

MAIZE VARIETY AND POPULATION STUDIES IN A
CASSAVA/MAIZE INTERCROPPING SYSTEM

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by
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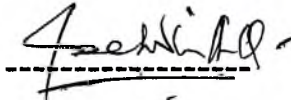
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DECLARATION

I hereby declare that, except for references to other people's work which have been duly cited, this work is the result of my own original research and that this thesis has neither in whole nor in part been presented for another degree elsewhere.

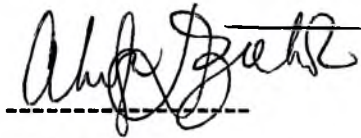


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ABSTRACT

This study was conducted to identify some agronomic characters of maize plants which make them suitable for use in cassava/maize intercropping systems. The feasibility of intercropping cassava with high maize populations was also studied.

A strip-split plot design with a parallel-row systematic arrangement in which five maize varieties, IK84A-2135, IB84A-203, TZSR-Y-1, 1368 x 5012 and 9450 x 4001 at five population densities of 10,000, 20,000, 40,000, 80,000 and 160,000 plants/ha intercropped within two cassava spacings, 100 x 100cm and 100 x 67cm was used.

Increasing maize population in the mixture from 10,000 to 160,000 plants/ha caused a decrease in leaf area, stalk diameter, leaf angle, ear weight, delayed silking, increased ear and plant height, leaf area index, root and stem lodging, barrenness and stover weight of maize. Maize yields peaked at 80,000 plants/ha and declined thereafter. Cassava spacing did not affect maize yields. Correlations between maize yields and agronomic characteristics of the maize varieties were not consistent.

Agronomic characteristics of cassava observed at 8 weeks, four months and seven months after planting indicated that maize plant height and maturity had an effect on cassava growth.

Cassava plant height and internode length increased whilst stem diameter, number of branches and leaves, root yield and its related components, shoot and root dry weight, and harvest index decreased with increasing intercropped maize population.

Land Equivalent Ratio (LER) values indicated that shortness and earliness are desirable agronomic characteristics too be incorporated in maize varieties intended to be used in cassava/maize intercropping. Suggested optimum maize population in the intercrop for IK84A-2135 was 80,000 plants/ha. This population gave the highest LER. At the same range of cassava spacings, 40,000 plants/ha of the other maize varieties could be used.

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LIST OF ABBREVIATIONS AND SYMBOLS

a.i.	-	active ingredient
°C	-	Degrees Celsius
cm	-	Centimetre
d.f.	-	Degrees of Freedom
DMRT	-	Duncan's Multiple Range Test
%	-	Percentage
MAP	-	Months After Planting
plts/ha	-	Plants Per Hectare
R ²	-	Coefficient of determination
WAP	-	Weeks After Planting

CHAPTER 1

INTRODUCTION

Recent concern over the world's food situation has called for more attention to be paid to the cropping systems in the less developed countries in the tropics particularly in Africa. Studies of the traditional farming systems in Africa have revealed that there are several field systems. These include semi-permanent systems, permanently cultivated compound farms, bush fallowing or land rotation systems and finally the classical shifting cultivation system which is gradually becoming a practice of the past (Okigbo and Greenland, 1976; Benneh, 1972; Ruthenberg, 1980). All these system are characterised by smallness of farm size, most of which do not exceed 2 hectares, and a widespread use of bush fallowing in maintaining soil fertility. Land clearance is mainly by the slash and burn technique. There is minimal use of mechanical and animal power in the farming operations. In addition, there is a general lack of capital or credit facilities for the purchase of inputs and services. Productivity and returns are often considered to be low (Okigbo and Greenland, 1976; Okigbo, 1981). The traditional farming system is highly diversified. The various cropping systems in existence have evolved over several years and are adapted to the climate, soils, vegetation and the needs of the inhabitants in given areas. This accounts for a great variation in the types and numbers of crops grown as well as the pattern of land use. The commonest feature of the traditional farming system is, however, the practice of

intercropping. This involves the growing together of two or more crops at the same time in a given season (Ruthenberg, 1980; Okigbo and Greenland, 1976). Intercropping is very complex especially in the rain forest areas (Karikari, 1981). There is always a major crop grown with some subsidiary crops. Dominant staples such as maize, cassava, yam and plantains are grown in various combinations and may also be planted together with subsidiary crops like legumes and leafy vegetables. In most practices, crops in the mixture are rarely grown in rows.

The growing of crops in pure cultures referred to as sole cropping or monoculture is a recent introduction in the tropics. Perennial cash crops like oil palm, rubber, cocoa and coffee are grown in monocultures whilst annual cash crops like cotton and some vegetables are grown in sole cropping systems. Despite the introduction of these cash crops and their subsequent establishment in plantations, the traditional farmer still incorporates some elements of intercropping into his farming operations. It is very common to find cocoyams, bananas and plantains growing together in young rubber and cocoa holdings. Similarly maize, cassava and plantains can be found in young oil palm plantations.

The traditional cropping systems have been considered in the past to be primitive, less productive and less efficient than sole cropping (Jurion and Henry, 1969). This misconception has been based on inadequate research possibly because of the difficulty in conducting experiments on these

cropping systems or the tendency at that time for research workers to pursue research patented after agricultural practices in the developed countries from where most of the research workers came and from where their students obtained their education (Baker, 1978).

The changes in socio-economic conditions in developing countries marked by economic depression, food shortages and population increases has been beneficial. Much attention is now being given to the study of the traditional farming systems. Researchers have realised that intercropping has several advantages. Aiyer (1949) and Norman (1974) have given reasons why farmers practise intercropping. The most important is that yields are stable and dietary needs of the farmer are met in an environment where rainfall not being reliable is aggravated by the abundance of pest and diseases. Further, the traditional cropping system are well adapted to the ecological, socio-cultural and socio-economic conditions of tropical agriculture (Steiner, 1982). It has also been found that despite the efforts of extension services to promote sole and monocropping practices, there is still no indication of any decrease in the importance of intercropping (Steiner, 1982).

Intercropping cassava with maize is one of the most popular crop combinations in mixed cropping under rainfed agriculture in the tropics. These two crops of varying growth duration and rhythm supply the bulk of the calorific requirements of the inhabitants of the humid and subhumid

tropics (Ezeilo, 1979; Mureno and Hart, 1979; Kumar and Hrish, 1979).

A practical advantage of intercropping is increasing land productivity per unit area. Maximisation of yield entails the use of optimum plant populations of component crops (Baker, 1981; Freyman et al., 1977) and the minimisation of above and below ground competition for growth factors (Trenbath, 1976) by using suitable varieties and improved crop protection measures. Considerable work has been done on the suitability of improved varieties bred in monocrop situations in intercropping systems. Varieties which perform well in monoculture may not do so when they are grown in intercropping systems and may adversely affect the growth and yield of the associated crop(s). It has been shown that plant height, maturity and canopy architecture of maize are very important factors in maize/bean mixed cropping systems (Wahua et al., 1981; IITA, 1982).

Kang and Wilson (1981) and Guritno (1984) have obtained variable results with improved maize varieties in a maize/cassava mixture with varying population levels. It is believed that this variation is related to the maize genotype used. In all these studies, the yield of cassava was reduced at higher maize populations; the intensity of reduction being related to the associated maize variety. Research workers have accounted for this yield reduction of component crops on the basis of increased competition for light, moisture and soil nutrient with increasing population. Differences in plant

height and canopy architecture of maize observed in maize/bean associations have been speculated to be the cause of the different amount of light transmitted to the lower canopy in a maize/cassava intercrop system (Ezumah and Lawson, 1983; IITA, 1982).

Though large intercropping advantages have been recorded for some of these studies in maize/cassava intercropping systems, the effects of maize genotype and population levels on cassava calls for a clearer definition of plant characters of maize required in a maize/cassava intercropping system as breeders continue to release new maize varieties, if the efficiency of the system is to be improved.

The objective of the study was therefore to explore a range of maize varieties recently released at IITA to determine some of the major characters which make them suitable for intercropping with cassava and also examine the feasibility of intercropping cassava with these maize varieties at higher than the optimum recommended population.

CHAPTER TWO

LITERATURE REVIEW

2.1 Concept of Multiple Cropping

The growing of two or more crops in the same field in a given season is an ancient farming technique that has persisted as a method to maximise land productivity per unit area per season. This practice which is widespread and varied is referred to as multiple cropping (Andrews and Kassam, 1976).

There are basically two forms of multiple cropping, sequential cropping and intercropping. According to Andrew and Kassam (1976) sequential cropping is the growing of two or more crops on the same field in sequence per year. Crop intensification is only in time dimension. There is no intercrop competition. Farmers manage only one crop at a time on the same field. Intercropping on the other hand is the growing of two or more crops simultaneously on the same field. Crop intensification is in both time and space. There is intercrop competition during all or part of the period of crop growth. Farmers manage more than one crop at a time on the same field.

Variants of these basic types have also been classified by Andrews and Kassam (1976). These are double, triple, quadruple and ratoon cropping for sequential cropping and mixed, row, strip and relay cropping for intercropping.

Other related terms defined by Andrews and Kassam

(1976) to streamline terminologies in multiple cropping include the following:

- Sole cropping - One crop variety grown alone in pure stand at normal density; opposite of intercropping.

- Monoculture - The repetitive growing of the same crop on the same land.

- Rotation - The repetitive cultivation of an ordered succession of crops (or crops and fallows) on the same land. One cycle takes several years to complete.

- Cropping Pattern - The yearly sequence and spatial arrangement of crops and fallow in a given area.

- Cropping System - The cropping pattern used on a farm and their interaction with farm resources, other farm enterprises and available technology which determine their make-up.

- Mixed Farming - Cropping system involving the raising of crops, animals and/or trees.

Cropping Index - The number of crops grown per annum on a given area of land multiplied by 100.

2.2 Intercropping and its Advantages

Intercropping is practised widely in the tropics by small scale farmers as a strategy for increasing crop yields, crop diversity and the stability of crop production (Gomez and Gomez, 1983). Until the beginning of the 1970s very little research on intercropping had been done (Pinchinat et al., 1976). The work of Bradfield (1970) at IRRI stirred interest in the study of this aspect of crop production. It has been realised that there are numerous advantages compelling traditional farmers to stick to the practice.

Yield stability often cited as a major advantage of intercropping essentially means less variability of yield over different seasons or different situations. This is now considered to be one of the major reasons why intercropping remains an extremely important practice in developing countries on the grounds that it offers the desired insurance against uncertainties (Osiru, 1983). Crop mixtures in intercropping mimic natural ecosystems and are more dynamic biologically than pure stands and are less susceptible to adverse environmental conditions such as drought, diseases and insect pests (Andrews and Kassam, 1976). Yield stability is achieved in a number of ways. The commonest example is the situation in which one crop may fail or only grow poorly either because of

damage caused by diseases, pests or damage by rainstorms. Under this situation, compensation by the remaining crop(s) may occur (Fisher, 1977). The risk of total crop loss is therefore minimal.

Growing crops with varying growth rhythm and duration in mixtures produce a rapid vegetative cover on the soil most of the time than in monoculture. This tends to prevent weed growth as light transmission to the undergrowth is reduced. Further the overlapping layers of leaves protect the soil from the direct impact of the rain thereby lessening water and soil erosion. Soil conservation is further achieved by the use of minimum tillage in the farming operations. In addition, crops with differing canopy configurations make better use of light whilst nutrients which would otherwise have been leached away is utilised by the quicker growing crops as well as those with extensive tap root systems.

Instances of reduced pest and disease incidence in mixed cropping have been reported. It is believed that the microenvironmental changes such as reduced light intensity, production of roots exudates, etc. within the intercrops become unfavourable to pests and spread of diseases.

Intercropping crops like cereals with legumes which fix nitrogen to supplement the nitrogen needs of both the current and subsequent cereal crops have been reported. Agboola and Fayemi (1971) concluded from a study of intercropping maize with five different tropical legumes that cowpeas (Vigna sinensis), green gram (Phaseolus aureus) and

calapo (Calapogium muconoides) could satisfy the nitrogen needs of maize during the growing periods whilst Bandyopadhyay and De (1986) in India reported relative advantages by a succeeding wheat crop which followed sorghum intercropped with cowpea, mung bean (Vigna radiata), and groundnuts (Arachis hypogea L.). The depleting effect of continuous cropping on soil fertility is therefore lessened by the incorporation of legumes in intercropping systems, a practice which ensures the maintenance of soil fertility at minimal expense.

The growing of crops together in mixtures is likely to provide diversity in the diet of the farmer. The combination of starchy staples and legumes appears to satisfy the high energy and protein requirements of the farmer. The varying maturities of the crops also ensures a regularity of supply and may allow for a better exploitation of market opportunities.

Labour use which is quite critical appears to be more efficiently used. Norman quoted by Osiru (1983) suggests that labour requirement is lower in intercropping. This may be achieved in a number of ways. First when one crop is planted after another such as when phaseolus beans are planted in maize fields, or groundnuts in cassava fields in Uganda, it can be argued that this practice may lead to lower labour requirement since the process of weeding the first crop prepares a seedbed for the second crop. The possibility of a quick crop cover causes weeds to be out-competed and consequently the number of weeding times may be reduced.

Several experiments have shown that higher yields per



nit area in a given season could be achieved in intercropping than by growing the crops separately. Maize and beans mixture in a replacement series trial by Willey and Osiru (1972) gave up to 38 percent more total yields than would be achieved by growing these species as pure stands. Andrews (1972) examining mixtures of sorghum with maize, millet and cowpea found that it was more advantageous than growing sorghum alone. The higher yield achieved may have been due to the fact that the mixtures made more efficient utilization of environmental resources. f)

A number of disadvantages often cited against the practice of intercropping include the difficulty of mechanising operations such as planting, application of inputs, such as fertilizers and herbicides and the harvesting of the crops as well as the difficulties in managing experiments involving intercrops (Okigbo and Greenland, 1976).

Considering the advantages of intercropping, to discourage the practice on the basis of the disadvantages mentioned is an evasion of the issue of finding a solution to the food problem in the developing countries. More research is rather needed to improve the productivity of the system.

2.3 Plant Interactions in Crop Mixtures

When plants are grown together in sole or in intercropping systems, individual or component plants react to the modified environment due to the presence of the other plants. Broadly, this response of plants to their modified environment has been referred to as competition (Palaniappan, 1986) but Harper (1961) and Hall (1974) prefer the term

interference as competition is only one facet of interference.

In mixed crop communities, associated species share for their growth, resources such as light, water and nutrients from a common pool. Under certain conditions the growth of both component plants are not affected. This situation is referred to as complementarity and usually leads to increases in yields of the component crops (Trenbath, 1976). Complementary use of resources by exploiting the environmental supplies in different ways by the components of a community has been termed annidation (Trenbath, 1976).

Annidation can be in the form of space or time. Annidation in space occurs when the canopies of a multispecies plant community occupy different vertical layers with the tallest component having foliage tolerant of strong light and high evaporative demand and the shorter component(s) having foliage tolerant of shade and/or relatively high humidity. This advantageous combinations is often found in cocoa farms in West Africa where shade trees and crops are used to protect the young growing cocoa. Exploitation by the root systems of intercrop components of different layers of the soil is another example of annidation in space and may lead to higher combined yields of components crops. Annidation in time are possible in crops with differences in growth cycle. When the earlier component has matured conditions become favourable for the other component.

The interaction becomes competitive or inhibitive when one or more growth factors become limiting and the yield of

each component crop is reduced below the average yield of the pure stands. Competition or interaction is said to be compensatory when the yield of one component increases whilst that of the associated component crop decreases by a proportionate amount (Willey, 1979a; Donald, 1963). Under limiting conditions of resources, the mixture component which is better equipped to use a greater share of the growth resources or limiting factors is the dominant component and gains at the expense of the dominated component which is less competitive (Huxley and Miangu, 1978).

Under competitive conditions plants respond in various ways. Donald (1951) relating plant weight of subterranean clover (Trifolium subterraneum) to the density of seeds sown found a progressive reduction in plant weight with density as plants developed while competing for light. Cassava root yield decreased by 32 percent when light transmission was reduced 5-10 percent by a maize variety with spreading leaves. (IITA, 1982). Other responses to competitive situations include reduced dark respiration, greater leaf area/leaf weight ratio, the tendency for the stem of plants to elongate rapidly in response to shaded conditions (Trenbath, 1976).

Agronomically, these responses are very important as the influence they exert on the growth and yield of component crops often manifest themselves in the yield of the mixture. The skill of successfully managing crop combinations in a mixture depends therefore on understanding and minimising these competitive effects by appropriate manipulation and exploitation

of the beneficial effects of competition (Nair, 1979).

Trenbath (1976) reviewed possible mechanisms which make intercropping efficient. He concluded that competition for light, water and nutrient may be reduced through temporal partitioning of growth and resource demand, and spatial partitioning of roots and leaf systems of components in mixtures. Harwood (1974) emphasises that intercropping systems are most rewarding in terms of the yield of the component crops when there is a gap between the period when the crops involved are making maximum demands on environmental resources. All these suggest the importance of crop compatibility in intercropping systems.

Allelopathic interaction whereby exudates from the roots of one species or decomposition products of residues of one species may affect the growth of the associated species leading to either an increase or decrease in yield of the mixture is also a form of competition (Trenbath, 1976).

2.4 Formulation of Crop Mixture

In sole crops, plant population is defined as the number of plants per unit area. In intercropping, plant population has to be defined both in terms of the total population (both crops combined) and component populations (each crop individually) (Willey and Rao, 1981). Considering plant population pressure on resources, a single plant of one crop is seldom directly comparable to a single plant of another crop (Willey and Osiru, 1972). To overcome this problem, Willey (1979^b) regards optimum populations of sole crops as

comparable. If they are taken as 100, component populations can be expressed on a relative basis. For example, a simple intercrop treatment having half the sole crop optimum of each of the two component is expressed as a 50:50 component. Total optimum population of intercrops may be higher than that of either sole crop on a relative basis, for example a 60:70 optimum population may be obtained.

Formulation of crop mixtures can be based on two major models namely additive or superimposed and replacement or substitutive models. In an additive model, the mixture contains the optimum sole crop population of each of the component species. In such additive models, total population of the mixture is greater than that of either sole crop. The substitutive or replacement model as used by de Wit (1960) involve complementary ratios of component crops in pure stand populations such that the intercrop land area remained the equivalent sole crop area. In intercropping systems, one crop is usually regarded as the main or dominant crop and the other as a minor or subsidiary crop (Enyi, 1973; Okigbo and Greenland, 1976). With regard to this fact, May (1982) classifies intercropping systems as additive or replacement. In additive intercropping, the monoculture populations per hectare of the two crops are added together with the aim of producing the usual yield of the dominant crop and a bonus yield from the second crop. In replacement intercropping, part of the monoculture population of one crop is replaced by an equivalent portion of the second crop to sacrifice a small part

of the usual yield of the first crop in monoculture in return for a much higher yield of the second crop than is obtained from additive intercropping. Baker (1981) also recognizes two types of mixtures; a replacement mixture and a superimposed mixture. Replacement mixtures generally consist of mixtures from the same phenological group whereas superimposed mixtures are usually drawn from different phenological groups; the replacement mixture satisfies the requirements of the substitutive model whilst the superimposed mixtures fits into the additive model.

Experiments have shown that optimum population density can be increased in all intercropping systems where interference between neighbouring plants is less than in sole crops (i.e. where intercrop competition is less than intracrop competition). Population increases are most likely to cause increases in yield in mixtures where there are large temporal differences in growth patterns of component crops (Trenbath, 1976). Baker (1979) obtained yield increases at higher populations from mixtures of 75-day and 85-day sorghum varieties. Similarly, Leihner (1982) reported higher total yields from a cassava/bean mixture where higher than normal sole-crop planting densities were used.

2.5 Assessment of Mixture Productivity

Various mathematical expressions have been advanced to explain competition and its effect in crop mixtures (Willey, 1979b). These expressions include:

- Relative Yield Total (RYT)
- Land Equivalent Ratio (LER)
- Relative Crowding Coefficient (RCC)
- Aggressivity (A)
- Competitive Ratio (CR)
- Competition Index (K)

Most of these were initially used for investigations involving competition between genotypes of a particular species rather than between intercropped species. Further some of these indices are restricted to interpreting replacement series experiments which have dominated most research in competition (Mead and Riley, 1981).

Amongst the functions, LER appears to have a wider applicability. It also gives a magnitude of yield advantage. Hence it is preferred to assess competition effect as well as productivity in mixtures.

The LER is defined as the relative land area under sole crop that is required to produce the yield achieved under intercropping at the same level of management.

$$\text{LER} = \frac{(\text{Yield of Intercrop})Y_a}{(\text{Yield of sole crop})Y_{aa}} + \frac{(\text{Yield of Intercrop})Y_b}{(\text{Yield of sole crop})Y_{bb}}$$

The LER of a mixture is thus the sum of the LERs or partial LERs for each intercrop. A LER ratio greater than one signals yield advantage, and a ratio less than one disadvantage.

When LER is measured at a uniform overall density of the crop grown as the intercrop and sole crop with which it is to be compared, LER will be equal to the relative yield total (RYT) suggested by de Wit and Van den Bergh (1965).

There are two difficulties with LER as defined and both arise from its use as a measure to compare different intercropping situations. Because LER is defined as a ratio, large values can be obtained because of large yields in intercropping but also because of small yields in corresponding sole crops. The second difficulty in using LERs as a measure of biological efficiency to compare different situations of the two crops is the assumption that the harvested proportions of the two crops are exactly those that are required in each situation (Mead and Willey, 1980).

To simplify the issue, calculation of an LER value can be regarded as essentially standardizing the two component crop yields (Mead and Willey, 1980). The method of standardization should vary according to the form and objective of the experiment. A good example where standardizing sole crop yield would be agronomically valid is where the treatments consist of different plant populations and spacings. Huxley and Maingu (1978) emphasize in such experiments that yields should be compared with the sole crop at its optimum population and spacing. Trenbath (1976) also suggests that if the objective of a trial is to determine beneficial crop combinations, the LER can be computed using the optimum sole crop populations.

Willey and Rao (1980) recommends the usefulness of LER

in the evaluation of the degree of competitiveness between intercrops. To establish the degree of competitiveness between component crops, the competitive Ratio (CR) proposed by Willey and Rao (1980) is used. It is simply the ratio of the LERs of the two component crops but correcting for the populations in which they were initially sown. The CR for A in association with crop B is then:

$$CR_a = \frac{LER_a}{LER_b} \times \frac{Z_b}{Z_a}$$

where Z_a and Z_b are the relative spaces occupied by crop A and B respectively. For a 50:50 mixture, with LER of 0.8 and 0.4 a CR value of 2 for the first crop would be obtained. This means that component crop is produced twice as much as expected and it is twice as competitive. Different growth and yield attributes of a component crop can be correlated with its CR value and based on the significance of the correlation coefficient values, the factor deciding the competition can be decided.

Willey and Rao (1980) cautions that care must be exercised in interpreting the term. For example, in an experiment with pigeon pea and sorghum, Willey and Rao quoted by Palaniappan (1985) obtained good correlation between CR value of pigeon pea and maturity differences between pigeon pea and sorghum. However, this does not mean that pigeon pea is more competitive. Actually pigeon pea avoids competition since it has a greater time to compensate for the early competition from sorghum due to its longer duration. When the LER of a

particular crop is plotted against its CR, the optimum balance of competition between component crops can be identified by observing the peaks.

Hiebsch, cited by McCollum (1983) proposed the concept of Area-Time Equivalency ratio (ATER). This concept evaluates the productivity of mixtures in both area and time dimensions. It has not been much used. Other measures of productivity of crop mixtures are based on plant constituents, such as nutritional value (crude protein, proportion of essential amino acids etc), calorie value and economic returns. Using economic returns as a criteria for evaluating mixture productivity not only compares the biological efficiency of the system but also takes into account the fact that inputs, such as labour have to be used in different amounts for different cropping systems (Steiner, 1982).

2.6 Maize

2.6.1 Origin and Distribution

Maize is a member of the family Gramineae, subfamily Panicodae, subtribe Tripsacine and included in the genus *Zea* (Clayton, 1973). Cultivated maize belongs to the species *Zea Mays* L. Maize is considered to have originated in the New World. Mangelsdorf and Reeves, quoted by Fischer and Palmer (1984) indicated that the ancestors of modern varieties of maize occurred somewhere in the lowlands of Paraguay, north-eastern Bolivia or south-western Brazil with secondary centres of diversities in the Andean regions and Central

America where great diversity of types were observed.

