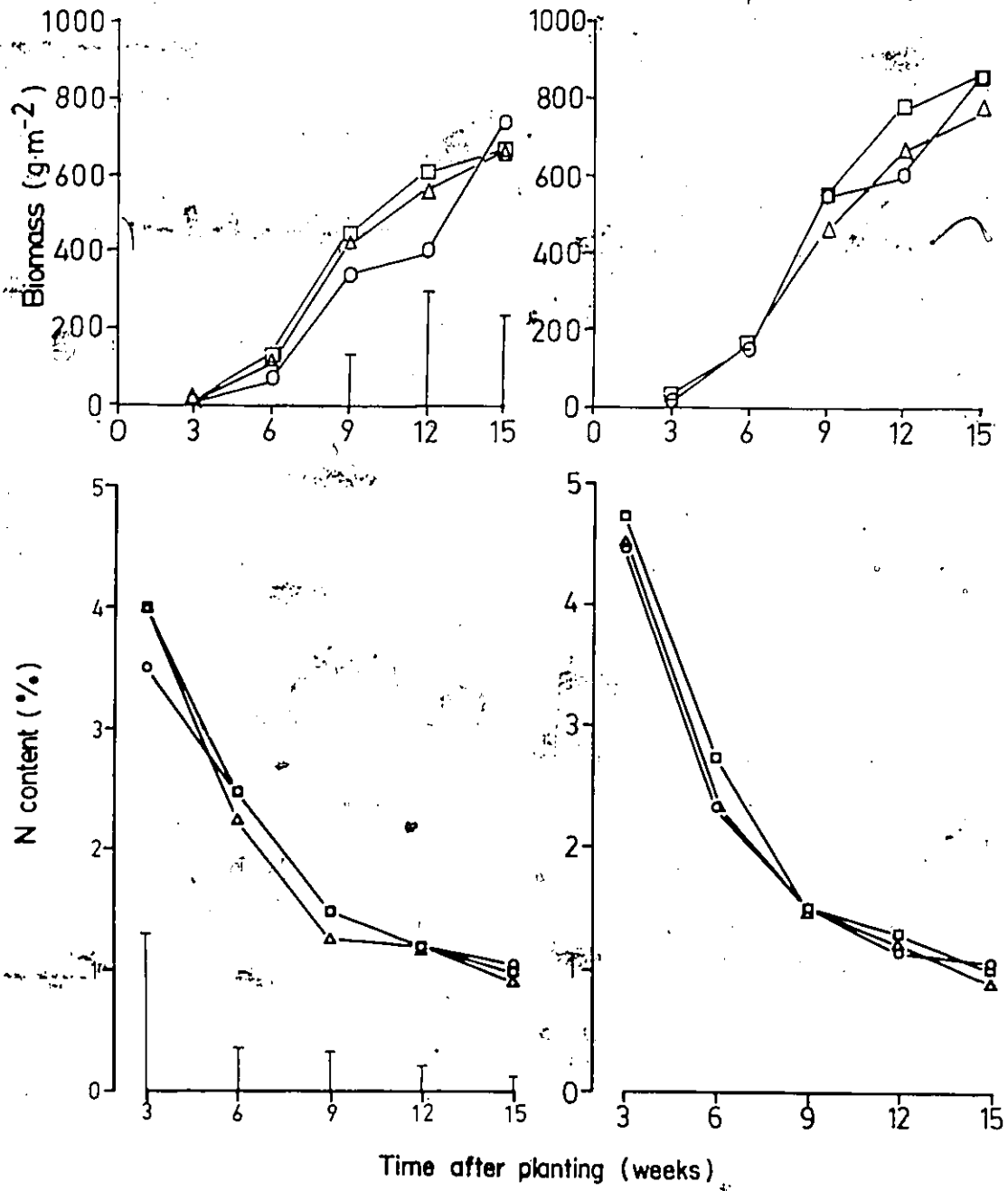
○ : Sole maize

△ : Maize + unfertilized cane

□ : Maize + over-fertilized cane, i.e. given 3

times the recommended NPK rate.

Vertical bars are LSD($P=0.05$), and are identical for unfertilized and fertilized maize.



Tissue concentrations of N,P, and K were higher in the fertilized maize than in the unfertilized maize at the 3rd week; thereafter concentrations while decreasing were similar for all treatments (figures 13 and 14). Intercropping with cane had no significant effects on the N,P and K content of maize. In particular, there was no evidence that the N,P, and K content of unfertilized maize intercropped with over-fertilized cane was at any time higher than that of unfertilized maize intercropped with unfertilized cane. This confirms that the maize did not absorb nutrients applied to cane even when they were present in excess.

At harvest, intercropping with cane had no significant effect on final above-ground maize biomass, and on average, reduced harvest index (table 21). Intercropping reduced grain yield, and the reduction was independent of the rates of fertilizer applied to maize. Here again, biomass and grain yield of unfertilized maize were not higher when the maize was intercropped with over-fertilized cane compared to unfertilized cane, thus confirming the results observed with the biomass and with the tissue NPK contents of samples obtained during the growth.

3.2.2.2 Cane responses

In contrast to its effects on maize, intercropping significantly reduced cane growth measured as tiller density and above-ground biomass. Moreover, the effects of maize on cane were dependent on the rates of fertilizer applied to maize. Intercropping reduced tiller density

Figure 14 : Effect of NPK and intercropping with plant sugar cane on P and K content of maize.

Top : P (ppm)

Bottom : K (ppm)

Left : Unfertilized maize

Right : Fertilized maize, i.e. given the recommended NPK rate.

○ : Sole maize.

△ : Maize + unfertilized cane

□ : Maize + over-fertilized cane, i.e. given 3 times the recommended NPK rate

Vertical bars are LSD($P=0.05$) and are identical for unfertilized and fertilized maize.

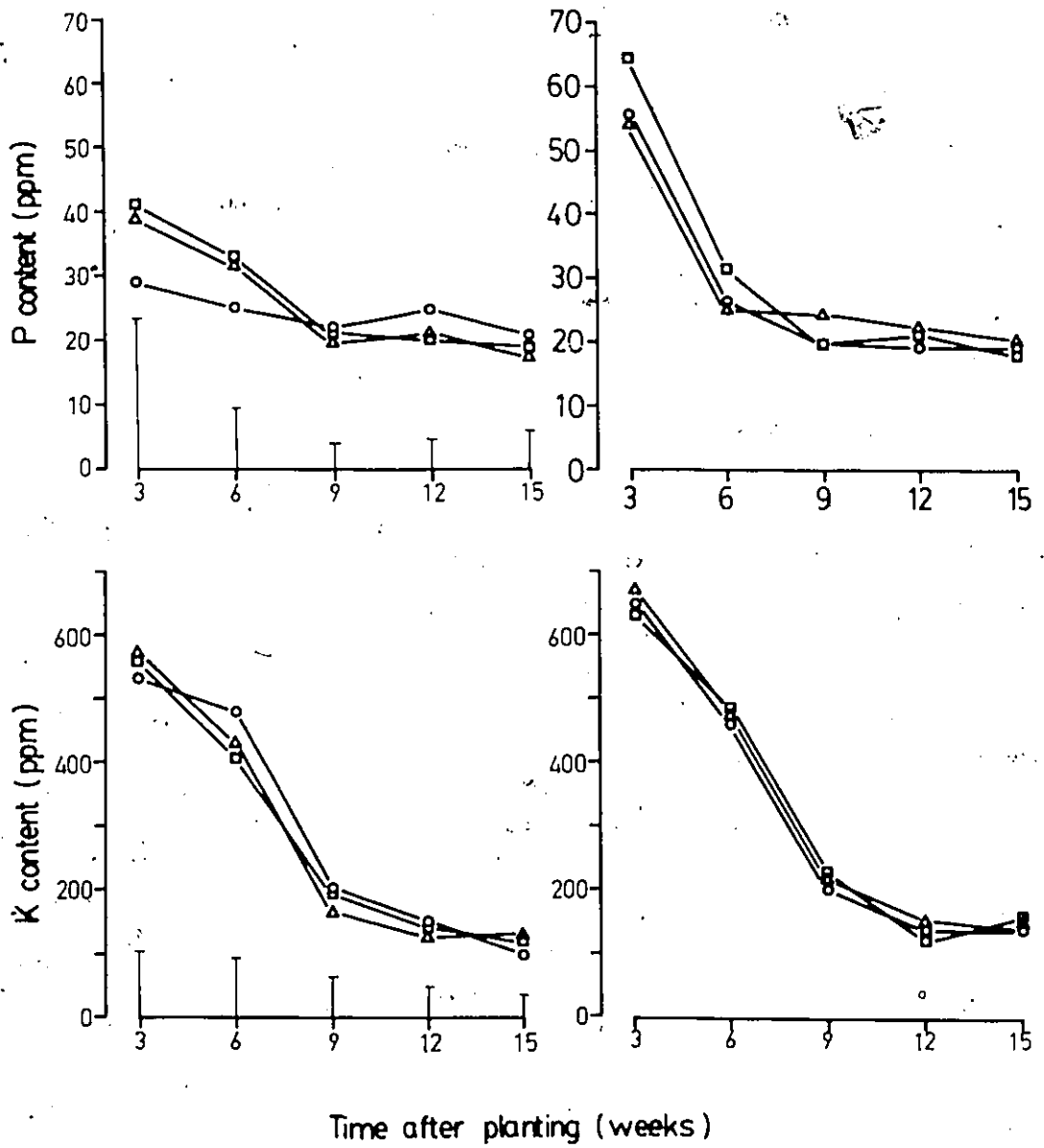


Table 21: Influence of the rate of fertilizer on maize intercropped with plant Sugar Cane at Bambous.

Treatment	Maize biomass	Harvest index	Grain yield at 12% m.c.
	(t.ha ⁻¹)	(%)	(t.ha ⁻¹)
<u>Unfertilized maize</u>			
Sole maize	7.15	54.2	4.29
Maize+ unfertilized cane	6.45	50.7	3.67
Maize+ fertilized cane	6.98	47.7	3.65
Maize+ over-fertilized cane	6.66	54.8	3.99
Mean	6.81	51.9	3.90
<u>Fertilized Maize</u>			
Sole maize	8.49	57.9	5.53
Maize+ unfertilized cane	7.74	56.8	4.64
Maize+ fertilized cane	8.76	51.9	5.13
Maize+ over-fertilized cane	8.64	47.8	4.63
Mean	8.41	53.6	4.98
<u>Over-fertilized maize</u>			
Sole maize	7.69	56.1	4.87
Maize+ unfertilized cane	8.11	41.4	3.87
Maize+ fertilized cane	7.90	45.8	4.02
Maize+ over-fertilized cane	9.13	37.4	3.84
Mean	8.21	45.2	4.15
C.V.(%)	15.5	20.0	11.4
S.E.	0.70	5.8	0.27
L.S.D.(P=0.05)	2.02	17.0	0.78

significantly from the 8th to the 25th week (figure 15). On unfertilized cane, the reduction in tiller number was more pronounced when the intercropped maize was over-fertilized than when it was not fertilized (figure 15). This differential response was less evident in fertilized cane. The results show that the addition of fertilizers to the maize, far from improving cane growth, in fact reduced it further, especially when cane itself was not fertilized.

The differential effect of over-fertilized maize compared to unfertilized maize was confirmed by the cane biomass data (figure 16a). Intercropping reduced cane biomass significantly from about the 12th week. As was observed on tiller density, intercropping with over-fertilized maize had a larger adverse effect than with unfertilized maize, and this differential effect was more marked on the unfertilized cane than on the fertilized cane.

From about the 9th to about the 15th week, the N content of intercropped cane was less than that of sole cane, the difference being observed on unfertilized as well as on fertilized cane (figure 16). From the 15th week onwards however, the situation was reversed, and the sole cane had a lower N content than the cane intercropped with over-fertilized maize.

Figure 15 : Effect of NPK and intercropping with maize on the tillering of plant sugar cane.

Top : Unfertilized cane.

Bottom : Fertilized cane, i.e. given the recommended NPK rate.

○ : Sole cane

× : Cane + unfertilized maize

△ : Cane + over-fertilized maize, i.e. given 3 times the recommended NPK rate.

Vertical bars are LSD ($P=0.05$) and are identical for unfertilized and fertilized cane.

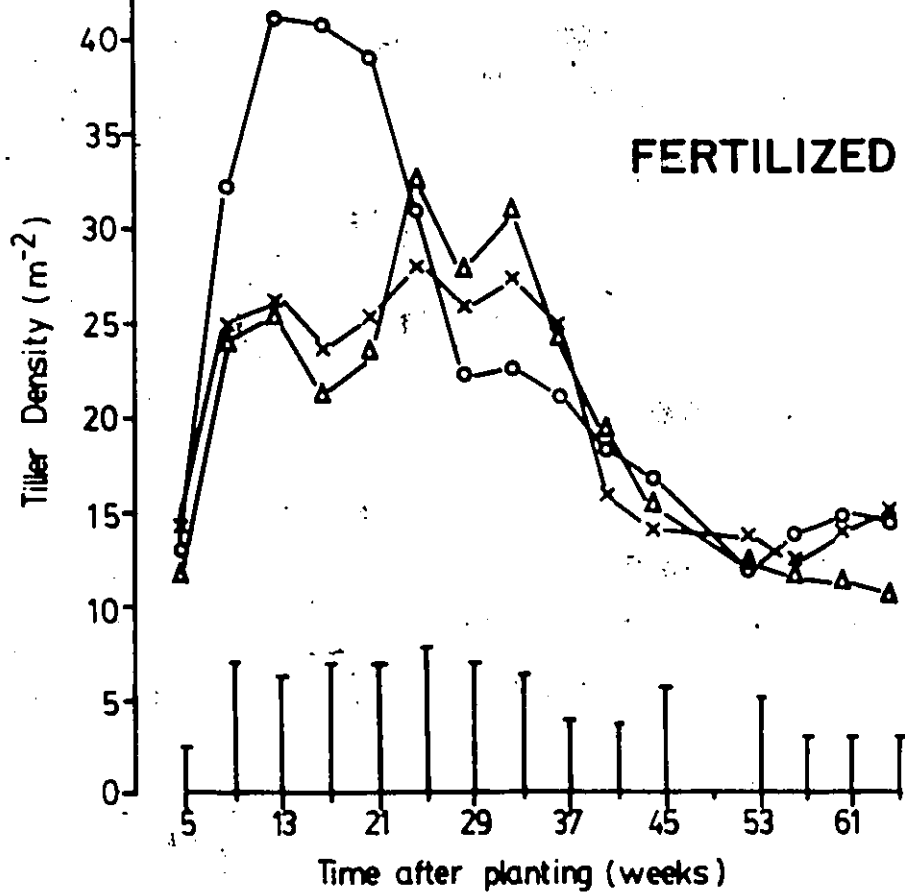
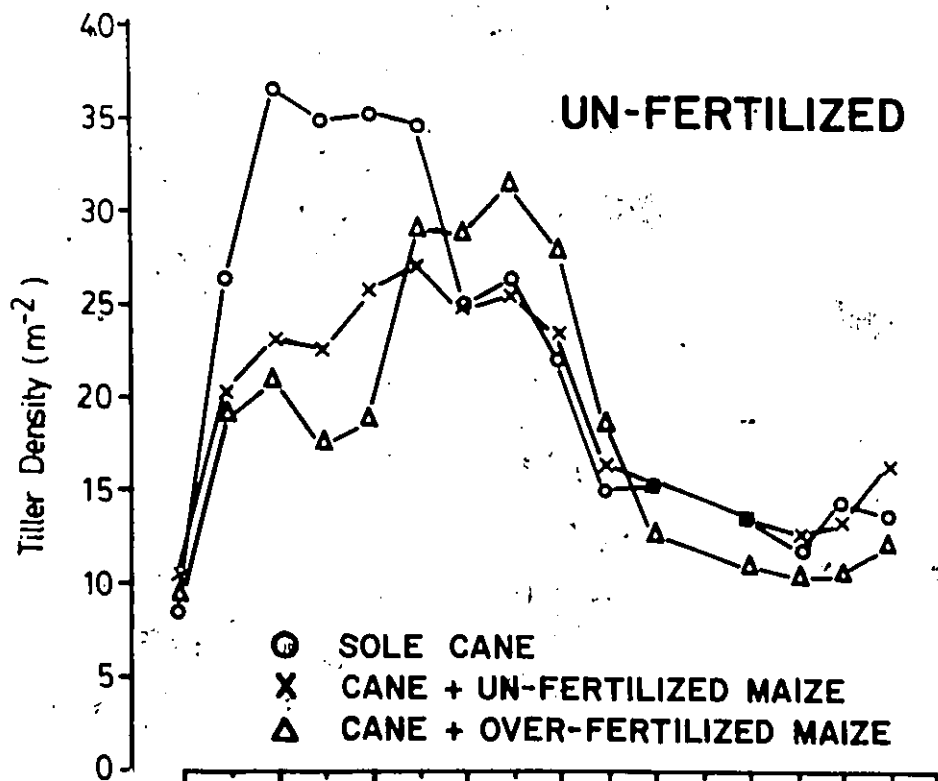


Figure 16 : Effect of NPK and intercropping with maize on the biomass and N content of plant sugar cane.

Top : Cane biomass(g/m^2), oven dry basis

Bottom : N content(%)

Left : Unfertilized cane

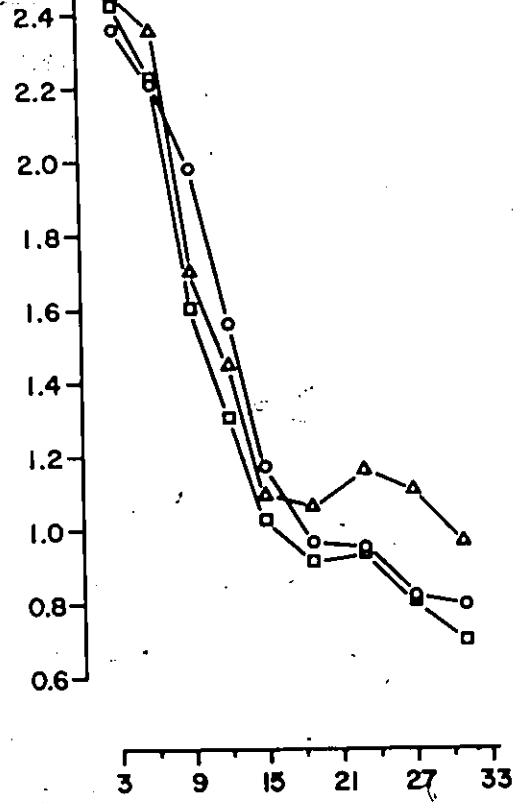
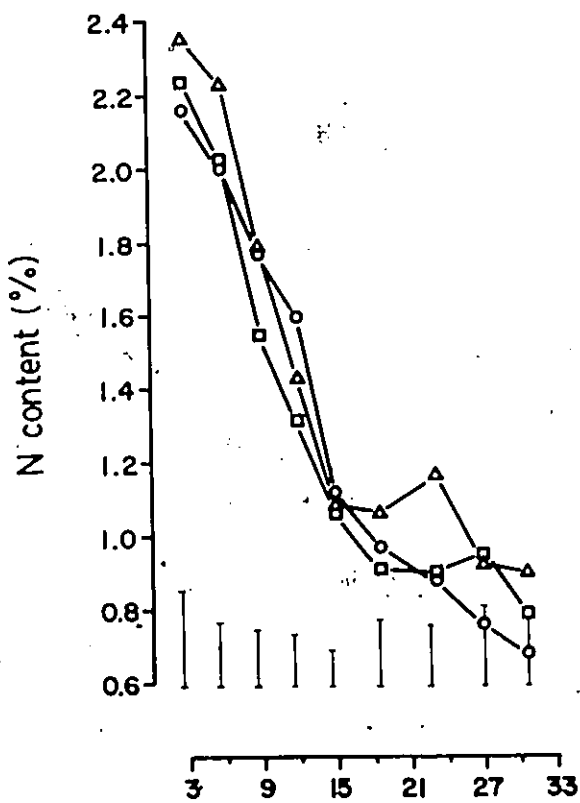
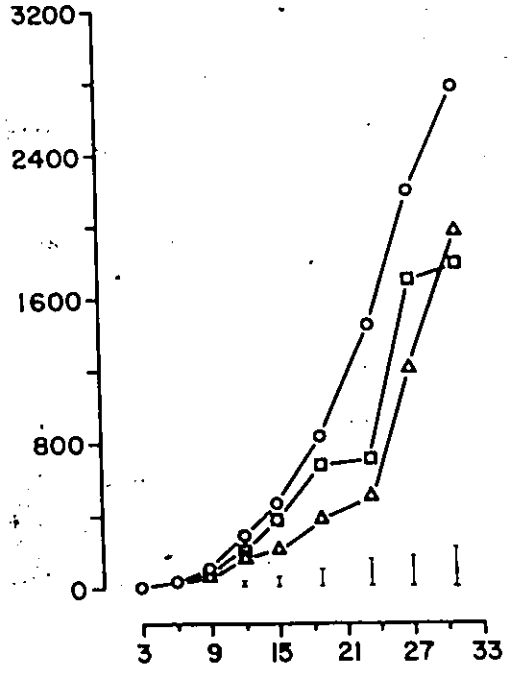
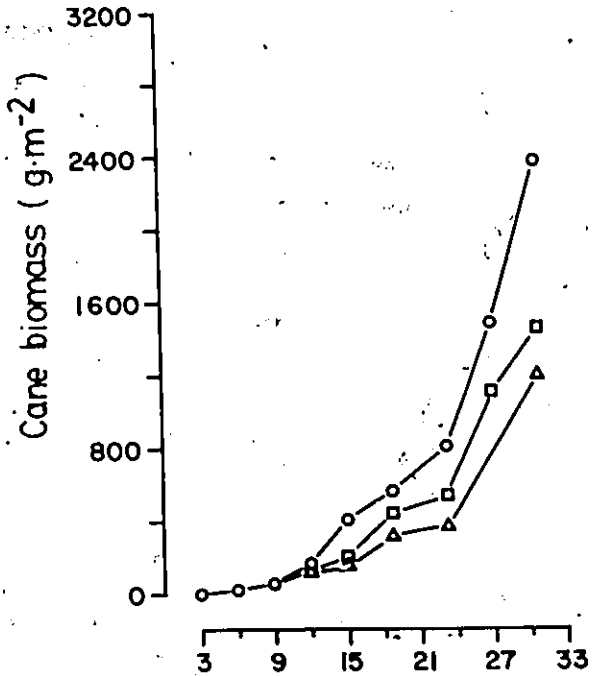
Right : Fertilized cane, i.e. given the recommended rate.

○ : Sole cane

□ : Cane + unfertilized maize

△ : Cane + over-fertilized maize, i.e. given 3 times the recommended NPK rate.

Vertical bars are LSD($P=0.05$) and are identical for unfertilized and fertilized cane.



Time after planting (weeks)

The P content of cane (figure 17) showed effects similar to those observed for N. With K, however, the initial reduction of K content with intercropping was not observed (figure 17). On the contrary, the increase in K content associated with intercropping with over-fertilized maize was observed as from the 6th week although the difference was not always significant at the 5 per cent level.

The cane suffered from severe water stress due to general drought conditions in Mauritius. From the 25th week, sprinkler irrigation was stopped on account of lack of water. In an attempt to save the crop whose growth was severely reduced, whose leaves had dried up and whose stalks were dying out in several plots, surface irrigation was provided on an irregular basis as from the 34th week. The final yield was therefore very poor, the effects of treatments were erratic and should therefore be viewed with caution.

Notwithstanding several exceptions, the general trend was for sugar yield and its components not to respond to rates of NPK but to be affected by intercropping with maize (table 22). On average, intercropping with unfertilized maize was associated with a slight increase, and intercropping with over-fertilized maize with a slight decrease in sugar yield and in the following yield components: biomass, millable cane and cane stalk yield. The two other yield components, unit stalk weight and sucrose content were not significantly affected by treatments.

Figure 17 : Effect of NPK and intercropping with maize on the P and K content of plant sugar cane.

Top : P (ppm)

Bottom : K (ppm)

Left : Unfertilized cane

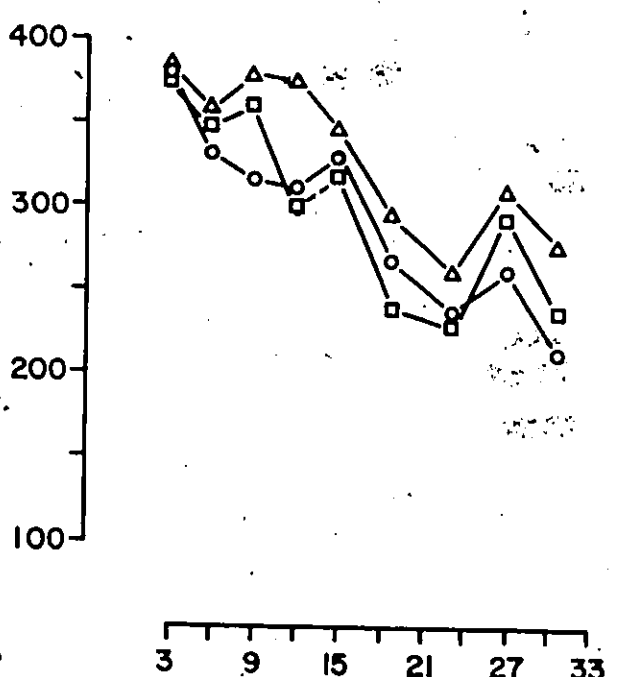
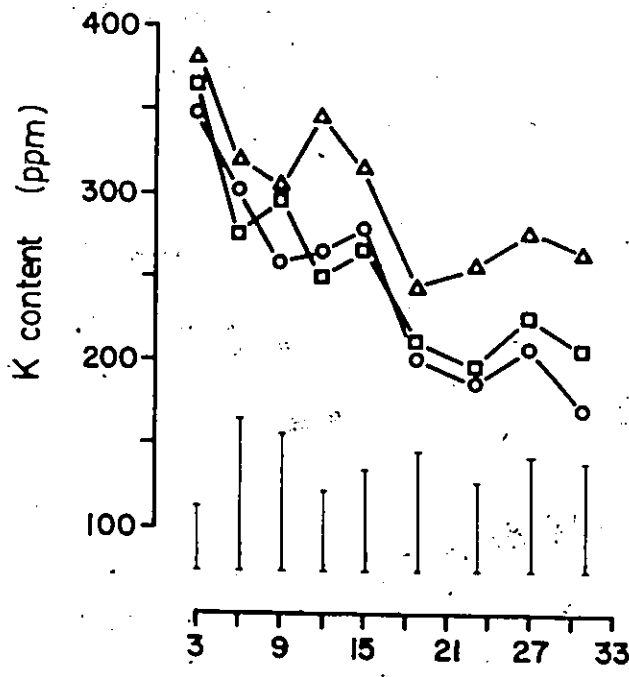
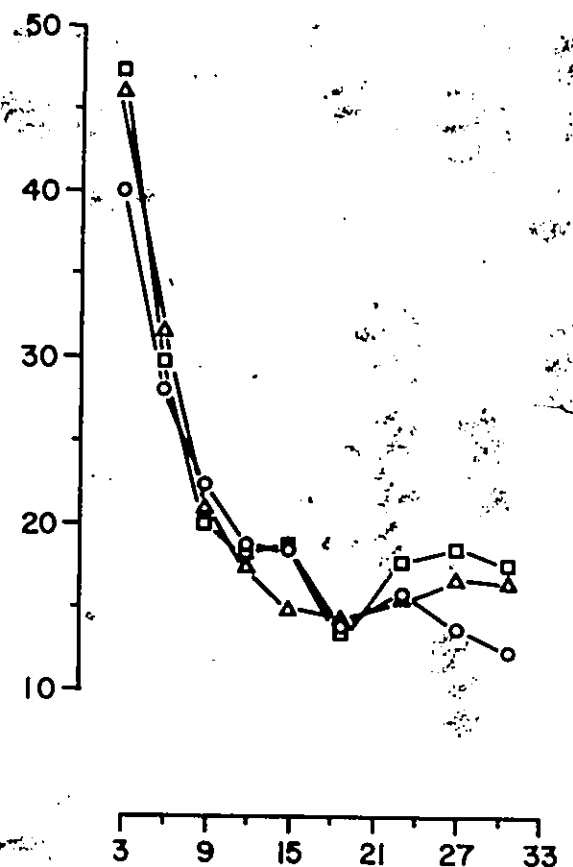
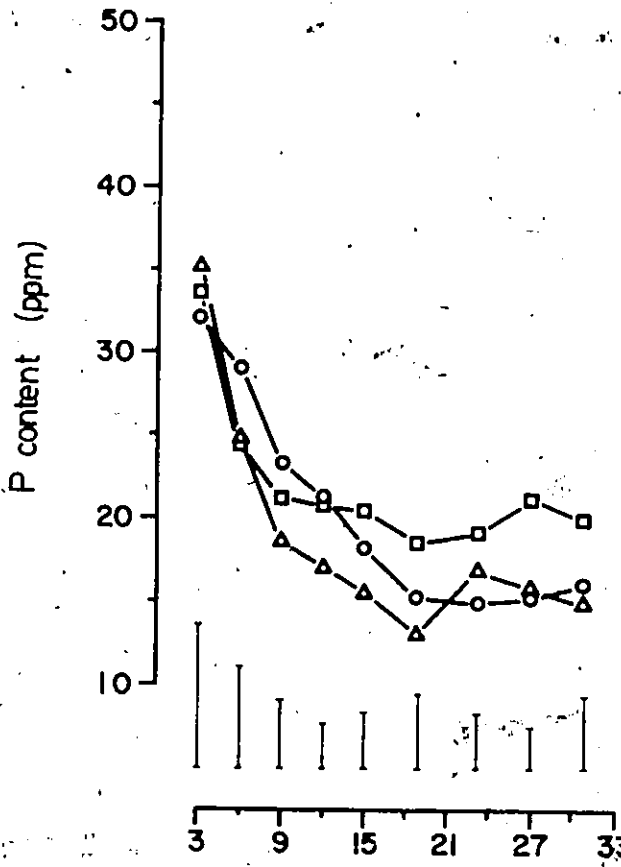
Right : Fertilized cane, i.e. given the recommended NPK rate

○ : Sole cane

□ : Cane + unfertilized maize

△ : Cane + over-fertilized maize, i.e. given 3 times the recommended NPK rate.