It is generally believed that maize was introduced into the Old World from America following the second voyage of Columbus in 1492. From Europe it spread rapidly into Asia and Africa. Two main routes of introduction into the West African subregion have been identified. The northern route across the desert from Egypt and the southern route through the Atlantic ocean. These routes of introduction brought into the region, from the north the flinty maize types with generally a light yellow or sometimes white colour and from the south flinty and floury grained varieties (van Eijnatten, 1965).

Maize is now grown from about 55°N to 45°S and from sea level to 3800m altitude thereby making it the most adapted cereal (Fischer and Palmer, 1984). The production of maize now covers more than 100 million hectares of moist fertile land in the temperate, subtropical, tropical lowlands in the United States, West Germany, Italy, China, Argentina, Brazil and the Republic of South Africa (Galinat, 1979). There is also substantial production in Zimbabwe, Zambia, Botswana, Uganda, Nigeria and Ghana.

There are extensive reports about maize improvement programmes in many places. At IITA, research efforts are geared towards the breeding of high yielding varieties with resistance to specific diseases in Africa such as streak and pests and parasites such as the pink stem borer (Sesamia calamitis) and Striga (Striga hermonthica).

2.6.2 Production and Importance

Between 1978-1983, some 380 million tonnes of maize were produced annually on 120 million hectares of land, representing nearly a quarter of world cereal production (FAO, 1984). Even though, the larger portion of land acreage under maize cultivation is in the developing countries in the tropics, two thirds of the world's maize is produced in the developed countries whose climates are entirely temperate (FAO, 1984).

Two-thirds of maize produced in developing countries is used directly for human food (Fischer and Palmer, 1984). High consumption of maize is characteristic of most developing countries of Africa and Latin America having low per capita income. Most of these countries have special dishes made from maize. In Nigeria, dry maize is usually ground and made into a paste called "ogi" in the south and "masara" in the north (van Eijnatten, 1965). In Ghana, the cooked ground paste is called the kenkey. It is also common to find green cob (soft dough stage) being harvested for roasting or boiling (personal observation). In developed countries, different food items are derived from maize. Some of these are; cornflakes, corn flours, thickenings and pastes, maize syrups, soft drinks, juices, cooking oil and liquor (CIMMYT, 1984).

Maize is important in livestock production since it is a major constituent of animal feed. About 90 percent of the maize produced in countries like the United States, the United Kingdom is utilized for livestock production and as raw material for industrial byproducts. Stem and foliage of the

maize plant are used for green chop, hay, silage and pasture (Islam and Kaul, 1986).

The most important industrial uses of maize is in the manufacture of starch. The cob and the stalk find use in the paper and cardboard industry. They are also used in the production of chemicals, plastics and alcohol. Maize steep water has much use in the pharmaceutical industry (Islam and Kaul, 1986).

2.6.3 Maize in the Cropping System of the Tropics

Maize is a C₄ crop, and is an important component of cropping systems in the middle rainfall zone of the tropics where the annual rainfall is about 750-1750mm (Norman et al., 1984). In more arid regions where the rainfall is too short for genotypes of high yielding potential and the incidence of within season dry spells too severe, it is replaced in Africa and Asia by sorghum and pearl millet. In high rainfall zones, maize tends to be replaced as a staple by tuber crops or plantains which can take advantage of the long growing season, though it may still form a component of the cropping system (Norman et al., 1984).

Maize is commonly grown in mixtures in mixed cropping situations. Okigbo and Greenland (1976) reports that about seventy-five percent of the area of maize in Nigeria and eighty four percent in Uganda is in association with other crops. The following associated crops are found in mixed cropping patterns

that include maize: Cassava/yam/cocoyam/bean/vegetables in Nigeria, upland rice/banana/cassava in Liberia; upland rice/cassava/okra/pepper in Sierra Leone; plantain/cocoyam/cassava/vegetables in Ghana; sweet potato/cassava/melon/tobacco in Central African Republic and beans/groundnuts/sweet potato/sorghum/legumes/upland rice in Tanzania (Okigbo and Greenland cited by Norman et al., 1984).

In most of these cropping mixtures, maize is either the first crop or one of the earliest crops to be planted and may be the first to be harvested. It is common to find maize, which is cultivated mostly on ridges or on the flat growing on the wide of yam mounds in Eastern Nigeria (Onwueme, 1978).

In regions with dependable amounts of rains during the minor season or where there is an extended period of rainfall, a second crop of maize may be planted. The nutrient requirement of maize is relatively high and as such in Africa, intercropping maize is generally practised in the early phases of the opening of the virgin forest or clearing of a fallow (Braun, 1974). Ruthenberg (1980) reports that maize is commonly grown with perennials during their early establishment phase; for example, oil palm and coconut are often interplanted with maize in West Africa. Maize is also intercropped with coffee in Tanzania and Ivory Coast.

In Asia, the intensive cropping of rice places maize in a subsidiary position. Maize is found in association with legumes or vegetables following a wet-season rice crop. Maize/upland rice/cassava and maize/upland rice followed

sequentially by maize is the dominant cropping pattern associated with maize in Indonesia (McIntosh et al., 1979).

Thailand has developed a major export industry in maize, much of which comes from large acreages under partial mechanization. Monoculture maize is the first crop, followed by beans, sorghum or cotton (Ruthenberg, 1980). Maize in association with the common beans (Phaseolus vulgaris) is the most widespread upland cropping pattern involving maize in tropical America. According to Francis et al. (1976), about 80 percent and more than 50 percent of the bean and maize area respectively is intercropped.

2.7 Cassava

2.7.1 Origin and Distribution

Cassava (Manihot esculenta [Crantz]), a perennial woody shrub belongs to the family Euphorbiaceae, which includes rubber (Hevea brasiliensis) and castor bean (Ricinus communis). Cassava originated in the New World. Its exact area of original domestication is not known with certainty but it is believed to have originated in north-east Brazil where there is a major centre of diversity and secondary centre in central America (Cock, 1984). Cassava was first introduced into Africa by Portuguese explorers into the Congo Basin around 1558. It spread rapidly to now Angola, Zaire and Gabon and later into West Africa. According to Jones (1959), separate introductions were made to the east coast of Africa and then to Madagascar (Malagasy Republic) in the eighteenth century. The introduction into Asia occurred probably in the seventeenth

century and by the end of the nineteenth century, it was widely grown throughout the low land areas of the tropical Asia and Oceania (Cock, 1984).

Cassava is a crop of the lowland tropics. It is grown between latitudes 30°N and S of the equator. Near the equator, it is found growing at altitudes up to 2300m but the highest altitude at which it is found becomes progressively lower further from the equator (Cock, 1984). Tuber formation is under photoperiodic control. Under short days tuberizing occurs readily but it is delayed when the daylength is greater than 10-12 hours. For this reason, cassava is most productive between latitudes 15° north and south of the equator. It does best in a warm moist climate where mean temperatures range from 25°C-29°C. Under cold climate, it does poorly and growth is arrested at temperatures below 10°C. It cannot withstand frost for any length of time during its growing period (Onwueme, 1978). Cassava is relatively drought tolerant and can survive even 4-6 months of dry weather. Under favourable conditions, it can recover from severe damage caused by insect pest such as the grasshopper (Zonecerus variegatus L.), cassava mealybug (Phenacoccus manihoti Mat.-Ferr.) and cassava green mite (Mononychellus tanajoa Bondar) and diseases such as cassava mosaic, bacteria blight, leaf spot, stem and root rot (Hahn et al., 1979).

2.7.2 Production and Importance

Cassava is the fourth most important source of energy which is both produced and consumed in the tropics. (Cock, 1984). Total world production is estimated at 118 million tonnes with 46 million tonnes in Africa, 44 million tonnes in Asia and 30 tons in South America. Zaire, Nigeria and Tanzania are major Africa producers. The average yield is approximately 8 tons/ha (Cock, 1984). Approximately sixty-five percent of total production is used for human consumption, about nineteen percent as animal feed and five percent for industrial use. The remainder goes to waste (FAO, 1984).

The importance of cassava in the lowland tropics particularly in Africa where it is a staple cannot be overemphasized. "Agbeli" meaning "there is life" is the name given to cassava by the Ewe-speaking tribe of south eastern Ghana and neighbouring Togo. This name appropriately sums up the importance of cassava to the inhabitants of the lowland tropics in Africa. The tubers may be eaten raw or they may be boiled or roasted and eaten. Alternatively they may be boiled and pounded into a paste referred to as fufu in Ghana. Small balls of the pounded paste are dipped into stew or broth and eaten. Other meals obtained from processing the tuber include gari, farinha de manioc and meal of retted cassava. These meals and flour forms account for the bulk of cassava used for human food in the tropics. Gari is the most popular form in which cassava is consumed in West Africa particularly in the urban areas (Onwueme, 1978) Farinha de manioc which is very

much like gari is the most common form in which cassava is consumed in Brazil and other parts of South America. Meal of retted cassava is consumed in the rural parts of West Africa and the Congo basin.

The fresh tuber is an important feed for livestock. It is an excellent energy source for sheep, goats, cattle and pigs. In many rural households, cassava peels are fed to domestic animals instead of being discarded.

Cassava chips, pellets, and starch are major industrial products that enter into international trade. The chips and pellets are used in animal rations whilst cassava starch has uses in the food industry, the manufacture of paper and lubricant for oil wells and in the textile industry. Alcohol is produced from cassava in Brazil as a cheaper alternative to petroleum products (Cock, 1984).

Cassava leaves have been found to be nutritious. The leaves and tender shoots are used as base for making sauces and soups particularly in the Congo basin, Tanzania, Cameroun and parts of West Africa (Onwueme, 1978).

2.7.3 Cassava in the Cropping System of the Tropics

Cassava is a significant component of cropping systems across a wide range of the tropical environment. It is grown both as a cash crop and as a subsistence crop. The cultivation of cassava in monoculture has been thoroughly reviewed by Toro and Atlee (1980). Its place and cultivation in traditional

agriculture in Africa has been also been documented by Ezeilo (1981), Ezumah and Okigbo (1980) and Onwueme (1978). The major crop combinations found associated with cassava in West Africa include: yam, pineapple and yam/maize (Ezumah and Okigbo, 1980). In East Africa, cassava is found associated with crops like plantain, beans, sweet potato, maize and groundnuts in various combinations. It is usually planted on mounds, ridges or on flats. In Nigeria, Okigbo and Greenland (1976) observed that cassava is planted on the sides of mounds, about 1m high and 3m wide at the base; the top of the mound is occupied by yams and upland rice is grown in the intervening flat areas.

Cropping sequences in parts of West Africa involving cassava have been reported by Karikari (1971) and Onwueme (1978). Whether alone or intercropped, cassava is the last in the sequence before the land is allowed to return to fallow. Two reasons have been assigned to this position of cassava in the cropping sequence. Onwueme (1978) states that in a fertile soil or a newly cleared fallow or virgin forest cassava removes a large amount of nutrients. In soils of low fertility, cassava still gives reasonably good yield. Thus if such a crop precedes other crops it will deplete the soil too severely for subsequent crops to perform well (Onwueme, 1978).

The performance of cassava on poor soils has been attributed to the mycorrhizal fungal association with the roots. These appear to be very important for the uptake of phosphorus and other nutrients (CIAT, 1980). Potassium requirement is very high. Obigbesan (1974, 1977) has observed

that depending on the rate of application, potassium can improve the root/top ratio, increase starch concentration and depress HCN concentration.

Description of cassava based cropping systems for Asia have been reported by Kumar and Hrishii (1979) for India, Effendi (1979) for Indonesia and Sinthuprama (1979) for Thailand. In Asia, intercropping cassava is most widespread in Indonesia where the greater part is grown as a subsistence in intercrop patterns with upland rice and/or maize. There is very little intercropping in Thailand, as cassava cultivation is a cash crop enterprise. Moreno and Hart (1979) and Lorenzi et al., (1980) have discussed the place of cassava in the cropping systems of tropical America. In Central America, it is grown as a subsistence crop featuring in perennial and semi-perennial crops of the lowland tropics or interplanted with maize and common beans in the wet and dry climates at moderate altitudes. Brazil is the largest producer of cassava and the bulk of the crop comes from subsistence farms where maize/cassava/beans intercrops are widespread.

Rogers and Appan (1972) and Onwueme (1978) have attributed the popularity of cassava in the cropping system of the tropics to the following characteristics:

- High calorie yield
- Flexibility and ease of production
- Ideal planting material
- Hardy plant characteristics
- Famine security crop
- Low cost of production

2.8 Research on Cassava/Maize Intercropping

Despite the predominance of maize/cassava mixture in the tropics, maize/legume mixtures have received much more study. Agboola and Fayemi (1971) concluded from their trial that calopo (Calopogonium muconoides), cowpea (Vigna sinensis) and green gram (Phaseolus aureus) could satisfy the nitrogen needs of maize during its growing period. Maize/bean intercrops have received much attention at CIAT and CATIE in recent times. Francis et al. (1978) found that when maize was planted at low densities that are common in farming practices, the presence of the associated bean had no detrimental effect on the grain yield of maize. Fisher (1977) in a study of the effect of population pressure in maize/bean mixtures reported that yield of both maize and beans in pure stands increased with increasing planting density. In the mixtures, maize yields were not significantly different from pure stand at any given density, but bean yields were much reduced in mixtures.

Research reports on cassava/maize mixtures are mostly obtained from the international research centres of IITA and CIAT. It appears very little work has been done at national research centres. Characteristics of component crops suitable for intercropping are being studied. Constraints such as diseases and pests which limit yield are being controlled. The effect of component crop population, spacing, time of planting, fertilizer use in mixtures are still under study.

LER values greater than one for cassava/maize mixture has been reported for various situations. Oeshligle et al.

(1974) at CATIE conducted an experiment on different levels of nitrogen applied to cassava alone, maize alone, cassava/maize intercrop and obtained a LER of over 2.0 for the intercrop system. Agboola (1979) indicated that on a nitrogen deficient soil, maize with its high requirement for nitrogen responded more to applied nitrogen than the associated cassava. Kang and Wilson (1981) also reported that cassava root yield was depressed on a highly fertile soil by the application of nitrogen fertilizer but maize yield was not affected. These reports suggest that cassava/maize mixture has a high land utilization potential and fertilizer recommendation for sole crop is quite adequate for the mixture on the poor soils of the lowland tropics.

Weed control is the most expensive cost aspect in cassava/maize intercropping. The leaf area index (LAI) of cassava at three month after planting is between 0.5 and 1.0 implying that the slow initial growth of cassava permits the wastage of incident radiation which encourages weed growth (IITA, 1982). Higher yields have been obtained from two to three hoe weedings, the first within thirty days after planting and all within twelve weeks after planting. Investigations at IITA suggest that the use of pre-emergence herbicide, for weed control is feasible and would increase farmers income. (IITA, 1982).

On the basis of research, no spacing has been found to be universally applicable for intercropped cassava because spacing varies with cassava variety, the rate of development of

leaf cover and soil moisture conditions (Ezumah and Okigbo, 1980). Based on the result of work by several agronomists, Leihner (1982) reports that cassava population in a maize/cassava intercrop range from 4,000 to 18,000 plants/ha. In general, a population of 10,000-15,000 plants/ha of cassava is economic and gives a good crop of cassava (Ezumah and Okigbo, 1980).

IITA (1985) reported a range of 10,000 and 40,000 plants/ha of maize in a maize/cassava mixture. Varying total plant population from 25,000 plants/ha to 45,000 plants in a cassava/maize mixture in which maize population ranged from 20,000-30,000 plants/ha, Akobundu (1981) obtained a LER of 1.6 the 30,000 plants/ha mixture. Kang and Wilson (1981) working on a simple two-crop mixture of cassava/maize also reported LER values ranging between 1.29 to 2.5 with a maize population of 30,000 plants/ha and 10,000 plants/ha of cassava as the optimum combination. Guritno (1984) found from his study of a cassava/maize mixture that optimum density for maize interplanted with cassava at a spacing of 100cm x 75cm and 150cm x 150cm were 66,000 plants/ha and 88,000 plants/ha respectively. At all these populations, maize yields were not affected by intercropping.

At higher maize populations, cassava yields were depressed. Ezumah and Bjarnasson (1984) indicated that the varying degree of yield reduction on cassava at different maize populations were due to morphological characteristics of the varieties used in the mixtures. In their report, maize

population significantly affected maize yield. Recorded maize yields were 2.3 tons/ha and 3.1 tons/ha for maize populations of 40,000 plants/ha and 80,000 plants/ha respectively. Maize variety had a highly significant effect on cassava and maize yield. Cassava yields were significantly greater when intercropped with the shorter maize varieties than with the tall spreading varieties. Similarly early maturing varieties of maize caused less reduction in root yield of cassava than with late maturing varieties (Kang and Wilson, (1981). Ezumah and Lawson (1982) explained that reduction in root yield may be related to the degree of light transmission in a cassava/maize mixture. Tall varieties of maize with spreading leaves were found to reduce light transmission by about 5-10 percent accounting for 32 percent yield reduction in cassava. These reports suggest that using the right maize variety, maize populations in a cassava/maize mixture can be increased with minimal effect on cassava yields to obtain higher total yields.

In most cassava intercropping systems, cassava may be planted late (June-August in the northern hemisphere, March-April in the southern hemisphere) or early (March-May in the northern hemisphere, and September-November in the southern hemisphere). Higher yields are usually obtained from crops planted early because they are exposed to more months of rains. Information on relative time of planting of the component crops is limited. Okigbo (1978) has reported that for high total yields, cassava should not be planted later than two months after planting maize. Thung and Cock (1979) have

also shown that the greatest total yields in a cassava/bean intercrop were achieved when both crops were planted at the same time or with a difference in planting time of less than one week. A practical implication of simultaneous planting of cassava and maize is that the practice would require one operation especially if the system is mechanised.

The possibility of using herbicides for weed control, adjusting spatial arrangement to increase component populations (without much reduction in total yield) and simultaneous planting indicates that there is a structural flexibility in this intercropping system which would facilitate mechanization (Ezumah et al., 1986). The potential for higher yield in improved agriculture involving intercropping with higher crop component crop populations beyond optimum recommended sole-crop populations has not received much attention.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Site

The study was conducted on Plot EE12 at the International Institute of Tropical Agriculture (IITA) during one cropping year May 1986 to April 1987. The area which was first opened up in 1971 has been cropped until March 1986 to various combinations of maize, cassava, sweet potatoes, yam and melon. In the previous cropping year, the land had been under a maize/cassava mixture.

IITA is situated on longitude 3° 54' and latitude 7° 30' in the forest zone of the tropical lowland. The elevation varies between 186m and 240m. The dominant upland soil of the experimental area is an Alfisol which according to the USDA classification is an oxic paleustalf. These contain predominantly kaolinite minerals and are abundant in iron oxides. Locally, the uplands soils are classified as the Egbeda series which is associated with soils obtained from basement complex rocks characterised by a deep red clayey profile with a sandy loam or sandy clayey surface underlain by angular and subangular quartz gravels (Moorman et al., 1975).

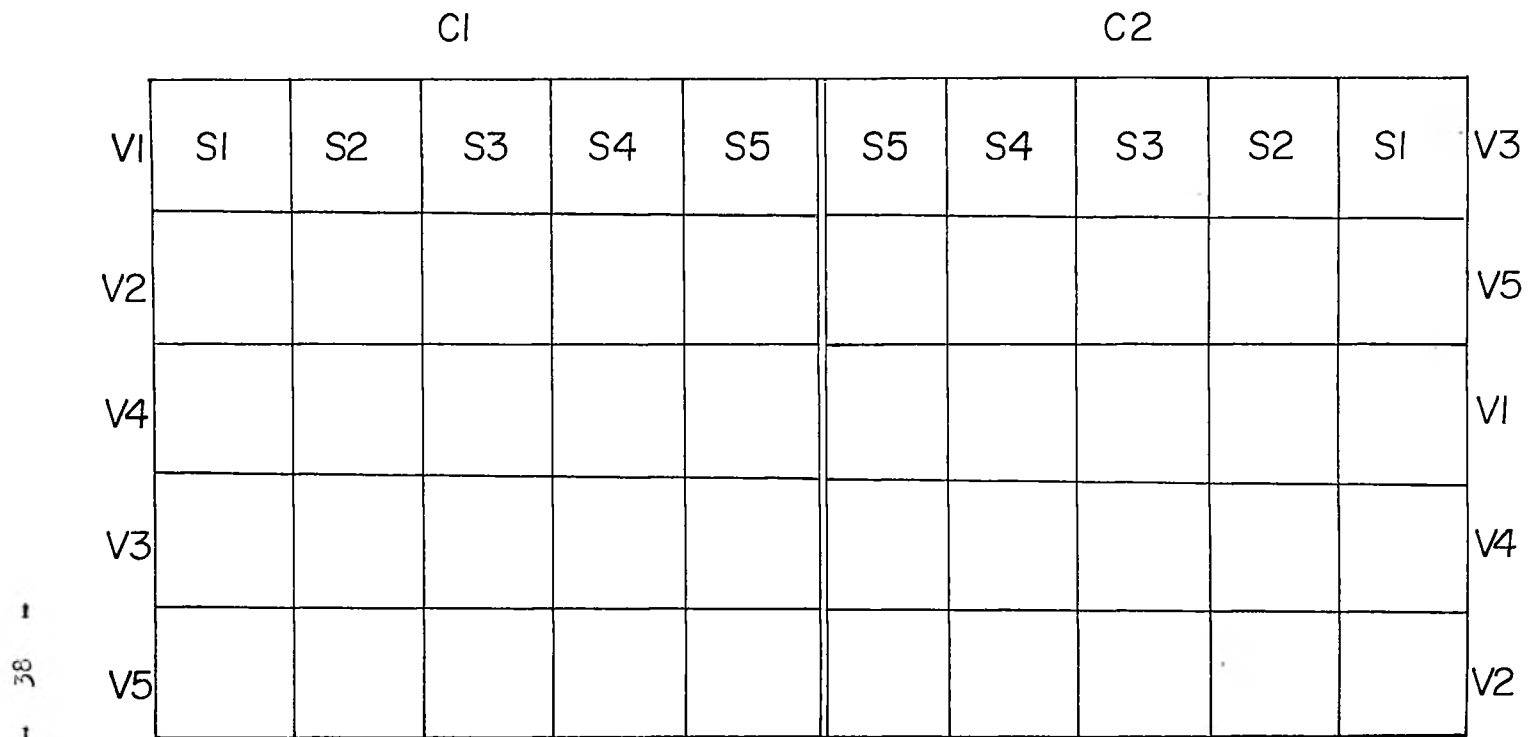
The climate, according to Moorman et al. (1975) falls within the humid and subhumid tropical climates. The rainfall has a characteristic bimodal distribution pattern with peaks in June and in September and a period of low precipitation in August. December through February constitute the major dry season. This rainfall pattern results in two distinct growing

seasons, one from April to July and the second from mid-August to September or November. According to a 1953-1972 University of Ibadan meteorological data, (Moorman et al. 1975) the annual rainfall is variable ranging from 788mm to 1884mm. Periods of five days with less than 2.5mm of rainfall are common throughout the rainy season. The probability of such dry periods is more than 55 percent for most months except during June and September and have very important effects on shallow rooted crops.

The temperature regime is characterised as equatorial with no great variation throughout the year. Annual temperatures range from average minimum of 21.3°C to an extreme average of 31.2°C. During the dry season, the cool north-east Trade Winds blowing southwards across the Sahara desert helps keep the weather cool for most of the four months dry period.

3.2 Design and Layout of Experiment

The planting plan for the study was laid out in a strip-split plot design with a parallel row systematic arrangement. Cassava spacing was laid out in two vertical strips facing each other with maize varieties as the horizontal treatment. The cross plot between the strip plots of cassava spacing and maize variety was split into five subplots. These were systematically assigned to the maize populations. Each maize population was mirror-imaged in the opposite strip (Fig.1). The set of cassava and maize variety treatments were arranged in three randomised blocks.



C1 — Cassava spacing 100 X 100 cm

C2 — Cassava spacing 100 X 67 cm

V1-V5-Maize varieties

S1-S5-Maize populations, 160,000 - 10,000 plants / ha

Fig.1. Illustration of field arrangement of treatments.

There were two cassava spacings (100 x 100cm and 100 x 67cm) and five maize varieties and five maize populations. The maize populations were 10,000, 20,000, 40,000, 80,000 and 160,000 plants/ha (Table 1).