Vertical bars are LSD($P=0.05$), and are identical for unfertilized and fertilized cane.



Time after planting (weeks)

Table 22: Influence of fertilizer rate on the yield and yield components of plant sugar cane intercropped with maize at Bambous.

Treatment	Total Biomass	Millable Cane	Unit Stalk Weight	Cane Stalk Yield ^a	Sucrose Content	Sugar Yield
	t.ha ⁻¹	m ⁻²	kg	t.ha ⁻¹	(Pol% cane)	t.ha ⁻¹
Unfertilized cane						
Sole cane	42.1	9.80	0.81	77.8	14.7	8.93
Cane+ unfertilized maize	44.0	10.83	0.89	94.3	13.6	9.88
Cane+ over-fertilized maize	30.6	8.02	0.79	61.2	14.1	(6.66)
Mean	38.9	9.55	0.83	77.8	14.1	8.49
Fertilized cane						
Sole cane	39.8	10.31	0.77	77.6	13.6	8.14
Cane+ unfertilized maize	42.9	12.45	0.76	84.9	14.2	9.34
Cane+ over-fertilized maize	35.0	9.06	0.73	66.9	13.6	7.38
Mean	39.3	10.61	0.76	76.5	13.8	8.29
Overfertilized cane						
Sole cane	39.5	(12.81)	0.59	73.4	(12.3)	6.87
Cane+ Unfertilized maize	36.5	9.40	0.86	83.0	13.5	8.61
Cane+over-fertilized maize	35.1	10.00	0.62	60.7	14.3	6.78
Mean	37.0	10.74	0.69	72.4	13.4	7.42
C.V.(%)	15.7	9.4	12.0	18.3	5.1	20.2
S.E.	3.4	0.59	0.05	7.8	0.41	0.92
L.S.D.(P=0.05)	10.0	1.75	0.15	22.6	1.2	2.68

Thus, there was no evidence that fertilization of maize improved the performance of cane. On the contrary, there was evidence to show that over-fertilization of maize made it more competitive to the cane, presumably for resources other than nutrients.

3.2.3 Role of water

It has already been shown (section 3.2.1) that under conditions of adequate water supply, maize competes with sugar cane and probably not for water. Moreover, the effects of drought observed at Bambous (section 3.2.2) indicate a possible interaction between competition for light and for water. Therefore a trial was laid out at Belle Vue on the role of water.

3.2.3.1 Maize responses

Irrigation had significant effects on maize biomass, harvest index and grain yield (table 23). Biomass responded positively to irrigation, the effect of the no-stress water regime being highly significant ($P=0.01$). Harvest index was significantly higher in the mild stress water regime than in the 2 other water regimes. Grain yield increased significantly with irrigation but there was no significant difference ($P=0.05$) in grain yields under the 2 irrigation regimes.

In contrast to the effect of irrigation, intercropping had no significant effect on any of the 3 maize response

variables (table 23). Moreover, the interaction between water regime and cropping system was not significant at the 5 per cent level thus indicating that in its response to water regime, the intercropped maize was not different from the sole maize. There was therefore no evidence that the maize suffered from competition from the cane for water, not even under rainfed conditions, or that it benefited from its association with the cane.

3.2.3.2 Cane responses

Water regime per se had no significant effects on cane tiller density but intercropping did (figure 18). From about the 8th to the 18th week, intercropping with maize reduced tiller formation almost completely, and this effect was not dependent on water regime. Of special relevance is the fact that the tiller density of intercropped cane was not higher under the no-stress water regime than in the rainfed regime, indicating that the reduction in tiller density was not associated with competition for water. Tiller-
ing resumed in all intercropped plots after the maize was removed at 18 weeks. Tiller formation was more rapid in the irrigated than in the rainfed cane, and the peak tiller densities achieved were also higher in the irrigated than in the rainfed cane indicating that water regime played a role in 'rattrapage'.

Table 23: Response of maize to intercropping with plant sugar cane under 3 water regimes at Belle Vue.

Treatment	Biomass	Harvest Index	Grain Yield @12%mc
	(t.ha ⁻¹)	(%)	(t.ha ⁻¹)
<u>Not irrigated(Rainfed)</u>			
Sole maize	6.48	47.8	3.53
Intercropped maize	6.17	44.7	3.16
Mean	6.33	46.3	3.35
<u>Mild-stress regime</u>			
Sole maize	7.25	55.0	4.53
Intercropped maize	6.58	54.4	4.06
Mean	6.91	54.7	4.29
<u>No-stress regime</u>			
Sole maize	8.38	47.8	4.56
Intercropped maize	8.82	48.3	4.82
Mean	8.60	48.1	4.69
C:V. (%) (a)	11.7	8.9	13.8
(b)	13.1	4.8	13.8
S.E. (a)	0.48	1.6	0.20
(b)	0.30	1.2	0.28
F.Test			
Water regime	**	*	**
Cropping system	N.S.	N.S.	N.S.
Interaction	N.S.	N.S.	N.S.

In the no-stress regime, water was applied daily at rates calculated to supply all of the crops' theoretical requirements. In the mild-stress regime, between half and two-thirds of the calculated requirements were given.

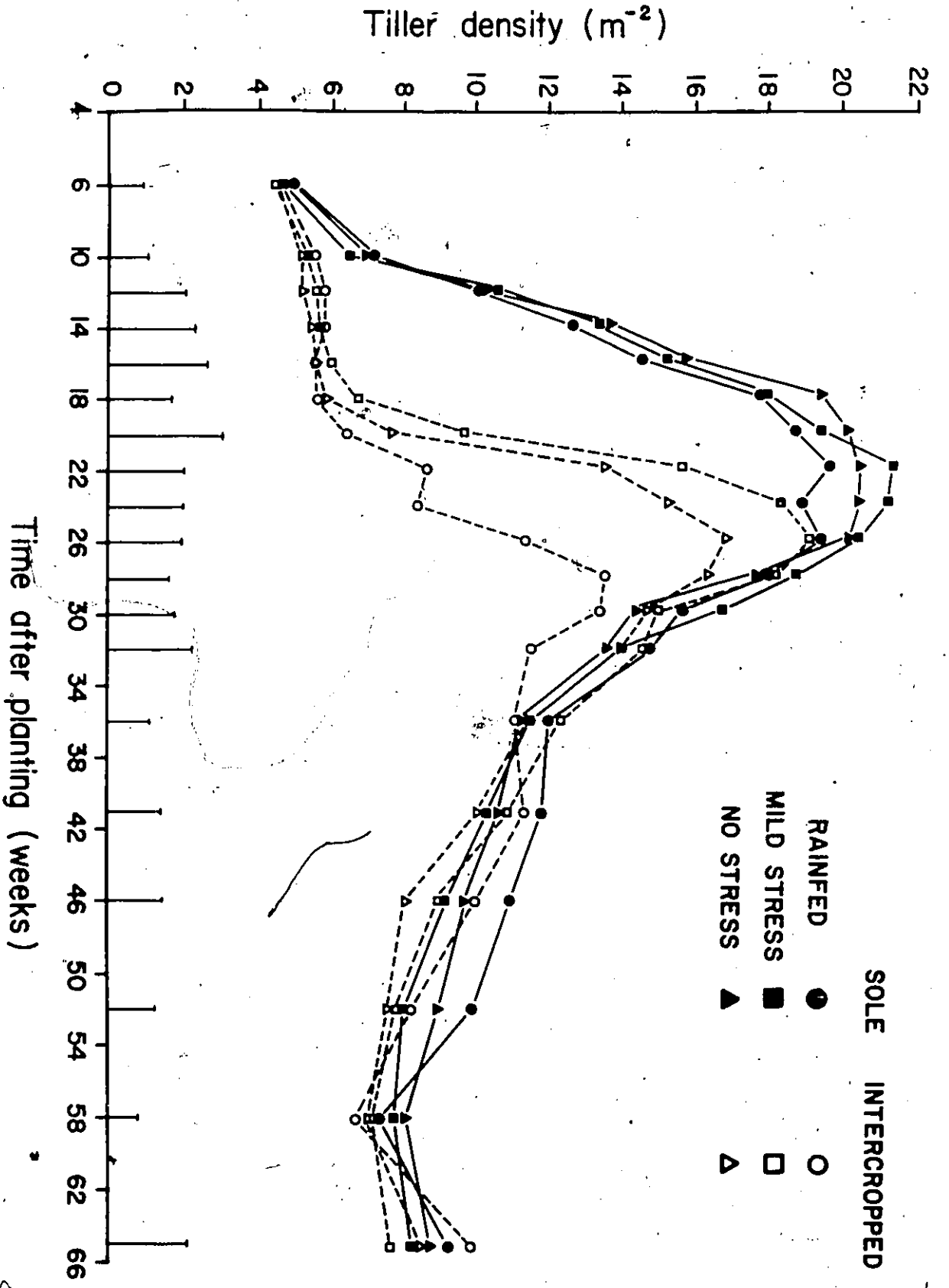
S.E.(a) For testing differences between means of water regimes.

S.E.(b) For testing differences between means within a water regime.

Figure 18 : Effect of water regime and intercropping with maize on the tillering of plant sugar cane.

	Sole cane	Intercropped cane
Rainfed(No irrigation)	●	○
Mild water stress	■	□
No water stress	▲	△

Vertical bars are LSD(P=0.05).



As with tiller density, the effect of intercropping on cane biomass was dependent on water regime (figure 19). In the no-stress regime, intercropping reduced biomass for a short period, from the 12th to the 24th week. In the mild stress regime, the reduction was larger and lasted longer, from the 12th to the 30th week. In the rainfed plots, the reduction was larger still and the cane had not caught up completely at harvest. Hence, the data confirms that 'rat-trapage' was strongly influenced by water regime.

There was also an interaction between the effect of intercropping and that of water regime on spindle elongation, an indicator of internal water stress (figure 20). From about the 12th to the 19th week, intercropping was associated with a significant reduction in spindle elongation of the rainfed but not of the no-stress cane, indicating that the intercropped cane in the rainfed plots probably suffered from more water stress than did the sole cane.

Cane stalk and sugar yield responded positively to irrigation (table 24), the increase being very highly significant ($P=0.001$). Between the two irrigation regimes, there was a small, non-significant difference in favour of the no-stress regime. On average, intercropping led to a reduction in cane stalk yield and sugar yield, the difference being significant at the 10 per cent level. Notwithstanding the non-significant interaction according to analysis of variance, inspection of the data revealed and student's t

Figure 19 : Biomass of sole and intercropped plant sugar cane under 3 water regimes.

Biomass(g/m^2) was transformed to natural logarithms.

	Sole cane	Intercropped cane
Rainfed(No irrigation)	●	○
Mild water stress	■	□
No water stress	▲	△

Vertical bars are LSD($P=0.05$) on log biomass, i.e. least significant ratios.

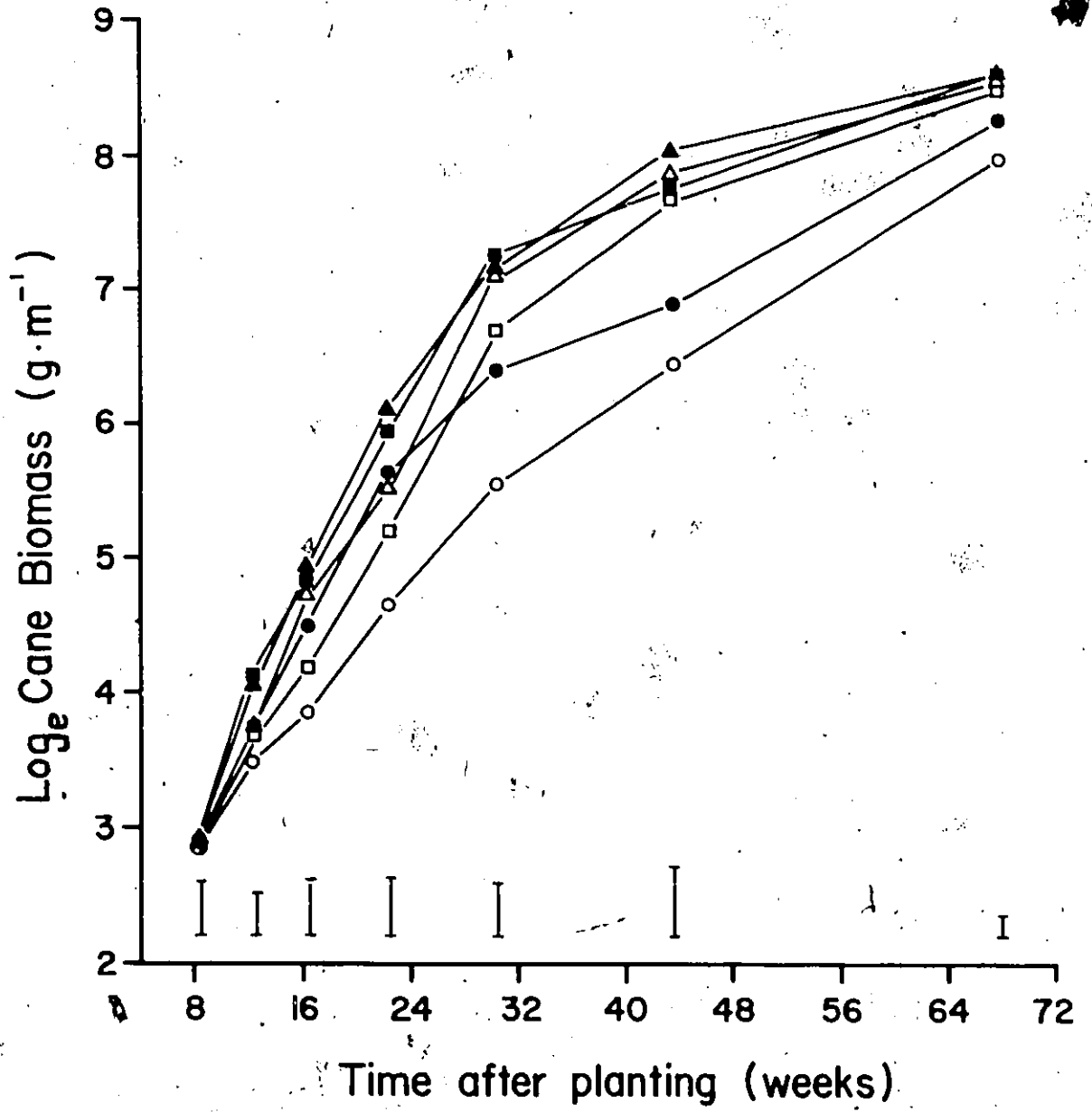
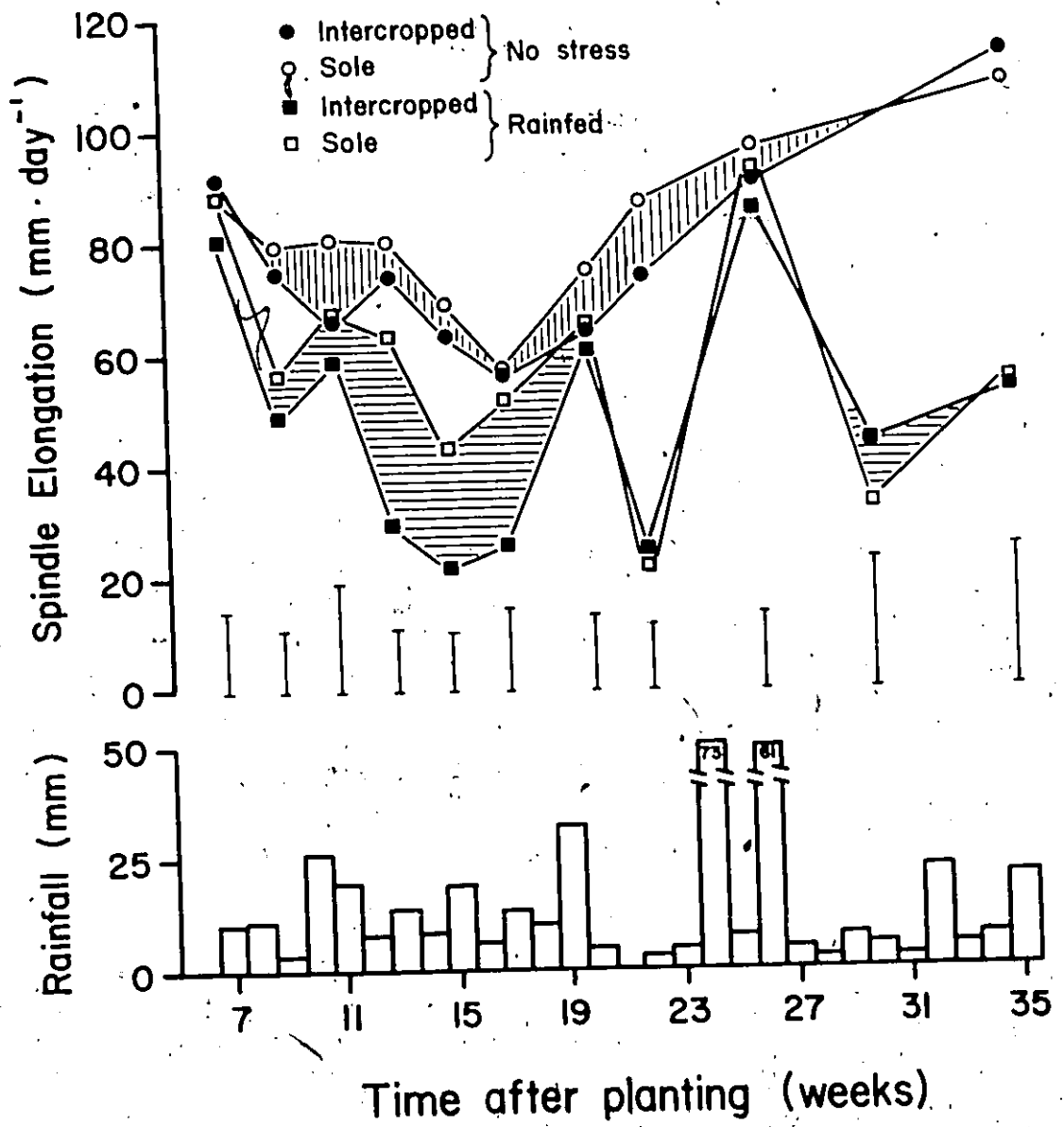


Figure 20 : Spindle elongation of sole and intercropped plant sugar cane under 2 water regimes.

Mean of 10 measurements in 4 replicates. Vertical bars are LSD(P=0.05).



tests confirmed, that intercropping had a slightly significant effect ($P=0.10$) on yield of cane stalk and of sugar in the rainfed and the mild stress plots but not in the no-stress plots. Intercropping had no significant effects on the other three yield components but irrigation led to an increase in number of millable canes, unit stalk weight and sucrose content, the difference being significant at $P=0.05$, $P=0.001$ and $P=0.10$, respectively. 'Rattrapage' was therefore complete in the no-stress regime but partial in the mild-stress and rainfed regimes.

3.2.3.3 Joint responses

At the sampling points, there was less water in the soil under maize than under cane, and under intercropped than under sole cane, up to about the 23rd week (figure 21). The effect of intercropping on soil water content was not significant in the no-stress regime but it was significant for a short period, from the 10th to the 15th week in the mild-stress and the rainfed regimes. After the removal of the maize and the heavy rains of the 19th week, the differences faded away, except in the mild-stress regime where the water content under the intercropped cane was slightly and non-significantly less than under the sole cane.

Root counts completed after maize harvest showed that the sole maize had a more extensive root system than the sole cane, in lateral spread as well as depth, under the rainfed as well as the no-stress regime (figure 22). Cane roots

Table 24: Yield and yield components of plant sugar cane as influenced by intercropping with maize under 3 water regimes at Belle Vue.

Treatment	Millable cane	Unit stalk weight	Cane stalk yield	Sugar content	Sugar yield
	m ⁻²	kg	t.ha ⁻¹	Pol% Cane	t.ha ⁻¹
<u>Not irrigated</u>					
Sole cane	6.06	1.36	82.6	14.70	9.46
Intercropped cane	5.40	1.25	67.0	14.90	7.75
Mean	5.73	1.30	67.0	14.90	7.75
<u>Mild-stress regime</u>					
Sole cane	6.48	2.01	129.5	15.65	15.92
Intercropped cane	6.32	1.79	113.5	15.63	13.91
Mean	6.40	1.90	121.5	15.64	14.91
<u>No-stress regime</u>					
Sole cane	6.48	1.96	126.7	15.35	15.18
Intercropped cane	6.30	2.00	125.4	15.68	15.36
Mean	6.39	1.98	126.0	15.51	15.27
C.V. (%) (a)	8.9	6.9	5.7	5.1	5.2
(b)	7.8	11.8	11.3	3.9	11.8
S.E. (a)	0.19	0.04	2.2	0.27	0.24
(b)	0.24	0.10	6.1	0.30	0.76
F. Test					
Water regime	*	***	***	(*)	***
Cropping system	N.S.	N.S.	(*)	N.S.	(*)
Interaction	N.S.	N.S.	N.S.	N.S.	N.S.

S.E(a): For testing differences between means of water regimes.

S.E(b): For testing differences between means within a water regime.

(*), *, *** Significant, at P=0.10, 0.05, and 0.001, respectively.

Figure 21 : Water content in the soil under sole plant sugar cane, sole maize and plant sugar cane intercropped with maize under 3 water regimes.

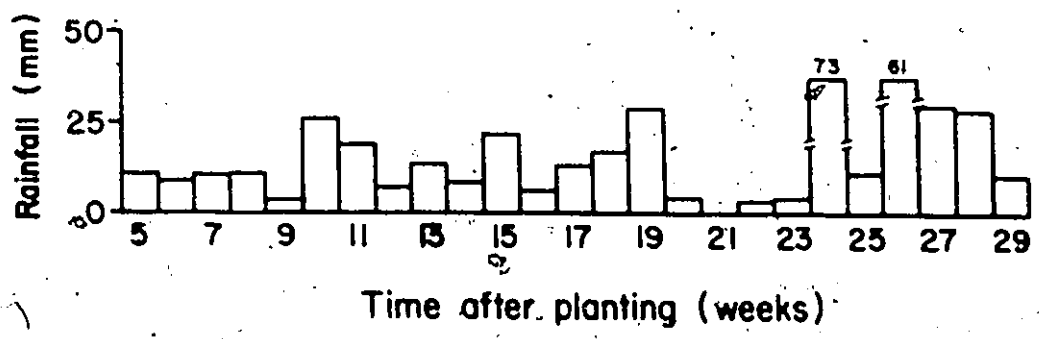
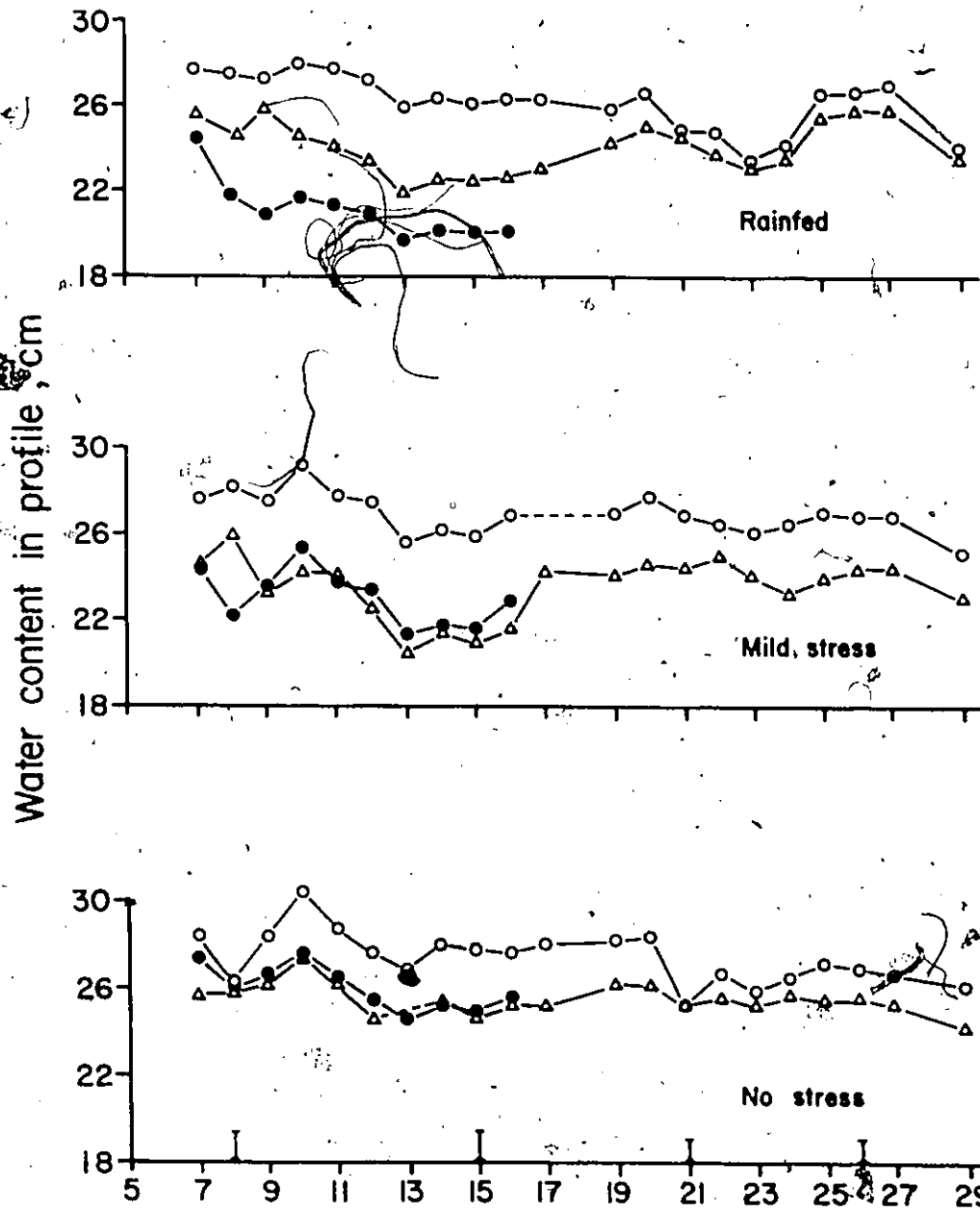
Water content was measured with a neutron probe.

Open circle (○) : sole cane; Closed circle (●) : sole maize;

Triangle (△) : cane intercropped with maize.

Vertical bars are LSD(P=0.05).

- Sole maize
- Sole cane
- △ Intercropped, cane & maize



were observed not to have extended beyond 50cm nor maize roots beyond 70cm in spite of the presence in the no-stress regime, of a dripper line at 80cm. There was no evidence that the maize roots had been affected by intercropping in the rainfed or the no-stress regime. However, intercropping was associated with changes in the cane root system; in the irrigated plots there was a slight reduction in root density and depth whereas in the rainfed plots there was a slight reduction in density not depth (figure 22).

Bivariate analysis of the yields of sugar and of maize showed that there was almost no background relationship between them, the residual correlation being only 0.15. The effects of treatments on the joint yields are therefore not presented as they are expected not to differ from the effects on the yields separately.

3.2.4 Role of light

When maize was grown as one row in every interrow of plant sugar cane, it competed with cane for light (section 3.2.1), but the magnitude of this shading effect had not been determined prior to the trial at Redit.

3.2.4.1 Magnitude and development of shade

In the sole cane, solar transmittance at ground surface started to decrease at about the 8th week, and by the 16th week, it had dropped to 50 per cent (figure 23). In the intercropped plots, maize reduced transmittance at the top

Figure 22 : Root density of sole plant sugar cane, sole maize and plant sugar cane intercropped with maize under 2 water regimes.

Values are number of root ends (mean of 2 observations in 3 replicates). Each square is 10 cm X 10 cm. Vertical profiles were dug perpendicular to the crop rows. In the no stress regime (right) water was applied by means of dripper lines (●) located as shown.

and the bottom of the cane canopy. Shading by maize, measured as the reduction in transmittance started earlier at the bottom of the canopy and increased in magnitude as maize density increased. Mean transmittance and cumulative mean transmittance declined with time in an approximate inverse-S fashion (figure 24), and the minimum mean transmittance of about 25 per cent was attained at the highest maize density at 8 weeks. At this time, there was no measurable drop in mean transmittance in the sole cane.

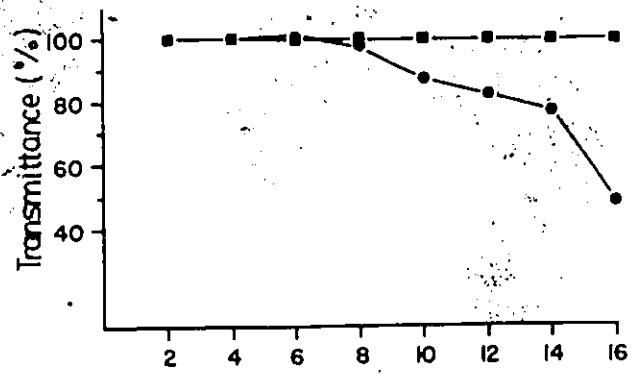
3.2.4.2 Cane responses.

The intercropped maize had no effect on cane tiller density until about the 8th week (figure 25). Thereafter, and until about the 31st week, tiller density was reduced by intercropping, and the magnitude of the reduction was dependent on maize density. With maize at the lowest density, tiller formation was reduced but it did not stop altogether, as was the case however, with maize at the highest density from the 8th to the 18th week. There was no evidence of tiller mortality. After the harvest and removal of the maize at the 18th week, tillering resumed rapidly and the peak tiller density achieved by the cane intercropped with maize at the 3 densities was almost as high as that of the sole cane.

At the 3 maize densities, the tiller density to 18 weeks of the intercropped cane relative to that of the sole cane varied with time in an inverse-S fashion (figure 26). The

Figure 23 : Transmittance of light in sole and intercropped plant sugar cane before and after removal of maize.

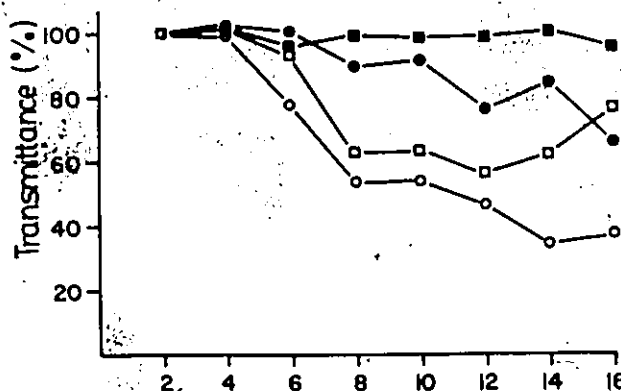
Transmittance was measured with tube solarimeters at the bottom (○) and the top (□) of the cane canopy, after (closed symbols, ●, ■) and before (open symbols, ○, □) the removal of maize. Transmittance was expressed as per cent of light reaching a control tube in open space. There were 3 densities of intercropped maize, from top to bottom: 15625, 31250 and 62500 plants per hectare.



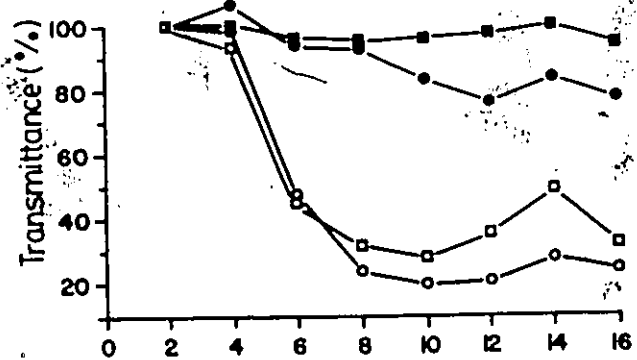
SOLE CANE



CANE + MAIZE
at 1.5 plants/m²



CANE + MAIZE
at 3.1 plants/m²

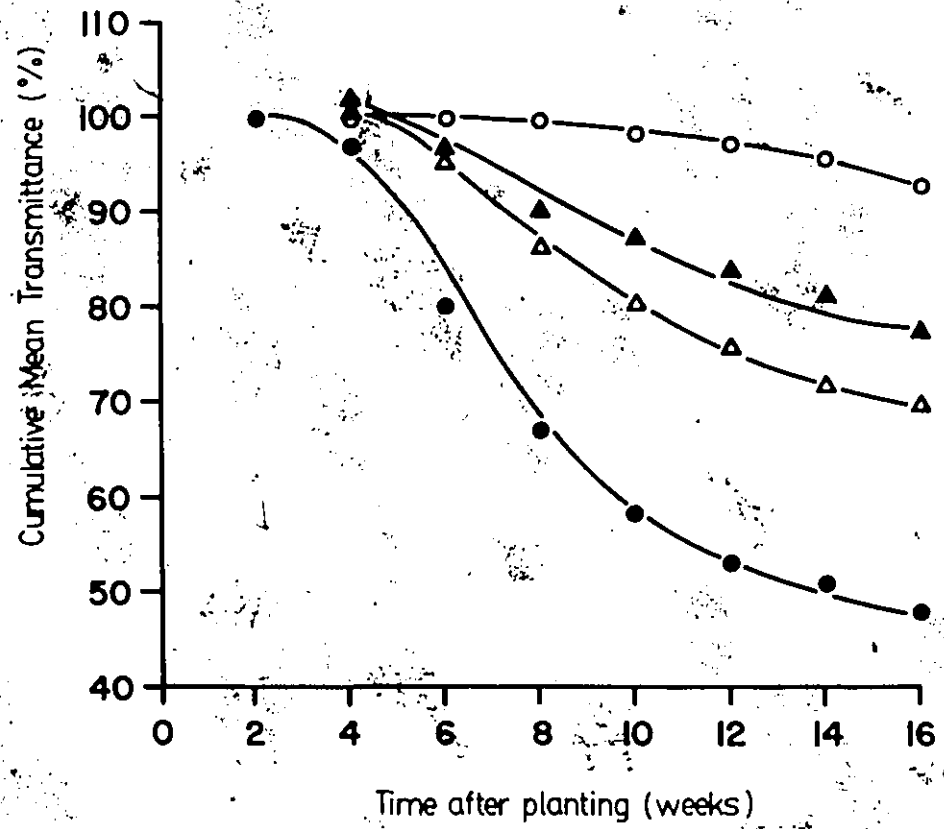
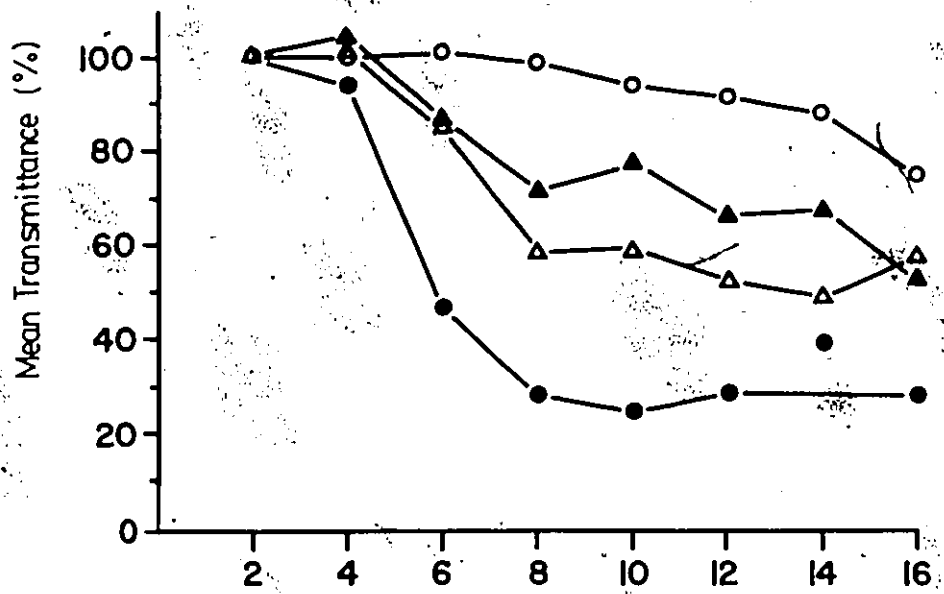


CANE + MAIZE
at 6.2 plants/m²

Time after planting (weeks)

Figure 24 : Mean and cumulative mean transmittance of light in sole and intercropped plant sugar cane in the presence of maize.

There were 3 densities of intercropped maize : 15625 (\blacktriangle), 31250 (\triangle) and 62500 (\bullet) plants per hectare. Mean transmittance is the mean of transmittance measured by the solarimeters at 2 points, i.e. at the bottom and the top of the cane canopy. Cumulative mean transmittance is the mean transmittance cumulated over time. Transmittance was expressed as percent of light reaching a control tube in open space.



relative tiller densities were minimum in the 3 cases at about week 17, and were equal to 65, 40 and 25 per cent for maize densities of 1.56, 3.12 and 6.25 plants per square metre, respectively.

At 36 weeks when "rattrapage" in tiller density was complete, there were nonetheless large differences in stalk heights (figure 27). The higher the maize density, the lower the average stalk height. There were also large differences in the frequency distribution of stalk heights. In the sole cane, the distribution was bimodal with a peak at 20-35 cm and another at 110-125cm. As maize density was increased, the distribution became less bimodal and more skewed to the left (figure 27).

The cane in this trial will be harvested in August 1986.

3.3 Temporal relations

3.3.1 Maize responses

At Bambous where the sole maize was planted at the same density as the intercropped maize, time of planting per se or season had highly significant effects on the response variables, biomass, harvest index and grain yield (table 25). Intercropping with cane had no significant effect on harvest index, and reduced biomass and grain yield, but only when the maize was planted 8 weeks after cane, were the differences significant.

Figure 25 : Effect of maize density on the tillering of intercropped plant sugar cane.

The arrow denotes when the maize was removed. Maize densities were 15625(Δ), 31250(\blacktriangle) and 62500(\bullet) plants per hectare. LSD(P=0.05) are given.

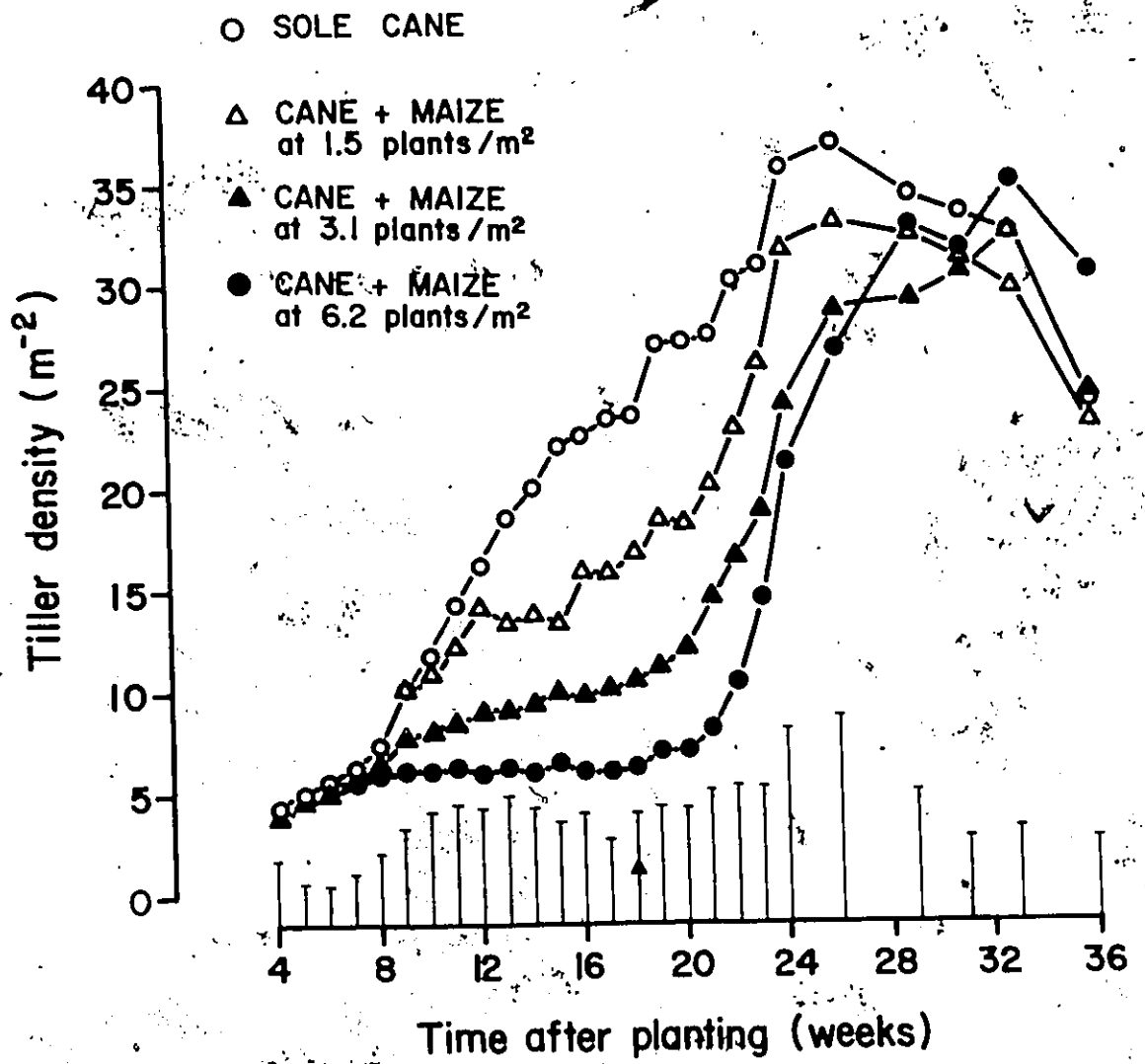
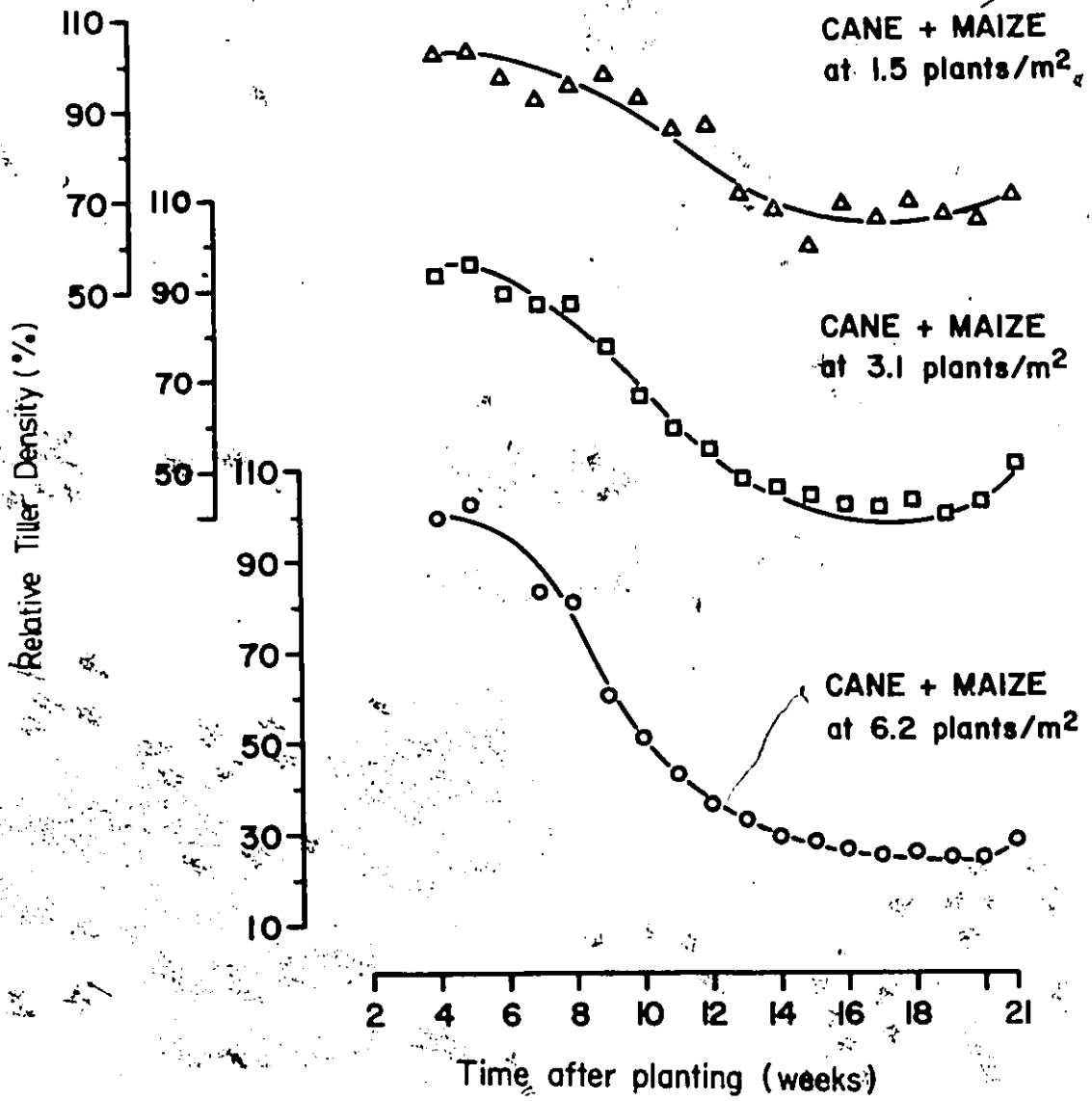


Figure 26 : Relative tiller density of plant sugar cane intercropped with maize at 3 densities.

Tiller density of intercropped cane was expressed as percent of sole cane. The densities of intercropped maize were, from top to bottom : 15625 (Δ), 31250 (\square) and 62500 (\circ) plants per hectare

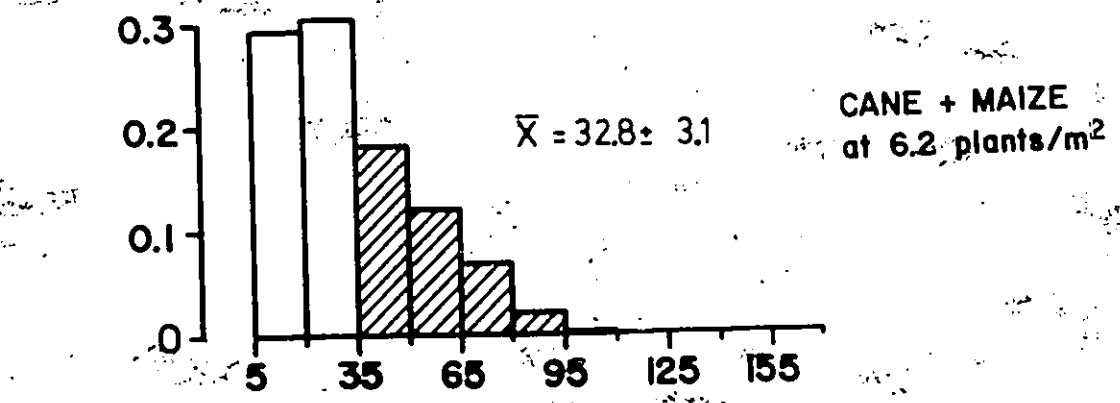
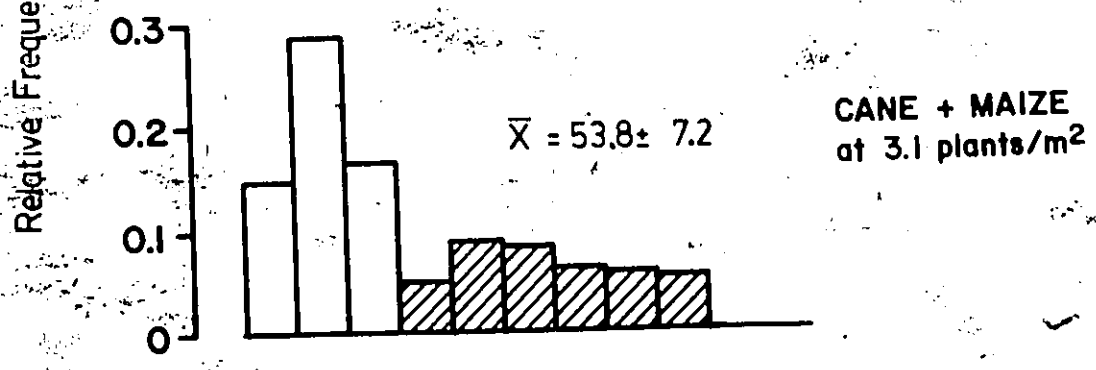
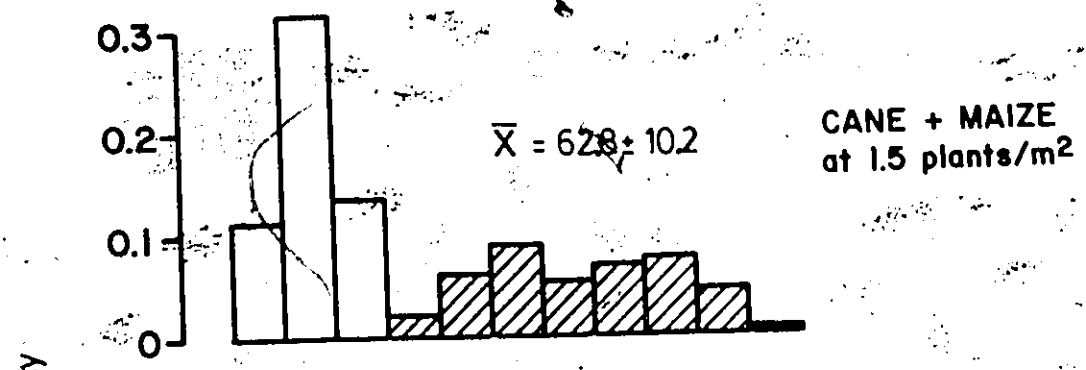
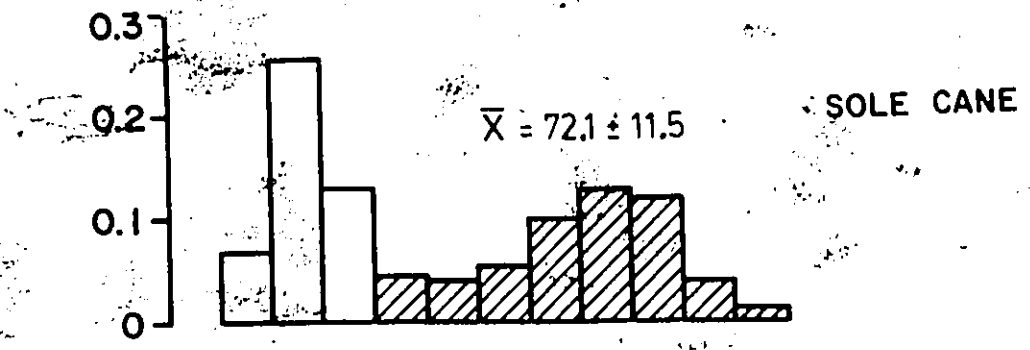


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Figure 27 : Frequency distribution of stalk heights of sole and intercropped plant sugar cane.

From top to bottom : sole cane; Cane intercropped with maize at densities of 15625, 31250 and 62500 plants per hectare.

Mean heights and standard errors are given in cm.



Stalk Height (cm)

At Reduit where the density of the sole maize was twice that of the intercropped maize, the effects of density were separated from those of intercropping and of season by expressing biomass and grain yield per plant (table 26). As was the case at Bambous, seasonal effects were highly significant. Conversely, intercropping had no significant effect on any of the response variables. Thus, there was no evidence that delayed planting of maize was detrimental to its productivity in sugar cane interrows.

3.3.2 Cane responses.

At Bambous, depending on the time of planting, maize had variable effects on tiller density (figure 28). When planted either 8 weeks before or after cane, maize had the least effect on tiller density, and when planted at the same time or at 4 weeks after cane, it had the largest effect.

At Reduit, the effect of maize planted 8 weeks before cane was also small and transient (figure 28) but in contrast to Bambous, the effect of maize planted 8 weeks after cane was more severe. As at Bambous, maize had the most effect when it was planted either at the same time as the cane or 4 weeks after the cane.

At Bambous, drought was severe. From about the 25th week, irrigation was discontinued because of lack of water. The crop experienced severe water stress leading to the drying out of leaves and in some plots, the death of stalks. From the 34th week, surface irrigation was provided irregularly in an

Table 25: Effects on maize of time of planting maize relative to intercropped plant sugar cane at Bambous.

Treatment	Maize biomass		Harvest index	Grain yield at 12% m.c.	
	t.ha ⁻¹	%	%	t.ha ⁻¹	%
<u>8 weeks before cane(February)</u>					
Sole maize	6.55	100	47.1	3.51	100
Intercropped maize	5.63	86	48.9	3.13	89
<u>4 weeks before cane(March)</u>					
Sole maize	5.81	100	60.6	4.00	100
Intercropped maize	5.95	102	60.6	4.11	103
<u>At same time as cane(April)</u>					
Sole maize	4.50	100	49.9	2.58	100
Intercropped maize	4.92	109	46.7	2.61	101
<u>4 Weeks after cane(May)</u>					
Sole maize	5.64	100	50.3	3.27	100
Intercropped maize	5.40	96	53.4	3.29	101
<u>8 Weeks after cane(June)</u>					
Sole maize	6.17	100	54.4	3.80	100
Intercropped maize	3.59	58	61.6	2.51	66
C.V.(%)	12.5		7.5	14.7	
S.E.	0.39		2.3	0.28	
F. Test:					
Time of planting maize	**		***	**	
Cropping System	N.S.		N.S.	*	
Interaction	N.S.		N.S.	**	
L.S.D.(P=0.05)	1.16		6.9	0.83	

Table 26: Effects on maize of time of planting maize relative to intercropped plant sugar cane at Reudit.

Treatment	Maize biomass			Harvest Index		Grain Yield at 12% m.c.		
	(t.ha ⁻¹)	(g.plant ⁻¹)	(%)	(%)	(t.ha ⁻¹)	(g.plant ⁻¹)	(%)	
8 weeks before cane(February)								
Sole maize	9.50	151	100	42.7	4.62	73	100	
intercropped maize	4.42	140	93	42.0	2.12	67	91	
4 Weeks before Cane(March)								
Sole maize	11.49	185	100	38.4	5.00	80	100	
intercropped maize	5.16	168	91		40.7	2.41	78 97	
At same time as cane(April)								
Sole maize	9.69	157	100	44.9	5.22	79	100	
Intercropped maize	5.68	187	119	44.8	2.89	95	120	
4 Weeks after cane(May)								
Sole maize	12.71	205	100	46.7	6.78	109	100	
Intercropped Maize	7.32	232	113	46.4	3.85	122	111	
8 Weeks after cane(June)								
Sole maize	14.44	232	100	47.2	7.71	124	100	
Intercropped maize	6.65	219	94	50.5	3.81	126	101	
C.V.(%)		12.4		7.9		14.8		
S.E.		13.4		2.0		8.2		
F. Test:								
Time of planting maize		***		**		***		
Cropping System		N.S.		N.S.		N.S.		
Interaction		N.S.		N.S.		N.S.		
L.S.D.(P=0.05)		40		6.0		24		

Figure 28 : Effect of time of planting maize on the tillering of intercropped plant sugar cane at 2 sites.