The subplots consisted of three rows of maize, 8 metres long with 1 metre between rows. These were planted at the centre of single rows of the different cassava spacing levels spaced 1 metre apart and measuring 8 metres long as well. Maize populations in subplots were achieved by systematically varying the within-row distances between plants. Hence each population was bordered on one side by a lower population and on the other by a higher one (Fig. 2).

Each cross plot of cassava spacing and maize variety was 14 x 8m (112m²) separated by 1 metre border row. Sole crop plots at the same treatment and management levels were also established to serve as monocrop checks for computing land equivalent ratios of the intercrops. Cassava sole crop units occupied 56m² land area while each sole crop unit of maize variety at the different populations occupied 20m². The effective experimental area was 3972m². General characteristics of maize varieties and cassava used in the study are shown in Table 2.

3.3. Cultural Operations

The plot which was lying fallow after the harvest of the previous crop of cassava was cleared of weeds with gramoxone at 2.5kg a.i./ha around mid-April.

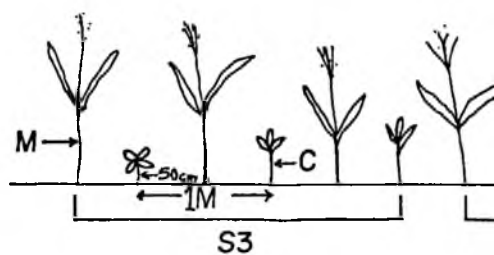
Table 1: List of Treatment Levels

1. Cassava spacing - 2 levels
 - (i) 100 x 100cm
 - (ii) 100 x 67cm

2. Maize variety - 5 varieties
 - (i) 1K84A-2135
 - (ii) 1B84A-203
 - (iii) TZSR-Y-1
 - (iv) 1368 x 5012
 - (v) 9450 x 4001

3. Maize population - 5 levels
 - (i) S1 - 160,000 plants/ha
 - (ii) S2 - 80,000 plants/ha
 - (iii) S3 - 40,000 plants/ha
 - (iv) S4 - 20,000 plants/ha
 - (v) S5 - 10,000 plants/ha

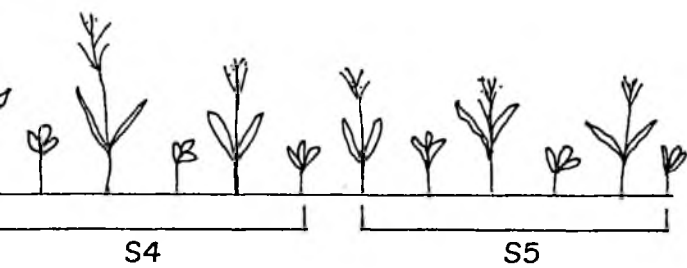
1
44
1



M - MAIZE

C - CASSAVA

Fig. 2 Illustration of planting



pattern used in the study.

Table 2: Variety and Characteristics of Test Crops

<u>Cassava</u>	
<u>Variety</u>	<u>Characteristics</u>
TMS 30572	Low branching and late canopy closure with good recovery from insect attack. It is high yielding with good gari and fufu characteristics. It is preferred in the West African subregion to other improved from IITA.
<u>Maize</u>	
1K84A-2135	Open-pollinated, short, early maturing with spreading leaves.
1B84A-203	Open-pollinated, tall, early maturing with spreading leaves.
TZSR-Y-1	Open-pollinated, tall, late maturing with spreading leaves.
1368 x 5012	Hybrid, tall, late maturing with erect leaves.
9450 x 4001	Hybrid, tall, late maturing with spreading leaves.

Planting of maize and cassava was done at the same time on 2nd of May 1986. Each row of maize was overplanted and thinned to the respective populations between 14-21 days later when full emergence had been achieved. Cassava was planted using about 25cm length of cuttings. Cuttings that had not sprouted within two weeks were replaced.

All plots were fertilized after planting with a basal application of 300 kg/ha of 15-15-15. A side dressing of nitrogen at the rate of 45 kg Urea/ha was applied to the maize 4 weeks after planting. No extra fertilizer was given to the cassava neither was there any supplemental supply of water.

Two hand weedings were done to control weed populations which grew during the period between seedling emergence and harvesting of maize and thereafter when necessary. From December through February, 0.25 percent solution of Gammalin 20 was sprayed to control grasshoppers (Zonocerus variegatus).

3.4 Data Collection

Grain yields on central rows of each subplot 8m² were measured when maize reached harvest maturity with both leaves and ears turned brown. Total ear weight, number of plants in the harvested area were recorded. After harvesting, 10 percent of husked ear sample were bagged and oven-dried at 50°C for five days. Grain yield per plot was then determined from the shelling percentage and field weight of ears per plot after adjusting the moisture level of grains to 15.0 percent.

The stover per plot was removed and weighed. Five

percent of the sample in each population was used in dry weight determination. The fresh and dry weights of the sample were used in determining stover dry weight per plot.

Other measurement taken on maize were plant height at tasselling and at harvest, days to 50 percent silking, ear height, stalk diameter, root and stem lodging, leaf angles and leaf area. Plant height at harvest was measured from the soil surface to the base of the tassel. Before showing tassels, plants were measured from the soil surface to the apical leaf. Ear height was measured from the soil surface to the node bearing the first ear. Diameter of the stalk was calculated from the circumference of the stem above the prop roots. The number of days to 50 percent silking was defined as the number of days from sowing until half the plants within the central rows had silks emerged from ear shoots. Leaf angles were measured from the first four leaves above the ear leaf; the angle between first leaf above the ear leaf and the stalk being the last to be measured. Leaf area per plant was estimated as the leaf length multiplied by the greatest width, multiplied by the constant 0.75 (Moll and Kamprath, 1977; Saxena and Singh, 1965) and leaf area index (LAI) by dividing leaf area per plant by land area occupied by each plant. (Waston, 1952). Root lodged plants were taken as those that leaned at an angle of 30° or more from the vertical while stem lodged plants were those that were broken below the ear. All measurements were taken on 5-10 plants depending on the maize population on particular plots.

Measurements on cassava were made at silking of

maize (8WAP), at maize harvest (4MAP), three months after maize harvest (7MAP) and at cassava harvesting. The central cassava rows were used in the measurements. The measurements included plant height, stem girth, number of leaves and branches per plants, and internode length. Stem girth was obtained from the circumference of the stem, 10cm above the soil level. Internode length was estimated from the plant height averaged over the number of nodes per plant. At cassava harvest, central rows of each subplot were harvested carefully by digging out the roots. All harvested plants were separated into roots and shoots after counting number of harvested plants per row. The harvested roots were counted and fresh weight determined. Samples of about five percent fresh weight were taken for dry weight determination. Root number per plant, average fresh root weight and fresh yield per plant were determined on the basis of the number of plants harvested. Shoot and root dry weight as well as harvest index were calculated on the basis of the sample dry weight determination.

Estimates of LER were obtained using the yields from sole crop optimum of 40,000 maize plants/ha for maize and 10,000 plants/ha for cassava as standardizing factors.

The statistical significance of treatment effects on maize and cassava were assessed separately using analysis of variance techniques as described by Willey and Rao (1980). Some effects of maize population on the response variables were modelled using linear and quadratic models. Mean comparison was done using DMRT procedures (Steel and Torrie, 1960; Little and Hill, 1972; Gomez and Gomez, 1984).

CHAPTER FOUR

RESULTS

4.1 Weather Report

Rainfall in the first week of May was sufficient to give a good stand of both maize and cassava. Thereafter, even though the amount of rainfall was about normal the distribution was poor. (Table 3). No quantitative soil moisture measurements were made but visual observation of plants with wilting leaves suggested that the maize plants were under moisture stress. Rainfall in June and July appeared adequate for plant growth as the plants were seen to be relieved of stress. From November 1986 through February 1987, cassava came under the influence of the long dry season and as there was no supplemental irrigation during this period, the cassava plants suffered from drought stress. In general, the amount of rainfall during the cropping year (Table 3) compared to the 20-year average obtained from the University of Ibadan meteorological data (Moorman et al. 1975) showed a considerable deviation from the normal pattern.

Temperatures were generally normal throughout the cropping year.

4.2 Maize

4.2.1 Grain Yield and Related Characters

Stand count made at harvest indicated that the number of plants per hectare were very close to the intended populations. All data used in the construction of graph and tables were therefore based on the intended populations in the intercrop.

Table 3: Monthly Rainfall During the Growing Period

Month	Days Without rain	Rainfall (mm)	Deviation*
April 1986	21	94.8	-34.5
May "	23	148.6	- 2.4
June "	16	262.1	+77.5
July "	17	152.4	+ 6.9
August "	19	32.6	-79.7
Sept. "	11	215.3	+20.3
Oct. "	14	179.0	- 3.7
Nov. "	29	0.4	-36.7
Dec. "	31	0.0	- 7.7
Jan. 1987	30	10.0	+ 6.6
Feb. "	26	10.6	-19.6
March "	21	135.8	+33.1

Source: IITA Weather Station Report (1986).

IITA Weekly Bulletin (Jan-April 7, 1987)

where:

*-deviation from 20-year rainfall data.

Highly significant differences for grain yield per hectare were observed due to maize populations in intercrop regardless of cassava spacing and maize varieties (Appendix 1). Figure 3 shows the relationship between grain yield and maize population in intercrop. Grain yield per hectare increased from 10,000 plants/ha, peaked at 80,000 plants/ha and declined thereafter. The mean grain yield per hectare was 1541kg/ha.

Grain yield per plant differed significantly among maize varieties at the 5 percent level and within maize populations ($P < 0.01$) (Appendix 1). The variety TZSR-Y-1 produced the highest grain yield per plant followed by 1368 x 5012 while 9450 x 4001 produced the lowest grain yield per plant (Table 4). However differences in grain yield per plant between maize varieties, 1K84A-2135, 1B84A-203 and 9450 x 4001 were not significant (Table 4). Grain yield per plant decreased as maize population in the intercrop was increased from 10,000 plants/ha to 160,000 plants/ha (Fig. 4).

Highly significant difference for ear weight was observed among different maize populations (Appendix 1). Ear weight decreased as maize population increased from 10,000 plants/ha to 160,000 plants/ha (Fig.5).

The analysis of variance (Appendix 1) shows a significant F-test for 1000-grain weight among maize varieties ($P < 0.05$) and maize populations ($P < 0.01$). The 1000-grain weight ranged from a high of 264.7g for 1368 x 5012 to a low of 229.2g for 1B84A-203 but the difference in 1000-grain weight between 1K84A-2135, 1368 x 5012 and

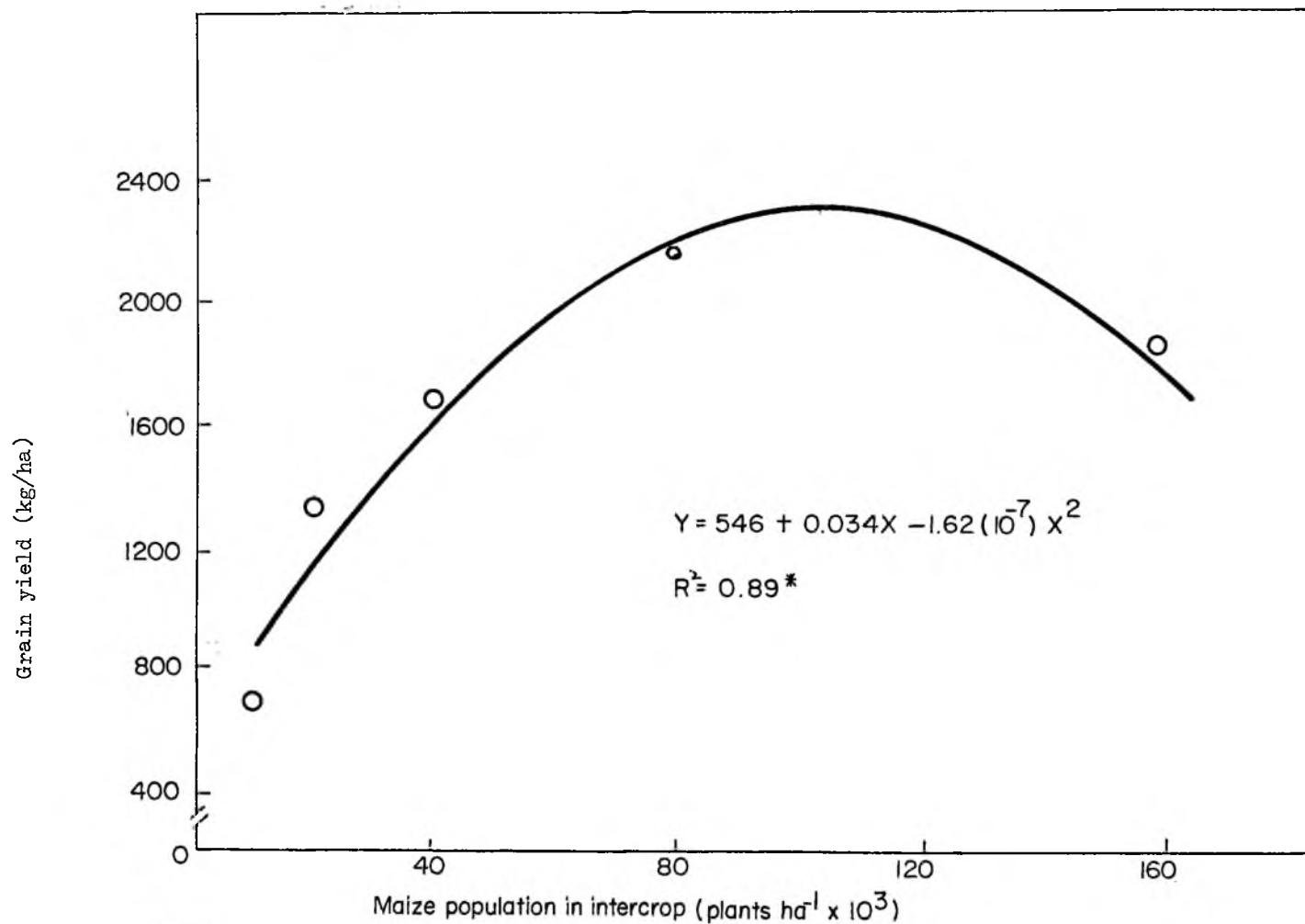


Fig 3 Effect of maize population on grain yield.

Table 4: Mean Yield Per Plant of Maize Varieties

Maize variety	Yield/Plant (g)
1K84A-2135	55.3abc
1B84A-203	46.0c
TZSR-Y-1	60.1a
1368 x 5012	60.0ab
9450 x 4001	45.9c

* Mean separation by DMRT at 5% level. Means followed by a common letter are not significantly different.

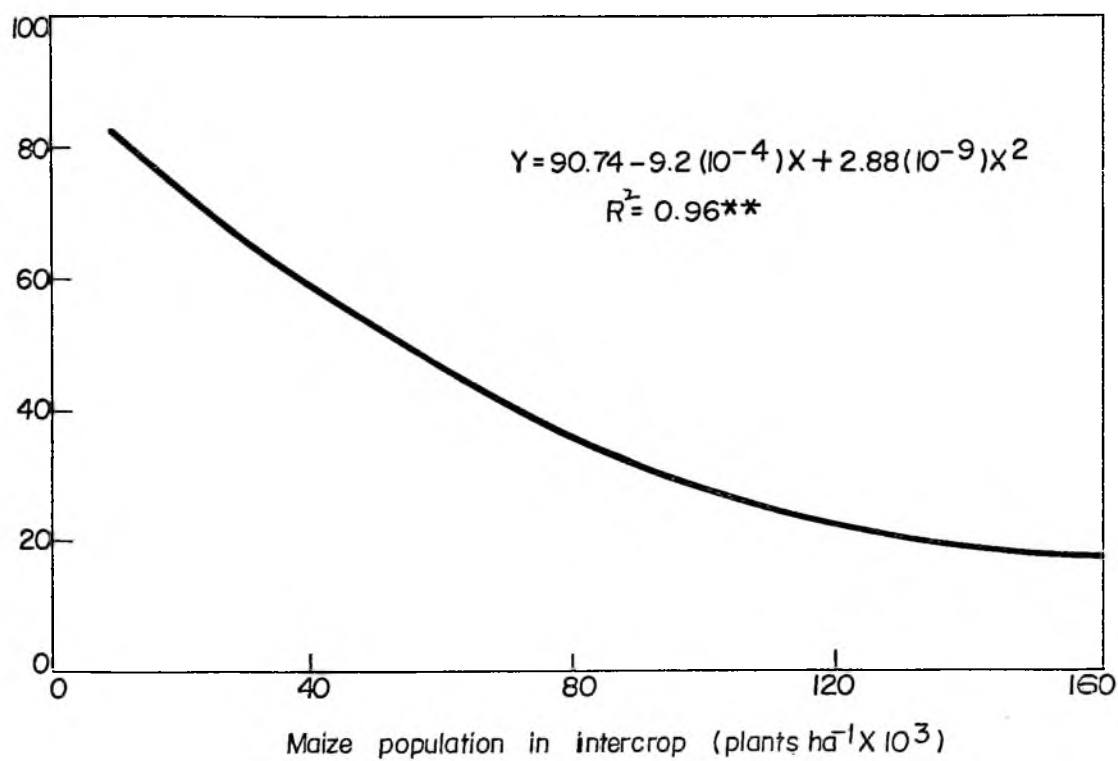


Fig. 4 Effect of maize population on grain yield per plant .

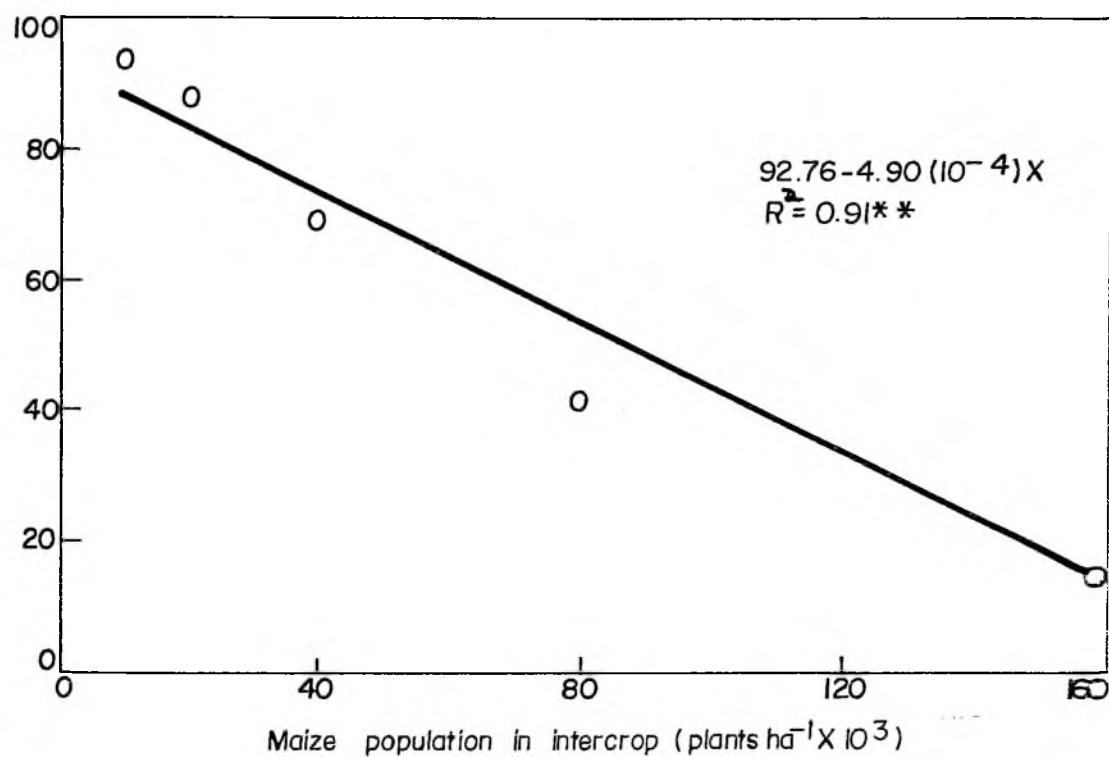


Fig. 5. Effect of maize population on ear weight.

9450 x 4001 was not significant (Table 5). The 1000-grain weight decreased as maize population in intercrop increased (Fig.6).

Percentage barren plants differed significantly among different maize populations ($P < 0.01$) (Appendix 2). Percentage barren plants increased from 7.04 percent to 13.63 percent from a maize population of 10,000 plants/ha to 160,000 plant/ha (Table 6). Significant differences were however not observed between maize populations of 10,000 and 20,000 plants/ha or between 20,000 plants/ha and 40,000 plants/ha.

Stover dry weight increased significantly with maize population (Appendix 2). There was a clear increase in stover dry weight with increasing maize population in the intercrop (Fig. 7). A mean stover dry weight of 2878 kg/ha was obtained.

4.2.2 Agronomic Characteristics

Plant height at tasselling showed significant variability at different maize populations (Appendix Table 3). A trend towards taller plants with increasing maize population in intercrop was observed (Fig.8).

Highly significant difference for plant height at harvest and ear height were observed among maize varieties and at different maize populations (Appendix 3). Table 7 shows that TZSR-Y-1 was the tallest variety and 1K84A-2135 was the shortest. Differences in plant height between TZSR-Y-1 and 1368 x 5012, on one hand and 1B84A-203 and 9450 x 4001 were not significant. Ear height of maize varieties showed a similar trend as maize plant height at harvest (Table 8). There was a linear increase in maize plant height at harvest with

Table 5: Mean 1000-grain Weight of Maize Varieties

Maize variety	1000-grain weight (g)
1K84A-2135	251.0ab
1B84A-203	229.2d
TZSR-Y-1	248.1abc
1368 x 5012	264.7a
9450 x 4001	249.2abc

* Mean separation by DMRT at 5% level. Means followed by a common letter are not significantly different.

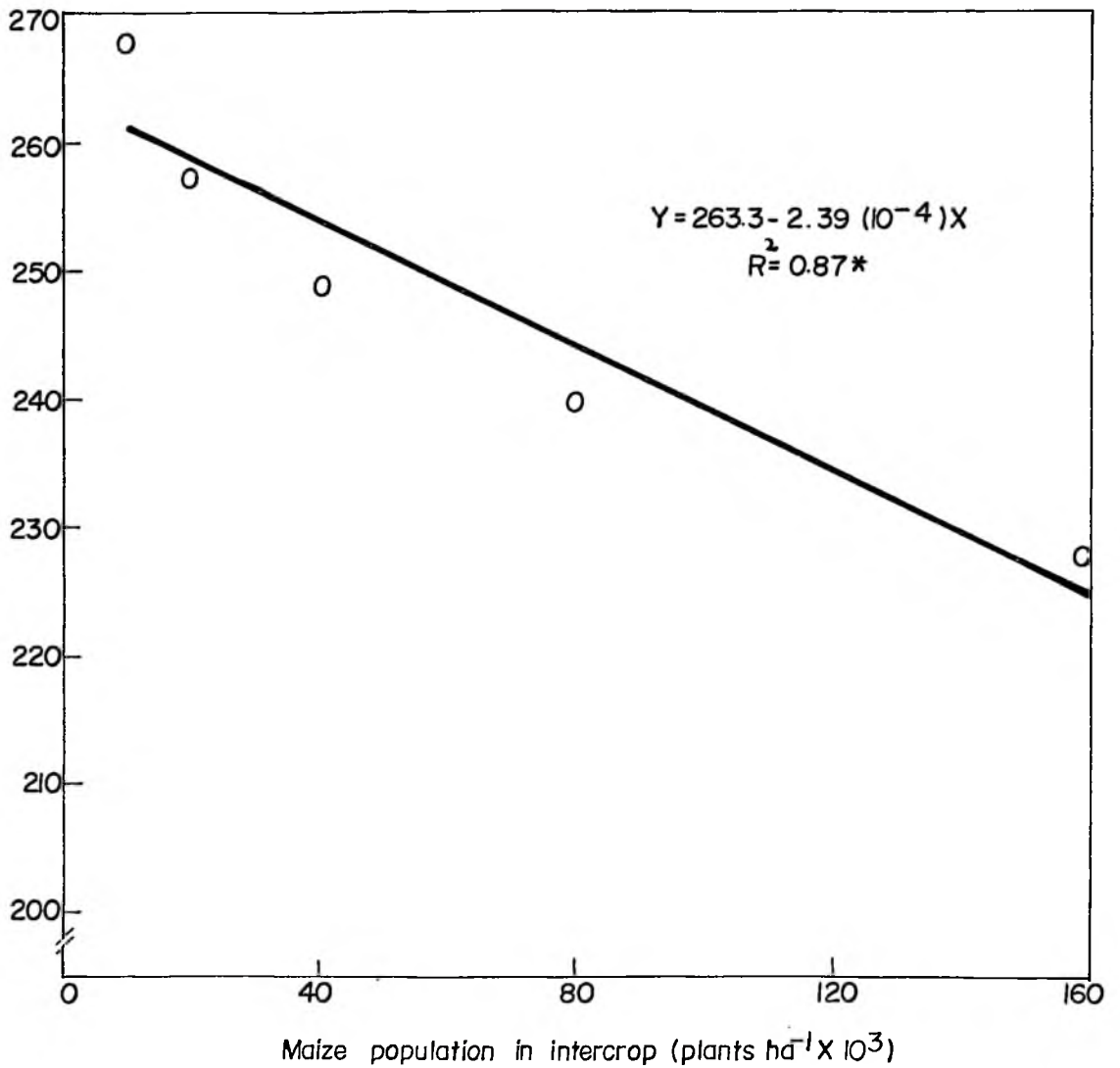


Fig. 6. Effect of maize population on 1000-grain weight.

Table 6: Effect of Maize Population on Percentage Barren Plants

Maize Population (plants/ha)	Percentage barren plants, (%)
10,000	7.0d
20,000	11.5cd
40,000	14.9c
80,000	24.1b
160,000	31.6a

* Mean separation by DMRT at 5% level. Means followed by a common letter are not significantly different.

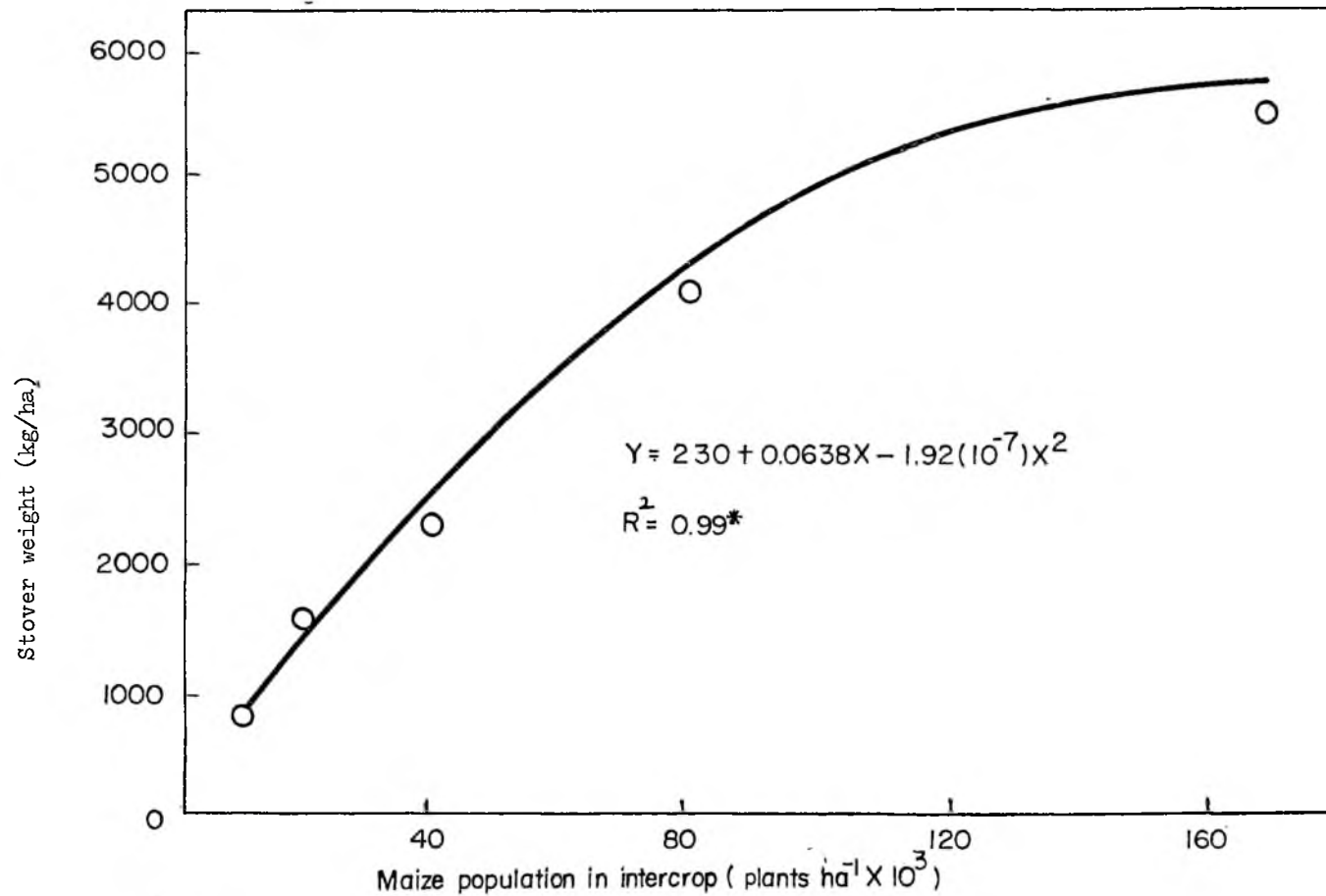


Fig. 7 Effect of maize population on stover weight .

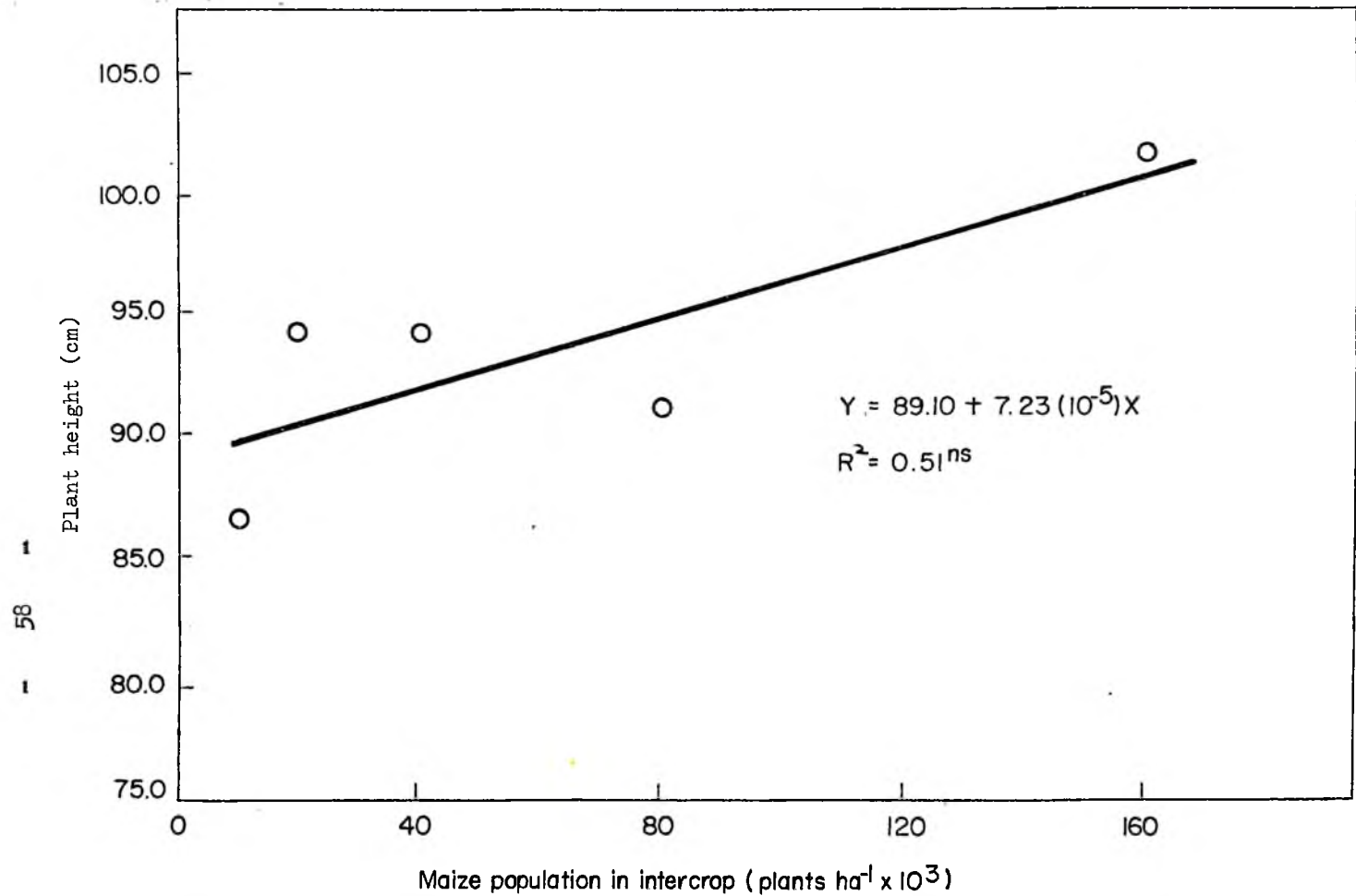


Fig. 58 Effect of maize population on maize plant height at tasselling.

Table 7: Mean Plant Height of Maize Varieties
at Maize Harvest

Maize Variety	Plant Height at Harvest, (cm)
1K84A-2135	155.2c
1B84A-203	178.9b
TZSR-Y-1	197.5a
1368 x 5012	192.5a
9450 x 4001	174.3b

* Mean separation by DMRT at 5% level. Means followed by a common letter are not significantly different.

Table 8: Mean Ear Height of Maize Varieties

Maize Variety	Ear Height (cm)
1K85A-2135	50.8d
1B84A-203	60.3bc
TZSR-Y-1	68.8a
1368 x 5012	65.0ab
9450 x 4001	58.9c

* Mean separation by DMRT at 5% level. Means followed by a common letter are not significantly different.

increasing maize population in intercrop (Fig. 9). Significant differences in ear height were observed among maize varieties 1368 x 5012, 1B84A-203 and 1K84A-2135. The effect of maize population on ear height is shown in Figure 10.

Days from planting to 50% silking differed significantly among maize varieties and ~~maize~~ populations ($P < 0.01$) (Appendix 4). Table 9 shows that 1B84A-203 was the earliest while 1368 x 5012 was the latest in developing silks. There was however no variation between days to silking among TZSR-Y-1, 1368 x 5012 and 9450 x 4001. Difference between days to 50% silking for 1K84A-2135 and TZSR-Y-1 were also not significant. The delay in silking was linearly related to the maize population in the intercrop (Fig. 11).

Maize variety x leaf position interaction effects on leaf angles were significant. Leaf angles differed significantly among maize varieties, ~~maize~~ maize populations and leaf positions (Appendix 5). Table 10 shows that the largest mean leaf angle of 43.1 degrees was recorded for the erect leaved hybrid 1368 x 5012 with the smallest of 36.1 degrees for the spreading hybrid 9450 x 4001. Across different leaf positions, leaf angles generally increased from the top to the bottom leaf. The leaf angle of the third leaf for all varieties was however larger than that of the other leaves at the other positions. Except for 1368 x 5012 no significant differences were observed between the leaf angles of the first, second and fourth leaves of the late maturing varieties. For the early maturing varieties, differences between leaf angles

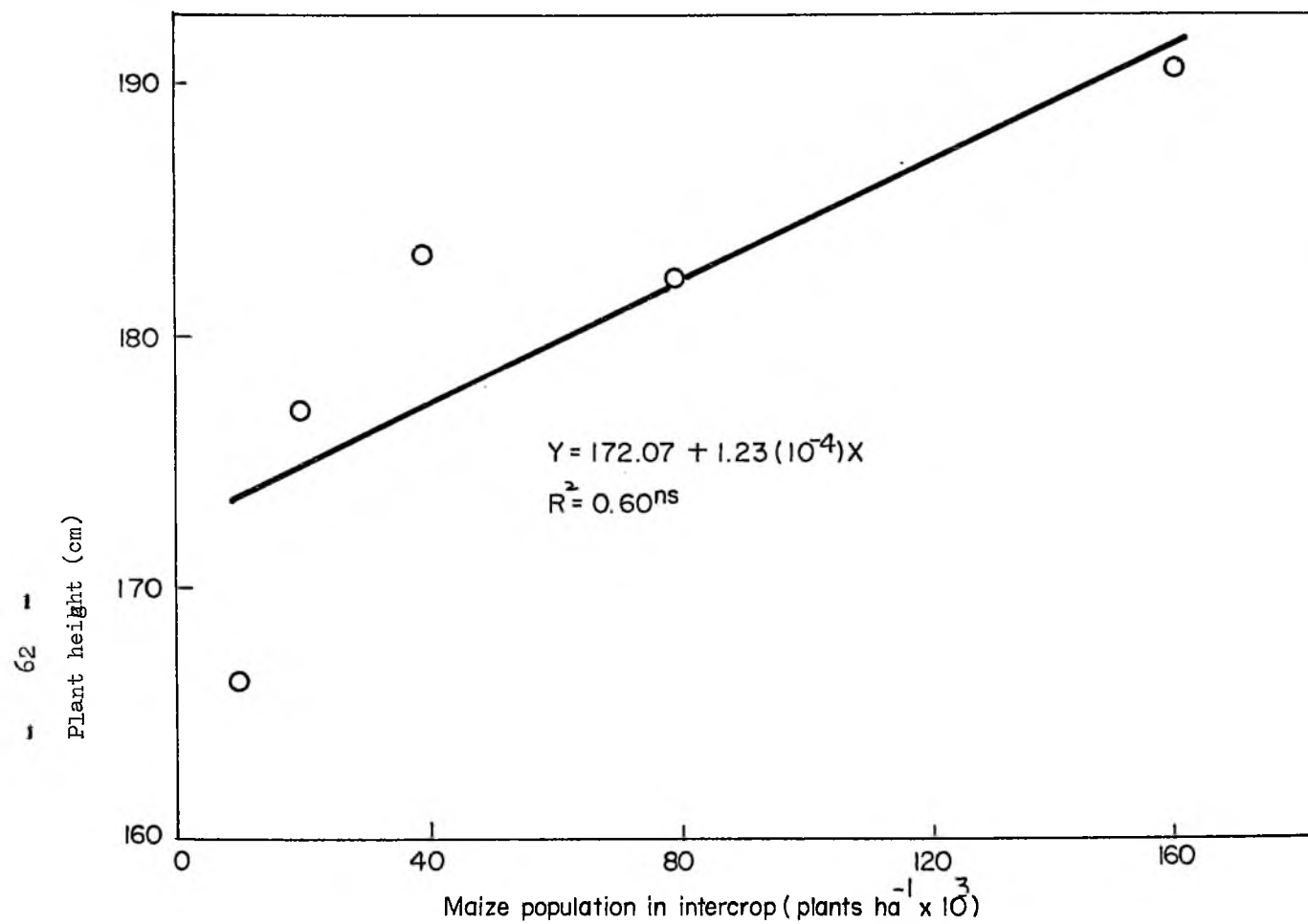


Fig. Effect of maize population on maize plant height at harvest.

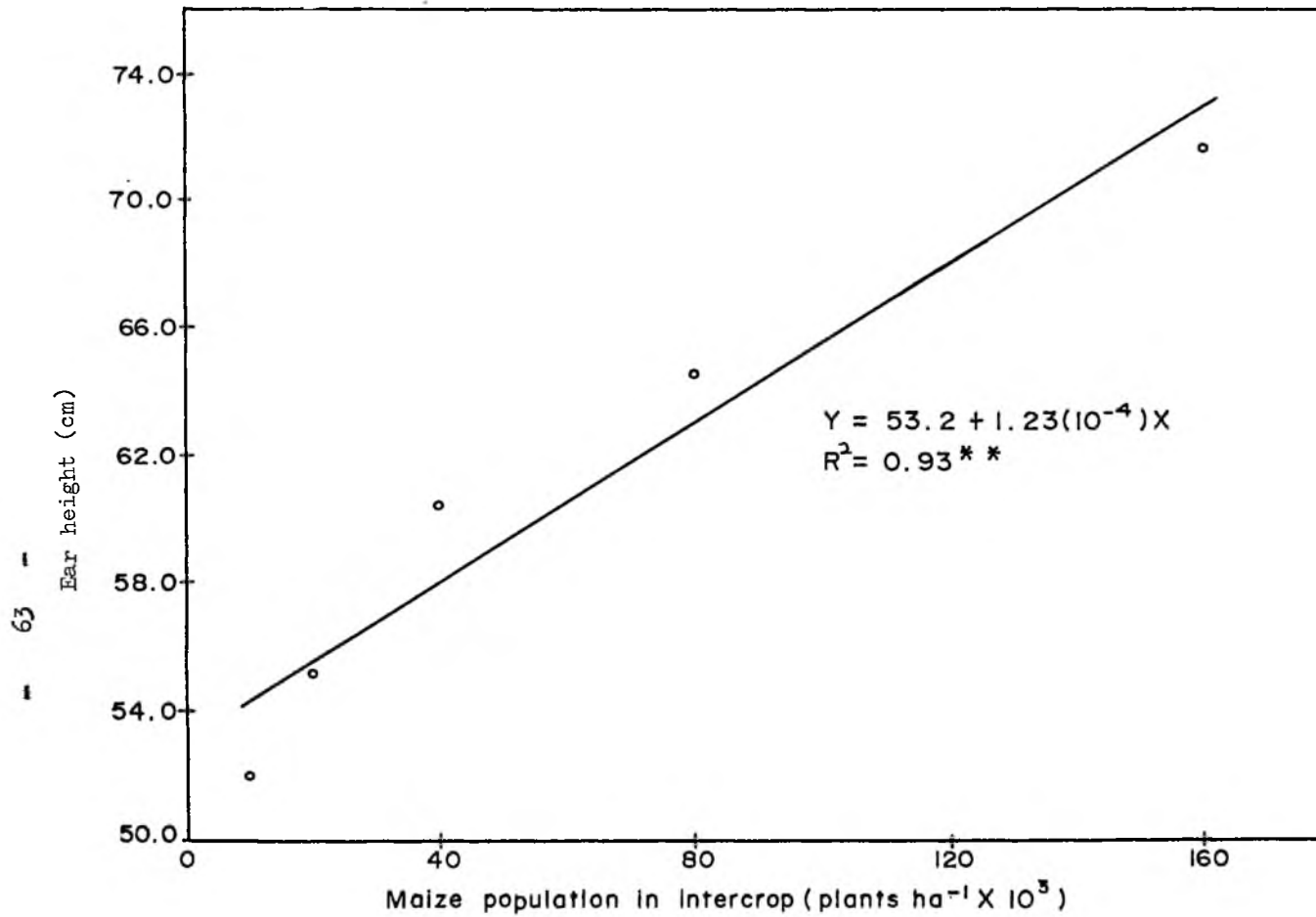


Fig. 19 Effect of maize population on ear height.

Table 9: Mean Days to 50% Silking of Maize
Varieties

Maize Variety	Days to 50% Silking
1K84A-2135	56.0cd
1B84A-203	54.5d
TZSR-Y-1	57.4abc
1368 x 5012	58.0a
9450 x 4001	57.8ab

* Mean separation by DMRT at 5% level. Means followed by a common letter are not significantly different.

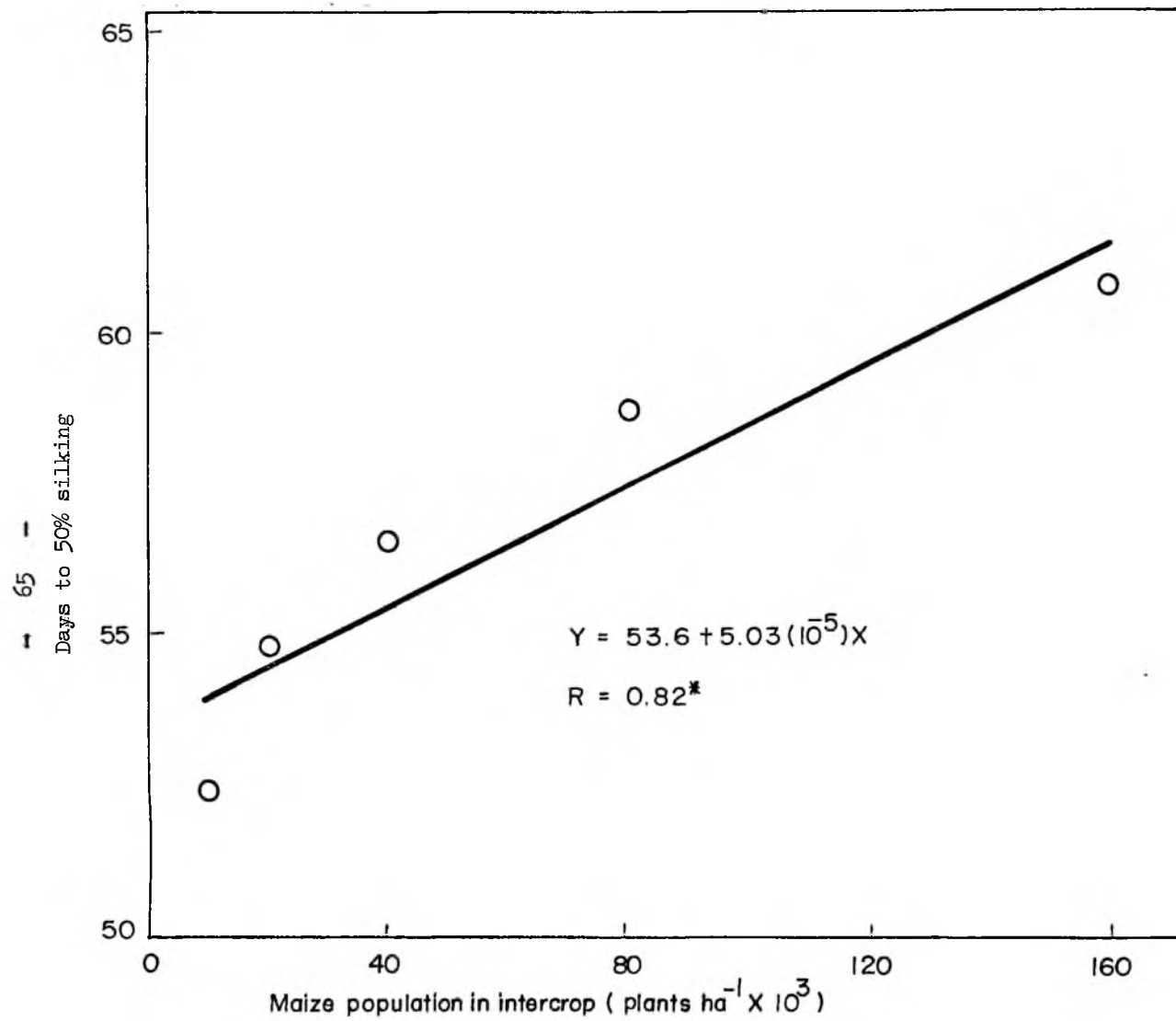


Fig. 11. Effect of maize population on days to 50% silking.

of the third and fourth leaves were not significant but was significant when the leaf angle of the third leaf was compared to that of the first and second leaves (Table 10). Leaf angle decreased by 13.2% as maize population in intercrop increased from 10,000 plants/ha to 160,000 plants/ha (Table 11).

Maize variety x population interaction for leaf area per plant was highly significant (Appendix 4). Leaf area/plant for all varieties decreased as maize population in the intercrop increased but at different rates of increase with maize population (Fig. 12). The largest decrease in leaf area per plant of 63.2 percent from a population of 10,000 plants/ha to 160,000 plants/ha was observed for maize variety 1B84A-203 while the lowest percentage decrease of 45.5 was observed for 1K84A-2135. Leaf area indices for all maize varieties on the other hand increased as maize population in the intercrop increased (Fig. 13).

Maize population effect on stalk diameter was highly significant (Appendix 4). Figure 14 shows that stalk diameter decreased with increasing maize population.