Top : Bamboos

Bottom : Redit

Maize was planted at

8 weeks before (X)

4 weeks before (□)

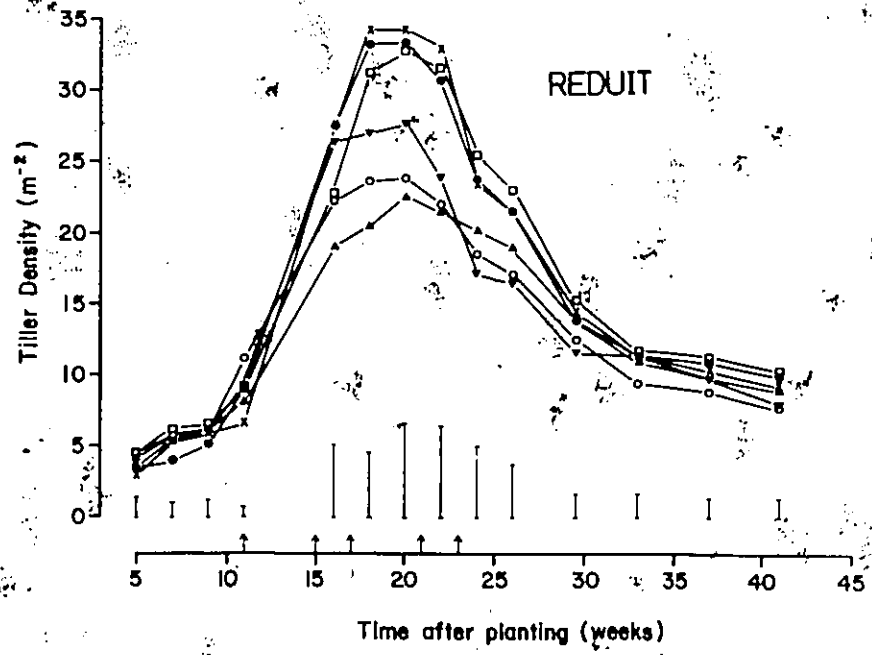
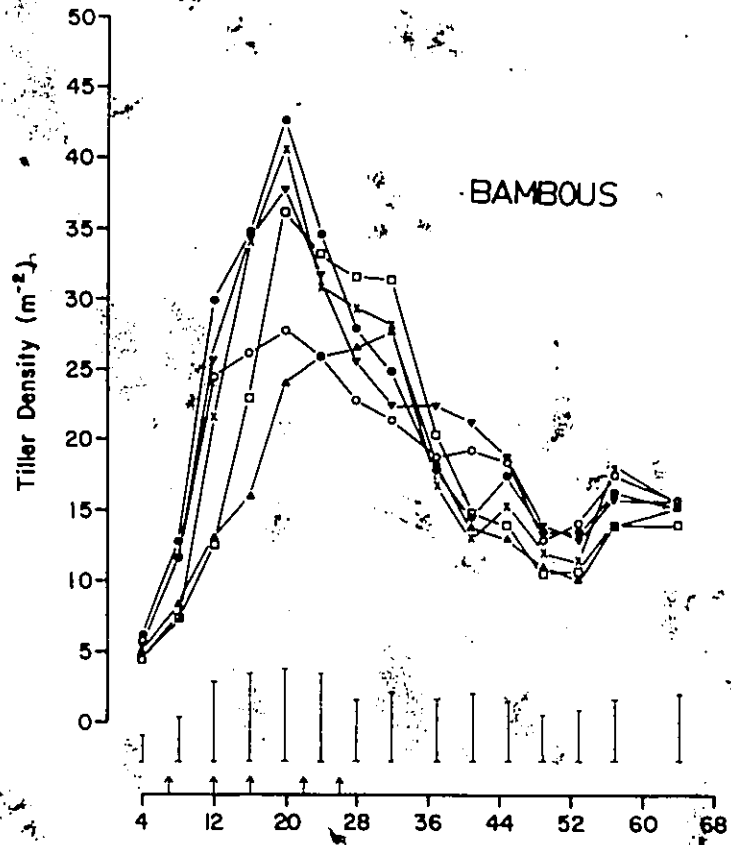
same time (Δ)

4 weeks after (O)

8 weeks after (▽) sole cane (●)

Arrows denote in chronological order when the maize was harvested.

Vertical bars are LSD(P=0.05).



effort to save the crop but yield was nevertheless low and very variable. Results were therefore not conclusive. There were no significant effects of maize on cane responses (table 27).

At Reduit, on the other hand, maize did affect the cane responses significantly, except unit stalk weight and sugar content (table 28). Of particular importance is the finding that the sugar yield was significantly reduced by maize planted at 8 weeks after cane but not at the other times. There was also small non-significant reductions, especially on millable cane and in cane stalk yield, with maize planted at 4 weeks after cane. Thus the results show that delaying of maize plantation was of no value in minimizing the deleterious effect of maize on cane; on the contrary, the practice was more harmful.

3.4 Spatial relations and productivity

3.4.1 Intercropping with plant sugar cane

3.4.1.1 Maize responses.

The actual maize grain yields were much higher at Pamplémousses and Union Park in the second season (August plantation) than at Bambous and Reduit in the first season (March plantation) (table 29). Conversely, yields of intercropped maize relative to sole maize were higher in the first than in the second season. For instance, the grain

Table 27: Yield and yield components of plant sugar cane intercropped with maize at Bamboos as influenced by time of planting maize.

Treatment	Millable cane	Unit stalk weight	Cane stalk yield	Sugar content	Sugar yield
	(m ⁻²)	(kg)	(t.ha ⁻¹)	(Pol% Cane)	(t.ha ⁻¹)
Sole cane	9.3	0.84	76.0	15.77	9.4
Cane+ maize at 8 weeks before	9.4	0.75	70.1	15.27	8.4
Cane+ maize at 4 weeks before	9.5	0.84	75.3	14.97	8.8
Cane+ maize at same time.	9.1	0.84	72.9	14.87	8.4
Cane+ maize 4 weeks after.	9.6	0.76	71.1	15.23	8.5
Cane+ maize 8 weeks after.	10.7	0.82	68.4	15.13	8.1
C.V.(%)	14.7	11.6	19.2	3.5	19.7
S.E.	0.81	0.05	7.9	0.31	0.97
F. Test:	N.S.	N.S.	N.S.	N.S.	N.S.
L.S.D.(P=0.05)	2.41	0.15	23.3	0.90	2.9

Table 28: Yield and yield components of plant sugar cane intercropped with maize at Redit as influenced by time of planting maize.

Treatment	Millable cane	Unit stalk weight	Cane stalk yield	Sugar content	Sugar yield
	(m ⁻²)	(kg)	(t.ha ⁻¹)	(Pol% Cane)	(t.ha ⁻¹)
Sole cane	9.51	1.33	126.6	11.57	10.92
Cane+ maize 8 weeks before	9.14	1.29	118.5	10.90	9.48
Cane+ maize 4 weeks before	9.87	1.21	119.0	11.43	10.02
Cane+ maize at same time.	9.09	1.36	124.0	10.63	9.65
Cane+ maize 4 weeks after.	8.15	1.32	107.6	11.90	9.59
Cane+ maize 8 weeks after.	6.77	1.43	97.7	11.37	8.09
C.V.(%)	6.5	6.8	10.3	7.7	11.2
S.E.	0.33	0.05	6.9	0.50	0.63
F. Test:	***	N.S.	*	N.S.	*
L.S.D. (P=0.05)	1.04	0.18	21.6	1.58	1.96

yields per plant of maize at 33 per cent in uniformly-spaced cane were 44 and 43 per cent higher than those of sole maize at Redit and Bambous, respectively whereas at Pamplémousses and Union Park, the increases were only 14 and 4 per cent, respectively. Except at Union Park where plant stands were irregular, grain yields per plant of intercropped maize decreased as maize density increased. At two sites, Pamplémousses and Redit, yield per plant of intercropped maize at 100 per cent was significantly less than that of sole maize. At the other 2 sites, there were no significant ($P=0.05$) differences.

The effect of planting pattern on relative yield per plant of intercropped maize was dependent on maize density. At the density of 33 per cent, there were no significant differences in planting patterns at the 3 sites where the comparison was possible. Likewise, at the density of 67 per cent, there were no significant effects of planting pattern at Bambous and Union Park, but there were significant differences at Pamplémousses and Redit; at both sites, the yields per plant were higher in uniformly-spaced cane than in differentially-spaced cane.

3.4.1.2 Cane responses

Peak tiller density was reached earlier in the second than in the first season (figures 29 and 30). Intercropping reduced tiller numbers for periods that varied from site to site. At each site, the magnitude and duration of tiller inhibition were dependent on maize density and planting pat-

Table 29: Grain yield of maize intercropped with plant sugar cane at 4 sites as influenced by maize density and planting pattern.

Treatment	Grain Yield at 12% m.c.							
	Redit		Bambous		Union Park		Pamplermousses	
	(t.ha ⁻¹)	(g.plant ⁻¹)	(t.ha ⁻¹)	(g.plant ⁻¹)	(t.ha ⁻¹)	(g.plant ⁻¹)	(t.ha ⁻¹)	(g.plant ⁻¹)
<u>Cane at 1.6m</u>								
Cane +33% maize	1.70	82	2.07	114	2.21	119	3.15	158
Cane +67% maize	3.17	77	3.72	105	3.98	119	6.28	155
<u>Cane at 2.25/0.95m</u>								
Cane +33% maize	-	-	2.18	119	1.96	113	3.04	151
Cane +67% maize	2.52	61	3.69	101	4.05	111	5.40	135
Cane +100% maize	2.78	45	4.72	87	5.69*	113	6.34	105
Sole maize(100%)	3.48	57	4.75	80	7.18	114	8.37	136
C.V.(%)	11.7	8.4	15.3	8.4	9.4	9.0	7.4	5.0
S.E.	0.16	2.7	0.31	4.9	0.20	5.2	0.20	3.6
LSD (P=0.05)	0.49	8.3	0.98	16	0.59	16	0.61	11

* Poor stand at harvest because recruited plants did not develop.

tern. As maize density increased, tiller density decreased, so that in all trials the 100 per cent maize had the most adverse effect on tiller density. At this density, maize inhibited tiller formation completely in the first season whereas in the second season, it was retarded but not completely inhibited. There was also an interaction of maize density with planting pattern. For instance, the adverse effect of 33 per cent maize was more pronounced on uniformly than on differentially-spaced cane. In all trials, tiller formation resumed or accelerated after the removal of maize. In the first season, the peak tiller densities eventually achieved by the intercropped cane were quite large, and in several treatments, as large as in the sole cane. In the second season, on the other hand, the peaks achieved by the intercropped cane were much less than those of sole cane.

Intercropping also reduced cane stalk height. Notwithstanding some minor variations from site to site, two broad effects were recognized. In general, cane stalk heights decreased as maize density increased although the differences were not always significant at $P=0.05$ (figures 31 and 32). With few exceptions, there was little evidence of a change in relative stalk height with time; the difference observed at the beginning of the elongation phase tended to remain unchanged until very late in the season when, on account of flowering, the sole cane stopped elongating first and the intercropped cane caught up.

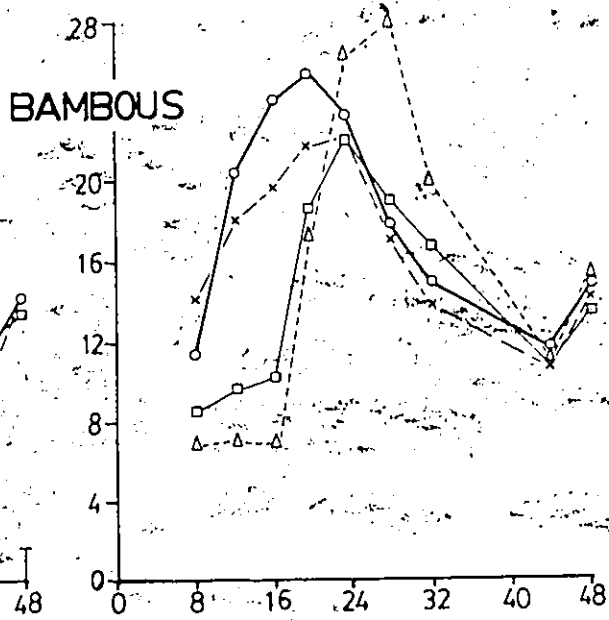
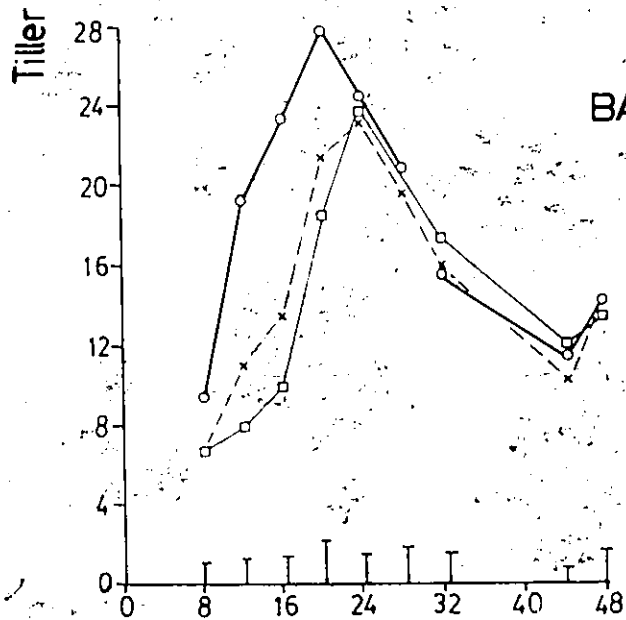
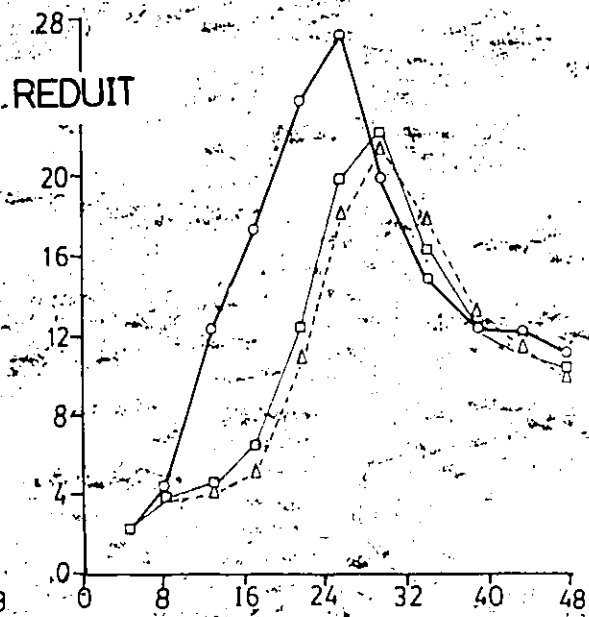
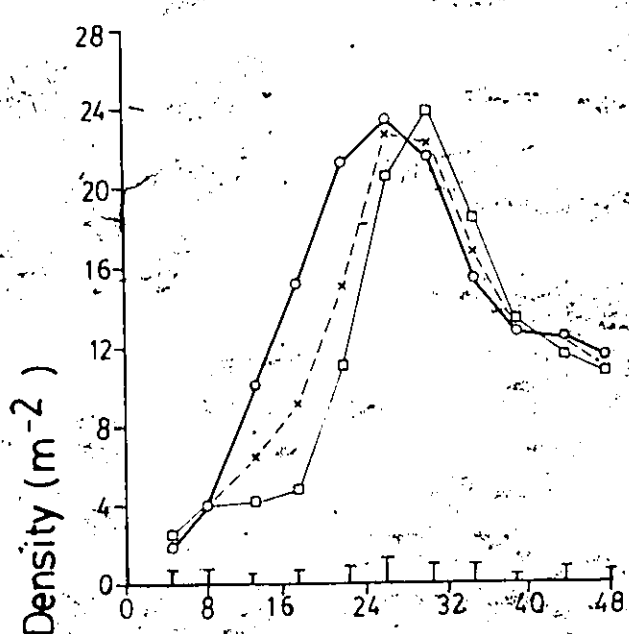
Figure 29 : Effect of maize density and planting pattern on the tillering of intercropped plant sugar cane in the first season at 2 sites.

The sites were : Reduit (top); Bambous (bottom)

Left : Cane planted in rows uniformly spaced at 1.6m.

Right : Cane planted in paired rows spaced alternately at 2.25 and 0.95m.

The densities of intercropped maize were 33% (X), 67% (□) and 100% (Δ) of sole maize (62500 plants/hectare). Bold line is for sole cane (O). Vertical bars are LSD (P=0.05) and are identical for the two patterns of planting cane.



Time after planting (weeks)

Figure 30 : Effect of maize density and planting pattern on the tillering of intercropped plant sugar cane in the second season at 2 sites.

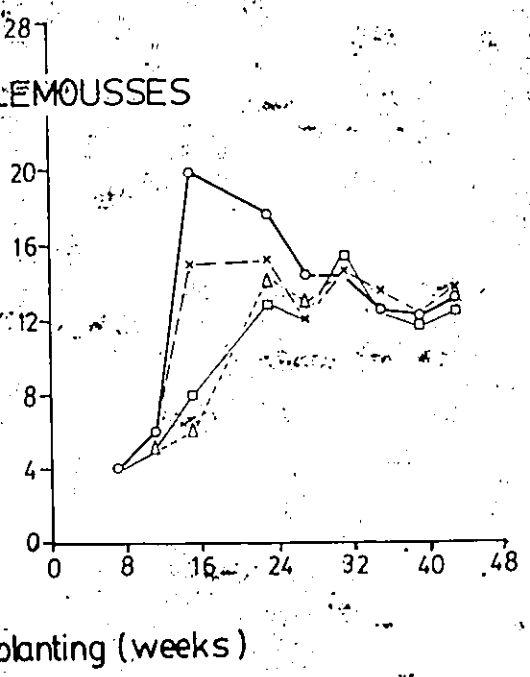
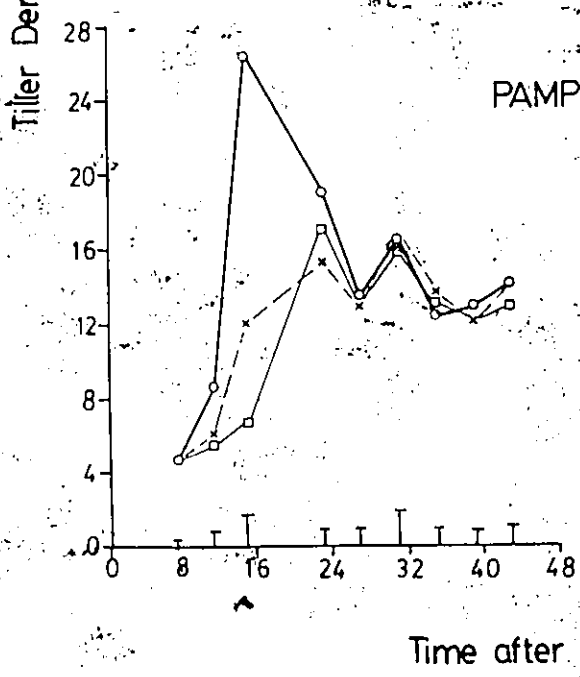
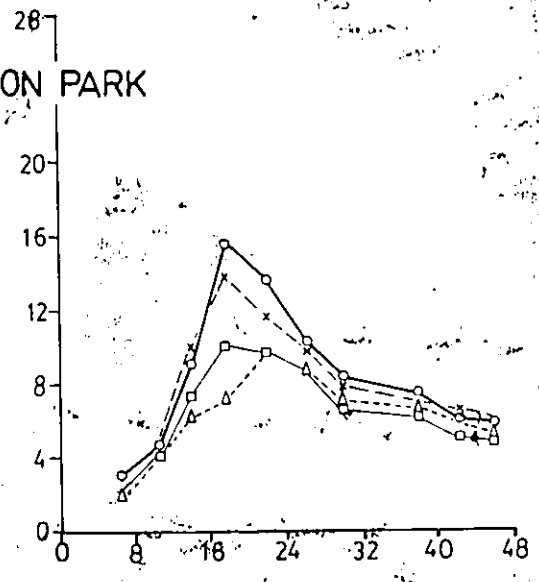
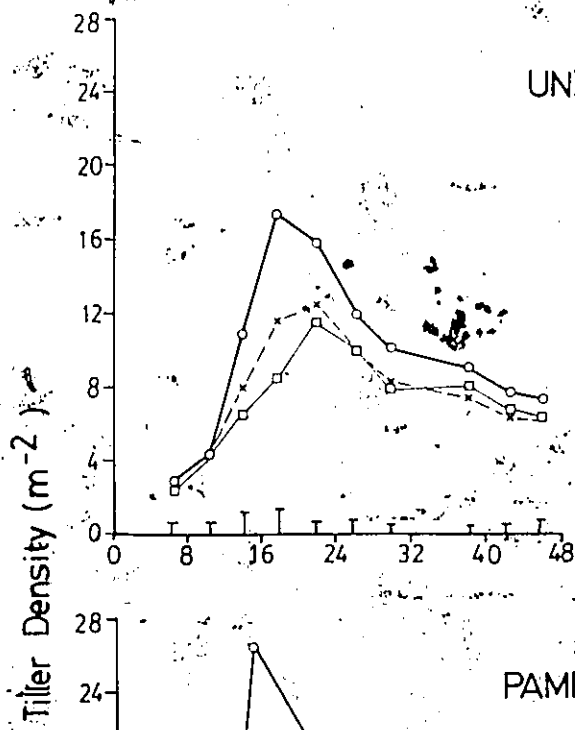
The sites were : Union Park (top) and Pamplémousses (bottom).

Left : Cane planted in rows uniformly-spaced at 1.6m.

Right : Cane planted in paired rows alternately at 2.25 and 0.95m.

The densities of intercropped maize were 33% (X), 67% (□) and 100% (△) of sole maize (62500 plants/hectare). Bold line is sole cane (○).

Vertical bars are LSD(P=0.05) and are identical for the two patterns of planting cane.



Time after planting (weeks)

Figure 31: Effect of maize density and planting pattern on the elongation of stalks of intercropped plant sugar cane in the first season at 2 sites.

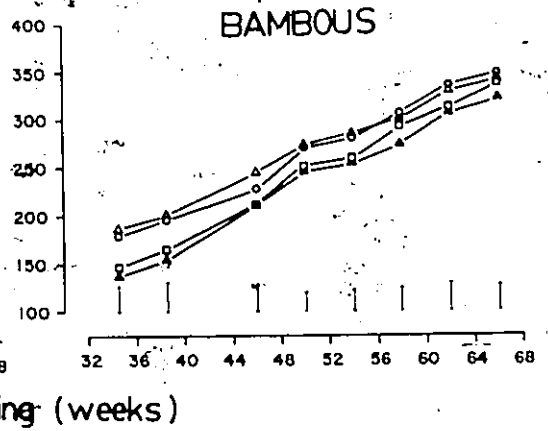
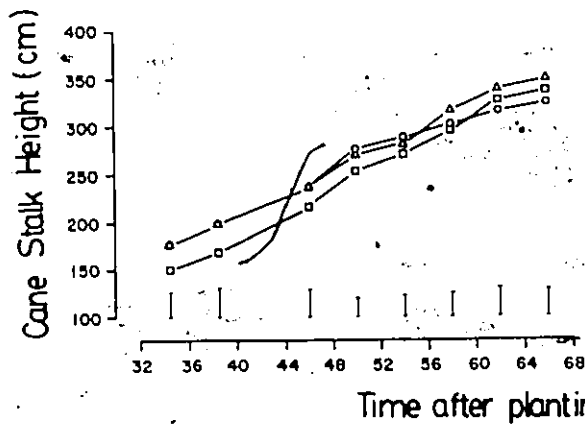
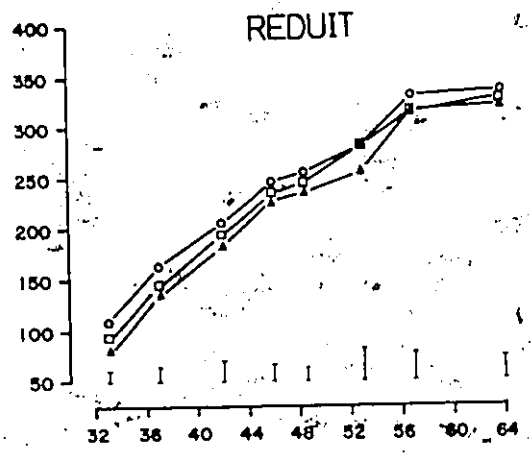
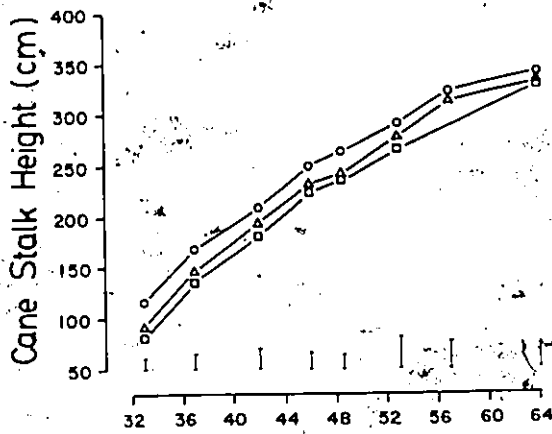
The sites were : Reduit (top) and Bambous (bottom).

Left : Cane planted in rows uniformly spaced at 1.6m.

Right : Cane planted in paired rows alternately at 2.25 and 0.95m.

The densities of intercropped maize were : 33% (Δ), 67% (\square) and 100% (\blacktriangle) of sole maize (62,500 plants/hectare). The sole cane is (\circ).

Vertical bars are LSD ($P=0.05$).



Time after planting (weeks)

Figure 32 : Effect of maize density and planting pattern on the elongation of stalks of intercropped plant sugar cane in the second season at 2 sites.

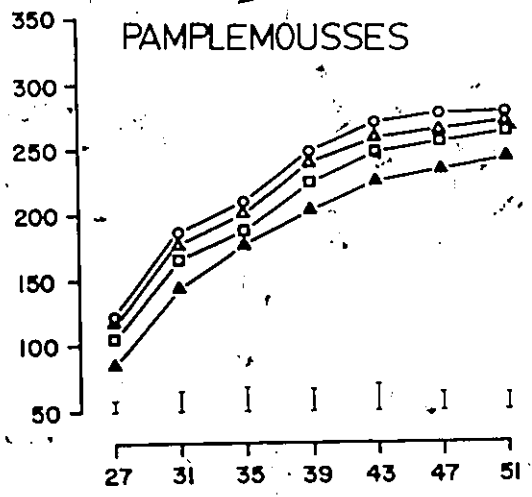
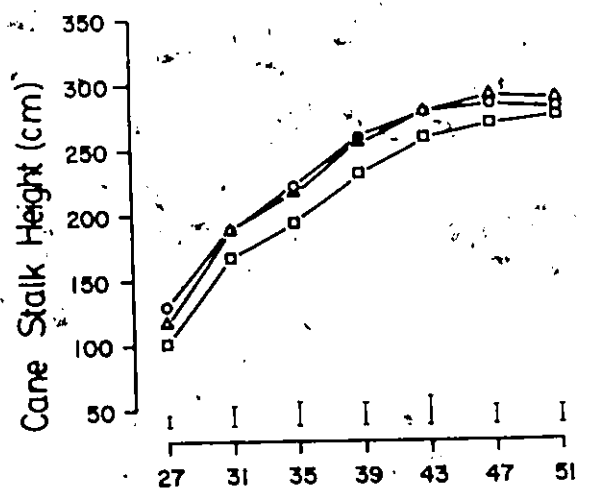
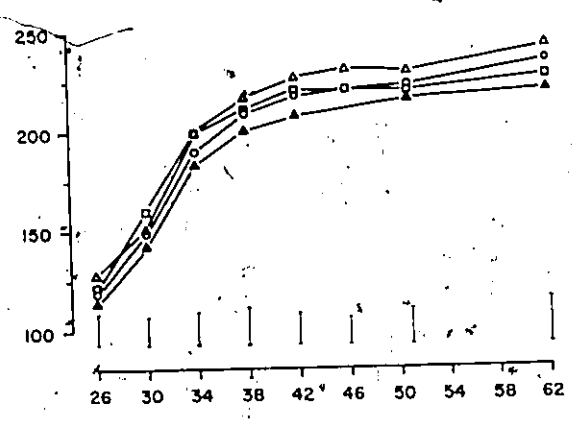
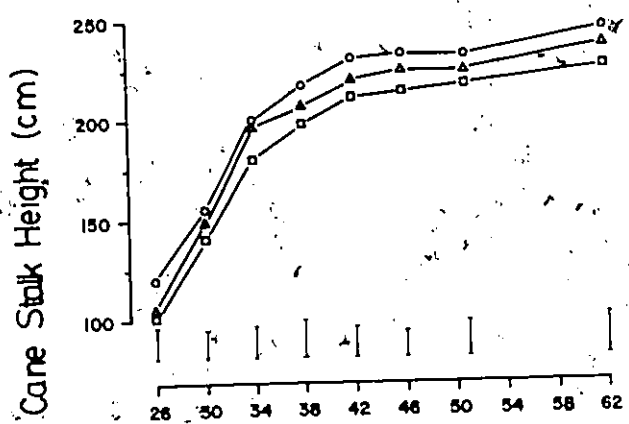
The sites were Union Park (top) and Pamplémousses (bottom).

Left : Cane planted in rows uniformly spaced at 1.6m.

Right : Cane planted in paired rows alternately at 2.25 and 0.95m.

The densities of intercropped maize were 33% (Δ), 67% (\square) and 100% (\blacktriangle) of sole maize (62,500 plants/hectare). The sole cane is (\circ).

Vertical bars are LSD(P=0.05).