Cassava spacing and maize population interaction for root lodging was significant. Highly significant differences in root lodging among maize varieties were also observed (Appendix 6). At both cassava spacing, root lodging increased with increasing maize population in intercrop. The slope of the regression line of root lodging on maize population was greater in the closer cassava spacing of 100 x 67cm than that of the wider cassava spacing of 100 x 100cm (Fig. 15). The incidence of root lodging was markedly observed in maize

Table 10: Effect of Leaf Position on Leaf
Angles of Maize Varieties

Leaf Angles (Degrees)					
Leaf Position	Maize	Variety			
	IK84A-2135	IB84A-203	TZSR-Y-1	1368x5012	9450x4001
X1	40.4b	38.9b	39.4b	41.9b	33.9b
X2	40.1b	38.7b	40.0b	38.1c	34.0b
X3	44.1a	43.5a	47.6a	50.3a	43.3a
X4	41.5ab	40.2ab	38.8b	42.0b	33.3b

* Mean separation by DMRT at 5% level. Means in a column followed by a common letter are not significantly different.

Table 11: Means of Leaf Angles at Different Maize Population in the Intercrop

Maize Population (Plants/ha)	Leaf Angle (degrees)
10,000	43.2a
20,000	41.1abc
40,000	41.3ab
80,000	39.4bcd
160,000	37.5d

* Mean separation by DMRT at 5% level. Means followed by a common letter are not significantly different.

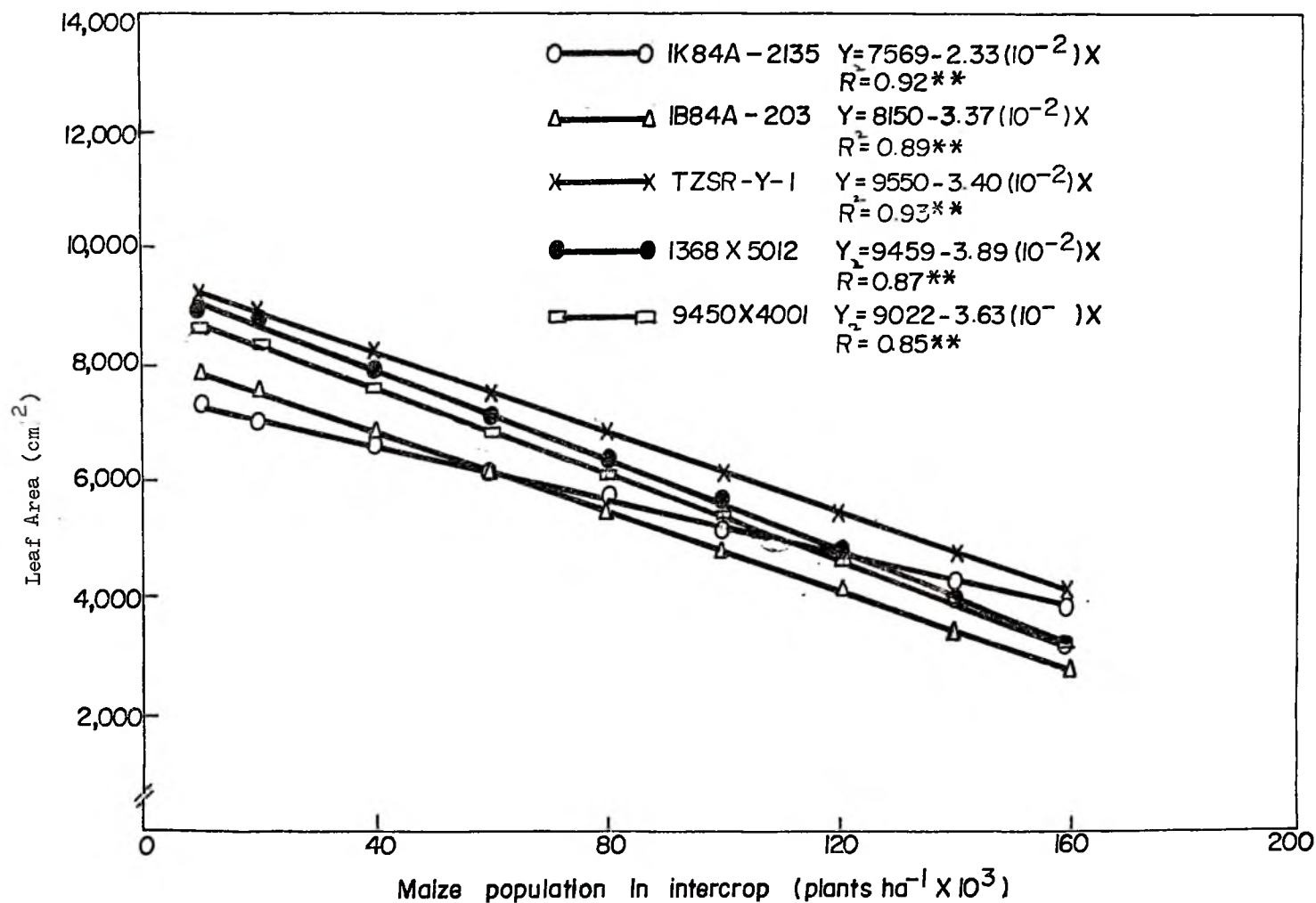


Fig.12. Effect of malze variety and population on leaf area of malze.

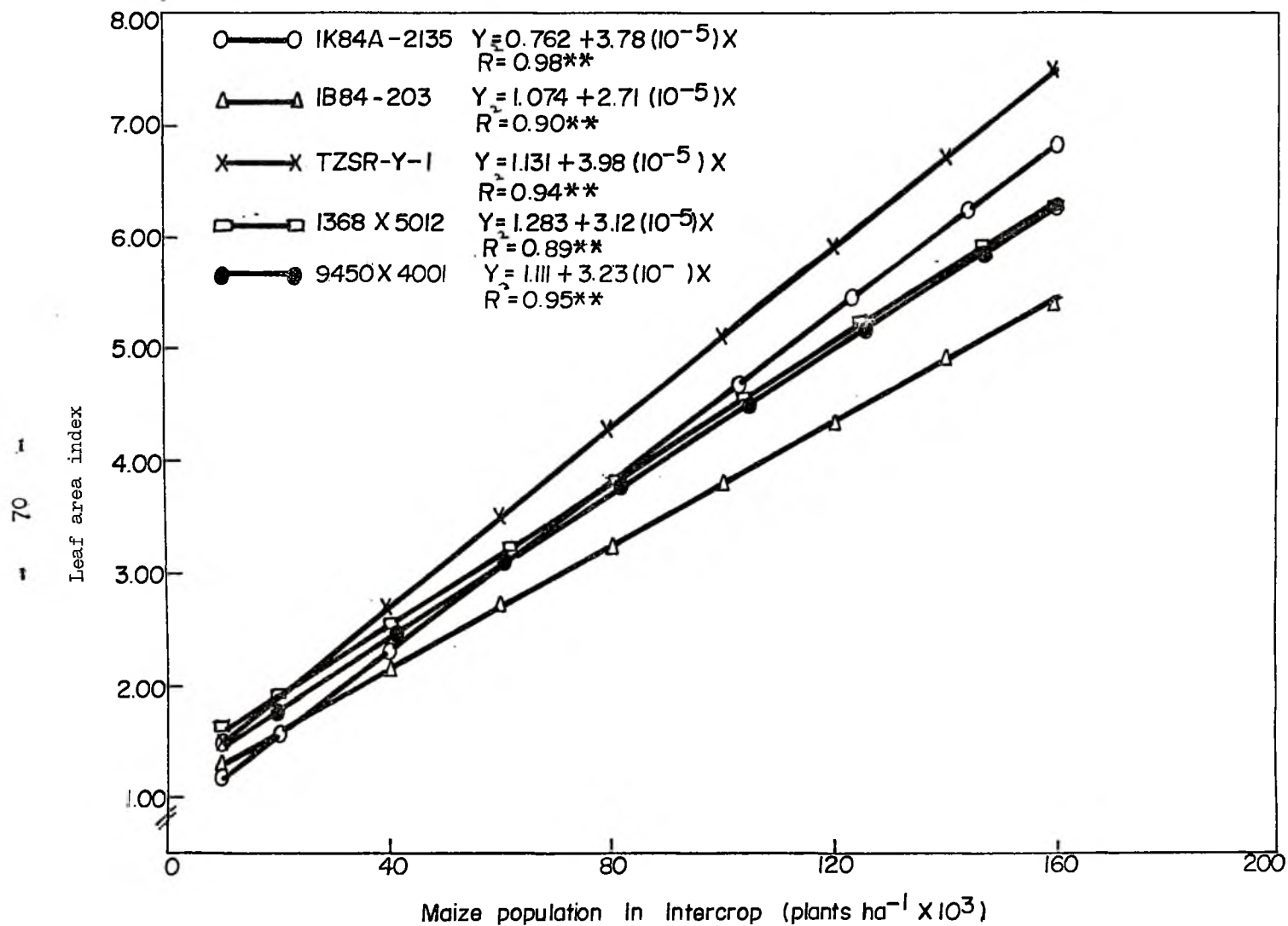


Fig.13 Effect of maize variety and population on LAI of maize

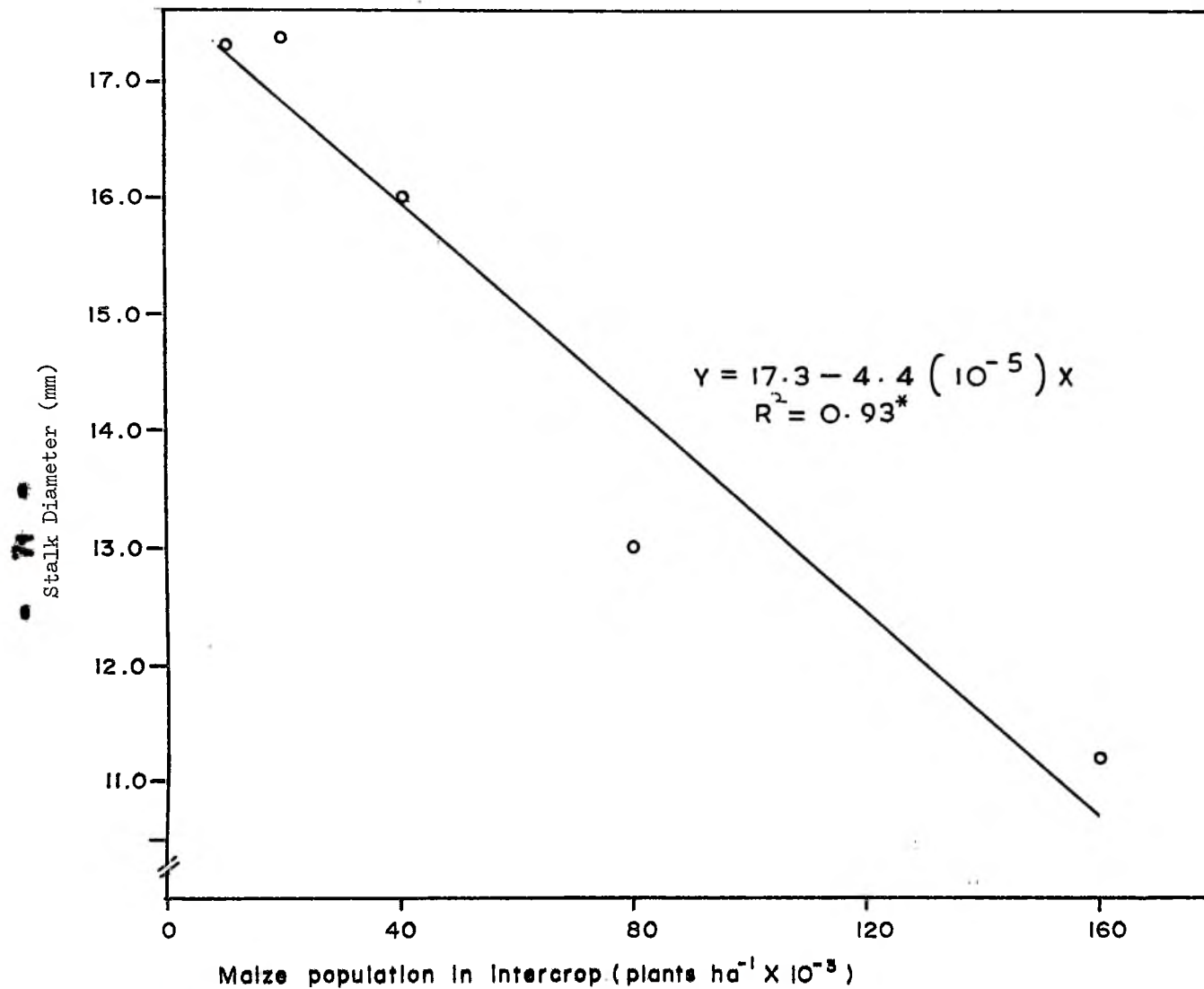


Fig. 4.1. Effect of maize population on stalk diameter of sorghum

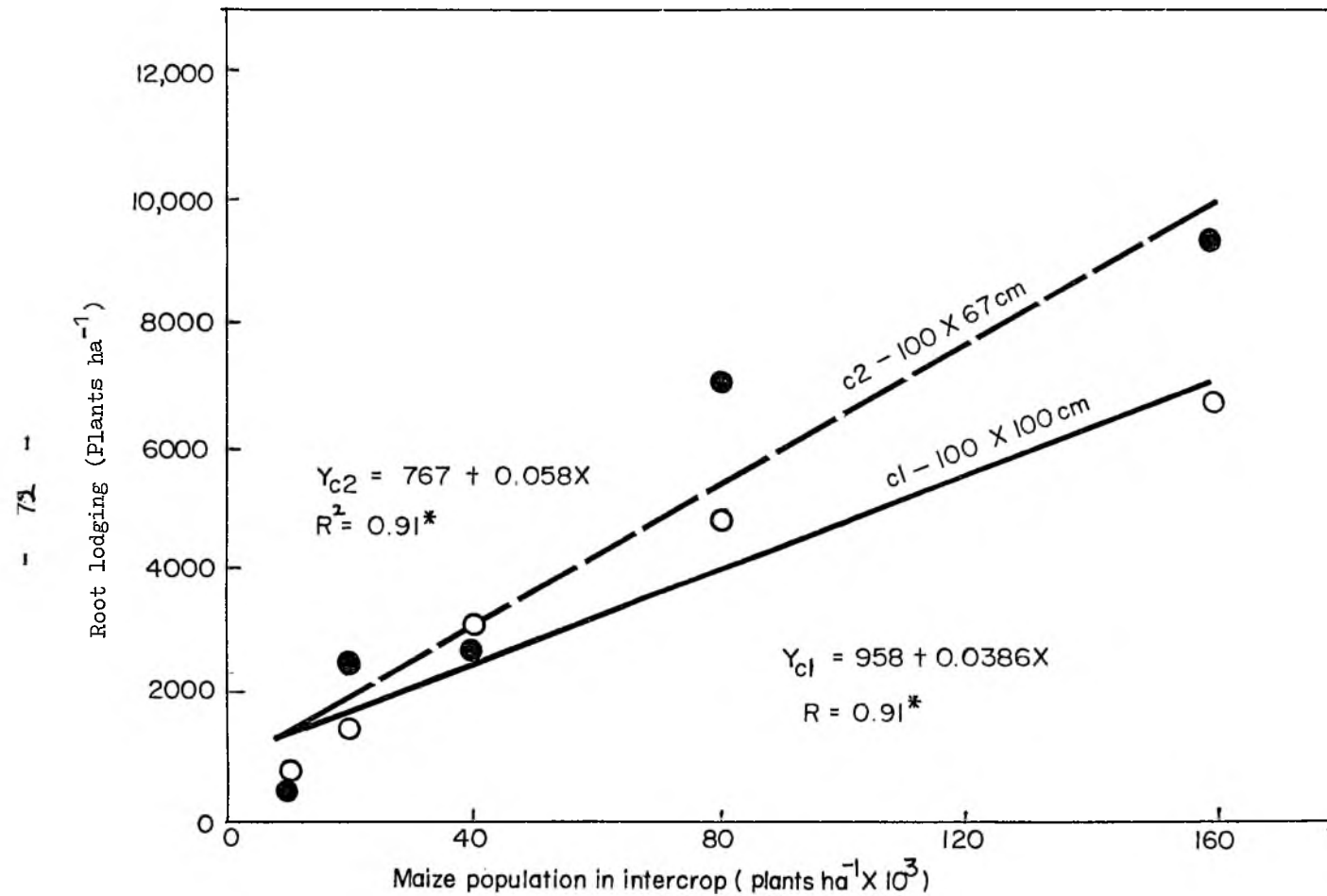


Fig. 15 Effect of maize population and cassava spacing on root lodging of maize .

variety 9450 x 4001 (Table 12). The effect of maize population on stem lodging was significant (Appendix 4). The stem lodging function formed a quadratic response curve with maize population in the intercrop (Fig. 16).

4.2.3 Correlation Between Maize Yield and Maize Characters

Correlation coefficients measure the intensity of association observed between any pairs of variables. They are useful in determining the effect of modifying one variable on another.

In this study, correlation coefficients between grain yield per hectare and maize plant characters measured are presented in Table 13. Grain yield per plant and grain yield per hectare of maize varieties was significant only for IK84A-2135. Days to 50% silking for all varieties correlated positively with grain yield per hectare and was significant for IK84A-2135, 1368 x 5012, 9450 x 4001 ($P < 0.01$) and IB84A-203 ($P = 0.05$). Apart from IB84A-203, significant and positive correlations between ear height and grain yield per hectare were obtained for IK84A-2135 and 9450 x 4001 ($P < 0.01$) and for TZSR-Y-1 and 1368 x 5012 ($P < 0.05$). Similarly plant height at tasselling was strongly correlated with grain yield per hectare of maize varieties. IK84A-2135 and 9450 x 4001 ($P < 0.01$); TZSR-Y-1 and 1368 x 5012 ($P < 0.05$). Plant height at harvest for IK84A-2135 and 9450 x 4001 showed highly significant correlations while that of IB84A-203 and 1368 x 5012 had negative non-significant correlations with grain yield per hectare respectively. Apart from IB84A-203, stalk diameter

Table 12: Rootlodging Means of Maize Varieties

Maize Variety	Root Lodging (Plants/ha)
1K84A-2135	2708d
1B84A-203	4000b
TZSR-Y-1	3958bc
1368 x 5012	3667bc
9450 x 4001	5000a

* Mean separation by DMRT at 5% level. Means followed by a common letter are not significantly different.

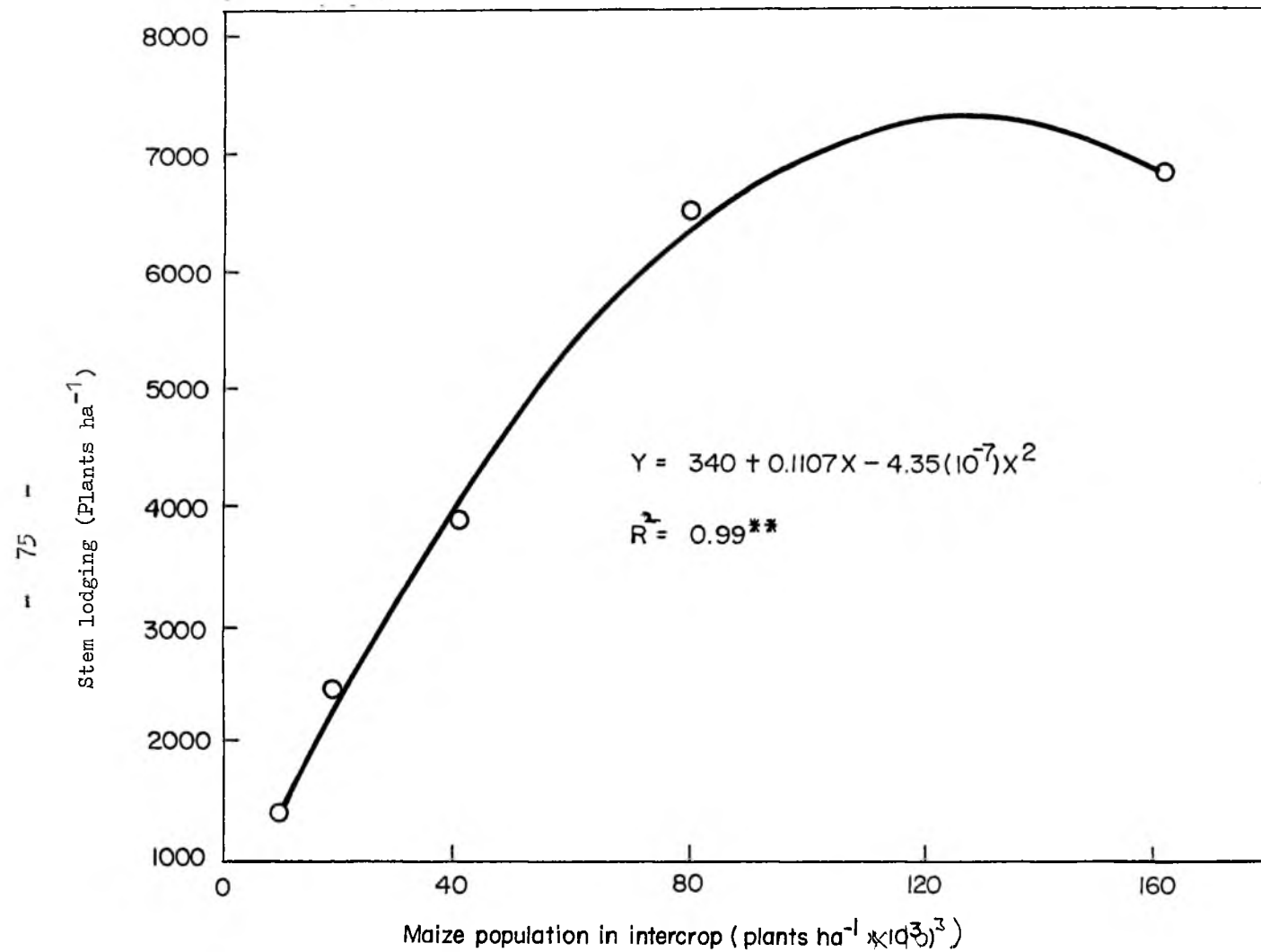


Fig. 16. Effect of maize population on stem lodging of maize.

showed a negative correlation but was significant for IB84A-2135 ($P = 0.05$) and 1368 x 5012 ($P < 0.01$). Negative correlations were obtained for all maize varieties with respect to leaf area but was highly significant for IK84A-2135, 1368 x 5012 and 9450 x 4001. Coefficient of correlation for root and stem lodging were positively correlated with grain yield per hectare for all maize varieties. Strong correlations were obtained for maize varieties IK84A-2135, and 9450 x 4001 with respect to rootlodging while IK84A-2135, 1368 x 5012 and 9450 x 4001 also showed a strong correlation with regards to stem lodging. Leaf angle and percentage barren plants for all maize varieties did not show significant correlations with grain yield per hectare.

4.3 Cassava

4.3.1 Agronomic Characteristics - 8WAP

Cassava spacing x population interaction effect on plant height was highly significant (Appendix 7). At both cassava spacings, plant height increased with increasing maize population in intercrop (Fig. 17). On the average taller plants were observed at the narrower cassava spacing.

Highly significant differences due to maize varieties were observed for cassava stem girth (Appendix 7). Table 14 shows the effect of intercropped maize varieties on cassava stem girth. Cassava plants intercropped with late maturing maize varieties had the largest stems.