Time after planting (weeks)

In the 4 trials, intercropping treatments had no significant effects on two of the components of sugar, namely, unit stalk weight and sucrose content (tables 30, 31, 32 and 33), except at Pamplémousses where there were small inconsistent differences in unit stalk weight. Millable cane, on the contrary, was reduced by intercropping with maize in 2 of the 4 trials. At Reduit and Union Park, intercropping reduced the number of millable canes significantly but at Bambous and Pamplémousses, differences were not significant at $P=0.05$, although at Bambous there was a trend for intercropping to reduce the number of millable canes.

In 2 of the 4 sites, Reduit and Union Park, cane stalk yield was lower in differentially-spaced sole cane than in uniformly-spaced sole cane, indicating that differential spacing was inferior in itself. At Reduit and Union Park, intercropping reduced stalk yield significantly. At Reduit, the adverse effect increased with maize density (table 30). At Union Park, this was also the case in differentially-spaced cane but not in uniformly spaced cane (table 32). At Bambous (table 31) and Pamplémousses (table 33), there were no overall significant differences between treatments but only a trend for the stalk yield of cane intercropped with 100 per cent maize to be lower.

Differences in sugar yields paralleled those of cane stalk yields. For example, differential cane spacing per se led to lower sugar yields at Reduit and Union Park. At all

Table 30: Effect of maize density and planting pattern on yield and yield components of intercropped plant sugar cane at Reduit.

Treatment	Millable cane	Unit stalk weight	Cane stalk yield	Sucrose content	Sugar yield
	m ⁻²	kg	t.ha ⁻¹	Pol. % Cane	t.ha ⁻¹
<u>Cane at 1.6m</u>					
Sole cane	11.96	1.22	145	12.90	14.2
Cane +33% maize	10.76	1.26	135	12.58	12.8
Cane +67% maize	10.23	1.15	118	11.90	10.5
<u>Cane at 2.25/0.95m</u>					
Sole cane	11.33	1.16	130	12.10	11.8
Cane +67% maize	11.03	1.09	120	12.00	10.8
Cane +100% maize	10.34	1.10	114	12.25	10.5
C.V.(%)	5.8	10.5	9.1	5.0	12.5
S.E.	0.32	0.06	5.8	0.31	0.74
LSD (P=0.05)	0.96	0.18	17	0.93	2.2

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Table 31: Effect of maize density and planting pattern on yield and yield components of intercropped plant sugar cane at Bambous.

Treatment	Millable cane	Unit stalk weight	Cane stalk yield	Sucrose content	Sugar yield
	m ⁻²	kg	t.ha ⁻¹	Rel. % cane	t.ha ⁻¹
<u>Cane at 1.6m</u>					
Sole Cane	11.29	1.64	170	12.90	16.5
Cane +33% maize	9.63	1.60	162	12.63	15.4
Cane +67% maize	10.33	1.68	162	12.33	15.0
<u>Cane at 2.25/0.95m</u>					
Sole cane	10.31	1.52	179	11.93	16.2
Cane +33% maize	10.31	1.57	182	11.77	15.9
Cane +67% maize	10.65	1.40	166	11.73	14.3
Cane +100% maize	10.75	1.63	144	12.27	13.3
C.V.(%)	7.4	7.3	15.2	6.4	13.3
S.E.	0.44	0.07	14.6	0.45	1.2
LSD (P=0.05)	1.38	0.20	45	1.39	3.6

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Table 32: Effect of maize density and planting pattern on yield and yield components of intercropped plant sugar cane at Union Park

Treatment	Millable cane	Unit stalk weight	Cane stalk yield	Sucrose content	Sugar yield
	m ⁻²	kg	t.ha ⁻¹	Pol. % cane	t.ha ⁻¹
<u>Cane at 1.6m</u>					
Sole cane	7.41	1.28	86.4	14.85	9.99
Cane +33% maize	5.86	1.38	70.7	15.00	8.27
Cane +67% maize	5.96	1.31	72.5	14.45	8.14
<u>Cane at 2.25/0.95m</u>					
Sole cane	(5.79)	1.24	(61.7)	14.58	(6.94)
Cane +33% maize	6.25	1.30	66.1	14.80	7.62
Cane +67% maize	4.70	1.28	60.1	14.63	6.77
Cane +100% maize	5.20	1.18	54.4	14.58	6.15
C.V.(%)	9.2	11.0	13.4	3.7	13.1
S.E.	0.27	0.07	4.5	0.27	0.50
LSD (P=0.05)	0.80	0.21	13.4	0.81	1.49

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Table 33: Effect of maize density and planting pattern on yield and yield components of intercropped plant sugar cane at Pamplermousses.

Treatment	Millable cane	Unit stalk weight	Cane stalk yield	Sucrose content	Sugar yield
	m ⁻²	kg	t.ha ⁻¹	Pol. % cane	t.ha ⁻¹
<u>Cane at 1.6m</u>					
Sole Cane	13.1	1.38	126	11.98	11.35
Cane +33% maize	12.9	1.46	124	11.50	10.72
Cane +67% maize	13.6	1.42	125	11.10	10.28
<u>Cane at 2.25/0.95m</u>					
Sole cane	12.1	1.31	126	11.58	10.85
Cane +33% maize	12.6	1.31	125	11.50	10.57
Cane +67% maize	12.4	1.46	120	11.63	10.31
Cane +100% maize	11.6	1.27	108	10.98	8.67
C.V.(%)	9.1	6.2	13.8	9.0	14.3
S.E.	0.57	0.04	8.4	0.52	0.74
LSD (P=0.05)	1.2	0.13	25	1.55	2.23

4 sites, there was a trend for sugar yield to decrease as maize density increased; with differentially-spaced cane, there was an inverse linear relationship of sugar yield with maize density (figure 33) although at Bambous and at Pamplemousses, the differences were not significant. With uniformly-spaced cane, there were significant differences at Redit and Union Park. At 3 sites and at the 2 maize densities, there was no evidence for an effect of maize planting pattern on sugar yield. At the 4th site, Union Park, maize at 67 per cent led to a lower sugar yield in differentially-spaced cane than in uniformly-spaced cane (table 32).

3.4.1.3 Joint responses

Bivariate analysis of variance of the yields of maize and of sugar from the mixed plots showed that:

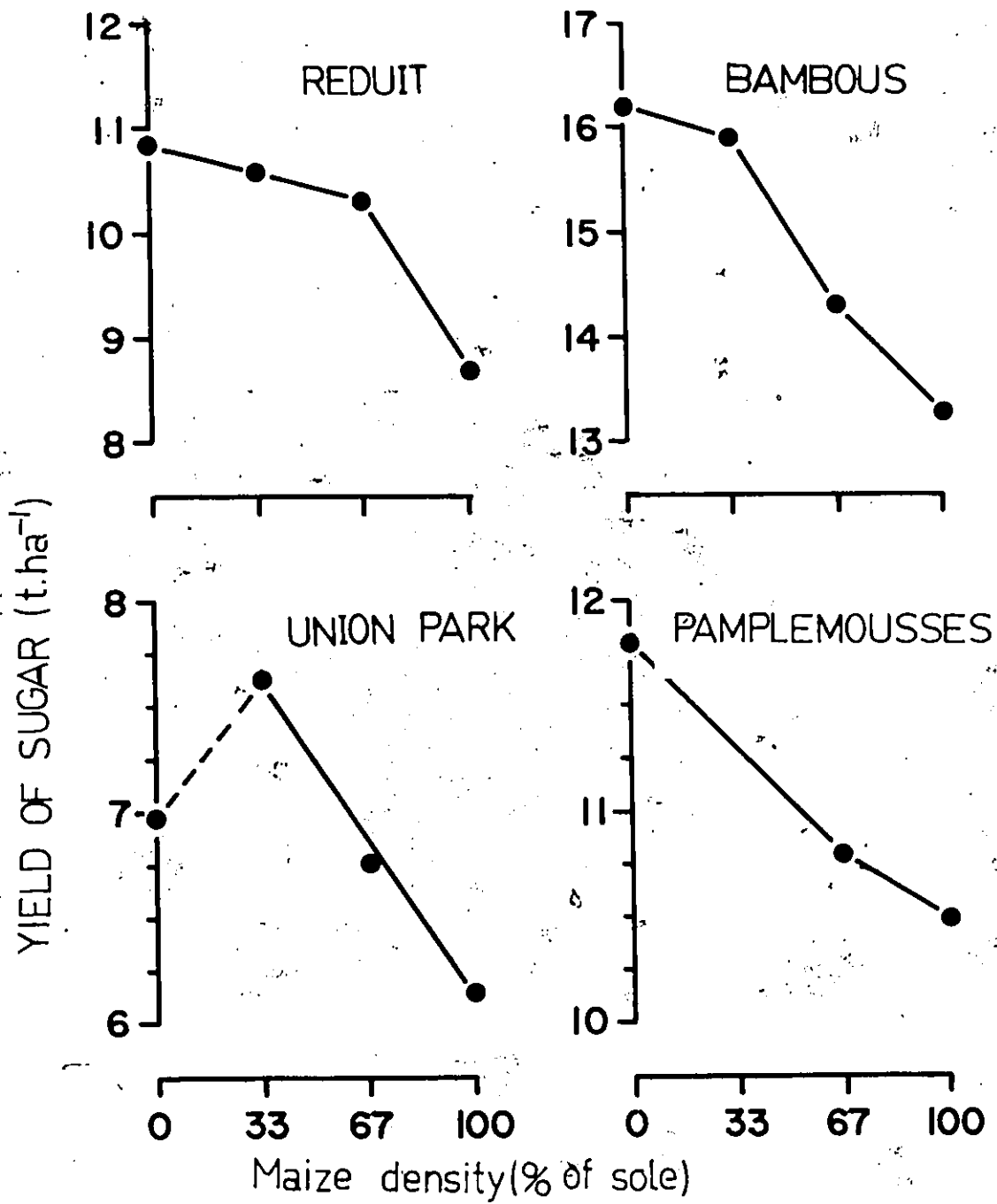
1. Data from the 4 trials should not be combined for analysis because the residual correlations at the 4 sites were very different: being equal to -0.04, -0.33, +0.46 and +0.81 at Redit, Pamplemousses, Union Park and Bambous, respectively. This means that at Redit, the experimental errors in maize and sugar yields were independent whereas at Bambous, 66 per cent of the variation in experimental error in sugar yields was attributable to variations in experimental errors in maize yields.

Figure 33 : Effect of maize density on the sugar yield of intercropped plant sugar cane grown in paired rows at 4 sites in 2 seasons.

First season (top) : Redit and Bambois.

Second season (bottom) : Union Park and Pamplémousses.

The densities of intercropped maize were 20,800(33%), 41,600(67%) and 62,500(100%) plants per hectare. The optimum density of sole maize was 62,500 plants per hectare.



2. There were significant differences in joint maize and sugar yields at all sites (figures 34 and 35). In these diagrams, the 5 per cent significance zones are bounded by circles.

3. As shown particularly clearly at Bambous (figure 34) and at Union Park (figure 35), but also at Pamplémousses (figure 35), the mixtures could be segregated into 3 groups on the basis essentially of maize yields. The groups corresponded to maize density planted, thus confirming the non-significance of planting patterns.

Maize and sugar yields were also combined by means of Land Equivalent Ratios. The sole maize yields used to standardize the mixture yields were estimated on the basis of two assumptions. Firstly, it should be possible to grow 3 maize crops sequentially in the time taken by the plant cane to come to maturity. Secondly, at a given site, the yields of the 3 maize crops would not necessarily be identical but they could be estimated from the yield of the first crop and from known seasonal effects. Factors used to convert the yield of the first maize crop into an overall yield for the entire cycle were 3.5, 3.15, 2.65 and 2.5 for Redit, Bambous, Union Park and Pamplémousses, respectively.

At Redit, the LER's were not different from unity indicating that there was no gain or loss from mixing the crops (table 34). Likewise, at Union Park, there was no yield advantage with the mixtures in uniformly-spaced cane.

Figure 34 : Joint sugar and maize grain yields of mixtures of plant sugar cane and maize in the first season at 2 sites.

The sites were : Redit (top) and Bambous (bottom). Adjustment for correlation between the yields of the 2 crops was by means of skewed axes. Circles represent confidence zones at $P=0.05$. Treatments were :

2 : Cane at 1.6m + maize at 33% (20,800 plants/hectare).

3 : Cane at 1.6m + maize at 67% (41,600 plants/hectare).

5 : Cane at 2.25/0.95m + maize at 33% (20,800 plants/hectare).

6 : Cane at 2.25/0.95m + maize at 67% (41,600 plants/hectare).

7 : Cane at 2.25/0.95m + maize at 100% (62,500 plants/hectare).

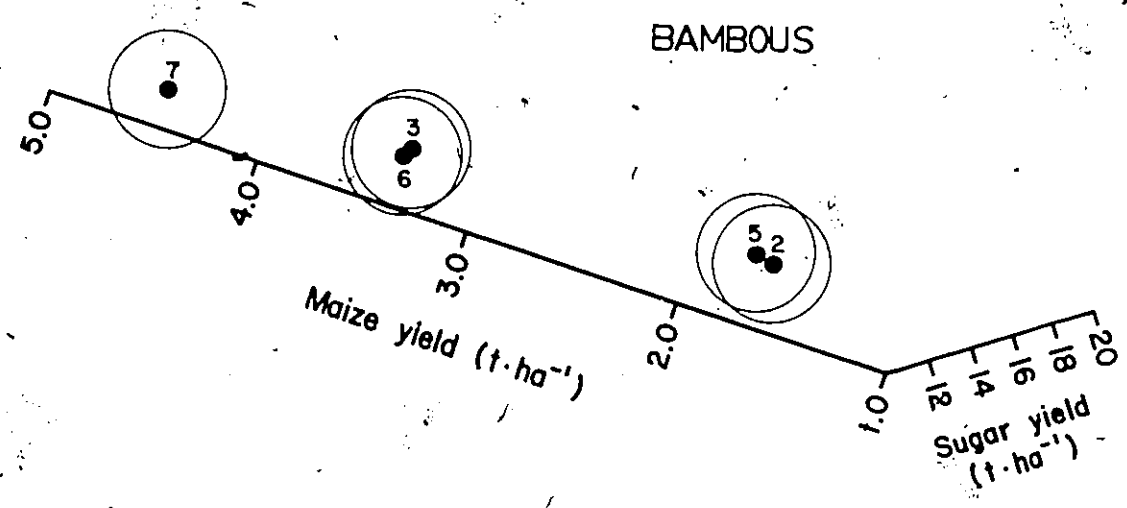
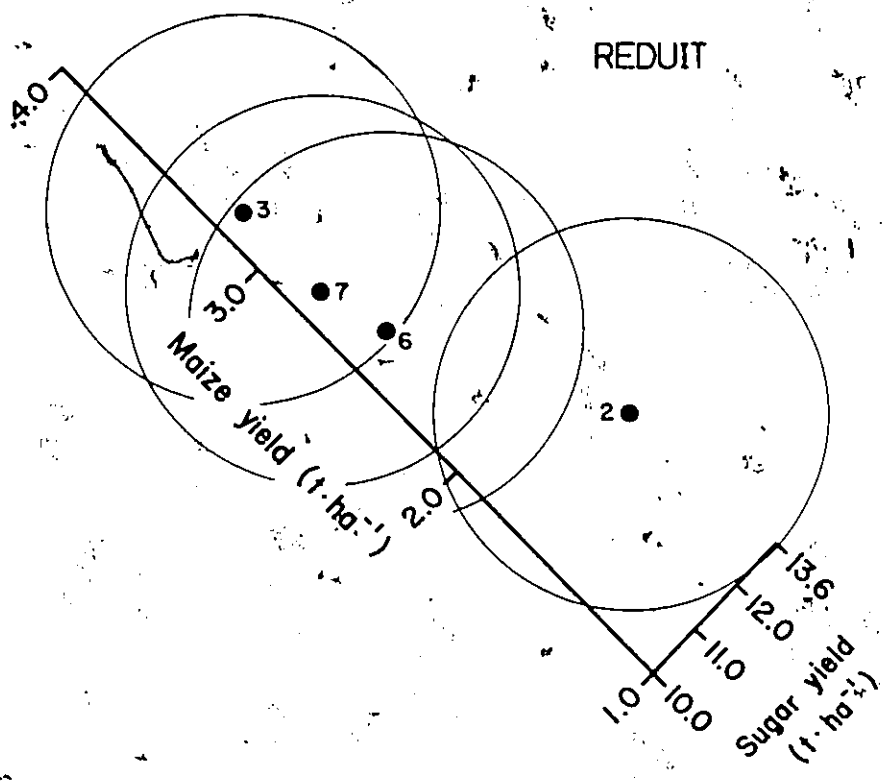


Figure 35 : Joint sugar and maize grain yields of mixtures of plant sugar cane and maize in the second season at 2 sites.

The sites were : Union Park (top) and Pamplémousses (bottom).

Adjustment for correlations between the yields of the 2 crops was by means of skewed axes. Circles represent confidence zones at $P=0.05$. Treatments were :

2 : Cane at 1.6m + maize at 33% (20,800 plants/hectare).

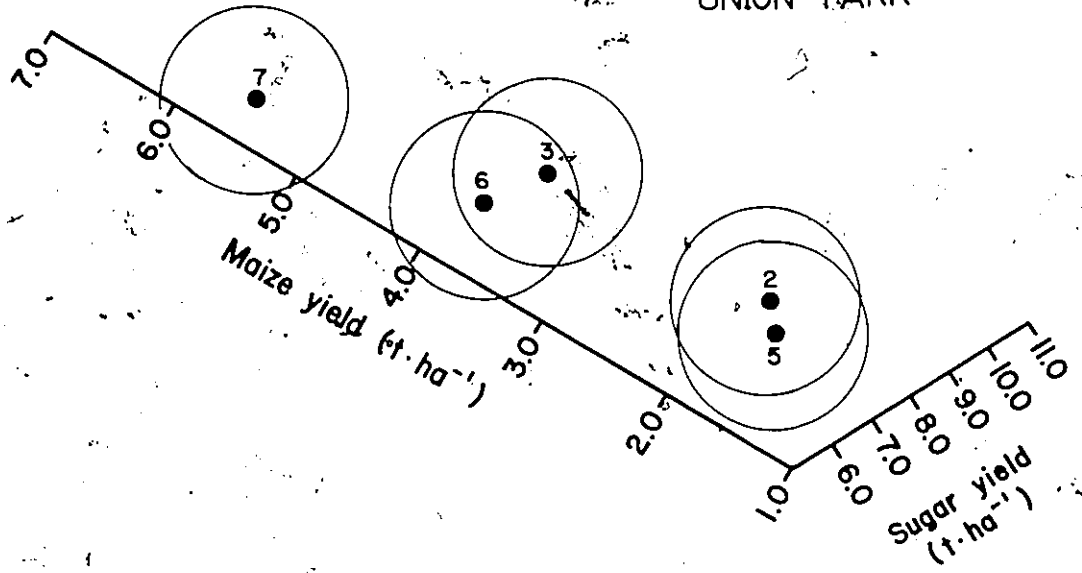
3 : Cane at 1.6m + maize at 67% (41,600 plants/hectare).

5 : Cane at 2.25/0.95m + maize at 33% (20,800 plants/hectare).

6 : Cane at 2.25/0.95m + maize at 67% (41,600 plants/hectare).

7 : Cane at 2.25/0.95m + maize at 100% (62,500 plants/hectare).

UNION PARK



PAMPLEMOUSSES

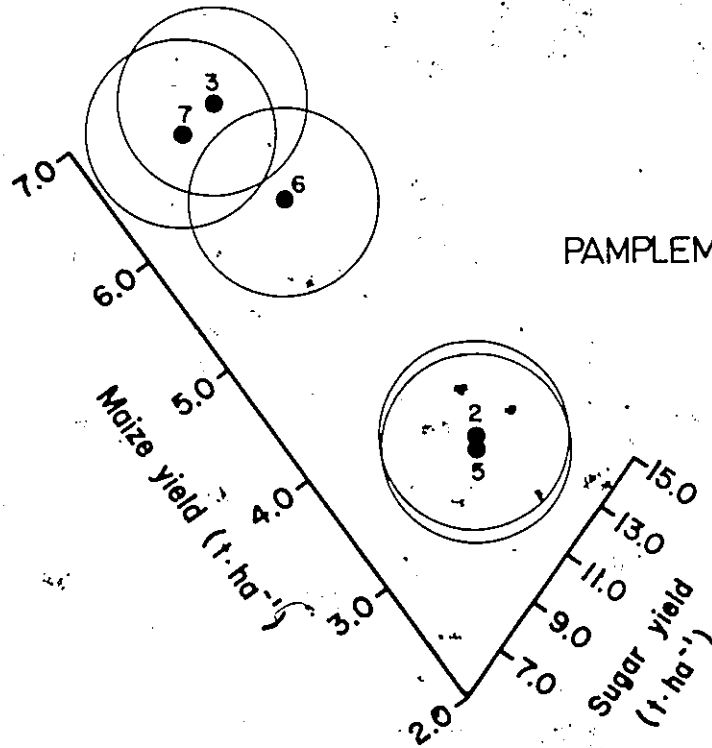


Table 34: Land equivalent ratio of mixtures of plant. sugar cane and maize at 4 sites as influenced by maize density and planting pattern.

Treatment	L E R			
	Redit	Bambous	Union Park	Pamplemousses
<u>Cane at 1.6m</u>				
Cane+33% Maize	1.04	1.07	0.95	1.10
Cane+67% Maize	1.00	1.15	1.02	1.21
<u>Cane at 2.25/0.95m</u>				
Cane+33% Maize		1.11	0.86	1.08
Cane+67% Maize	0.97	1.11	0.89	1.17
Cane+100% Maize	0.96	1.12	0.92	1.07
C.V. (%)	11.5	13.7	13.6	11.0
S.E. *	0.057	0.088	0.063	0.062
95% Confidence Interval(\pm)**	0.13	0.20	0.14	0.13

* Pooled

** Approximate because LER assumed to be approximately normally distributed.

whereas in differentially-spaced cane, there was a slight yield loss from mixing the crops. At Bambous and Pamplémousses, all the mixtures gave LER's larger than 1.00 but the differences were not significant ($P=0.05$) except in the case of the mixtures of 67 per cent maize at Pamplémousses. The effect of maize density on total LER's was generally quite small except at Pamplémousses where LER's increased as maize density was increased from 33 to 67 per cent. At the other sites, the increases in the maize component of LER with an increase in maize density was offset by concurrent reductions in the sugar component of LER. There was also little difference in the effect of planting pattern on LER except at Union Park where the mixtures in differentially-spaced cane were probably inferior in LER to those in uniformly-spaced cane.

3.4.2 Intercropping with ratoon sugar cane

3.4.2.1 Maize responses

At Belle Rive and Union Park, the yields per plant of intercropped maize were at par with those of sole maize when the density was 33 or 67 per cent. At a density of 100 per cent, on the contrary, the yield per plant of intercropped maize was significantly ($P=0.05$) lower than that of sole maize at Reduit but not at Union Park, possibly because of a lower maize stand at Union Park (table 35).

At Pamplémousses, in contrast to the other 2 sites, there was a trend for the intercropped maize at 33 and 67 per cent to produce higher yields than expected on the basis of density planted. But only in the case of the mixture of 33 per cent maize in differentially-spaced cane was the difference significant at $P=0.05$.

At none of the sites was the effect of planting pattern on yield per plant of intercropped maize significant at the 5 per cent level.

3.4.2.2 Cane responses

As was observed on plant sugar cane (figures 29 and 30), intercropping led to reductions in cane tiller density; the general trend was for tiller density to decrease as maize density was increased (figure 35). At a given density, the maize had slightly less adverse effect on differentially-spaced cane than on uniformly-spaced cane, but the differences were seldom significant at $P=0.05$.

At none of the sites was the effect of intercropping on sucrose content significant at $P=0.05$. (tables 36, 37 and 38). Similarly, intercropping with maize had no significant ($P=0.05$) effect on unit stalk weight except for one extreme treatment at Pamplémousses (table 38).

In contrast to the above-mentioned yield components, the number of millable canes was significantly ($P=0.05$) lower in the intercropped plots at the 3 sites. The general trend was for the number of millable canes to decrease as

Table 35: Grain yield of maize intercropped with ratoon sugar cane at 3 sites influenced by maize density and planting Pattern.

Treatment	Grain Yield at 12% m.c.					
	Belle Rive		Union Park		Pamplerohouses	
	(t.ha ⁻¹)	(g.plant ⁻¹)	(t.ha ⁻¹)	(g.plant ⁻¹)	(t.ha ⁻¹)	(g.plant ⁻¹)
Cane at 1.6m						
Cane +33% Maize	2.06	100	1.56	95	2.87	136
Cane +67% Maize	3.89	104	2.67	92	6.11	141
Cane at 2.25/0.95m						
Cane +33% Maize	1.96	100	1.38	98	3.26	153
Cane +67% Maize	3.52	96	2.93	90	5.51	130
Cane +100% Maize	4.40	87	3.80	89	6.91	113
Sole Maize(100%)	6.01	101	5.07	92	7.80	123
C.V.(%)	6.6	7.8	18.7	10.3	17.6	10.2
S.E.	0.12	3.8	0.27	4.7	0.48	6.8
LSD (P=0.05)	0.37	11	0.84	15	1.44	20

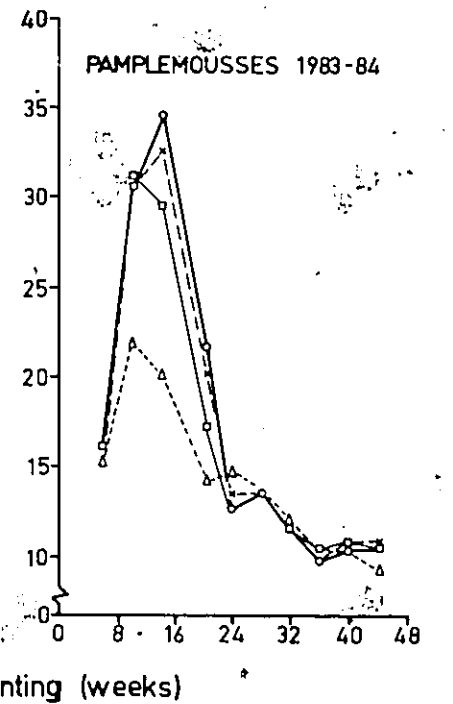
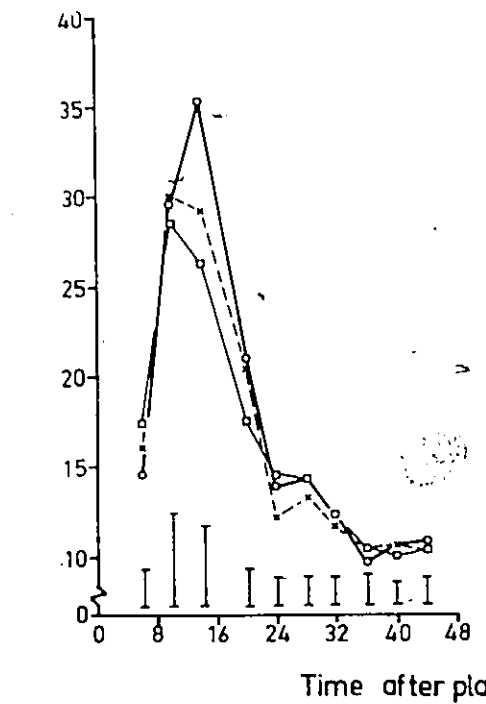
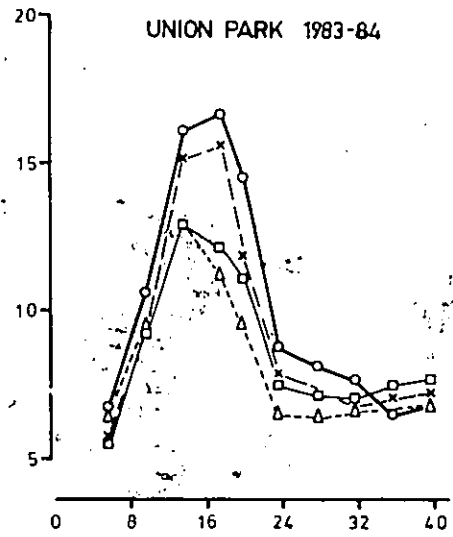
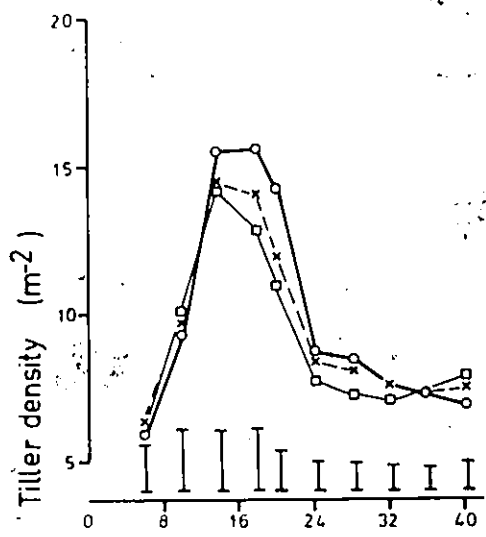
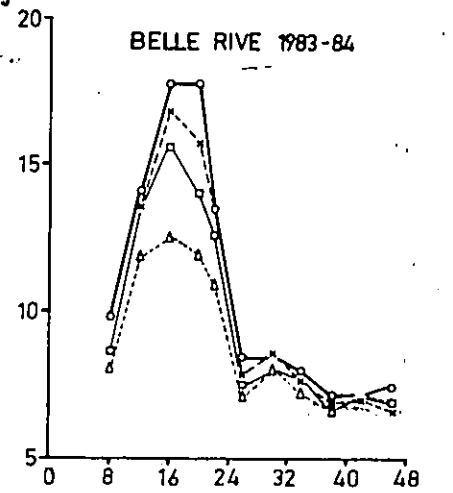
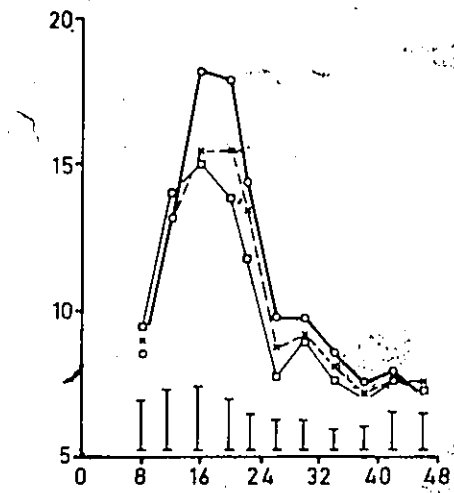
Figure 36 : Effect of maize density and planting pattern on the tillering of intercropped ratoon sugar cane at 3 sites.

The sites were : Belle Rive (top), Union Park (centre) and Pamplemousses (bottom).

Left : Cane planted in rows uniformly-spaced at 1.6m.

Right : Cane planted in paired rows alternately at 2.25/0.95m.

The densities of intercropped maize were 33%(X), 67%(□) and 100%(△) of sole maize (62,500 plants/hectare). Bold line is for sole cane (○). Vertical bars are LSD(P=0.05) and are identical for the two patterns of planting cane.



Time after planting (weeks)

Table 36: Effect of maize density and planting pattern on yield and yield components of intercropped first ratoon cane at Belle Rive.

Treatment	Millable cane	Unit stalk weight	Cane stalk yield	Sucrose content	Sugar yield
	m ⁻²	kg	t.ha ⁻¹	Pol. % Cane	t.ha ⁻¹
<u>Cane at 1.6m</u>					
Sole cane	6.15	0.94	56.1	13.95	6.03
Cane +33% maize	5.33	1.07	58.4	13.98	6.30
Cane +67% maize	5.31	0.95	46.1	14.50	5.18
<u>Cane at 2.25/0.95m</u>					
Sole cane	5.65	0.95	54.2	14.05	5.88
Cane +33% maize	5.44	0.96	51.4	13.50	5.32
Cane +67% maize	4.97	0.99	47.1	13.80	5.00
Cane +100% maize	4.14	0.95	39.7	13.65	4.18
C.V.(%)	9.1	6.3	9.8	3.5	10.9
S.E.	0.25	0.03	2.5	0.24	0.29
LSD (P=0.05)	0.76	0.09	7.3	0.71	0.87

Table 37: Effect of maize density and planting pattern, on yield and yield components of intercropped first ratoon cane at Union Park.

Treatment	Millable cane	Unit stalk weight	Cane stalk yield	Sucrose content	Sugar yield
	m ⁻²	kg	t.ha ⁻¹	Pol. % cane	t.ha ⁻¹
<u>Cane at 1.6m</u>					
Sole cane	6.41	1.00	64.1	16.98	8.63
Cane +33% maize	5.74	1.07	61.1	16.60	8.01
Cane +67% maize	5.67	1.00	56.9	16.73	7.56
<u>Cane at 2.25/0.95m</u>					
Sole cane	6.14	0.97	59.9	17.05	8.13
Cane +33% maize	5.19	1.01	59.0	16.63	7.78
Cane +67% maize	5.20	0.92	50.2	15.88	6.32
Cane +100% maize	4.91	1.02	49.4	16.10	6.21
C.V.(%)	15.3	8.2	15.1	3.3	14.6
S.E.	0.43	0.04	4.3	0.27	0.55
LSD (P=0.05)	1.28	0.12	13.0	0.80	1.64

Table 38: Effect of maize density and planting pattern on yield and yield components of intercropped second ratoon cane at Pamplémousses.

Treatment	Millable cane	Unit stalk weight	Cane stalk yield	Sucrose content	Sugar yield
	m ⁻²	kg	t.ha ⁻¹	Pol. % cane	t.ha ⁻¹
<u>Cane at 1.6m</u>					
Sole cane	9.28	0.90	81.1	15.73	9.98
Cane +33% maize	8.50	1.02	84.4	15.48	10.28
Cane +67% maize	8.34	0.94	75.0	15.38	8.97
<u>Cane at 2.25/0.95m</u>					
Sole cane	9.47	0.95	84.1	16.03	10.60
Cane +33% maize	9.11	0.93	81.8	16.05	10.35
Cane +67% maize	8.30	0.91	71.9	16.08	9.09
Cane +100% maize	8.34	0.76	61.0	15.63	7.46
C.V.(%)	7.4	8.5	10.4	4.5	10.7
S.E.	0.32	0.04	4.0	0.36	0.51
LSD (P=0.05)	0.96	0.12	11.9	1.06	1.52

maize density was increased, but the differences were not always significant $P=0.05$. At the 3 sites, there were no significant effects ($P=0.05$) of planting pattern on number of millable canes.

At a density of 33 per cent, maize did not significantly ($P=0.05$) affect the stalk yield of intercropped cane at the 3 sites.

As maize density was increased to 67 per cent, however, a reduction in stalk yield was observed at the 3 sites, the difference from the stalk yield of sole cane being significant ($P=0.05$) only at Belle Rive. The further increase in maize density to 100 per cent led to significant ($P=0.05$) and substantial reductions in stalk yields at the 3 sites.

The effect of intercropping on the yield of sugar was dependent on 3 factors: maize density, planting pattern and site. At a density of 33 per cent, the effect of intercropping on sugar yield was not significant at any of the sites, but the effect of planting pattern was significant at Reduit where yield of sugar was significantly higher ($P=0.05$) in uniformly-spaced cane compared to differentially-spaced cane. At a density of 67 per cent, the effect of intercropping on sugar yield was significant ($P=0.05$) at Union Park and Belle Rive but not at Pamplémousses. The effect of planting pattern was not significant ($P=0.05$) at any of the sites although there was a difference at Union Park in favour of planting in uniformly-spaced cane. Intercropping of

cane with maize at 100 per cent reduced sugar yield, the effect being highly significant ($P=0.01$) at all 3 sites.

3.4.2.3 Joint responses.

Bivariate analysis of variance of maize and sugar yields of the mixtures showed that the residual correlations between the yields were -0.18, -0.02 and +0.09 at Belle Rive, Union Park and Pamplemousses, respectively. This means that the background relationships between the yields of the two crops were negligible. Bivariate analysis of variance therefore did not reveal anything not already shown by the separate analyses of maize and of sugar yields.

Land Equivalent Ratios were calculated on the basis of two assumptions :-

1. Two maize crops could be grown sequentially as sole crops in the time taken by the ratoon cane to mature:

2. The two sole crops would not have the same yields because of seasonal differences.

The factors used to convert the first maize crop yield into the overall yield for the entire cycle were 1.5, 1.65, and 1.5 for Belle Rive, Union Park and Pamplemousses, respectively.

On the assumptions that LER's are approximately normally distributed and that the variance of the LER's of different treatments are homogeneous, standard errors and confidence intervals have been calculated for each of the mean LER's. The mean of each LER was then compared to unity. The

results indicate that many of the LER's were significantly larger than 1.00, indicating yield advantages. Among the LER's there were probably no significant differences (table 39).

Table 39: Land Equivalent Ratio of mixtures of ratoon sugar cane and maize at 3 sites as influenced by maize density and planting pattern.

Treatment	Land Equivalent Ratio		
	Belle Rive	Union Park ^o	Pamplemousses
<u>Cane at 1.6m</u>			
Cane +33% maize	1.27	1.11	1.28
Cane +67% maize	1.29	1.19	1.42
<u>Cane at 2.25/0.95m</u>			
Cane +33% maize	1.10	1.07	1.32
Cane +67% maize	1.22	1.08	1.38
Cane +100% maize	1.18	1.17	1.34
C.V.(%)	8.7	10.5	10.1
S.E. *	0.053	0.059	0.068
95 % Confidence interval (\pm)	± 0.12	± 0.13	± 0.15

* Approximate

Chapter IV DISCUSSION

4.1 Competitive relations

One major problem with the interpretation of studies on intercropping of sugar cane with maize arises from the large difference in the durations of the crop cycles of the component crops. In the 2 trials under review, (trials 1 & 2) plant cane matured and was harvested after 16-17 months whereas maize matured after 4-4 1/2 months. It is evidently not meaningful to compare the yield of a mature 4 month maize to either that of a young 4 month cane or of a mature 17 month cane. For this reason, relative competitive abilities and productivities were calculated for a range of situations offering each component crop variable competitive opportunities. The three situations defined in section 3.1.3 are hypothetical, and were chosen to cover a range of possible not necessarily, probable, situations.

4.1.1 Competition and yield advantage

The indices of competition, Aggressivity and Competitive Ratio measure the competitive ability of one component crop relative to the other. In situation 1, the competitive ability of maize was calculated from its yield at 4

months whereas that of cane was assessed from its yield at 16 months. The cane yield therefore reflects not only interaction with the maize but also possible compensation after the maize harvest. This partly explains why, in situation 1, the maize was sometimes rated as the less competitive of the 2 species (table 15) in spite of the fact that it over-yielded in all mixtures (tables 7 and 8). In such cases, over-yielding was relatively higher in the cane, possibly because of compensation. Nevertheless, the 2 indices were consistent one with the other and also with the observed responses of the component crops.

As an index of yield advantage, Relative Crowding Coefficient (RCC) has been shown previously to suffer from one drawback: the magnitude of the values are not meaningful (Willey, 1979a). The data (table 16) confirm this drawback. For instance, the largest LER (1.36) was 2.5 times the smallest LER (0.55), whereas the largest RCC value (4.63) was 38.6 times the smallest value (0.12).

In the calculation of ATER, it is implicitly assumed that the average yield per day given by the sole maize in the trial can be obtained over the entire plant cane crop cycle. This over-estimates the sole crop yield used to standardize the mixture yields and hence under-estimates the yield advantages of the mixtures. The errors could be corrected by first including in the crop durations the inevitable delays between one harvest and the next replantation, and also by adjusting the yields for seasonal variations.

LER, as defined by Willey and Osiru (1972), suffers from the main drawback that the differences in crop durations tend to inflate the yield advantages. As has been observed by many authors in many instances (Fisher, 1977a; Wade and Sanchez, 1984), the yield advantages of many mixtures often disappear or are reduced when differences in crop durations are taken into account. The results of this study (Table 16) support this observation: advantages were obtained in situation 1, but not in situations 2 and 3.

In order to allow for the differences in crop durations, it is necessary to estimate the sole maize yield that can realistically be expected over the entire cane crop cycle. In this trial, it was possible to plant 3 sole maize crops sequentially; their actual yields were therefore added. In situations where this is not possible, it would be necessary to estimate seasonal effects.

Except in the highly unrealistic situation 1, yield advantages were not found in the 2 trials. This result is not so surprising in view of the numerous studies in which it was shown that yield advantages did not occur in non-additive replacement series mixtures. Donald (1963) has reviewed 70 non-additive mixtures of pasture crops and has concluded that in most cases the yield per plant of one species was greater, and that of the other species in the mixture lower than those of the sole crops. According to Trenbath (1976), such results occur when there is at least

one factor limiting growth. The results of the two trials show that in the most realistic situation (situation 3), the yield per plant of cane in the mixture was larger and that of maize, lower than their sole crop yields.

The absence of yield advantage in non-additive mixtures of maize and sugar cane should not be taken to imply that all mixtures of these 2 species have no practical value. It does suggest however, that in many of the additive mixtures of sugar cane in which yield advantages have been found (See Literature Review), the advantages may have been the result of the increased plant population densities rather than of mixing the species per se, as has also been shown to be the case with other crop mixtures (Fisher, 1977b).

4.1.2 Crop responses

The first maize crop over-yielded in all mixtures indicating that the maize was more competitive than the young cane. Moreover, the higher maize yields were not the result of a reallocation of dry matter since harvest indices were unchanged (tables 7 and 8). They were the result of higher production of biomass and grain. This implies that the maize either made use of extra resources or that it used the available resources more efficiently. There is some evidence to suggest that intercropping may lead to a change in the efficiency of resource use and even more evidence on the availability of extra resources (See Literature Review). In the case of maize and sugar cane, if it is assumed that the

maize made use of extra resources, was this because the resources were over-abundant or was this because the maize out-competed the cane for its share of a limiting resource? Many authors have hypothesized that sugar cane is successfully intercropped with fast growing crops by virtue of its slow early growth. They thereby imply that early in the season, some resources are present in excess of the requirements of sugar cane. It has indeed been confirmed that sugar cane grows slowly for the first few months, much slower than maize (e.g. Allison and Haslam, 1982) and that canopy closure does not occur until 3-6 months (eg. Loh and Tseng, 1956). Hence, sugar cane may be expected not to make major demands on growth resources early in the season.

The results obtained in these trials do not lend much support to the view that maize may be complementary to sugar cane. The fact that the growth of the young cane, as shown by tiller density data, was suppressed, indicates that the maize competed with the cane for growth resources. In the first phase of growth, corresponding to cane germination and early tiller formation, the maize had no effect on the cane. This conforms to other reports that show that germination of cane is not affected by intercropping with other crops (Bhoj and Kapoor, 1970; Gawhane and Patil, 1976). It stands to reason that the maize did not compete with cane until it had grown to a certain size. Adverse effects of maize became detectable from the 16th week at Belle Rive and probably

well before the 12th week at Bambous, and the effects persisted for about 2 months. Differences in cane tiller density arising from intercropping disappeared by about the 25th week. Indeed after this time, there were more tillers per plant in the intercropped plots than in the sole crops indicating that the cane was more competitive than the maize. This inference is supported by the poor yields of the second and the failure of the third maize crops. The cause of the poor growth of the second and of the failure of the third maize crops may obviously be found in the fact that they were planted in increasingly older canes. The maize seeds germinated but the seedlings soon became spindly and etiolated, no doubt as a result of shading by the cane, and yields were poor. The fact that in the trials, the crops were fertilized separately and water was probably not limiting either at Belle Rive in the super-humid zone or at Bambous under irrigation suggests that competition may have been for light.

The change in competitive ability of cane with time has several important implications. Firstly it draws attention to what has been termed 'rattrapage' whereby initial adverse effects may be overcome. Secondly, it suggests that under certain circumstances, the outcome of competition between sugar cane and its intercrops may be determined not so much by what happens when the crops are actually in association as what happens after the intercrops are harvested.

Thirdly, the results emphasize that time itself is a factor in competition; the time dimension is an important determinant of cane yields, through the phenomenon of catching up or 'rattrapage'. And finally, the suggestion that maize competes with sugar cane for light points to the importance of spatial relations, in particular, relative size, plant height and leaf display.

It may therefore be concluded, on the basis of crop responses and of competition indices, that in the non-additive replacement series the maize competed with the young sugar cane. However, the cane caught up with time in spite of subsequent maize plantations. This led to the cane producing higher yields than expected on the basis of density planted. Nevertheless, the higher relative yields of the intercropped cane was not adequate to compensate entirely for the reductions in cane density. Yield advantages did not occur except under an un-realistic hypothetical situation.

4.2 Resource use

4.2.1 Relative importance of above and below-ground interactions.

It was hypothesized on the basis of results from the replacement series trials (Section 4.1.3), that in these trials maize probably competed with sugar cane for light. The trial with soil partition (trial no 3) was laid out to test this hypothesis under set conditions, and the results

show conclusively that, under the conditions of the trials, maize competed with cane for light, not nutrients or water.

The finding that the partition had a relatively small effect on the maize biomass and no effect on the canopy height (table 17) may be taken to mean that in terms of competition for light, the competition potential of maize was not much reduced by the partition. The effect of maize on cane, in so far as competition for light is concerned, may therefore be assumed not to have been sub-normal. The observation that at 15 weeks the partitions had been effective in keeping the root systems separate indicates that the maize could not have competed with the cane for below-ground resources. Moreover, the finding that the partitions by themselves had no effect on cane biomass (table 18) and tillering at 15 weeks (figure 11) indicates that the partitions did not interfere with the normal growth of the cane. It may therefore be concluded that all the adverse effects of maize on cane observed at 15 weeks can be attributed to competition for above-ground resources, in all probability, light. Competition for the other above-ground resource, carbon dioxide, has not been shown to occur under field conditions, and is certainly most unlikely in the relatively open, wind-blown canopies of maize and sugar cane at the densities used in this trial.

The findings indicate that the adverse effects observed on the yield of cane at harvest were also the consequence of

competition for light by maize earlier on. After the maize was harvested, the intercropped cane was allowed to grow normally except for the presence of the soil partition. That the partition did not interfere unduly with the growth of the cane is evident; firstly, from the fact that the cane biomass at harvest was not affected by the partition (table 18); secondly, the growth of the cane, measured by stalk height (figure 12) was also not affected by the partition. If anything, the root distribution of the intercropped cane was better in the presence of the partition (table 19). Hence, the adverse effects on sugar yields were also caused by competition for light by the maize.

Although the reduction in sugar yield was essentially through millable cane and cane stalk yield, the significant effects on stalk weight and sucrose content must be underlined since they have seldom been observed. The reduction of stalk weight is consistent with the reduction in height and has been observed in other situations (Tse and Shiu, 1966; Narwal and Malik, 1981). The reduction in sucrose content, on the other hand, conflicts with a review of work in India stating that several intercrops had a slight positive effect on sucrose content (Gill, 1963), but is consistent with other observations (e.g. Mathur, 1975) of small, mostly non-significant reductions (e.g. tables 13, 14, 30-33)

The results support the hypothesis (section 4.1.2) that time is an important factor in intercropping of maize and sugar cane and throw additional light on the relevance of 'rattrapage'. At 15 weeks, maize had reduced cane biomass by about 50 per cent; by harvest time, the reduction was only approximately 16 per cent (table 18). The maximum reduction of tiller density occurred at 14 weeks and was equal to 60 per cent; by the 25th week, there was no difference as mortality occurred in the sole cane but not in the intercropped cane (figure 11). This phenomenon whereby the cane, by various means, is able to offset the effects of perturbations to its growth is known to Mauritian cane agronomists as 'rattrapage', a term that implies more than compensation. 'Rattrapage' implies that there is at first a negative influence or stress that puts a strain on the cane and retards its growth and that, with time, the negative effect disappears through enhanced cane growth or other means. For instance, it has been reported that intercropped wheat reduced tiller density by 66% at 24 weeks but that the reduction was only 38% at 38 weeks (Narwal and Behl, 1978b). Compensatory growth plays an important part in 'rattrapage'. In the replacement series trials there was strong evidence of compensation when, for instance, sugar yield per metre increased to compensate for a reduction in plant density (tables 11 and 12). There was no evidence for such compensation in the trial with soil partition.

The results show that partial 'rattrapage' took place. The fact that there was no difference in the yield of sugar between the partitioned and un-partitioned plots (table 20) suggests that the partitions had no effect on 'rattrapage'. 'Rattrapage' was not complete for reasons other than the presence of partitions.

It may therefore be concluded that under the conditions of this trial, in particular when the crops are fertilized separately and given irrigation, maize grown as one row in every interrow of plant sugar cane causes a reduction in yield of sugar through competition for light.

4.2.2. Role of nutrients

It has already been shown (section 4.2.1) that when nutrient supply is adequate, maize competes with sugar cane for light. This may not necessarily be the case when the supply of nutrients is limiting, hence the trial at Bambous to examine the role of nutrient under contrasting fertility situations (trial no. 4).

It is argued that if cane competes with maize for nutrients, the growth and yield of the intercropped maize will be less than that of sole maize and vice versa. Moreover, competition is likely to be more severe, and the detrimental effects larger, when nutrients are limiting. Conversely, competition is expected to be less and growth better if extra fertilizers are given to the weaker competitor. The addition of fertilizers has indeed been shown to improve the growth and yield of sugar cane intercropped with cotton

(Hsiung et al, 1963), of maize (Bhoj and Kapoor, 1970) and of onion, blackgram and cowpea (Venktaraman et al, 1978).

In the trial at Bambous, the NPK content of maize tissues and biomass (figures 13 and 14) were not affected by intercropping with cane under the contrasting treatments. This suggests that the maize and the cane did not compete with one another for nutrients. It suggests further that the maize did not absorb NPK from the cane rows even when excess was present. This contrasts with the reports about crops such as sweet potato that at 3 months had absorbed labelled P^{32} (Chang and Lai, 1963) and labelled P and Rb (Chang et al, 1969) applied to the cane row. There could be several explanations for the differences. For instance, the difference could result from the fact that the sweet potato was only 50 cm from the cane whereas in this trial, maize was 80 cm away. It is also possible that by 3 months the sweet potato had sent roots closer still to the cane row because it rooted at each node as it crept on the soil surface. Maize, on the other hand probably did not send roots as far as 80 cm; this was indeed shown to be the case at Belle Vue (figure 22).

On average, maize grain yield was significantly less in the intercropped plots (table 21). It can be deduced that this reduction was not, however a result of competition for nutrients, for it occurred in the unfertilized as well as in the over-fertilized maize, and also when the maize was

intercropped with unfertilized as well as over-fertilized cane.

The reductions in cane tiller density and biomass observed during the early stages of the growth of the intercropped cane are in agreement with numerous published reports (see Literature Review) and confirms previous findings (figures 6, 7, and 11). The results show that the maize did compete with the cane, but not for nutrients. This can be deduced from the observations that the adverse effect of maize was found in over-fertilized as well as unfertilized cane, and that over-fertilized maize had larger adverse effects than fertilized maize (figures 15 and 16). Neither of the observations is compatible with the idea of competition between maize and cane for nutrients. The observations can however, be reconciled with competition for light. It is argued that because it made greater vegetative growth, the over-fertilized maize competed more strongly for light and hence had a larger adverse effect on cane tiller and biomass.

Competition for light which has been shown to be operative under certain conditions (section 4.2.1) in maize-cane intercropping systems does have indirect consequences on below-ground interactions. As shown by Donald (1958), competition for light has the direct effect of reducing photosynthetic activity and the indirect effect of impairing root growth and the absorption of nutrients and water. It is

suggested that such indirect effects may account for the initial reductions in N and P contents (figures 13 and 14) of the intercropped cane. A different explanation is proposed for the difference in K content (figure 14) and also for the relatively higher NPK contents after maize harvest. It is suggested that these are the result of a dilution effect, as has previously been observed in sugar cane (Van Dillewijn, 1952; Lakshmikantham et al, 1963; Chang et al, 1969) and is probably common in plants. On the one hand, cane biomass increased with time and on the other, NPK content decreased with time and therefore, NPK content decreased with an increase in biomass. As there were large differences in biomass of the intercropped compared to sole cane, these differences could account for the observed higher NPK contents of intercropped cane, particularly of the cane intercropped with over-fertilized maize. Such dilution effects may be expected to be more marked with K because of the existence for this element of luxury consumption.

The higher NPK content of intercropped cane after maize harvest could also have arisen from absorption of residual NPK left in the maize rows. If this did occur however, it was not reflected in sugar yield and yield components. In view of the effects of drought, this possibility cannot be ruled out.

Notwithstanding the effects of drought, one unexpected result should be underlined. The stalk and sugar yields of

cane was increased slightly when the cane was intercropped with unfertilized maize and reduced slightly with over-fertilized maize (table 22). It is hypothesized that this effect arose out of an interaction between intercropping and drought. The sole cane may have suffered more from the drought because it had a higher vegetative growth at the time drought occurred. The cane intercropped with unfertilized maize had a much lower vegetative growth at the time, and so may have suffered less. The growth of the cane intercropped with over-fertilized maize, on the other hand, had been so affected that it could not catch up in the face of drought.

The results of the trial suggest therefore that the maize did not compete with the cane directly for NPK although it may have had indirect effects via competition for light. Likewise, the cane did not compete with the maize for NPK. After the maize harvest, the cane may have benefited from residual NPK applied to the maize, but this point needs clarification because of the complications arising from a possible dilution effect and also from the occurrence of severe drought. Direct tracer experiments might be a way to confirm some of these results.

The findings have profound agronomic and social implications in Mauritius. They suggest that, since the maize does not have access to NPK placed in the cane rows, land-owners renting out their sugar cane interrows for the purpose of

intercropping need not fear that maize will "steal" NPK applied to cane. On the other hand, the NPK applied to maize is not of immediate benefit to the cane although the cane may eventually make use of the residual NPK. Therefore, the fact that the maize is fertilized does not mean that the rate of fertilizer to the cane can automatically be reduced.

4.2.3 Role of water

It has been shown already (section 4.2.1) that under conditions of adequate water supply, maize competes with sugar cane for light, not water. Moreover, it was reported (section 4.2.2) that the indirect effects of competition for light are also important on underground interactions, especially under non-optimum water supply.

Results of the trial at Belle Vue on the role of water (trial no 5) show that there were differences in the biomass, harvest index and maize grain yield as a result of the water regimes (table 23), and hence that in the rainfed plots, water supply was not adequate in spite of the heavier-than-normal rainfall (figure 21). The response of the maize to intercropping was identical in the rainfed and in the irrigated plots, showing that the maize neither benefited nor suffered from the association with cane; that is, the maize grew independently of the cane. This is supported by the finding that the rooting pattern of the maize was not changed as a result of intercropping (figure 22).

Even though the maize depleted soil water faster than the cane as shown by the lower water content under the sole maize (figure 21), the maize did not appear to have had more of its share of water when associated with sugar cane. This suggests that the volume of soil exploited by the maize probably imposed a limit on water absorption and also that water movement may have been limiting in this soil.

The finding that the maize roots did not extend beyond 70 cm explains why in the previous trial at Bambous (section 4.2.2), the maize did not absorb nutrients present in large amounts in the cane row 80 cm away. It indicates that one of the conditions under which direct competition for below-ground resources is not expected to occur is when the maize rows are at least 70-80 cm away.

In contrast to the observation that intercropping had no effect on maize irrespective of water regime, the effect on cane showed a limited dependence on water regime. During the early part of the cycle, when the maize was actually present, there was no evidence of an interaction of intercropping and water regime on cane tiller density. Tiller formation ceased altogether in the intercropped cane from the 8th week to the 18th week, even under conditions of no water stress. This shows clearly that at that time, competition for water was probably not the cause of the reduction in tiller density. This adds further support to the conclusion (section 4.2.1) that competition for light is the

main cause of reductions in tiller density. Nevertheless, there was some evidence of an interaction of intercropping with water regime during the period when the maize was present. For instance, spindle elongation (figure 20) was adversely affected by intercropping in the rainfed but not in the no-stress regime, indicating the development of water stress in the former but not the latter case. Another example of a similar effect was observed with cane biomass at 16 weeks (figure 19). These observations need not, however, imply competition for water; they could result from the indirect effects of competition for light. As mentioned previously (section 4.2.2), a large decrease in aerial parts in this case, number of tillers and biomass - as a result of shading may be expected to be associated with a decrease in root growth. Indeed, there was a slight reduction in root density of the intercropped cane (figure 22). The indirect effect of competition for light is also shown by the fact that the reduction in root density was observed not only in the rainfed plots but also in the no-stress plots in which competition for water was unlikely.

Intercropping also interacted strongly with water regime after the harvest and removal of the maize i.e. after competition for light had ceased. In the irrigated plots, 'rat-trapage' in tiller density was rapid and almost complete whereas in the rainfed plots, it was slower and incomplete (figure 18). An identical differential response was found

With cane biomass (figure 19). Confirmation of the role of water in 'rattrapage' was obtained with yield data (table 24). Full cane and sugar yields were obtained from the intercropped plots under no-stress conditions but not under the 2 other water regimes. Such complete rattrapage has also been observed in South Africa after intercropping with bean had reduced cane growth in the first summer and favorable rainfall was registered in the second summer (Leclézio et al, 1985).

The results show that although maize probably did not compete with the cane for water, the intercropped cane may still have suffered from water stress through indirect effects. In spite of a large reduction in growth early in the season resulting from the association with maize, the cane was nevertheless capable of giving a full yield so long as the water supply was not limiting.

4.2.4 Role of light

Attention has been drawn by many authors (e.g Van Dillewijn, 1952; Thompson, 1978) to the fact that the sugar cane canopy does not close in plant cane until about 4 to 6 months. From this, it may be deduced that for several months much light is not intercepted and would be wasted were it not for intercrops. Whereas in certain circumstances the intercrops are indeed complementary to the cane in light use, in other circumstances the intercrops compete with the cane for light by shading the cane. Although several researchers have observed that the cane was shaded by

intercrop (eg. Tang, 1963; Tse and Shiue, 1966), no evidence has been published to date. In particular, the magnitude and time course of shading had not been measured.