The effect of maize population on cassava internode length was significant (Appendix 7). Cassava internode length

Table 13: Correlation Between Yield and Agronomic Characteristics of Maize

Character	Maize Varieties in Intercrop				
	1K84A-2135	1B84A-203	TZSR-Y-1	1368x5012	9450x4001
Grain Yield/ Plant	-0.478*	0.058	0.138	-0.330	-0.255
Days to 50% Silking	0.641**	0.424*	0.059	0.603**	0.676
Ear Height	0.624**	0.060	0.392*	0.449*	0.750**
Plant Height at Tasselling	0.551**	0.441*	0.143	0.456*	0.597**
Plant Height at Harvest	0.623**	-0.054	0.394*	0.338	0.735**
Leaf Angle	0.019	-0.155	-0.091	0.033	0.183
Stalk Diameter	-0.456*	0.025	-0.023	-0.542**	-0.224
Leaf Area	-0.599**	-0.377	-0.207	-0.559**	-0.517**
Barrenness	0.132	-0.064	0.051	0.323	0.360
Root Lodging	0.516**	0.297	0.054	0.364	0.544**
Stem Lodging	0.574**	0.297	0.096	0.516**	0.512**

*, ** - Significant at 5% and 1% levels respectively

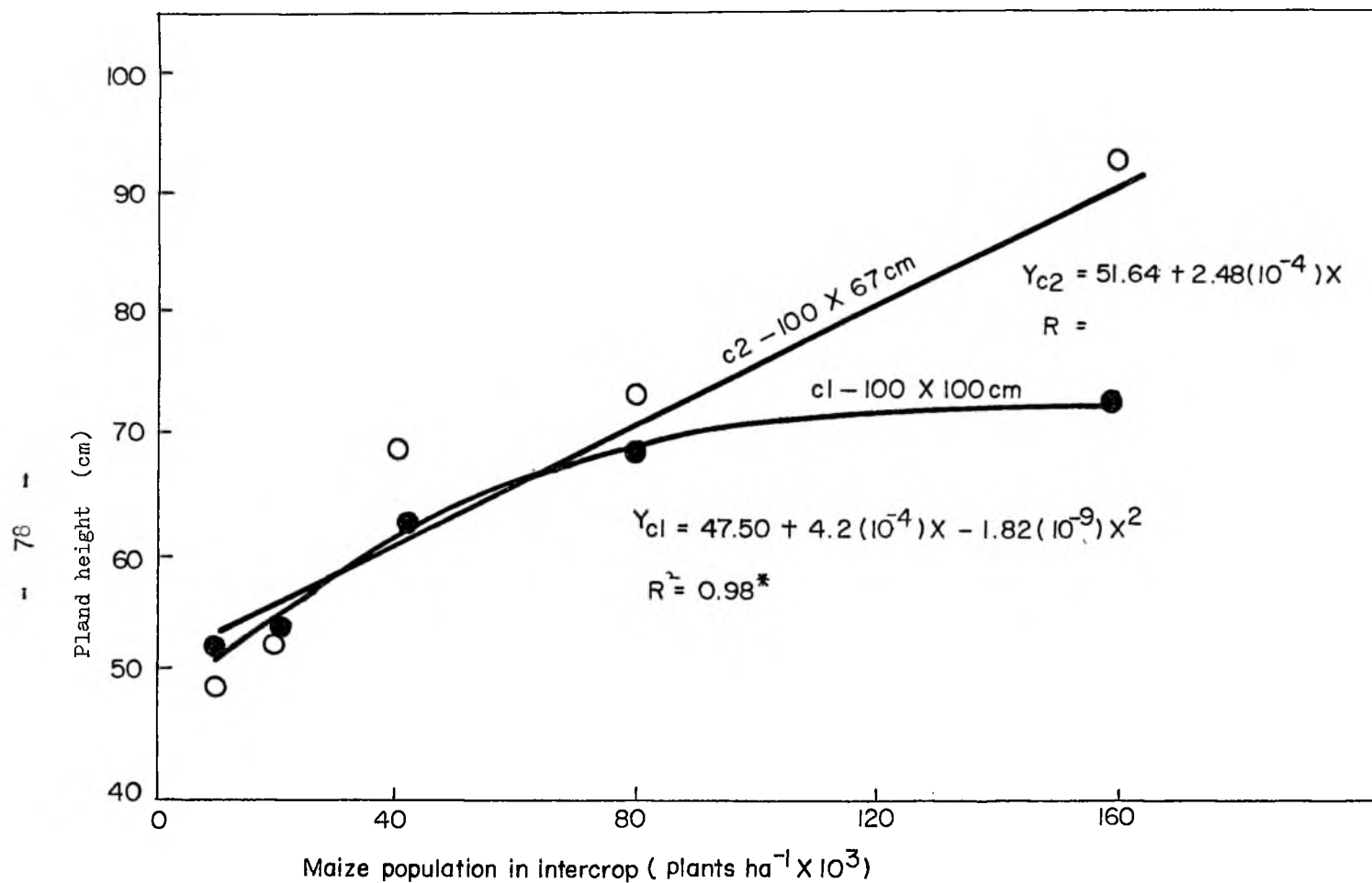


Fig. 17. Effect of maize population and cassava spacing on height of cassava 8WAP.

Table 14: Effect of Maize Variety on Stem Girth
Cassava - 8WAP

Maize Variety	Stem Girth (mm)
1K84A-2135	9.4d
1B84A-203	9.6d
TZSR-Y-1	10.7b
1368 x 5012	10.3c
9450 x 4001	11.0a

* Mean separation by DMRT at 5% level. Means followed by a common letter are not significantly different.

of plants increased as maize population in the intercrop increased (Fig. 18).

Significant differences ~~among~~ maize populations with regards to cassava leaves per plant were observed (Appendix 7). The number of cassava leaves per plant decreased from 21.1 to 17.9 from a maize population of 10,000 plants/ha to 160,000 plants/ha (Table 15). Differences in number of cassava leaves per plant between maize populations of 10,000 and 40,000 plants/ha as well as ~~from~~ 20,000 to 160,000 plants/ha were not significant.

4.3.2 Agronomic Characteristics - 4MAP

Cassava spacing x maize variety interaction effects on plant height was significant. Maize population effect on plant height was highly significant (Appendix 8). At the cassava spacing of 100 x 100cm, the tallest plants were observed among cassava plants intercropped with maize variety 1368 x 5012 while cassava intercropped with 1B84A-203 had the tallest plants at the narrower cassava spacing (Table 16). No significant differences in plant height of cassava were observed between means of cassava spacing for same maize varieties. Differences between plant height means for cassava intercropped with 1K84A-2135, 1B84A-203, 1368 X 5012 and 9450 x 4001 at cassava spacing 100 x 100cm and between 1B84A-203, TZSR-Y-1, 1368 X 5012 and 9450 X 4001 at cassava spacing 100 x 67cm were not significant. Cassava plant height increased with increasing maize population in the intercrop (Fig. 19).

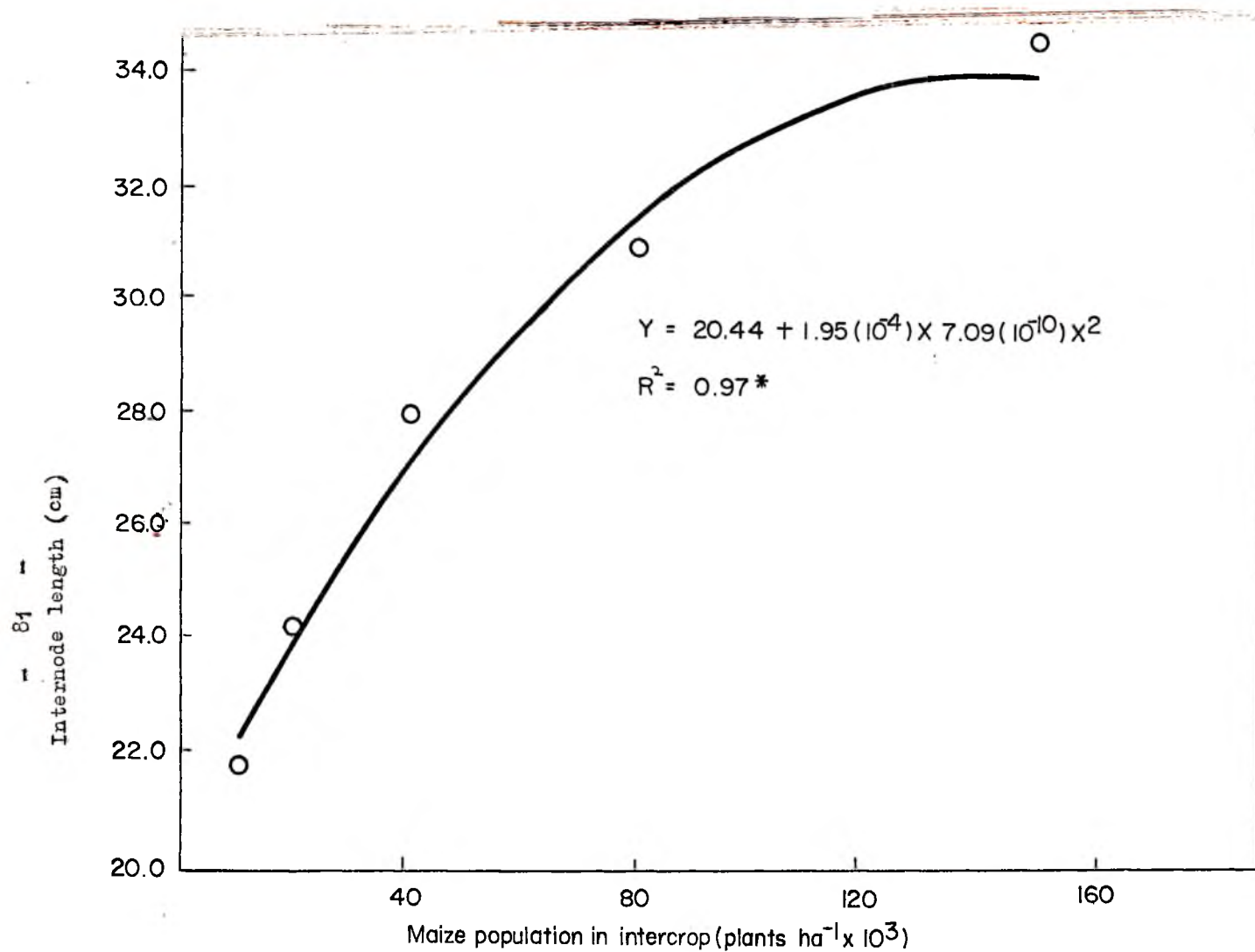


Fig. 18. Effect of maize population on internode length of Cassava 8WAP.

Table 15: Effect of Maize Population on Number
of Leaves Per Plant of Cassava - 8WAP

Maize Population (Plants/ha)	Leaves/Plant
10,000	21.1a
20,000	19.0ab
40,000	19.7ab
80,000	18.4b
160,000	17.9b

* Mean separation by DMRT at 5% level. Means followed by a common letter are not significantly different.

Table 16: Effect of Cassava Spacing and Maize Variety
on Plant Height of Cassava 4MAP

Cassava Spacing	Plant Height, (cm)				
	Maize Varieties in Intercrop				
(cm)	1K84A-2135	1B84A-203	TZSR-Y-1	1368x5012	9450x4001
100x100	105.6a	102.7a	94.1a	111.1a	101.2a
100x67	91.7a	113.8a	103.5a	109.8a	105.6a

* Mean separation by DMRT at 5% level. Means in a column followed by a common letter are not significantly different.

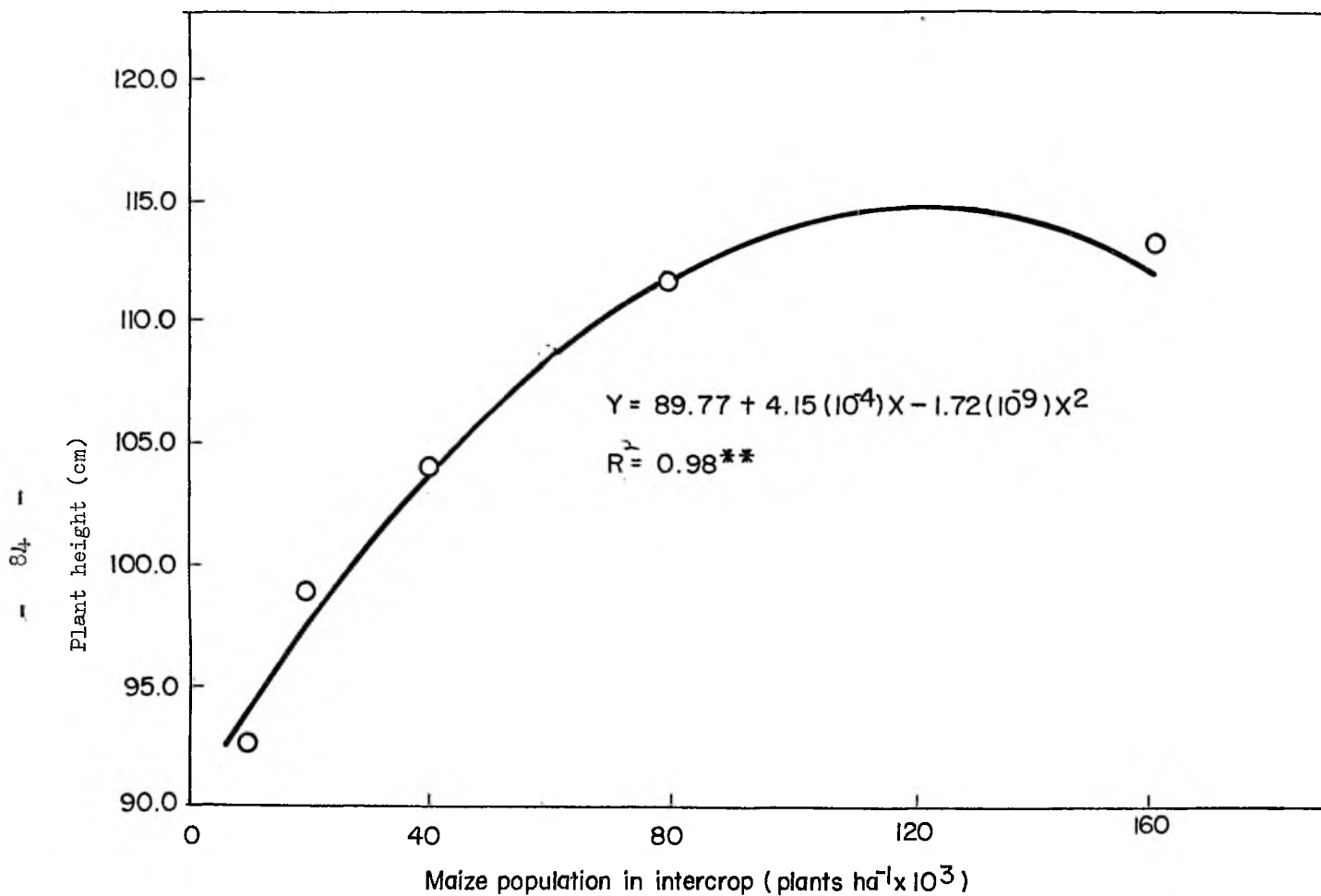


Fig. 19. Effect of maize population on cassava plant height at maize harvest.

The effect of cassava spacing x maize population interaction on internode length was significant (Appendix 8). Generally, plants at the narrower cassava spacing had longer internodes at all maize populations in the intercrop (Fig. 20).

Maize variety effects on internode length of cassava were also significant (Appendix 8). Cassava plants with significantly shorter internode length were found among the short and early maturing variety IK84A-2135 (Table 17).

The interaction effect of cassava spacing and maize variety on stem girth was highly significant (Appendix 8). At the wider cassava spacing, plants intercropped with 1368 x 5012 had the largest stems while those intercropped with IB84A-203 had the largest stems at cassava spacing 100 x 67cm (Table 18). Differences between the means of plants with the largest stems were however not significant.

Significant differences ~~due to~~ ^{due to} maize populations for branches per plant was observed (Appendix 8). Table 19 shows that cassava intercropped with moderate maize population levels produced more branches than those intercropped with the high maize populations of 80,000 - 160,000 plant/ha.

The effect of cassava spacing x maize variety interaction on leaves per plant was significant (Appendix 8). Apart from maize variety IK84A-2135, number of leaves produced by cassava plants intercropped with the other maize varieties did not differ significantly at the two cassava spacings (Table 20). Maize variety x population interaction effect on leaves per plant was also significant (Appendix 8).

Table 21 shows that except for IB84A-203 and 1368 x 5012, leaves produced by cassava intercropped with other maize

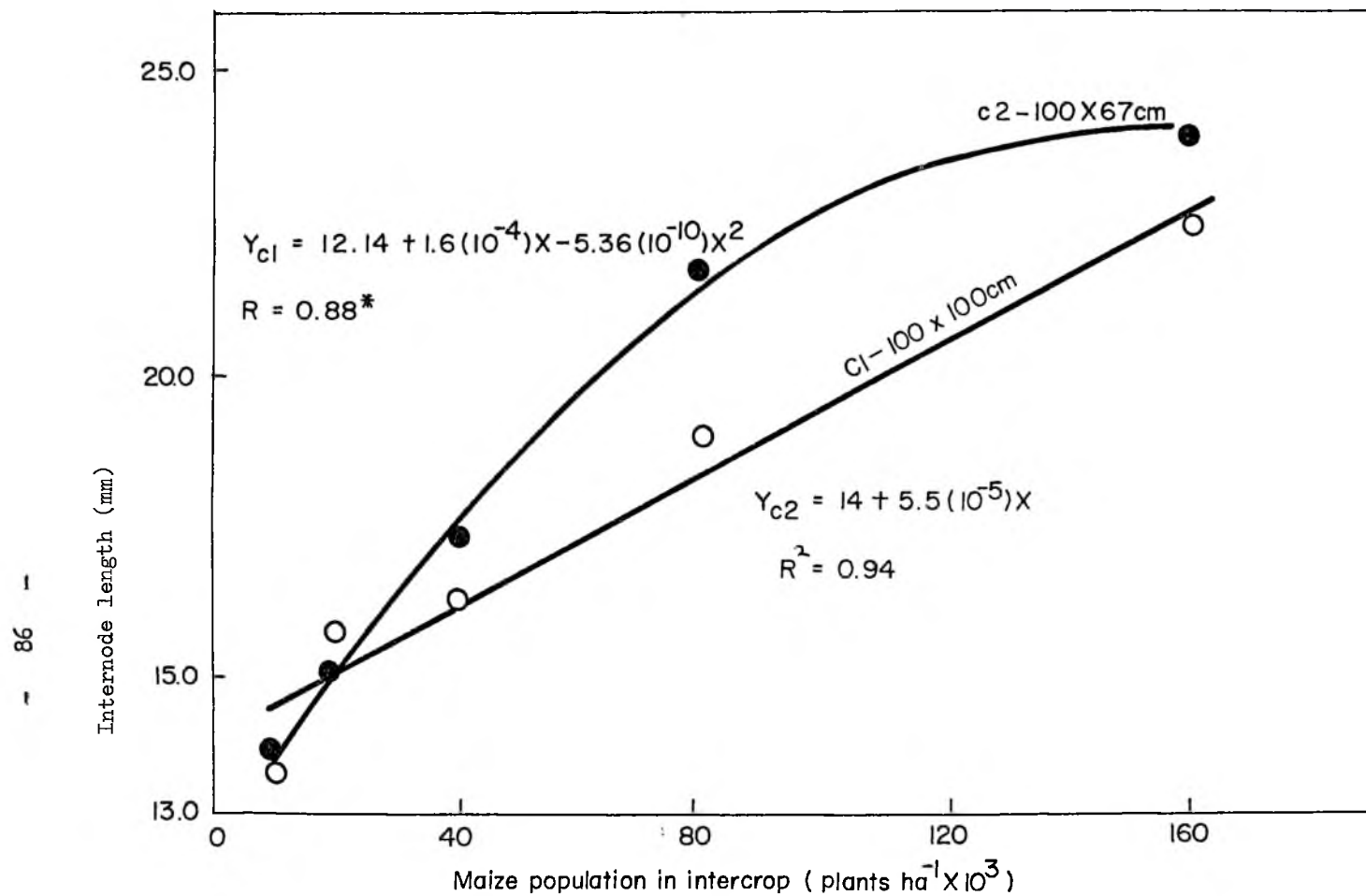


Fig. 20 Effect of maize population and cassava spacing on internode length of cassava at maize harvest.

Table 17: Effect of Maize Variety on Internode
Length of Cassava 4MAP

Maize Variety	Internode Length (mm)
1K84A-2135	16.6d
1B84A-203	17.7abcd
TZSR-Y-1	18.1abc
1368 x 5012	18.3ab
9450 x 4001	18.8a

* Mean separation by DMRT at 5% level. Means followed by a common letter are not significantly different.

Table 18: Effect of Cassava Spacing and Maize
Variety on Stem Girth of Cassava 4MAP

Cassava Spacing	Stem Girth, (mm)				
	Maize Varieties in Intercrop				
(cm)	1K84A-2135	1B84A-203	TZSR-Y-1	1368x5012	9450x4001
100x100	15.6a	15.8a	14.5a	16.0a	15.3a
100x67	14.2a	16.6a	14.8a	15.9a	15.6a

* Mean separation by DMRT at 5% level. Means in a column followed by a common letter are not significantly different.

Table 19: Effect of Maize Population on Branches
Per Plant of Cassava 4MAP

Maize Population (Plants/ha)	Branches/Plants
10,000	3.8a
20,000	3.2ab
40,000	3.2ab
80,000	2.6bc
160,000	2.3c

* Mean separation by DMRT at 5% level. Means followed by a common letter are not significantly different.

Table 20: Effect of Cassava Spacing and Maize Variety on Leaves Per Plant of Cassava 4MAP.

Cassava		Leaves Per Plant			
Spacing		Maize Varieties in Intercrop			
(cm)	1K84A-2135	1B84A-203	TZSR-Y-1	1368x5012	9450x4001
100x100	53.6b	55.3a	43.6a	50.9a	46.5a
100x67	44.0a	52.1a	43.7a	53.2a	43.7a

* Mean separation by DMRT at 5% level. Means in a column followed by a common letter are not significantly different.

varieties did not vary significantly maize populations. The highest and lowest number of leaves were produced under the associated maize varieties IB84A-203 and 9450 x 4001 at 10,000 plants/ha and 160,000 plants/ha respectively.

4.3.3 Agronomic Characteristics - 7MAP

The effect of maize population on cassava plant height, internode length, leaves and branches per plant were highly significant (Appendix 9). It was clear that taller cassava plants with longer internodes were observed with increasing maize populations in intercrop while branches and leaves per plant decreased as maize population in the intercrop was increased (Figs. 21-24).

4.3.4. Root Yield and Related Characteristics

The effect of maize population on cassava root yield was highly significant (Appendix 10). Figure 25 shows the relationship between cassava root yield and maize populations. Root yield decreased linearly with increasing maize population in intercrop.

Average root weight (root size) differed significantly maize populations (Appendix 10). The effect of maize population on average root weight followed a similar trend to that described for root yield (Fig. 26). The effect of maize population on root yield per plant was highly significant (Appendix 10). On the average, root yield per plant decreased as maize population in intercrop was increased (Fig. 27).

Interaction effects of cassava spacing and maize variety on the number of roots per plant was significant. The effect

Table 21: Effect of Maize Variety and Population
on Leaves Per Plant 4MAP

Leaves Per Plant					
Maize	Maize	Varieties	in	Intercrop	
Population	IK84A-2135	IB84A-203	TZSR-Y-1	1368x5012	9450x4001
10,000	51.6a	73.8a	48.6a	68.8a	44.4a
20,000	47.2a	46.9b	44.3a	58.2ab	55.5a
40,000	54.3a	59.5ab	43.8a	52.9ab	48.0a
80,000	50.5a	46.5b	42.9a	44.0ab	42.9a
160,000	40.5a	41.7b	38.4a	36.4b	35.1a

* Mean separation by DMRT at 5% level. Means in a column followed by a common letter are not significantly different.