Results of the trial at Reduit (trial no 6) confirmed that maize casts much shade on the cane (figure 23). The time course of shading can be related to the growth in size, particularly in height of maize. No effect was measurable until the maize was about 30cm, at 4 weeks. Thereafter shading increased with time until the maize tasselled and growth in height stopped at about the 8th week. The extent of shading did not increase any further after 8 weeks. However, shading was more severe at the higher than at the lower maize density, no doubt because of the denser canopy of the former. These results suggest that shading may be more severe with taller, later-maturing, leafier maize varieties.

Shading of intercropped cane was associated with a retardation or, in the case of intercropping with maize at the highest density, the complete stoppage of tiller formation (figure 25). The relationship between tiller density and cumulative transmittance was approximately linear (figure 37). Tiller formation was sensitive to small changes in transmittance, and stopped altogether when cumulative mean-transmittance dropped to about 65 per cent. However, the relationship was different for the 3 maize densities, that is, the lines in figure 37 do not overlap. This may be the result of a dependence on time; for instance, by the time

(14 weeks), the cumulative mean transmittance dropped to 80 per cent in the cane intercropped with maize at the lowest density, tiller formation had progressed to 15 tillers per square metre, whereas with maize at the highest density, at 6 weeks when cumulative mean transmittance dropped to 80 per cent, tiller density was less than 5 tillers per square metre.

The dependence on time was also evident in the plots of relative tiller density against relative cumulative mean transmittance (figure 37). The relationship was biphasic indicating that 2 processes may be affected. At first an increase in shading led to only a slight decrease in tiller number - the germination phase - Later, the reduction was more pronounced - the peak tillering phase.

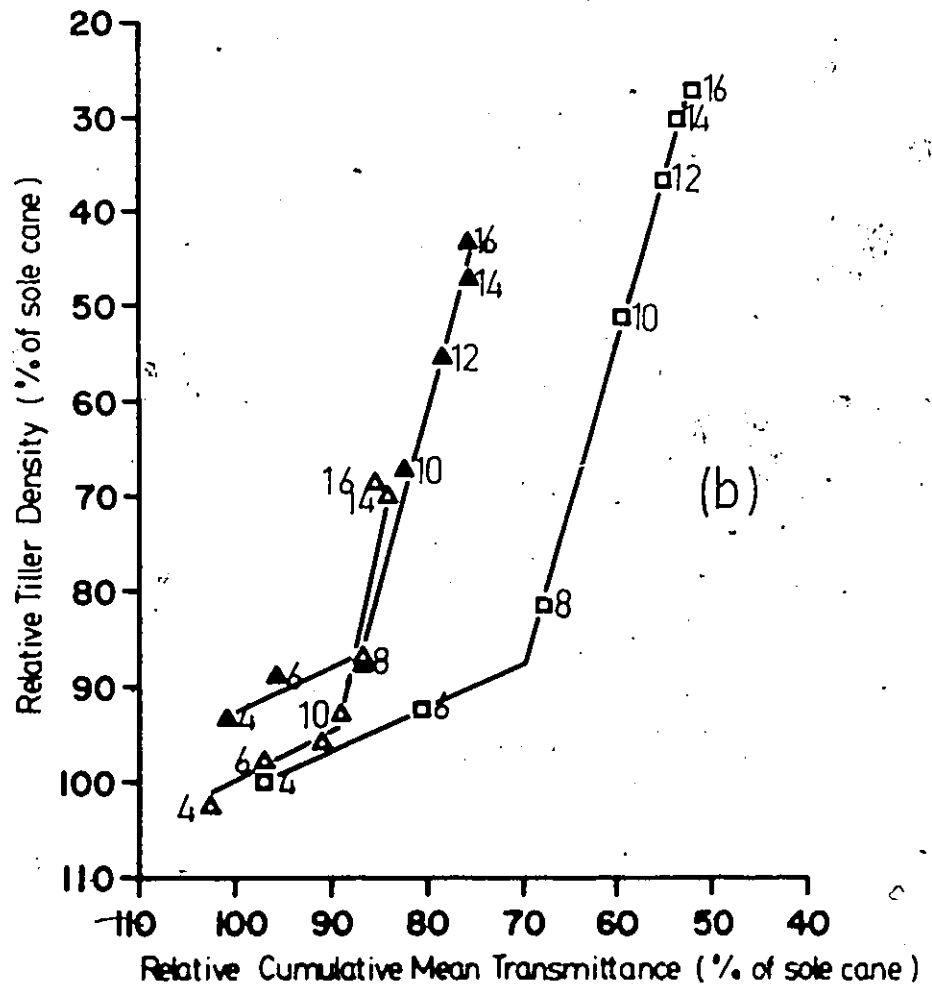
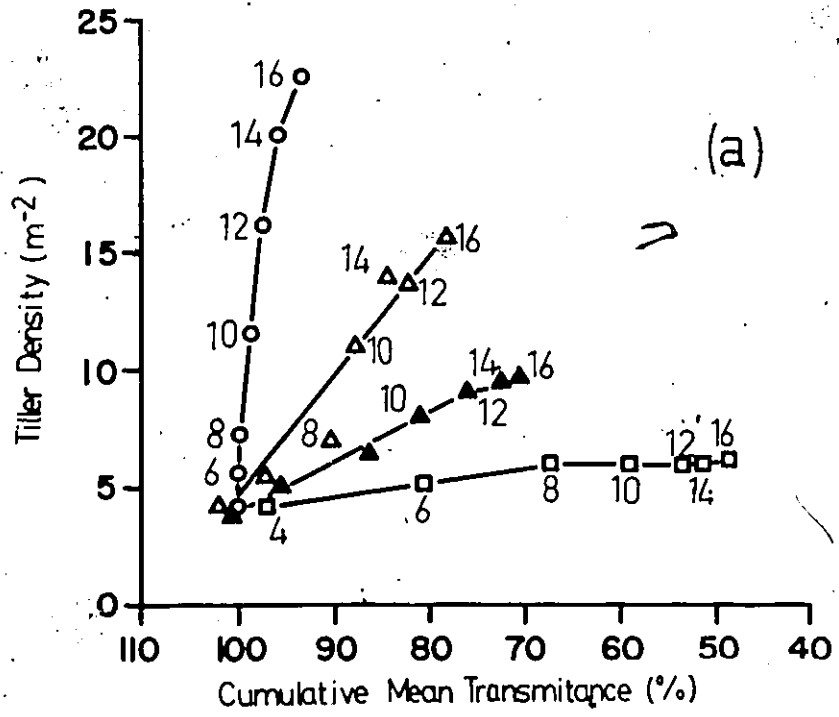
As found in previous trials (figures 11 and 18), the tillering ability of even the very shaded cane was not impaired. This was shown by the rapid resumption of tiller formation after maize harvest. However, complete rattrapage in tiller number did not occur until the 32nd week, by which time the cane has started to elongate. It is postulated that it is at about this time when elongation starts, that the number of millable cane is determined. When elongation starts, the taller the cane stalks the better their competitive ability, and therefore their chance of survival. From figure 27, it may perhaps be predicted that in the sole cane, all stalks greater than 65 cm would become millable

Figure 37 : The relationships between a) cumulative mean transmittance and tiller density and b) relative cumulative mean transmittance and relative tiller density of plant sugar cane as affected by intercropping with maize.

Treatments were :

- : Sole cane.
- △ : Cane + maize at 15,625 plants/hectare.
- ▲ : Cane + maize at 31,250 plants/hectare.
- : Cane + maize at 62,500 plants/hectare.

The labels are the times after planting cane in weeks.



cane. If such a prediction was also applicable to the intercropped cane, the effect of maize on millable cane observed previously could then be explained through an effect on tiller. Even though rattrapage in tiller number is complete, it sometimes occurs too late, at a time when elongation has started. As a result of competition between the tillers, the first formed and taller ones out-compete the late-formed and smaller tillers. These die. The phenomenon is identical to what occurs in stands of sole cropped sugar cane. As elongation starts, the taller stalks shade out the smaller ones (Van Dillewijn, 1952). If the tillers are formed later, after maize harvest, for instance, their likelihood of survival is even less.

4.3 Temporal relations

The need to study competitive relations in time as well as in space has previously been emphasized (Willey, 1979b). The role of time in intercropping of sugar cane has been alluded to by various authors (e.g. Kanwar, 1975; Dakshindas, 1975) when they state that early-maturing crops can successfully be intercropped with sugar cane because of its slow early growth. The practice of relay-intercropping of sugar cane with other crops e.g. cotton (Hsiung et al, 1963) is also based on manipulation of the time during which the crops interact. In the preceding sections, two critically important findings involving the time dimension have been

discussed. Firstly, maize competes with cane for light because of the faster growth, particularly in height, of the maize (sections 4.2.1 & 4.2.4). Secondly, with time, the cane catches up (sections 4.2.1 & 4.2.4).

In Mauritius, maize is usually planted at the same time as cane. However, it could be argued that the deleterious effect of maize on cane could be minimized by reducing the duration of the interaction between the two crops. Earlier planting of the maize would lead to its earlier harvest, less effect on cane tiller, more time for the cane to catch up and hence, less effect on yield. Delayed planting of the maize might also be expected to have less effect on tiller density because tiller formation would be well under way by the time the maize started shading the cane. In the first case, the time during which the crops interact would be reduced; in the second, the cane would be given time to become more competitive with the maize.

At Bambous but not at Reduit, maize yield was reduced when maize planting was delayed to 8 weeks after cane. This may be related to two observations. Firstly, the cane at Bambous was planted in April at the end of the summer, and, as shown by the rapid increase in tiller number during the first 12 weeks (figure 28), it grew rapidly whereas at Reduit, the cane was planted in August and its growth was less rapid at first. Secondly, at Bambous the maize was planted in June near the middle of winter: it grew slowly,

its cycle was lengthened (19 weeks) and it was not harvested until 27 weeks after the cane plantation whereas at Reduit, the maize was planted at the end of September at the end of winter: it grew faster, its cycle was short (15 weeks) and it was harvested at only 23 weeks after the cane plantation. These two observations indicate that at Bambous the cane may have been relatively more competitive, hence the reduction in yield of maize at Bambous but not at Reduit. Conversely, at Reduit the maize may have been relatively more competitive, hence the larger adverse effect on cane tiller at Reduit than at Bambous.

As was postulated, at both sites, the effect on cane tiller density of early planting of maize was not as marked as simultaneous planting. However, at neither site did this difference in tiller density lead to a significant difference in yield. It is suggested that at both sites, the cane intercropped with simultaneously-planted maize was itself able to catch up fully. As was also postulated, at both sites the adverse effect on tiller density of the maize planted at 8 weeks after the cane was less than that of the simultaneously planted maize. Yet at Reduit, the yield of the cane was less in the former. This result differs from that of Tang(1963), who found that delaying the plantation of sweet potato in cane interrows by one month led to an improvement in the yield of cane compared to simultaneous planting. It is suggested that at Reduit, the late-planted

maize may have had other adverse effects besides the reduction in tiller number. These effects were not investigated but are probably related to reduced photosynthesis.

The results indicate that delaying the plantation of intercropped maize was of no value as a method for minimizing the adverse effect on cane. If anything, it leads to lower maize and/or cane yields. Planting the maize before the cane, on the other hand, was neither advantageous nor practical.

4.4 Spatial relations and productivity of plant cane mixtures.

4.4.1 Competitive effects

In 1984, the average maize grain yield in Mauritius was about 4 t/ha (Govinden and Mauree, 1985). Therefore, the actual grain yields produced in the trials in the second season were excellent whereas those of the first season trials were low for experimental stations. The yields per plant of intercropped maize relative to sole maize were higher in the first than in the second season (table 29). This difference may be attributed to either one or both of two causes: higher relative yields per plant of intercropped maize or lower relative yields per plant of sole maize. Intercropped maize may be expected to give higher relative yields per plant if competition from sugar cane is less in the first than in the second season. This may have been the case since the growth of cane was slower in the first season

as shown by the longer time taken to reach peak tiller density (figures, 29 and 30). Alternatively, lower relative sole maize yields per plant may arise if competition is more severe in the sole maize in the first than in the second season. For instance, light is more likely to limit yield in the first season because the grain filling stage occurs in the middle of winter (June-July) whereas in the second season it occurs in the middle of summer (November-December).

Higher intra-specific competition for light as a result of overcrowding may also be the cause of the relatively lower yields per plant of the intercropped maize at 100 per cent. That it was not due to higher competition from the cane is evident from the lower growth and complete inhibition of tiller formation in the cane.

As shown in the previous section (4.2.4), shading of cane increased as maize density was increased and this in turn led to further inhibition of tiller formation. Much of the effects on tiller density of the cane may therefore be explained by differences in shading consequent to changes in maize density and planting pattern. For instance, it is suggested that at 33 per cent, maize had slightly less effect on tiller density of uniformly-spaced cane than of differentially-spaced cane because the maize rows were further away (110 cm) from the cane rows in the former than in the latter case (80 cm).

Likewise, differences in intra-specific competition may account for the relatively higher grain yields at 2 sites of mixtures of 67 per cent maize in uniformly-spaced cane compared to the same mixtures in differentially-spaced cane: the two maize rows were further apart (1.6m) in the first than in the second case (0.8 m).

The results of the 4 trials confirm previous findings (sections 4.2.1, 4.2.3 and 4.2.4) that sugar cane retained its ability to rapidly resume tiller formation after the removal of the maize. 'Ratrapage' was higher in the first than in the second season trials (figures 29 and 30) but in view of the many sources of variations between the trials, it is not possible to attribute the differences in ratrapage in tiller number solely to seasonal effects; site and varietal effects could also have been important.

'Ratrapage' was however, not evident in stalk height (figures 31 and 32). There were small, sometimes non-significant, differences in stalk heights at the beginning of the elongation phase thus confirming previous observations (figures 12 and 27). The differences were maintained until very late in the season when the cane flowered and measurement was stopped. These results paralleled those of Black (1957), who found that when subterranean clover was grown as spaced plants from small and large seeds, differences in dry weights observed at planting were maintained until harvest. On the other hand, in dense swards, competi-

tion started earlier in the larger plants and by harvest time, there were no differences in dry weights of plants from small and large seeds. The absence of rattrapage in stalk height therefore suggests that the average level of competition in the sole and the intercropped plots may have been similar, although there were fewer stalks in the latter. This was confirmed at harvest when the number of millable canes was found to be lower in the intercropped plots. The results suggest that a reduction in millable cane is not compensated for by longer stalks.

Sugar yield is dependent on 2 components: sucrose content and cane stalk yield. In none of the 4 trials were there significant differences in sucrose contents although at Bam-bous and Pamplemousses there were trends for intercropping to reduce sucrose content. The findings confirm previous reports (Misra, 1964; Pillay, 1980), and earlier results (tables 13 and 14) that maize intercrops had little effect on sucrose content. The variations in sugar yield were therefore more closely associated with variations in cane stalk yield which was itself determined by the number of millable canes and not by unit stalk weight. The results are in accordance with those of Soopramanien (1979) who found that in Mauritius, the number of millable canes was the main determinant of varietal differences in sugar yield.

At harvest, there were differences in the number of millable canes even though in the 4 trials at the 40th week or

earlier, there were no differences in tiller number. This apparent contradiction arose because all live tillers were counted but many did not become millable canes, especially in the intercropped plots.

Some of the results may perhaps be compared to those obtained by Pillay(1980) in the second season under irrigation at Ebene, a site located 2 km from Redit. Of his 8 maize treatments, 2 are comparable in density and planting pattern to 2 of the treatments in the present study. His treatment of 19.0 maize plants/m² grown as one row in every second interrow of uniformly-spaced cane, is comparable to the treatment of 33 per cent maize (20.8 plants/m²). Similarly, his treatment of 37.9 plants/m² may be compared to the present 67 per cent maize (41.7 plants/m²). His maize yields were even lower than those obtained in the present first season trials, probably on account of higher susceptibility to leaf diseases of the single cross hybrid, United 530 compared to U-R14 used in the present study. With the first maize density (19.0 plants/m²), he found no significant effect on cane stalk yield at Ebene, as was confirmed at Bambous and Pamplemousses, but not at Redit and Union Park. With the second maize density (37.9 plants/m²), he observed a 17 per cent reduction in cane yield comparable to the 19 per cent reduction at Redit and the 16 per cent at Union Park, but not comparable to the results at Bambous and Pamplemousses where the treatment had no significant effect

on cane stalk yield. The differences in the results could arise from differences in site, maize variety or even cane variety which Pillay did not report. Unfortunately, he did not report sugar yields either.

4.4.2 Total productivity and yield advantage

The major objective of the trials was to estimate total productivity and hence to determine whether there were any advantages in mixing the crops. The basis of comparison was either one or both of the sole crops. Sole crop yields are however, not considered in the bivariate analysis of variance; hence the analysis did not meet the objectives of the trials. The bivariate analysis of variance served to compare the joint yields of maize and sugar of the mixtures after the removal of a possible source of variations due to the residual correlation between the yields of the 2 crops. At Bambous, this residual correlation was quite high ($r^2=0.66$). It is believed that it arose because of soil heterogeneity; Bambous is a newly-opened station and the land was being cropped for the first time. In spite of the high residual correlation at Bambous, there was no change in the interpretation of the results, the separate analyses of the yields of the component crops having already shown that there were highly significant differences in maize yields but no significant differences in sugar yields.

Total productivity and yield advantages were assessed from Land Equivalent Ratios. In order to take account of

the difference in cycle of the two crops, the sole maize yield used to standardize the mixture yields was estimated on the basis of two assumptions. The calculations involved multiplying the sole maize yields by a factor equal to more than 3 for first season trials. (3.5 for Reduit and 3.15 for Bambous) and less than 3 for second season trials. (2.65 for Union Park and 2.5 for Pamplémousses.) before standardization of the yields of the mixtures. This meant that from 2.5 to 3.5 unit increases in relative maize yields were required to compensate for each unit decrease in sugar yield. This explains why yield advantages were rare, and when found, only modest in magnitude. (table 34). Unfortunately, the results could not be compared to results published in the literature because in most published reports, the second sole crop yields are not given. In the exceptional cases where they are given, there were no estimates of the yield of the second sole crops over the entire cane crop cycle. It is suggested that much of the yield advantage often reported may have been exaggerated because of the failure to consider sole crop yields over the entire cycle.

Only at Union Park were yield losses observed with intercropping. These were associated with very low relative sugar yields. It is suggested that at Union Park, rattrapage may have been less than at the other sites because the site itself is only marginal for sugar cane. Union Park is cool and wet, and has a poor, shallow soil. (FAO and MSIRI, 1973).

Indeed, the yield of sole sugar cane itself was relatively low, particularly in the differentially-spaced cane rows. At Union Park, Pamplémousses and Bambous, the best mixtures were those of 67 per cent maize in uniformly-spaced cane which had neither the highest maize nor the highest sugar yields. This suggests that a compromise may be necessary between high maize and high sugar yields. The implications of these and other findings will be discussed in a subsequent section (4.6). At Reduit, there was not much difference between the LER's of the 4 mixtures although maize density varied from 33 to 100 per cent. The cost of growing the maize at these densities is therefore likely to have a large effect on the choice of a suitable mixture.

4.4.3 Economic evaluation

The economic evaluation of the intercropping treatments was based on parameters and assumptions given in Appendix II. Gross margin was chosen as a suitable criterion for the comparison of the treatments. It was preferred over net profit because of the difficulties of estimating fixed costs which may be very variable from site to site. The gross margin of sole maize was not included in the analysis because several additional assumptions were required to calculate the variable costs as continuous cropping of sole maize is not presently practised in Mauritius.

There were large differences in the gross margin of sole maize (table 40) which was higher in the second season and

much lower in the first season than that of sole cane, probably reflecting the seasonal differences in sole maize yields. In 3 out of 4 trials, there were significant ($P=0.05$) differences in gross margins of the treatments; the exception was Bambois where differences were not significant at $P=0.05$. At Rduit, only in the mixture of 33 per cent cane was the gross margin of intercropped cane at par with that of sole cane; this was the treatment that had the highest sugar yield. At Union Park and Pamplemousses, the mixture giving the highest gross margin was that of 67 per cent maize in uniformly-spaced cane. Thus, in the first season trials, there was no economic justification for the adoption of intercropping. If, for some reasons, maize was required, it could equally well be grown as a sole crop or an intercrop. In the latter case, the best system at Rduit was one row of maize in alternate interrows (33 per cent) of uniformly-spaced cane whereas at Bambois, several alternatives were equally acceptable although there was probably a small advantage in favour of one row of maize in every interrow (67 per cent) of uniformly-spaced cane. In the second season at Union Park, there may have been a slight economic advantage in favour of intercropping but only in the case of 67 per cent maize in uniformly-spaced cane. This treatment was economically very attractive at Pamplemousses where additionally, cane could be planted in differentially-spaced rows so long as it was intercropped with 67 per cent maize.

Table 40: Gross margins of plant sugar cane intercropped with maize at 4 sites as influenced by maize density and planting pattern.

Treatment	Reduit		Bambous		Union Park		Pamplemousses	
	(Rs.ha ⁻¹ x10 ³)	(%)	(Rs.ha ⁻¹ x10 ³)	(%)	(Rs.ha ⁻¹ x10 ³)	(%)	(Rs.ha ⁻¹ x10 ³)	(%)
Cane at 1.6m								
Sole Cane	41.3	100	47.6	100	29.7	100	30.7	100
Cane+33% Maize	39.6	96	48.3	102	29.7	100	37.8	123
Cane+67% Maize	34.3	83	50.6	106	33.6	113	46.2	150
Cane at 2.25/0.95 m								
Sole Cane	32.5	79	46.2	97	18.7	63	28.8	94
Cane+33%Maize	-	-	49.6	104	26.3	88	36.7	119
Cane+67%Maize	32.9	80	47.6	100	29.1	98	43.0	140
Cane+100%Maize	30.2	73	46.2	97	30.9	104	38.3	125
Sole Maize (3 crops) *	5.0		16.5		38.3		43.4	
C.V.(%)	16.5		16.0		15.9		13.7	
S.E.	2.9		4.4		2.2		2.6	
L.S.D. (P=0.05)	8.7		13.8		6.7		7.7	
L.S.D. (P=0.10)	7.2		11.2		5.5		6.3	

* Not included in analysis.

4.5 Spatial relations and productivity of ratoon cane mixtures.

4.5.1 Competitive effects.

In Mauritius, intercropping of ratoon cane is not practised in the first maize planting season (March-April) because there are no young ratoons at this time; they do not occur until cane is harvested starting as from July. The three trials in ratoon sugar cane were therefore in the second season. Of the three, two were at the same sites, Union Park and Pamplemousses, as the two second season trials in plant sugar cane (section 4.4.1). Although comparisons between the results of the two pairs of trials cannot be made on the absolute responses because of possible year \times environment interactions, the comparisons can be made on relative responses such as for example, effect of intercropping on tiller density or sugar yield.

Although ratoon cane grows faster than plant cane, there was no evidence in the trials that the effect on maize yield of the ratoon cane was different from that of plant cane. At Union Park and Pamplemousses, the effect of ratoon cane on maize grain yield (table 35), measured as yield per plant of intercropped maize relative to sole maize was not different from the effect of plant cane previously observed (table 29) at the same sites. This showed that the cane had little effect on the yield of maize, thus confirming earlier observations (sections 4.2.3 & 4.4.1), and suggesting that the differences in maize grain yield were probably attributable to intra-specific rather than inter-specific interactions.

Likewise, there were many similarities between the effects of maize on tiller density of ratoon cane and of plant cane. For instance, in both situations, tiller density was reduced but for variable periods; the adverse effect increased with increasing maize density; there were lower effects on differentially-spaced than on uniformly-spaced cane. As discussed previously (section 4.4.1), these effects probably arose out of competition for light as the maize shaded the young cane. There was however one important difference in the effect of intercropping on tillering of ratoon cane compared to plant cane: the effect of maize was much less pronounced on tillering of ratoon cane than on plant cane (table 41). This difference may be related to the relative rates of tiller formation in the canes. It is well-known that tiller formation is more rapid in ratoon than in plant cane. This was confirmed by the tiller density data; at 6 weeks, there were twice as many tillers in ratoon (figure 36) as in plant cane (figure 30) at Union Park and a three-fold difference at Pamplémousses. Because tiller formation was more rapid in ratoon, more tillers were formed before maize grew to a sufficient size (height) to start shading the cane.

The differences in effects of maize on cane tiller density are probably the cause of the differences in effects on

Table 41: Comparison of the effects of maize density and planting pattern on tiller density of plant and ratoon sugar cane at 2 sites.

Treatment	Maximum reduction in tiller density (%)			
	Union Park		Pamplemousses	
	Plant	Ratoon	Plant	Ratoon
<u>Cane at 1.6m</u>				
Cane+33% maize	33	11	55	17
Cane+67% maize	51	19	75	26
<u>Cane at 2.25/0.95m</u>				
Cane+33% maize	21	2	43	8
Cane+67% maize	43	23	70	16
Cane+100% maize	59	29	77	44

yield of sugar (table 42) Intercropping with maize had a lower effect on the sugar yield of ratoon than on that of plant cane at Union Park. However, except at the density of 33 per cent, the effects at Pamplemousses were similarly on ratoon as on plant cane.

4.5.2 Total productivity and yield advantage

LER's of the mixtures of maize and ratoon cane (table 39) confirmed the findings with plant cane (table 34) that the best maize density at the 3 sites was 67 per cent, and the best planting pattern at Belle Rive and Union Park was one row of maize in every interrow of uniformly-spaced cane. At Pamplemousses, planting in differentially-spaced cane was equally good.

LER's of the mixtures with ratoon cane were much larger than those with plant cane. This difference was due partly to the smaller effects on sugar yields of ratoon and partly to the lower sole maize yield used in the calculation of LER's. The assumption was that in the time taken for the ratoon cane to mature, only 2 sole maize crops could be grown sequentially instead of 3 as was assumed in the trials with sole plant cane. Had it been assumed that, as for plant cane, 3 maize crops could have been grown, the LER's values would have been reduced by 5 to 15 per cent of those reported in table 39 at Union Park and by 8 to 18 per cent at Pamplemousses, depending on the relative maize yields. However even on the 3 crop basis, the LER's would still have been higher in ratoon cane.

Table 42: Comparison of the effects of maize density and planting pattern on sugar yield of intercropped plant and ratoon sugar cane at 2 sites.

Treatment	Reduction in sugar yield(%)			
	Union Park		Pamplemousses	
	Plant	Ratoon	Plant	Ratoon
<u>Cane at 1.6m</u>				
Cane+33% maize	17	7	6	+3*
Cane+67% maize	19	12	9	10
<u>Cane at 2.25/0.95m</u>				
Cane+33% maize	24	19	7	+4*
Cane+67% maize	32	27	9	9
Cane+100% maize	38	28	24	25

*Sugar yield of intercropped cane was superior to that of sole cane.

4.5.3 Economic evaluation

The economic evaluation of the treatments was based on essentially the same parameters and assumptions as those used in the trials with plant cane (Appendix II).

Gross margin of sole maize was lower at Union Park than at Belle Rive and Pamplémousses (table 43) and this probably reflects the lower grain yield at Union Park. Gross margin of sole maize at Union Park and Pamplémousses were much lower than in the previous trials with plant cane (table 40) probably because only 2 maize crops were considered instead of 3.

At Union Park, intercropping did not lead to significant economic benefit or loss as was also the case with plant cane. At the 2 other sites, several intercropping treatments gave large increases in gross margin, the best treatment being 67 per cent maize in uniformly-spaced cane. At Pamplémousses, the effect of planting pattern on gross margin was not significant at $P=0.05$, but at Redit, planting in uniformly-spaced cane gave significantly ($P=0.05$) higher gross margin. At Pamplémousses, the economic benefit with intercropping of ratoon was as high as with intercropping of plant cane. But in the trial in plant cane, at Pamplémousses, the sole maize was as economically attractive as the best of the mixtures whereas in the trial in ratoon cane, the gross margin of the mixtures were much higher than that of sole maize.

Table 43: Gross margin of ratoon sugar cane and maize mixtures at 3 sites as influenced by maize plant density and planting pattern.

Treatment	Belle Rive		Union Park		Pamplemousses	
	Rs.ha ⁻¹ x10 ³	(%)	Rs.ha ⁻¹ x10 ³	(%)	Rs.ha ⁻¹ x10 ³	(%)
Cane at 1.6m						
Sole Cane	15.9	100	26.0	100	28.9	100
Cane+33% Maize	22.2	140	27.6	106	38.0	131
Cane+67% Maize	23.0	145	27.5	106	43.7	151
Cane at 2.25/0.95m						
Sole Cane	15.4	97	23.6	91	31.2	108
Cane+33% Maize	18.2	115	25.6	98	40.0	138
Cane+67% Maize	20.8	131	23.9	92	42.0	145
Cane+100% Maize	18.6	121	24.5	94	38.9	135
C.V.(%)	11.2		17.2		12.6	
S.E.	1.1		2.2		2.4	
LSD(P=0.05)	3.2		6.5		7.0	
LSD(P=0.10)	2.6		5.3		5.8	
Sole Maize (2 crops)*	10.4		7.1		18.8	

* Not included in analysis.

4.6 Implications of the research findings

4.6.1 Returns to factors limiting production.

4.6.1.1 Returns to land.

It has been emphasized that the mode of assessment of intercropping advantages depends on the objectives of the experiment and that it is advisable to try several analyses. In this study, several approaches were tried. In the agronomic trials, the main objective was to compare cropping systems with respect to returns to the most limiting factor, land. It was not possible to determine directly from separate analyses of maize and of sugar yields which were the best overall treatments. This arose because of the association of high maize yields with low sugar yields. LER may not be the appropriate index for comparing the combined yields for 3 main reasons:

1. LER indicates the advantage of mixing per se of the crops, not of the mixtures relative to the sole cane.
2. Comparison of LER of mixtures, especially in the present context of changing proportions of the crops, may not be valid.
3. LER does not take into account the higher costs involved in producing the mixtures compared to the sole crops.

In areas where subsistence agriculture is practiced and some quantity of each of the 2 component crops is required, LER

may be a valuable indicator of the advantage of mixing over growing the component crops separately. This is not the case in Mauritius where both maize and sugar cane are cash crops. Clearly the main interest of growers is to maximize profits; they are probably not much concerned with whether their profit comes from cane, maize, cane and maize grown in association, or cane and maize grown separately. Apart from the large-scale continuous sole cropping of maize, all the alternatives are probably acceptable.

It is therefore proposed that gross margin is a suitable assessment of returns to land in the present context. However, it has been stated that one of the drawbacks of gross margin is that costs and prices fluctuate. Presently, this is probably less relevant in Mauritius where most of the sugar is sold at negotiated and guaranteed prices and the price of maize is fixed by the Government. Nevertheless, the influence of changing prices was investigated in the trial with ratoon cane at Pamplemousses (Table 44). At constant sugar prices, the advantage of the mixtures increased as the price of maize increased, and decreased with a decrease in the price of maize. Similarly, at constant maize price, the advantage of the mixtures increased with a decrease in sugar price and decreased with an increase in sugar price. Even under the unfavourable conditions of an increase in sugar price and a decrease in maize price (situation 7 in table 44), there would still be substantial

advantages of up to 31 per cent with the best mixture, even though under that particular condition the gross margin of sole maize itself was only 35 per cent of that of the sole cane. Simultaneous increases or decreases in the prices of the 2 crops had little effect on the relative advantage of the mixtures (compare 5 with 9 and 1). Similarly for the trial with plant cane at Union Park (table 45).

The concept of LER was also applied to gross margins in much the same way as to yield (Appendix III), and the LER (gross margin basis) was used to estimate the advantage on gross margin of mixing per se. With plant cane, mixing generally led to slightly more advantage on LER (gross margin) than on LER (Yield) (table 46). With ratoon cane, the effect of mixing was definitely higher on gross margin than on yield (table 47). This suggests that, the advantage on gross margin of the mixtures compared to the sole crops was probably not only the result of higher productivity, and therefore revenue, but also of relatively lower variable costs. In other words, the maize was complementary to the cane to some extent. Expenditure made for cane benefited the maize as well. e.g. irrigation.

4.6.1.2 Returns to capital.

Capital is the second most limiting factor in agricultural production in Mauritius, hence the need to propose cropping systems that also give acceptable returns to capital. In the agronomic trials on plant sugar cane (table 48), sole maize was much more capital intensive than the sole cane and




Table 44: The influence of changing sugar and maize prices on relative gross margins of mixtures of ratoon cane and maize at Pamplousses.

Treatment	1 S=3500 M=3100	2 S=3500 M=3600	3 S=3500 M=4100	4 S=4000 M=3100	5 S=4000 M=3600	6 S=4000 M=4100	7 S=4500 M=3100	8 S=4500 M=3600	9 S=4500 M=4100
Cane at 1.6m									
Sole cane	100	100	100	100	100	100	100	100	100
Cane+33% maize	130	137	144	126	131	137	122	128	132
Cane+67% maize	149	164	179	139	151	164	131	142	153
Cane at 2.25/0.95m									
Sole cane	108	108	108	108	108	108	108	108	108
Cane+33% maize	138	146	154	132	139	145	128	133	139
Cane+67% maize	143	157	170	134	145	156	128	137	147
Cane+100% maize	133	150	167	123	137	151	116	128	140
Sole maize (2 crops)	54	79	107	41	65	89	35	55	76

- Price of sugar, S=Rs 3500/t to Rs 4500/t. (includes molasses and bagasse)
- Price of maize, M=Rs 3100/t to Rs 4100/t. (humid grains on the cob)
- The gross margins are expressed as per cent of that of sole cane at 1.6m.
- Costs of production were assumed constant.

Table 45: The influence of changing sugar and maize prices on the relative gross margins of mixtures of plant sugar cane and maize at Union Park.

Treatment	1 S=3500 M=3100	2 S=3500 M=3600	3 S=3500 M=4100	4 S=4000 M=3100	5 S=4000 M=3600	6 S=4000 M=4100	7 S=4500 M=3100	8 S=4500 M=3600	9 S=4500 M=4100
Cane at 1.6m									
Sole cane	100	100	100	100	100	100	100	100	100
Cane+33% maize	98	103	109	95	100	104	94	97	101
Cane+67% maize	110	119	129	105	113	121	102	108	115
Cane at 2.25/0.95m									
Sole cane	63	63	63	63	63	63	63	63	63
Cane+33% maize	86	91	96	84	88	92	83	87	90
Cane+67% maize	94	104	113	90	98	106	87	93	100
Cane+100% maize	99	112	126	93	104	115	88	98	107
Sole maize (3 crops)	104	150	195	87	124	162	74	107	139

Price of sugar, S=Rs 3500/t. to Rs 4,500/t.(includes price of molasses + bagasse).
 Price of maize, M=Rs 3100/t. to Rs 4,100/t. of humid maize on the cob
 Assumption: Costs of production were assumed constant. The gross margins are expressed as per cent of that of sole cane at 1.6 m.

Table 46: The effect of mixing per se on the yield and gross margins of mixtures of plant sugar cane and maize at 4 sites as determined by LER.

Treatment	Reduit		Bambous		Union Park		Pamplemousses	
	LER (Yield)	LER (GM)	LER (Yield)	LER (GM)	LER (Yield)	LER (GM)	LER (Yield)	LER (GM)
Cane at 1.6m								
Cane+33% Maize	1.04	1.09	1.07	1.11	0.95	0.96	1.10	1.17
Cane+67% Maize	1.00	1.08	1.15	1.24	1.02	1.07	1.21	1.36
Cane at 2.25/0.95m								
Cane+33% Maize	-	-	1.11	1.14	0.86	0.86	1.08	1.13
Cane+67% Maize	0.97	0.99	1.11	1.17	0.89	0.92	1.17	1.28
Cane+100% Maize	0.96	0.92	1.12	1.19	0.92	0.95	1.07	1.13

LER(Yield)-LER, yield basis

LER(GM)-LER, gross margin basis

Table 47: The effect of mixing per se on the yield and gross margins of mixtures of ratoon sugar cane and maize at 3 sites as determined by LER.

Treatment	Belle Rive		Union Park		Pamplemousses	
	LER (Yield)	LER (GM)	LER (Yield)	LER (GM)	LER (Yield)	LER (GM)
<u>Cane at 1.6m</u>						
Cane+33% maize	1.27	1.49	1.11	1.21	1.28	1.41
Cane+67% maize	1.29	1.63	1.19	1.31	1.42	1.73
<u>Cane at 2.25/0.95m</u>						
Cane+33% maize	1.10	1.23	1.07	1.11	1.32	1.49
Cane+67% maize	1.22	1.48	1.08	1.20	1.38	1.65
Cane+100% maize	1.18	1.37	1.17	1.31	1.34	1.59

LER(yield)-Land Equivalent Ratio, yield basis.

LER(GM)-Land Equivalent Ratio, gross margin basis.

the mixed crops. The mixtures themselves had lower returns to capital than the sole cane, except for the best mixtures at Pamplémousses. It must be pointed out that at Pamplémousses and especially at Union Park, the gross margins of sole maize were higher than of sole cane and most mixtures. Nevertheless, returns to capital of sole maize were much lower. Hence, this is a point in favour of mixtures and against continuous sole cropping of maize. In the trials in ratoon cane (table 49), returns to capital of the best mixtures was only slightly less than that of sole cane. Another point in favour of mixtures compared to sole cane, not investigated in this study, is the more rapid rate of turnover of capital. With intercropping of maize, growers may expect cash as from 5 months after planting.

4.6.1.3 Returns to labour.

Although labour is presently not a limiting factor, it is necessary to examine returns to labour in order to check that systems being proposed are not too labour-intensive in view of the high costs of production and of the possible difficulty in mechanization. In the trials with plant sugar cane, the returns to labour of the best mixtures were not much lower than that of sole cane at Redit, Bambous and Union Park, while at Pamplémousses the returns to capital of the best mixture was just significantly ($P=0.05$) higher than that of sole cane (table 50). In the first season trials at Redit and Bambous, the returns to labour of sole maize was

Table 48: Returns to capital* of mixtures of intercropped plant sugar cane and maize at 4 sites as influenced by maize plant density and planting pattern.

Treatment	Reduit	Bambous	Union Park	Pample -mousses
<u>Cane at 1.6m</u>				
Sole cane	4.32	4.22	4.35	3.29
Cane+33% maize	3.20	3.42	3.22	3.06
Cane+67% maize	2.41	3.07	2.91	3.16
<u>Cane at 2.25/0.95m</u>				
Sole cane	3.48	4.19	2.93	3.08
Cane+33% maize	-	3.41	2.89	2.88
Cane+67% maize	2.31	2.90	2.57	2.92
Cane+100% maize	1.94	2.52	2.30	2.35
C.V. (%)	14.6	12.5	12.4	13.5
S.E.	0.21	0.25	0.19	0.20
L.S.D. (P=0.05)	0.65	0.76	0.55	0.60
Sole maize **	0.13	0.42	1.17	1.16

* Returns to capital is defined as $\text{Gross Margins} / \text{Capital Costs}$,

where $\text{Capital Costs} = \text{Variable Costs} - \text{Labour Costs}$

** Not included in analysis

Table 49: Returns to capital* of mixtures of ratoon sugar cane and maize at 3 sites as influenced by maize plant density and planting pattern.

Treatment	Belle Rive	Union Park	Pamplemousses
<u>Cane at 1.6m</u>			
Sole cane	2.65	4.21	3.85
Cane+33% maize	2.54	3.14	3.51
Cane+67% maize	2.11	2.46	3.31
<u>Cane at 2.25/0.95m</u>			
Sole cane	2.58	3.85	4.12
Cane+33% maize	2.25	2.92	3.70
Cane+67% maize	1.90	2.15	3.20
Cane+100% maize	1.43	1.86	2.57
C.V.(%)	11.7	15.5	10.9
S.E.	0.13	0.23	0.19
L.S.D.(P=0.05)	0.38	0.68	0.56
Sole maize **	0.46	0.31	0.76

*Returns to capital is defined as Gross Margins/Capital Costs, where Capital Costs=Variable Costs-Labour Costs.

**Not included in analysis.

very poor probably because of low yields. In the trials in ratoon cane (table 51), returns to labour of the best mixtures were slightly better than that of sole cane at Belle Rive and Pamplémousses, not Union Bark, probably because of the relatively lower maize yields at the latter site.

In general, the best mixtures were not more labour-intensive than sole cane. It should be pointed out that in the calculations (Appendix IV) of gross margins, labour for operations on maize in sugar cane interrows was charged at the normal factor cost as prescribed by the labour laws, on the basis of amount of labour required for each operation. Nevertheless, it is recognized that in most instances where permanent labour exists, there would be some idle labour that could be diverted from cane to maize, especially for planting in the first season and harvesting in the second season. This would lead to better returns to labour of the mixtures.

4.6.2 Implications on cultural practices

4.6.2.1 Differential cane spacing

In none of the 7 agronomic trials (trials no 9-15) were the highest gross margins to be found in mixtures in differentially-spaced cane, although in some trials (e.g. plant cane at Bambous, ratoon cane at Pamplémousses), the difference between the gross margins of the best mixture in uniformly-spaced cane and in differentially-spaced cane was

Table 50: Returns to labour* of mixtures of intercropped plant sugar cane and maize at 4 sites as influenced by maize plant density and planting pattern.

Treatment	Reduit	Bambous	Union Park	Pamplemousses
<u>Cane at 1.6m</u>				
Sole cane	6.87	6.53	8.77	5.68
Cane+33% maize	6.02	6.11	8.27	6.05
Cane+67% maize	5.15	5.85	7.79	6.75
<u>Cane at 2.25/0.95m</u>				
Sole cane	5.83	6.17	7.16	5.34
Cane+33% maize	-	5.80	7.64	5.97
Cane+67% maize	4.88	5.53	7.43	6.46
Cane+100% maize	3.83	5.29	7.06	5.50
C.V.(%)	11.9	9.9	8.9	11.3
S.E.	0.32	0.34	0.34	0.34
L.S.D.(P=0.05)	0.97	1.05	1.02	1.01
Sole maize **	0.63	2.09	6.07	5.51

* Returns to Labour is defined as Gross Margins/Cost of Labour.

**Not included in analysis.

Table 51: Returns to labour * of mixtures of intercropped ratoon sugar cane and maize at 3 sites as influenced by maize plant density and planting pattern.

Treatment	Belle Rive	Union Park	Pamplemousses
<u>Cane at 1.6m</u>			
Sole cane	7.21	10.54	8.25
Cane+33% maize	7.58	9.19	8.43
Cane+67% maize	7.20	7.58	9.07
<u>Cane at 2.25/0.95m</u>			
Sole cane	7.19	9.93	8.66
Cane+33% maize	6.70	8.58	9.09
Cane+67% maize	6.42	7.02	8.84
Cane+100% maize	5.07	5.98	7.68
C.V.(%)	5.4	9.3	8.7
S.E.	0.18	0.39	0.37
L.S.D.(P=0.05)	0.54	1.16	1.11
Sole Maize **	1.98	1.35	3.08

* Returns to labour is defined as Gross margins/cost of labour.
 ** Not included in analysis.

quite small and non-significant. In some trials (e.g. plant cane at Reduit and Union Park), cane yield and gross margins of sole cane in paired rows were less than those of sole uniformly-spaced cane showing that differential spacing per se was inferior. In other trials (ratoon cane at Union Park), the difference was small and non-significant. Although the results cannot be generalized, they nevertheless show that differential-spacing is not the optimum method of planting it was previously believed to be. More trials are required in different sites to clarify the situation and to determine under what conditions differential spacing is advantageous. In view of its potential merits (see Literature Review), the system should be studied further.

One of the merits hypothesized for differential spacing was that because of the larger space between the cane rows, it may be possible to grow more maize without any more effect on cane. The results of the trials showed that this was not the case. In none of the trials was the treatment consisting of 3 rows of maize in every large interrow of differentially-spaced cane better in gross margins than one row in every interrow of uniformly-spaced cane; in fact it was consistently worse. Even in maize yield, it was not always better (eg. plant cane at Reduit and Pamplemousses), and it consistently had the highest adverse effect on sugar yield. It has also been hypothesized that because of the larger space, maize is likely to have no adverse effect or

much less adverse effect on differentially-spaced cane than on uniformly-spaced cane. This was not the case in any of the trials, and in fact, with plant cane at Union Park and ratoon cane at Belle Rive, it was worse.

Differential spacing has, however other possible merits, not investigated in this study, that may justify further work. For instance, with larger interrow, it may be easier to mechanize operations on maize. Also, it may be possible to intercrop older ratoons, ie. older than 3 years. Moreover, in areas where cane is not burnt, should the best maize density be confirmed to be 67 per cent, it would not be possible to grow one row of maize in every interrow of ratoon cane because of trash. With differential spacing, it would be no problem to grow 2 rows of maize in every large interrow since all the trash could be placed in the narrow interrow.

4.6.2.2 Maize varietal characteristics and planting pattern.

Maize yields were relatively lower in the 2 first season trials (plant cane at Redit and Bambous), hence the relatively lower gross margins of the mixtures. On the other hand, there was no evidence that adverse effects on cane were more in the first than in the second season. These results may therefore imply that improvement of the yield of maize through the use of varieties with better adaptation to climate and disease complex is not likely to lead to an increase in the adverse effect on cane. Hence, the gross margins of the mixtures would be improved.

The competition studies have shown that the effect of maize on cane, under the conditions of the trials, was due to shading. This implies that, all things being equal, the taller and later-maturing the maize, the larger the adverse effects on cane. Shorter and earlier maturing maize varieties may be expected to have less adverse effects on cane. Unfortunately, there is a relationship between maturity (and plant height) and grain yield: the taller (and later-maturing) varieties tend to be higher yielding. Therefore trials will have to be conducted to compare total productivities. Moreover, the fact that in most trials (with plant cane at all 4 sites; with ratoon cane at Union Park), even at a density of 33 per cent, the maize reduced the yield of sugar, though not always significantly ($P=0.05$), suggests that the maize variety, U-R14 itself was too competitive. This confirms the competition studies done at a density of 67 per cent. Variety U-R14 grows to an average of 1.85-2.00m in the first, and 2.00-2.25m in the second season and matures in about 115-135 days in the first and 100-120 days in the second season. Since this variety is due to be phased out in 1986, its replacement should perhaps not be taller than 1.75m in the first and 1.90m in the second season and no later-maturing than 105 days in the first and 90 days in the second, in order to ensure that it does not compete with cane. Other characteristics such as leafiness are no doubt important too.

Evidence has been presented to the effect that at higher densities, there is intra-specific competition in the maize. This could mean that planting the maize at distances of 0.15m within the rows and 0.8m between the rows is not optimum. There is some preliminary evidence that a more uniform arrangement of the plants may lead to better maize yields without necessarily increasing the adverse effect on cane (Govinden, 1985, Unpublished.)

4.6.2.3 Cultural practices on sugar cane.

The finding that competition is for light implies that such practices as giving additional N-fertilizers or irrigation to the cane are not likely to improve cane growth very much while the maize is present. On the other hand, because of 'rattrapage', all cultural practices that improve cane growth and reduce stresses on the cane for the first few months after the maize is harvested are likely to be of value in promoting 'rattrapage' and hence, of reducing adverse effects on cane. It is suggested that the first few months after maize harvest are critical because this is probably the time when the number of millable canes is determined.

The fact that germination and early tillering of cane is not affected and that early tillering is probably more important than later tillering - the late tillers seem to die anyway-suggest that by increasing the density of cane at planting it may be possible to increase the number of primary tillers and this may increase the total number of early-tillers and hence, minimize the adverse effect of maize.

Chapter V

CONCLUSIONS

5.1 Main conclusions

When 3 sequential maize crops were grown in non-additive mixtures with plant sugar cane, the first crop, but not the second and third crops, gave higher grain yields than expected on the basis of the sown proportions. The cane over-yielded, but the extent of over-yielding was not enough to compensate for the reduction in cane plant density, and no yield advantage was obtained with the non-additive mixtures.

Intercropping with the maize reduced the cane yield drastically in a mixture of one row of maize in every interrow of plant sugar cane under excellent conditions of soil fertility and moisture. The yield reduction was attributed to competition for above-ground, not below-ground growth factors.

Even under less favourable growth conditions such as when the component crops were not fertilized, there was no evidence that the maize competed with the cane for nutrients. Similarly, under sub-optimal soil moisture conditions, there was no evidence of competition for water, possibly because the maize roots did not extend as far as the cane rows.

However, the intercropped cane may have experienced more water stress than the sole cane as an indirect consequence of competition for light. With optimum irrigation, excellent maize yields and full cane yields were obtained.

Maize started to shade the intercropped cane at the 5th week. Tiller formation in the cane was reduced to a variable amount depending on the extent to which the maize shaded the cane and this was itself a function of the density of the intercropped maize. Tiller formation resumed rapidly after the removal of the maize. Depending on the extent to which the young cane was affected by the maize, the final cane yield was more or less reduced.

In plant sugar cane, even at the relatively low density of 20800 plants per hectare, intercropped maize sometimes reduced the yield of sugar. In general, the gain in maize yield was offset by the loss in sugar, so that there was only a modest advantage from mixing the crops. Nevertheless, several maize-cane combinations were financially attractive in the second season.

Intercropping of ratoon cane, on the other hand, was more interesting in terms of the advantages in yield as well as of the economic benefits which were substantial with some combinations. This was because of lower effects of maize on the ratoon cane.

In view of the advantages in yield and gross margins observed in several trials with intercropping of sugar cane

with maize, it is recommended that the research work be pursued and that commercial trials be initiated along the lines mentioned in the subsequent section.

5.2 Further work.

It has been established that maize competes with intercropped sugar cane for light. An attempt to modelise this effect has been made. Further work along this line should be rewarding.

One of the most dramatic and easily-measured effects of maize on intercropped cane is the reduction in tiller formation. This reduction may or may not lead to a reduction in final yield depending on the extent of 'rattrapage'. This phenomenon appears to be of critical importance, and factors that influence the extent of 'rattrapage' should therefore be studied. In particular, the role of nutrients and of water should be thoroughly investigated.

In view of the possible practical importance of delayed planting of maize, and because one of the 2 trials that have so far been carried out was affected by drought, it is suggested that the temporal relations be re-examined at several sites.

The results of this study show that pairing of cane rows may not be of much value. However, because of the other possible benefits of the practice and in particular, of the possibility of intercropping older ratoons, and of the

potential which such a possibility represents, it is recommended that studies be initiated on a commercial or semi-commercial scale on planters lands in different agro-climatic zones.

The conclusions about the agronomic and the economic merits of intercropping cannot be generalized, and recommendations cannot be issued for the whole of Mauritius on the basis of only 4 trials in plant cane and 3 in ratoon cane. Prior to the final choice of one intercropping method, large-scale commercial tests should be undertaken. This is probably best done on planters' fields. The cooperation of the 3 groups of sugar cane planters, i.e. Sugar Estates, large, and small planters is essential for the success of this undertaking. Only one or two intercropping patterns need to be tested, but this should be done on fairly large fields in order to gather information on management problems, labour inputs etc. Enough on-farm trials would have to be laid down to separate the influence of such factors as planting season and agro-climatic zone on plant and ratoon sugar cane.

A number of important factors have not been considered in this study. Sooner or later they will have to be studied. The list includes maize and cane cultivars and the intimacy of mixing, all of which have been referred to in the literature.

Chapter VI

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APPENDIX I. VALUES OF SOME PARAMETERS USED IN
THE DETERMINATION OF WATER APPLIED IN 2 WATER
REGIMES IN A TRIAL AT BELLE VUE.

1. Duration of crop stages (weeks)

Stage	Maize	Sugar Cane
Planting to 0.25 canopy	0-2	0-8
0.25 to 0.50 canopy	3-4	9-13
0.50 to 0.75 canopy	5-6	14-19
0.75 to full canopy	7-8	20-24
Peak water use	9-12	25-50
Early Senescence	13-14	51-56
Ripening	15-16	57-66

2. Adjustment to crop factors, K_c which relate the crop water requirements to the calculated evapotranspiration, ET_o obtained from Penman's equation, by the method of Doorenbos and Pruitt (1977)

a. Sugar cane: Reduction of K_c by 25 per cent because of the use of a drip system and hence less losses by evaporation, run-off etc.

b. Maize : Reduction of K_c by 25 per cent as above.

Additional reduction by 25 per cent because the density was only 1/2 of normal density.

3. Actual Kc used in the trial compared to calculated Kc after adjustments.

Week	Calculated Kc		Actual Kc in trial	
	Maize	Sugar Cane	A2 Regime	A3 Regime
1	0.2	0.3	-	-
2	0.2	0.3	-	-
3	0.3	0.4	-	-
4	0.3	0.4	-	-
5	0.3	0.4	0.3	0.7
6	0.4	0.5	0.3	0.8
7	0.5	0.5	0.3	0.9
8	0.6	0.5	0.3	1.0
9	0.6	0.5	0.3	1.1
10	0.6	0.6	0.3	1.2
11	0.5	0.6	0.4	1.1
12	0.5	0.6	0.4	1.0
13	0.5	0.7	0.4	0.9
14	0.4	0.7	0.4	0.8
15	0.4	0.8	0.4	0.8
16	0.3	0.8	0.4	0.8
17-21	-	0.9	0.9	0.9
22-24	-	1.0	1.0	1.0
25-28	-	1.1	1.1	1.1
29-50	-	1.2	1.2	1.2
51-53	-	1.0	1.0	1.0
54-56	-	0.8	0.8	0.8
57-66	-	0.6	0.6	0.6

APPENDIX II. PARAMETERS AND ASSUMPTIONS USED IN
THE FINANCIAL EVALUATION OF MIXTURES OF SUGAR
CANE AND MAIZE.

CANE

1. Revenue ; Price of sugar(including molasses and bagasse)=Rs 4000/t

2. Variable costs per hectare

Item	Rs/ha	
	Plant cane	Ratoon cane
a) Machinery (subsoiling, ploughing levelling, furrowing).	832	624
b) Material inputs (cuttings, fertilizers, herbicides).	4420	4230
c) Labour(i) (planting, application of fertilizer etc., per hectare)	712	462
(ii)(harvesting and loading, per tonne of cane)	31	31
d) Transport charges (per tonne of cane)	18	18
e) Irrigation charges(per round)	200	200

* See notes on next page. Note : Certain costs made on plant cane such as for machinery, cuttings, labour and phosphate fertilizer also benefit the ratoons and were amortized over one plant and 7 ratoons in the following proportion: 16% for plant cane and 12% for each of the 7 ratoons.

Maize

1. Revenue ; Price of maize ears (at 25% moisture content, unshelled) = Rs 3600/t

2. Variable costs/ha

<u>Item</u>	<u>Rs / ha</u>			
	<u>Intercropped maize</u>		<u>Sole maize</u>	
	33%	67%	100%	100%
a) Machinery	119	238	356	5175
b) Material inputs (seeds, fertilizers, biocides).	2217	4154	6091	6205
c) Labour (planting, application of herbicide etc. harvesting)	656	1311	1967	2622
d) Transportation charges (per tonne of humid, unshelled ears)	110	110	110	110
e) Irrigation charges (per round)	200	200	200	200

*See notes on next page.

Note 1. Certain costs made for cane benefit the inter-cropped maize as well .e.g. land preparation, but sole maize have to bear all costs. In the calculation of the costs of sole maize over the entire cane cycle, it was assumed that the second and the third crop would not require sub-soiling but only shallow ploughing. The intercropped maize required only levelling and furrowing.

Note 2. In irrigated trials, 1 or 2 extra irrigations were given at planting to promote germination of maize and these were charged to the maize.

APPENDIX III EXAMPLE OF THE CALCULATION OF LER
ON YIELD AND ON GROSS MARGIN BASIS.

Parameters

-Trial no 12: Intercropping of plant sugarcane with maize at Pamplémousses.

-Treatment no 3: One row of maize in every interrow of uniformly-spaced cane

-Sugar yield of sole cane	:11.35 t/ha
-Sugar yield of mixture	:10.28 t/ha
-Grain yield of sole maize(3 crops)	:20.92 t/ha
-Grain yield of mixture	:6.28 t/ha
-Gross margin of sole cane	:Rs 30.7x10 ³ /ha
-Gross margin of sole maize(3 crops)	:Rs 43.4x10 ³ /ha
-Gross margin of mixture	:Rs 46.2x10 ³ /ha

Calculations

Area required as sole crop to produce 10.28 t of sugar

$$=10.28/11.35 = 0.906 \text{ ha}$$

Gross margin from sole cane on 0.906 ha

$$=0.906 \times 30.7 = \text{Rs } 27.81 \times 10^3$$

Area required as sole crop to produce 6.28 t of maize grain

$$=6.28/20.92=0.30 \text{ ha}$$

Gross margin from sole maize on 0.30 ha

$$=0.30 \times 43.4 = \text{Rs } 13.02 \times 10^3$$

Total area for 2 sole crops grown separately

$$=0.906 + 0.30 = 1.206 \text{ ha}$$

Total gross margin from 2 sole crops grown separately

(assume no charge for extra land)

$$=40.83 / 1.206 = \text{Rs } 33.86 \times 10^3$$

LER(yield basis)

=total area of 2 sole crops / total area of mixture.

$$=1.206 / 1.000 = 1.21$$

LER(gross margin)

=Gross margin per hectare of mixture / gross margin per hectare of 2 sole crops separately.

$$=46.20 / 33.86 = 1.36$$

Therefore:

$$\text{LER(Yield basis)} = 1.21$$

$$\text{LER(Gross margin basis)} = 1.36$$