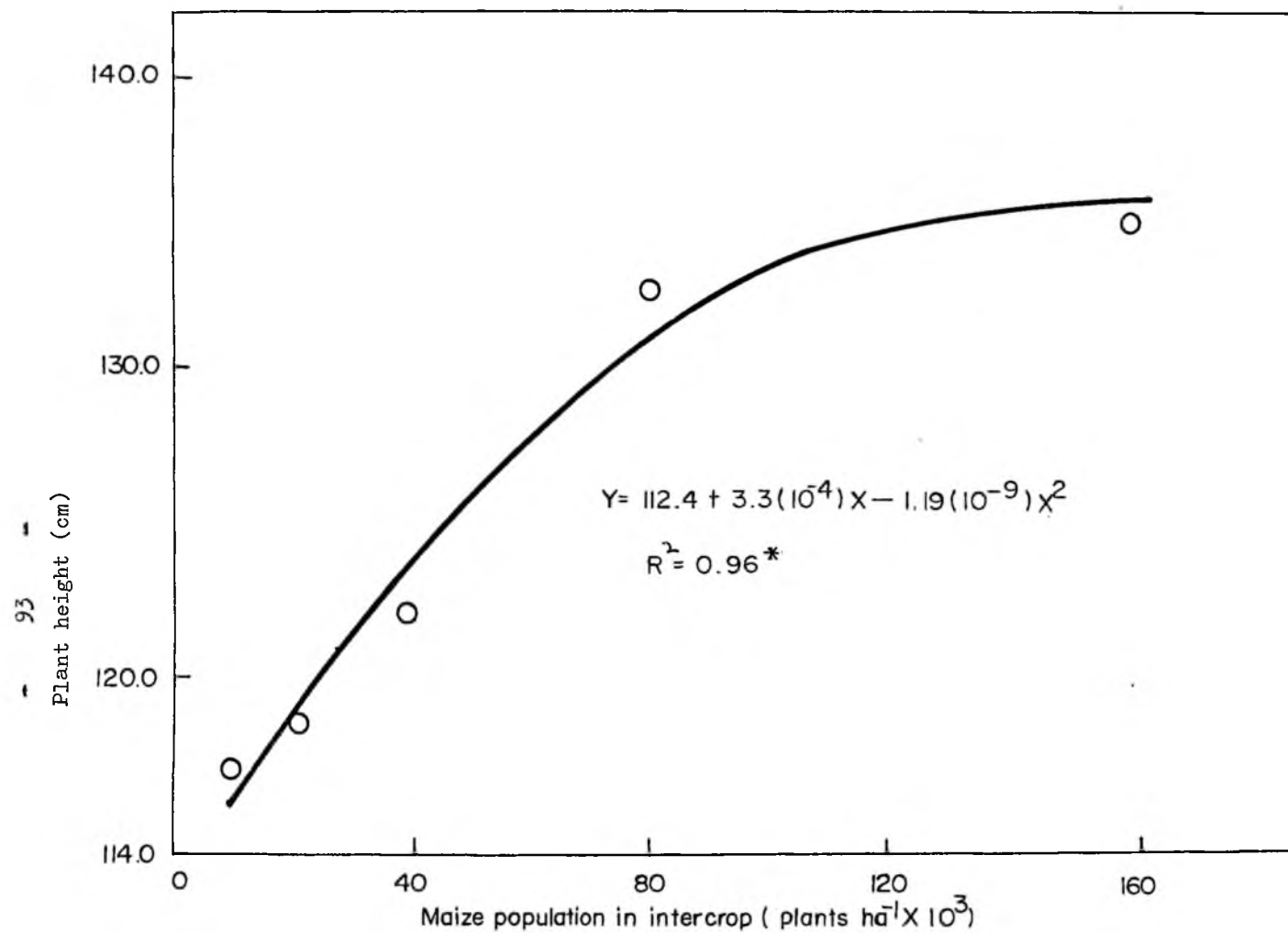


Fig. 2† . Effect of maize population on cassava plant height 7 MAP.

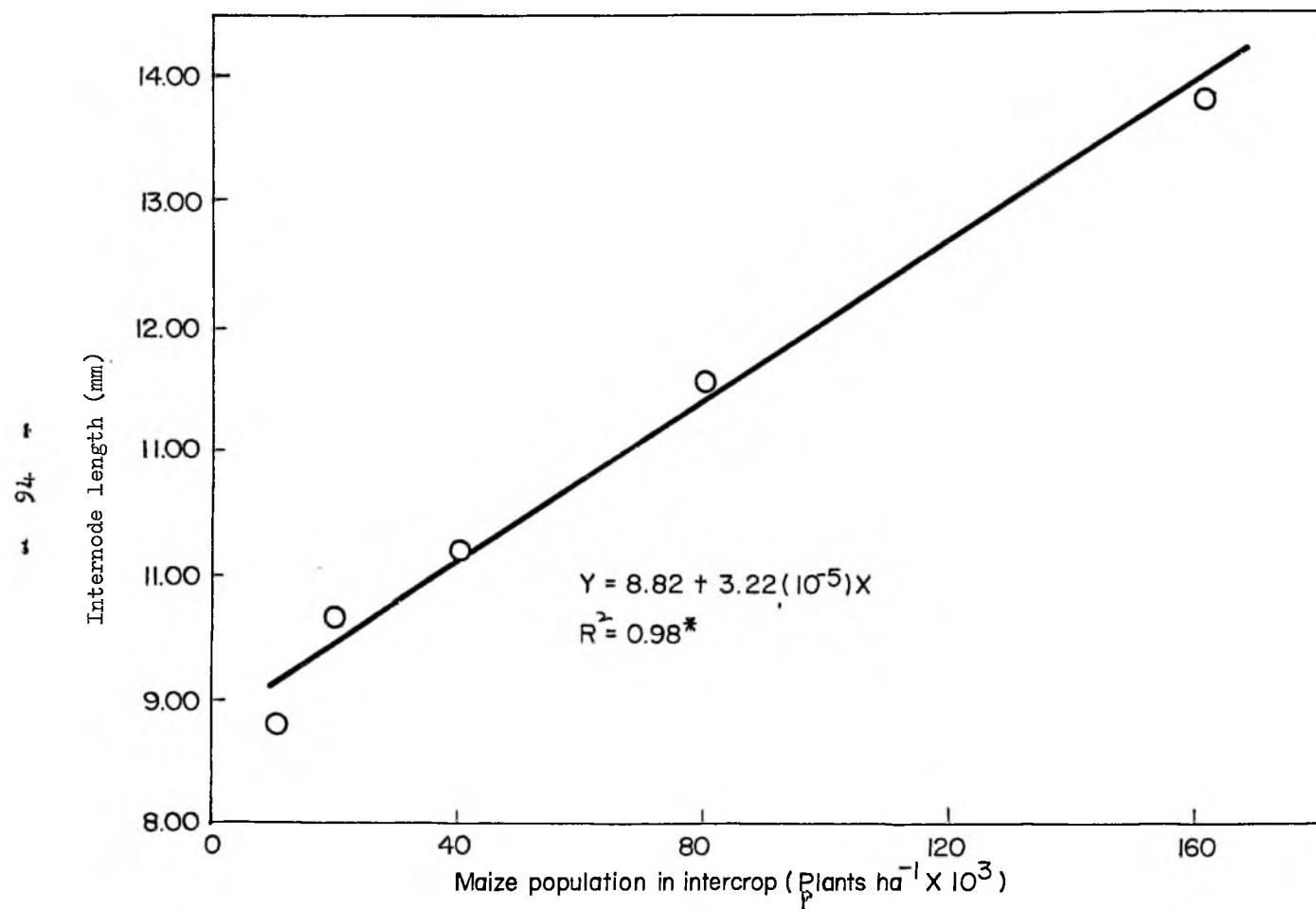


Fig. 22 . Effect of maize population on internode length of Cassava 7 MAP.

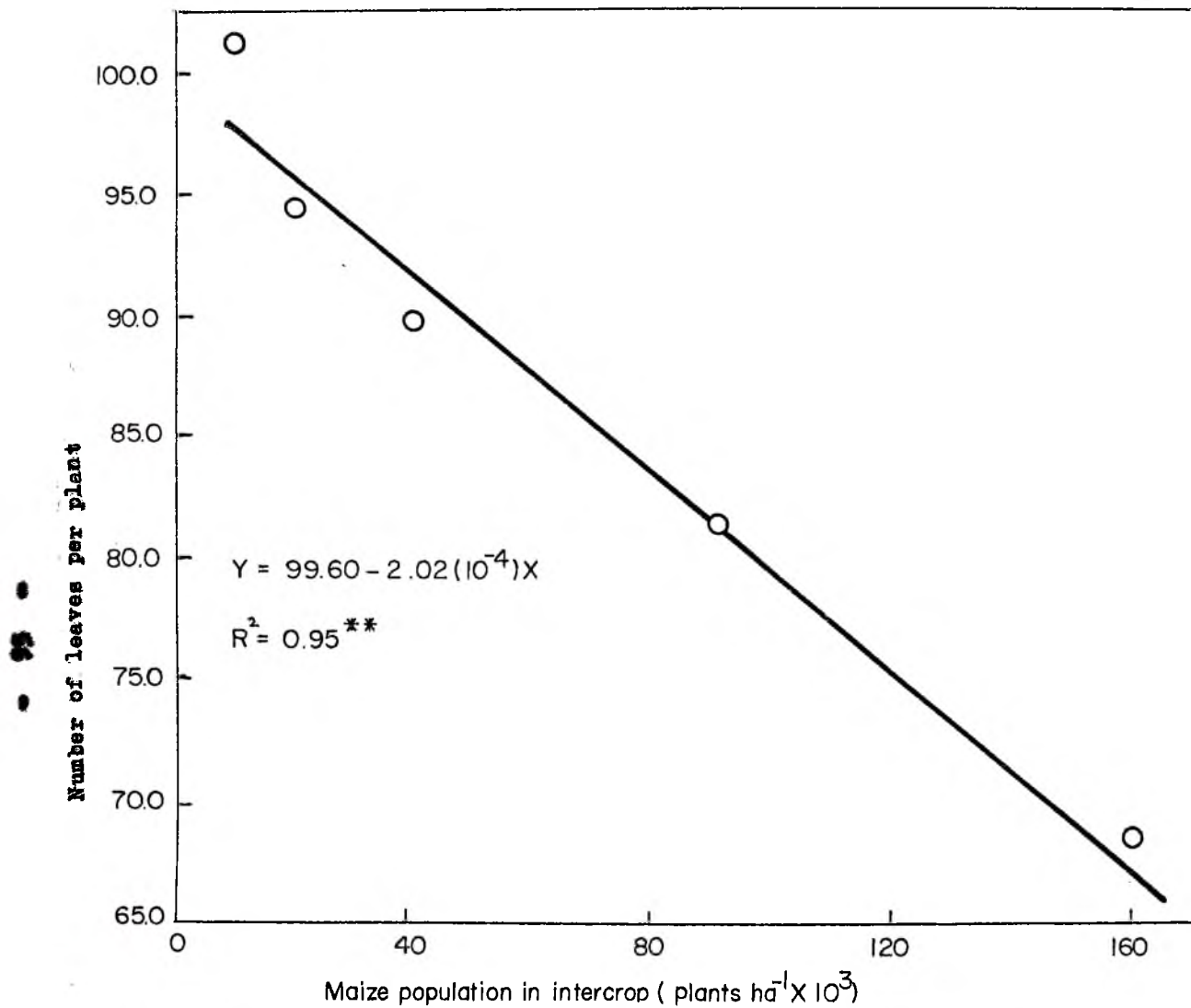


Fig. 2. Effect of maize population on the number of leaves per plant of cassava 7 MAP.

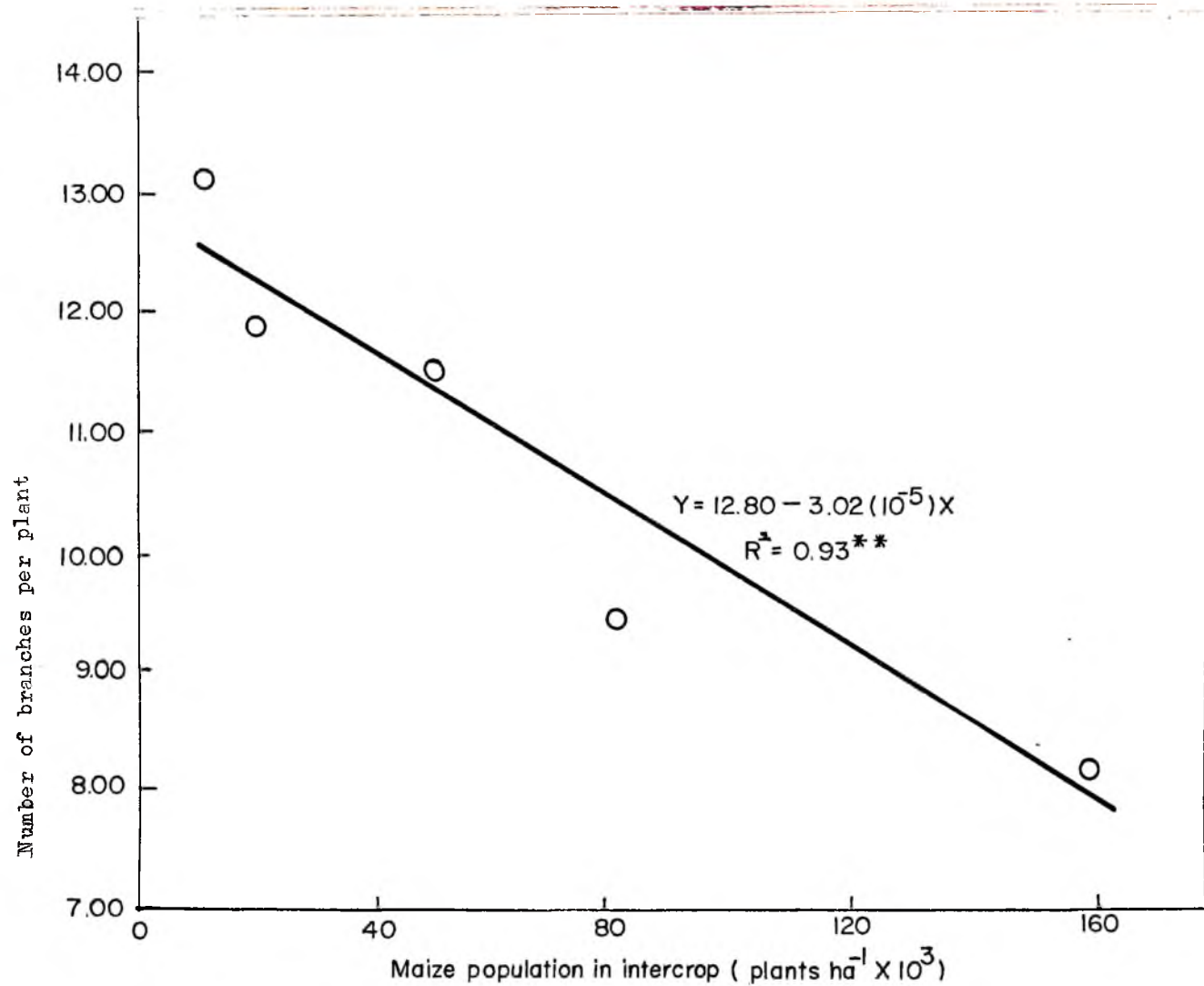


Fig. 24 . Effect of maize population on number of branches of cassava 7 MAP.

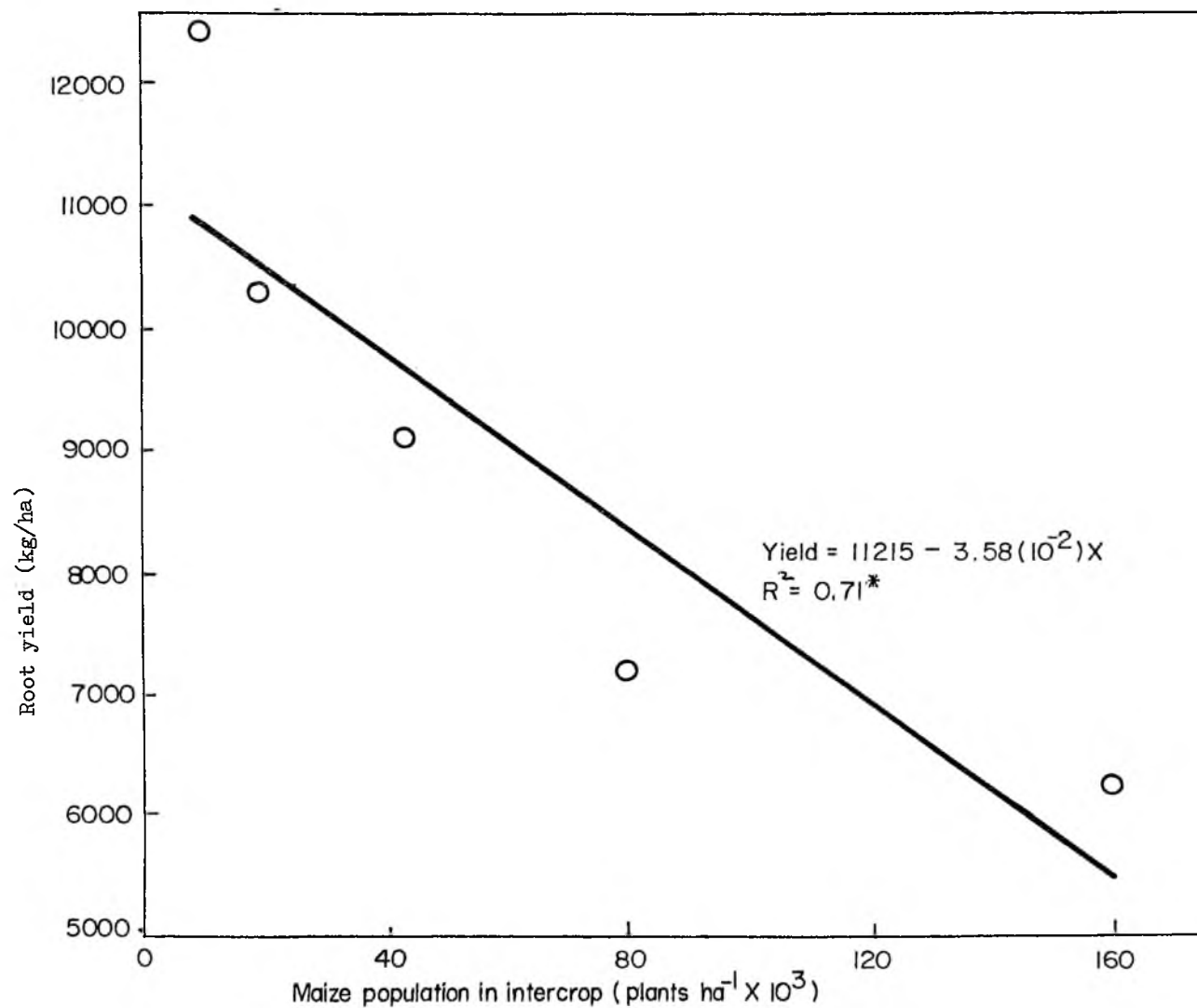


Fig. 25 . Effect of maize population on root yield of Cassava .

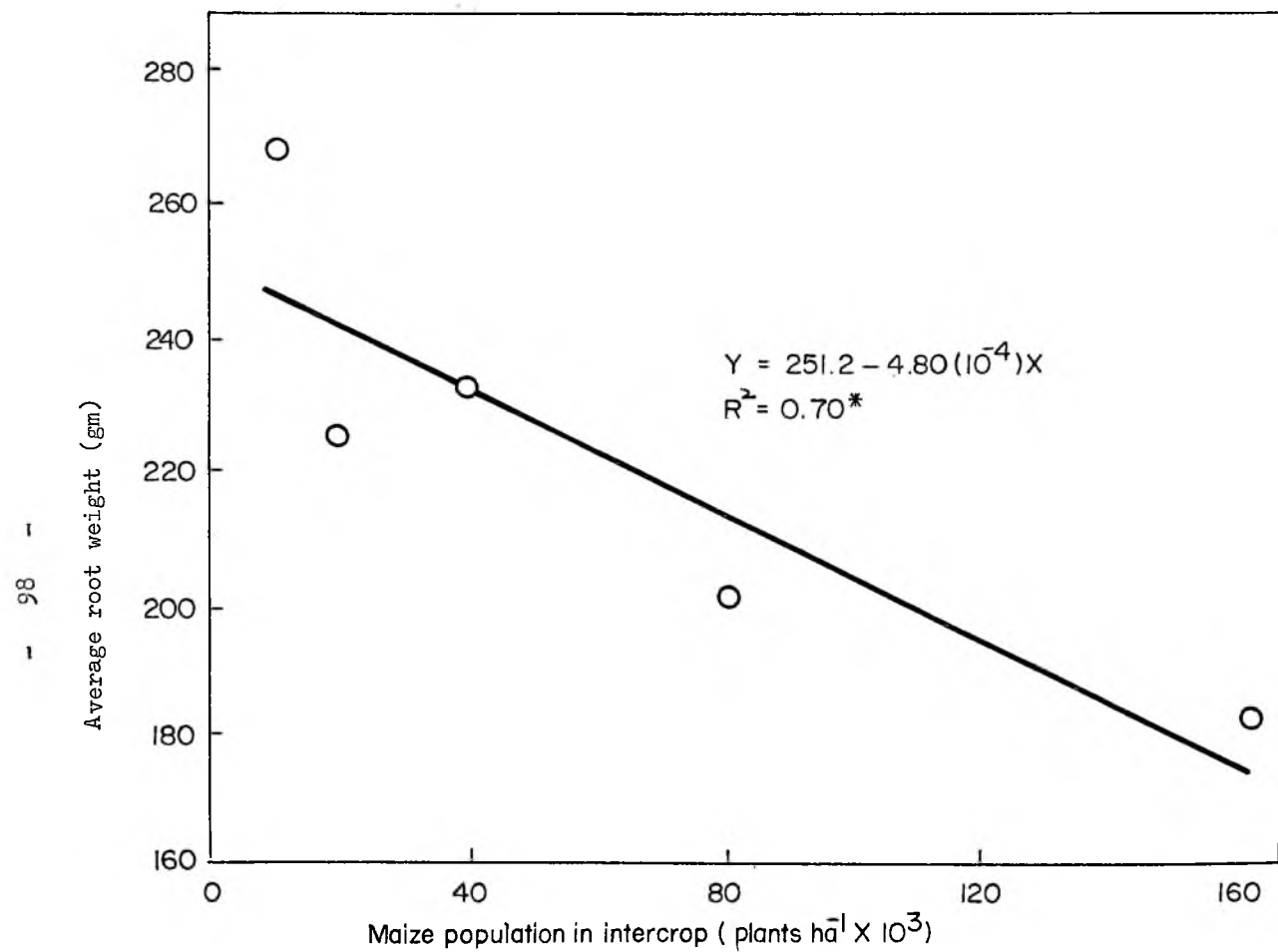


Fig. 26 . Effect of maize population on average root weight.

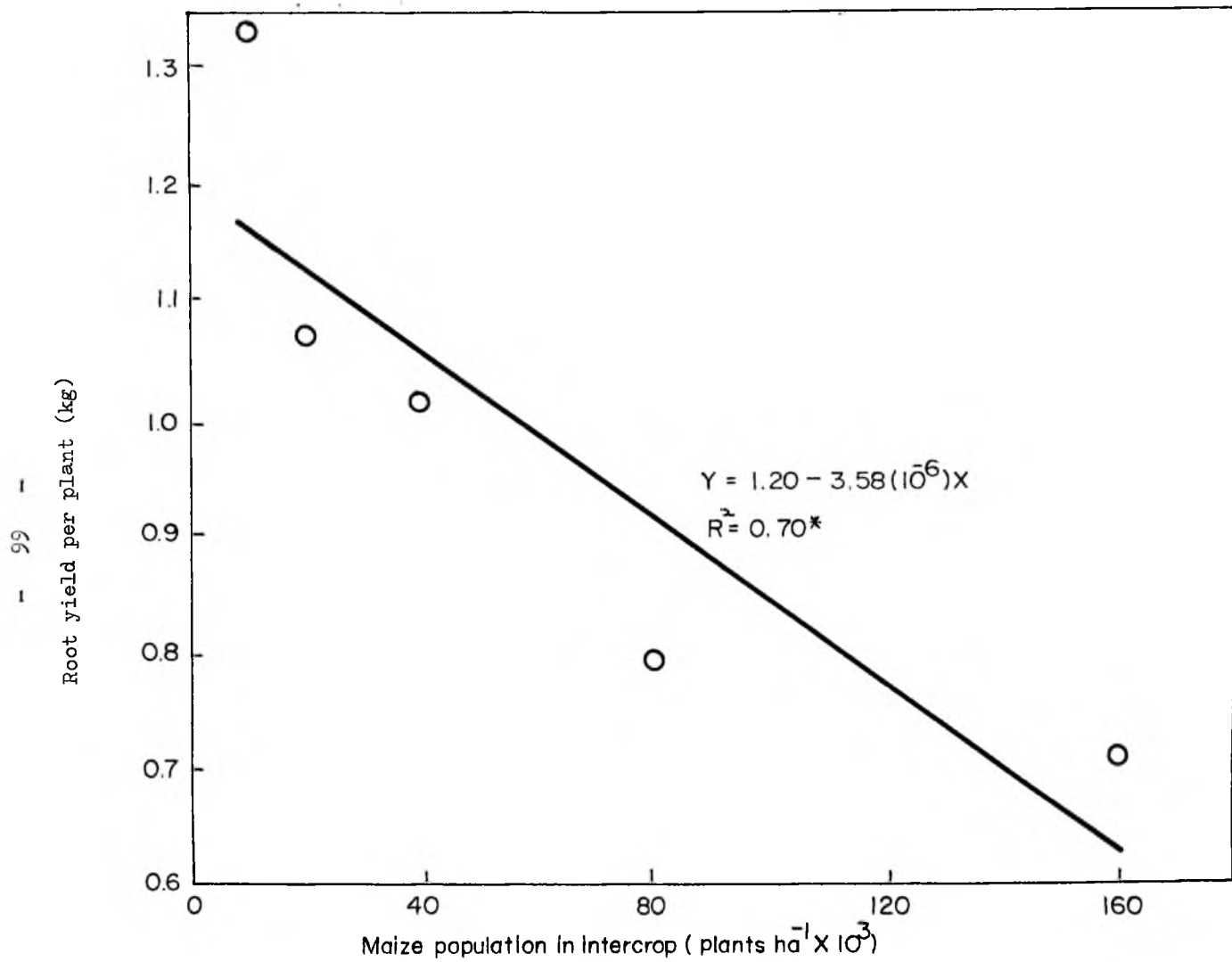


Fig. 27 . Effect of maize population on root yield per plant.

of maize population was also significant (Appendix 10). The lowest number of roots were observed on cassava spaced 100 x 67cm and intercropped with the spreading and late maturing TZSR-Y-1 while the highest number was recorded on those spaced 100 x 100cm and intercropped with maize late maturing hybrids 1368 x 5012 and 9450 x 4001 (Table 22). Apart from maize variety 9450 x 4001, the number of roots per plant observed were higher for the other maize varieties at cassava spacing 100 x 100cm. Differences between number of roots at the two cassava spacings for maize varieties 1K84A-2135 and 9450 x 4001 were not significant. Increasing maize population in intercrop decreased the number of roots produced but the differences were not significant at moderate maize population levels.

There was a significant cassava spacing x maize variety interaction on shoot dry weight at harvest. The effect of maize population on shoot dry weight was also highly significant (Appendix 11). Shoot dry weight was greatest at the cassava spacing of 100 x 100cm when intercropped with maize variety 1K84A-2135 while at 100 x 67cm, cassava intercropped with 1B84A-203 produced the highest amount. The difference in shoot dry weight observed under these two maize varieties was not significant (Table 24). At 100 x 100cm, no significant difference was observed for shoot dry weight between 1K84A-2135 and 1B84A-203 or between 1368 x 5012. There was a general decrease in shoot dry weight with increasing maize population in intercrop (Fig. 28). The effect of maize population on root dry weight per hectare was highly significant (Appendix 11).

Table 22: Effect of Cassava Spacing and Maize Variety
on Root Number Per plant at Cassava Harvest

Cassava Spacing	Roots Per Plant				
	Maize Varieties in Intercrop				
(cm)	1K84A-2135	1B84A-203	TZSR-Y-1	1368x5012	9450x4001
100x100	4.32a	5.16a	4.28a	5.54a	4.61a
100x67	3.79a	4.40a	3.56a	4.05b	4.91a

Mean separation by DMRT at 5% level. Means in a column separated by a common letter are not significantly different.

Table 23: Effect of Maize Population on Number
of Roots Per Cassava Plant at Harvest

Maize Population (Plants/ha)	Roots Per Plant
10,000	4.84a
20,000	4.81ab
40,000	4.57abc
80,000	4.09cd
160,000	4.00d

* Mean separation by DMRT at 5% level. Means followed by a common letter are not significantly different.

Table 24: Effect of Cassava Spacing and Maize Varieties on Shoot Dry Weight of Cassava at Harvest

Cassava Spacing	Shoot dry weight (kg/ha)				
	Maize Varieties in Intercrop				
(cm)	1K84A-2135	1B84A-203	TZSR-Y-1	1368x5012	9450x4001
100x100	1578a	1477a	868a	1450a	938a
100x67	1170a	1771a	972a	1334a	1564c

Mean separation by DMRT at 5% level. Means in a column separated by a common letter are not significantly different.

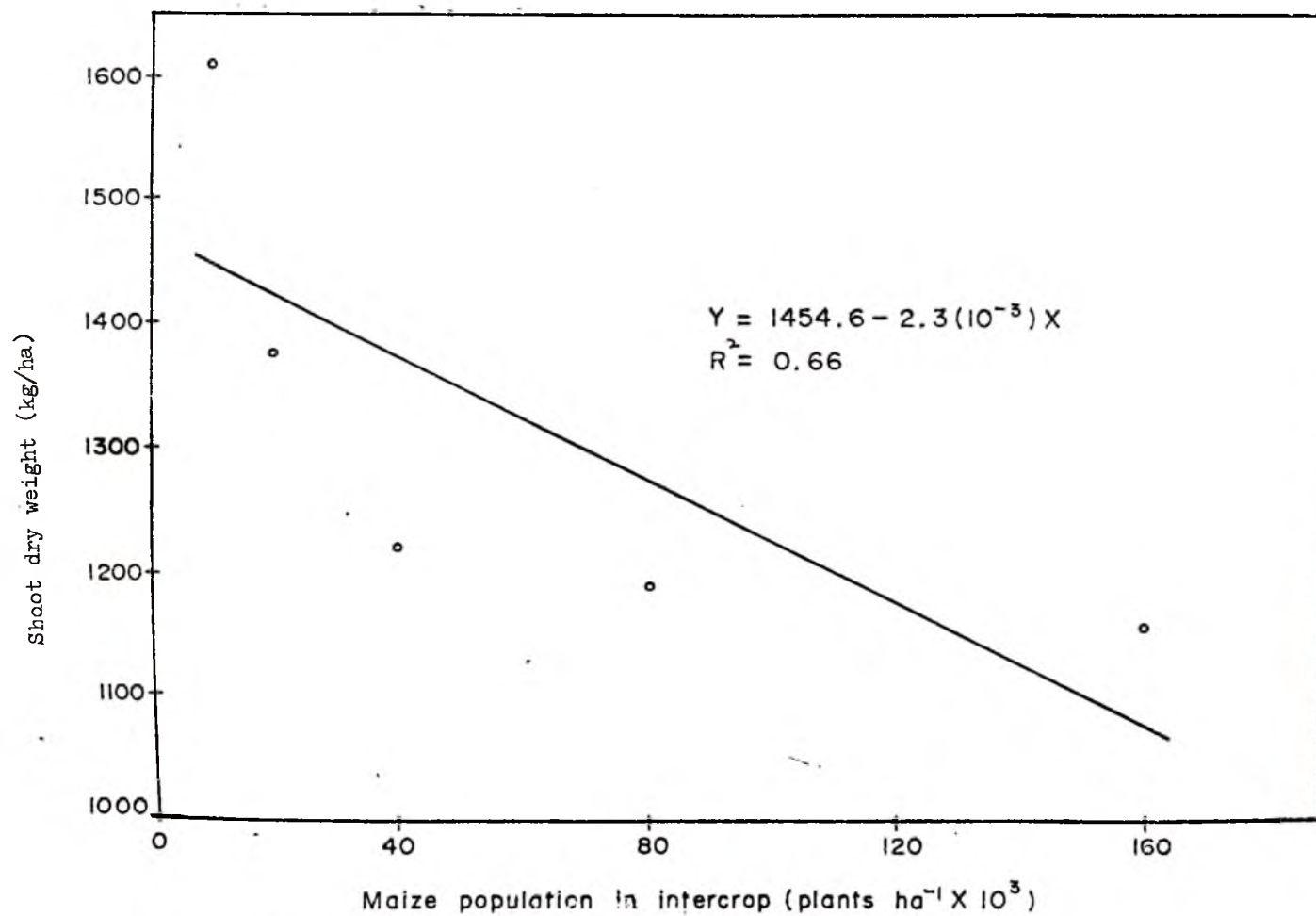


Fig. 26 Effect of maize population on shoot dry weight of cassava.

Root dry weight per hectare decreased as maize population in intercrop increased (Fig. 29). Maize population effect on harvest index of cassava was significant (Appendix 11). In general, harvest index decreased as maize population in intercrop was increased (Fig. 30).

4.3.5 Land Equivalent Ratios (LERs)

The effect of maize population on the LER of cassava was significant (Appendix 12). LER of cassava decreased with increasing maize population in the intercrop (Fig. 31). Maize variety x population effects on LER of maize were significant (Appendix 12). The highest LER was obtained for 1K84A-2135 at a maize population of 80,000 plants/ha with lowest for 1368 x 5012 at a maize population of 10,000 plants/ha (Fig. 31). Maize variety x population interaction effects on total LER was significant (Appendix 12).

Across maize variety and populations, 1K84A-2135 produced the highest total LER of 1.9 followed by 1B84A-203 with LER of 1.4 at the same maize population of 80,000 plants/ha. In general, LER for intercropped maize varieties 1K84A-2135 and 1B84A-203 increased with increasing maize population in intercrop up to the maize population of 80,000 plants/ha and declined thereafter. For TZSR-Y-1 and 9450 x 4001, the highest LER were obtained at 40,000 maize population followed by a decline. 1368 x 5012 did not show a consistent trend (Fig. 31).

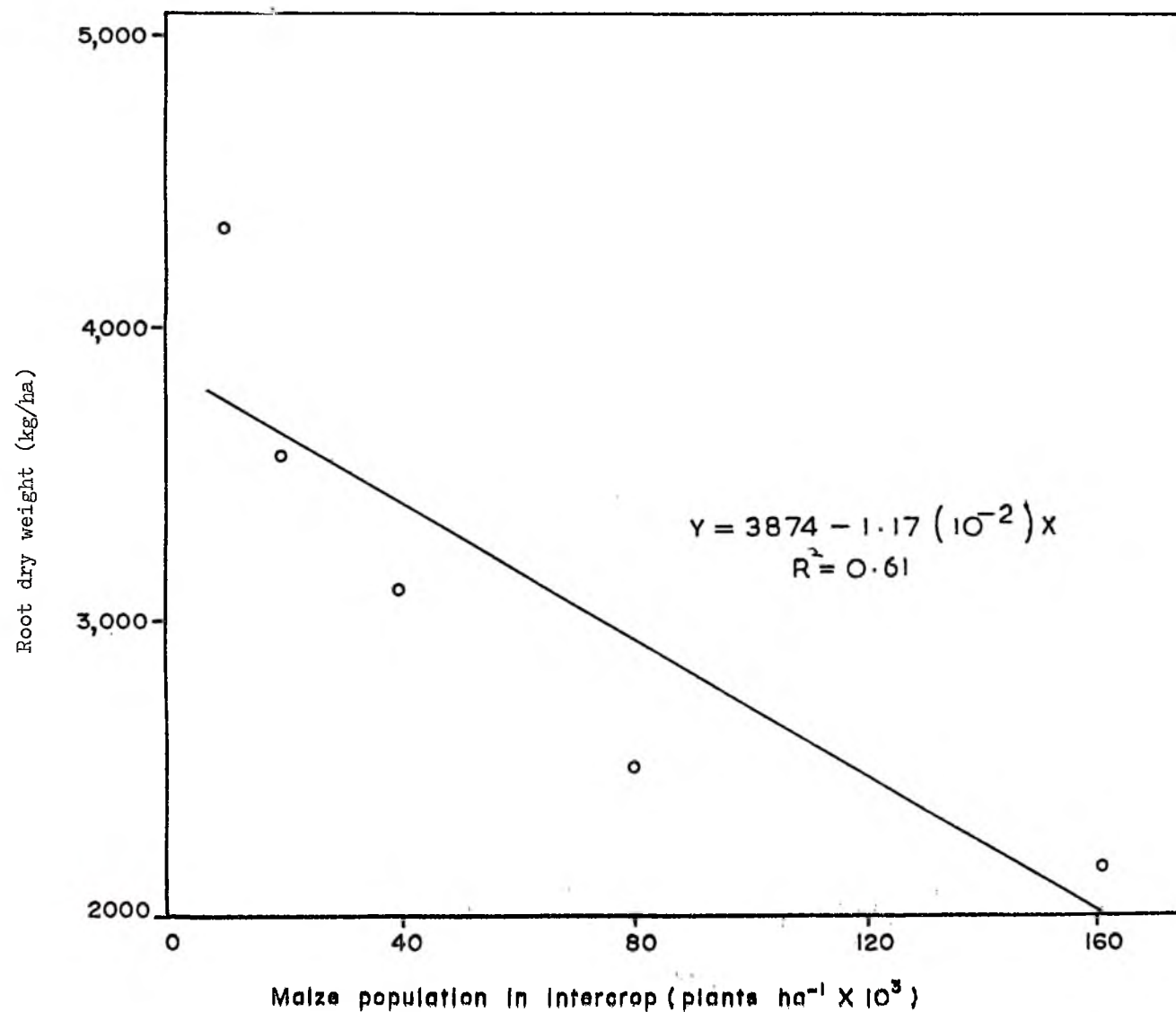


Fig. 29 Effect of maize population on root dry weight of cassava at harvest.

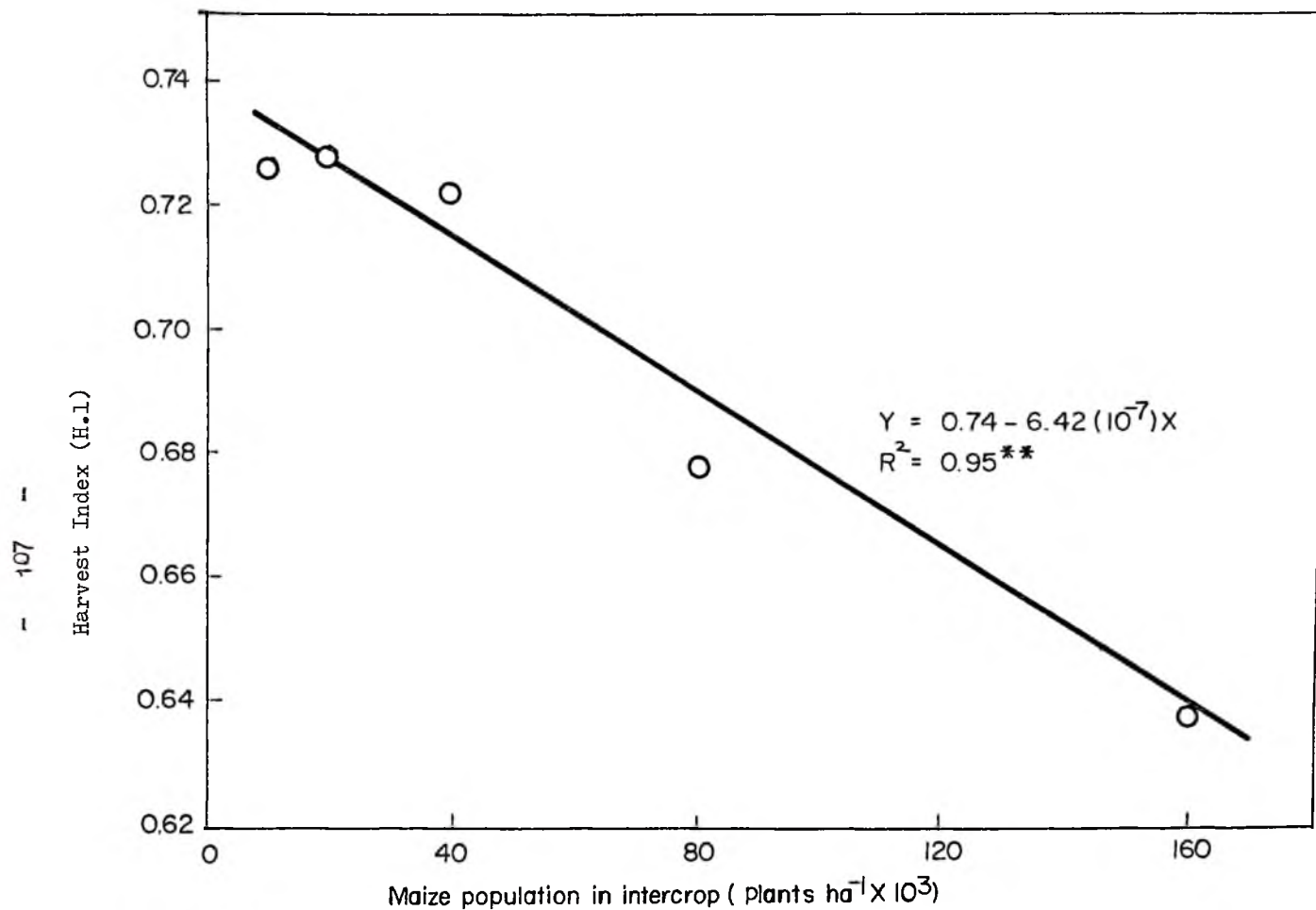


Fig. 30 . Effect of maize population on Harvest Index of Cassava .

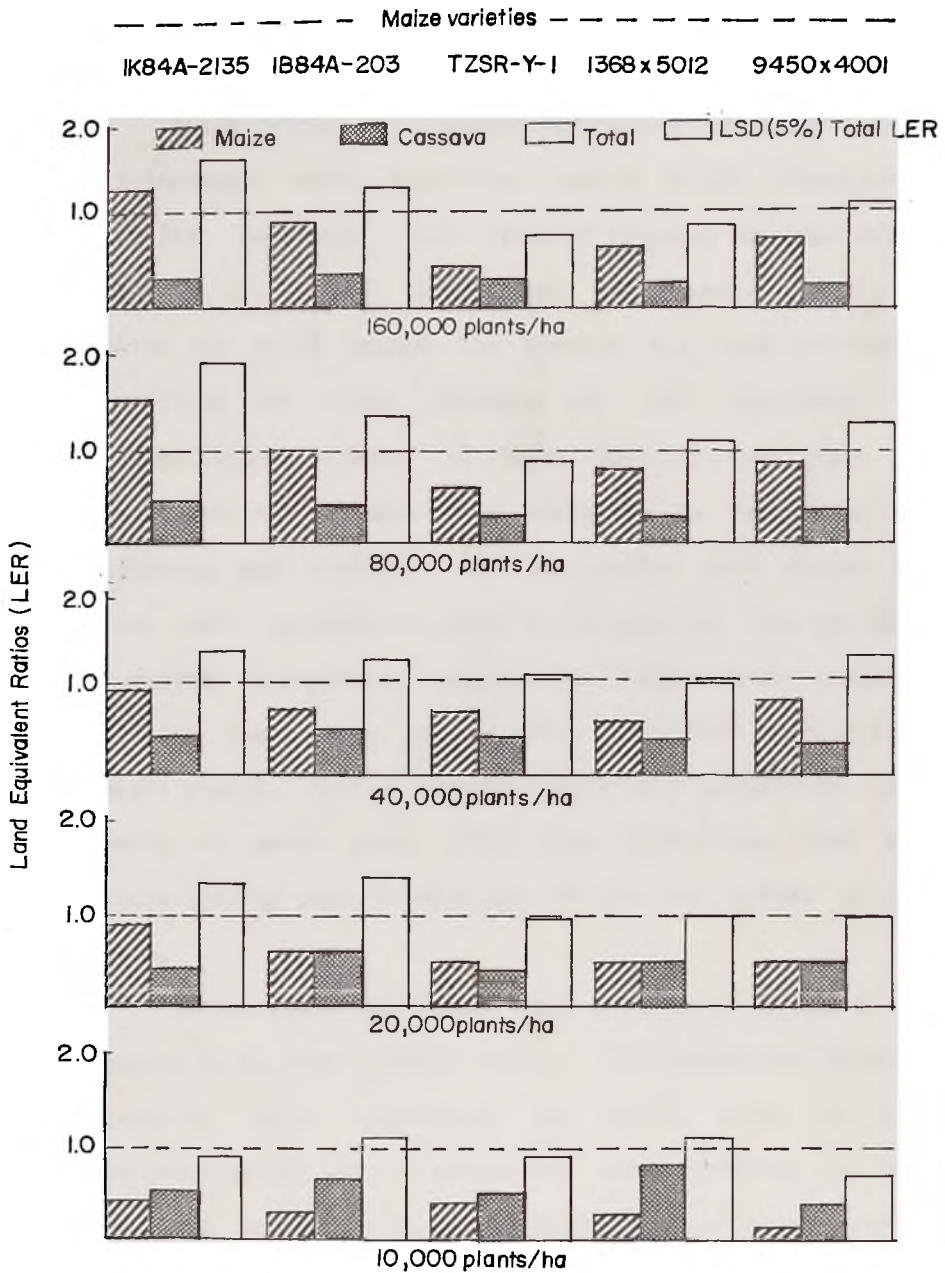


Fig.31 Land equivalent ratios for cassava and different population levels of maize varieties in the intercrop.

CHAPTER FIVE

DISCUSSION

Grain yield per hectare obtained in the study increased with increased maize population beyond 80,000 plants/ha and thereafter declined. This trend of response has been observed by Lang et al. (1956) and Rutger and Crowder (1967). The decline in yield beyond the optimum has been attributed to competition for light, moisture and soil nutrients. The non-significant effect of maize varieties on grain yield suggest that the response of the varieties to increasing maize population was similar. The implication that higher grain yields were obtained at higher maize densities than the optimum recommended in practice, suggest that high maize populations could be used in a cassava/maize intercrop to increase the overall yields. Further the non-significant effect of cassava spacing on maize grain yield give indications that at the cassava spacing used, cassava may not have any effect on maize yields.

Grain yield per plant and 1000-grain weight of maize appeared to be under genetic control. The depressive effect of increasing maize population on grain yield per plant, 1000-grain weight and ear weight has been explained by Donald (1963) as being due to the intensification of crop competition among plants as population increases.

Barrenness which is a peculiar problem associated with maize planted at high densities was observed in the study and agrees with trends reported by Moss and Stinson (1961) and Colville (1962) who suggested that barrenness is the result of

shading and a delay in silking and becomes intense as population is increased.

The increase in stover dry weight at maize population beyond the optimum observed for grain yield per hectare shows that the amount of grain produced per unit weight of stover decreased as maize population in the intercrop was increased. This trend suggests that at high populations the amount of assimilate translocated to the ear for grain filling is reduced due to a decreased rate of photosynthesis resulting from shading as well as intra and interplant competition for growth factors.

The wide variation in agronomic characteristics among maize varieties were to be expected as the maize varieties represented a selected sample with different genotypic background. Of particular interest among these characteristics was leaf angle which did not reflect the characteristics as given by the breeders.

The effect of maize population on agronomic characteristics observed in the study have been reported by several workers. Dungan et al. (1958), Early et al. (1967) and Rutger and Crowder (1967) indicated that the effect is mainly due to competition for light, moisture and soil nutrients. High incidence of lodging at high populations is due to an increase in plant height and a decrease in stalk diameter. These thin stalks tend to be weak and with ears placed higher in the stalks, a high degree of leverage is produced with the tendency to induce lodging and stem breakage. Leaf angle

adjustment with changes in maize population as reported by Williams et al. (1968) Duncan (1971) and Egharevba et al. (1975) and the variation of leaf area index among varieties at different populations suggest the need for management practices such as crop arrangement for better utilization of light and minimum competition for other growth factors at optimum densities.

Correlation coefficients were obtained for agronomic characteristics of maize varieties with grain yield to determine which of these characteristics contribute greatly to yield were variable. Days to 50 percent silking, ear height, plant height at tasselling, plant height at harvest leaf area, root and stem lodging showed consistent correlations with grain yield. The significant positive correlations of days to 50 percent silking, plant height at tasselling, ear height, root and stem lodging indicated that in some of the maize varieties grain yield was associated with these agronomic characters. Similarly, the significant negative correlation coefficient of leaf area with grain yield per hectare indicates that increases in leaf area caused a decline in grain yield in some of the varieties.

The presence of these significant correlations did not in all cases reflect the performance of the varieties in the intercrop. This may be due to the fact that the planting time of May was quite late as such the crop could not benefit from the high levels of radiations which peaks around March and April. In addition, periods of low moisture stress which

characterised parts of the growing seasons may not have favoured the fullest expression of the genotypic potentials of the maize varieties.

Observations on cassava made at the different periods show the effect of maize on cassava at these periods of growth. The effect of cassava spacing x maize variety interaction on plant height was difficult to explain as no consistent trend was observed among the maize varieties at the two cassava spacings. Additive effect due to cassava spacing and maize population were observed on cassava plant height 8WAP and internode length at maize harvest 4MAP respectively. In general, the closer cassava spacing only added to the already significant competition effect for light due to maize population increases. Maize population also exerted a strong effect on leaf and branch development of cassava. The trend towards taller cassava plants with increasing plant density has been observed by Enyi (1973). Kang and Wilson (1981) also observed that at age 4-5 months after planting intercropped cassava was etiolated with poor branching and smaller foliage.

Enyi (1973) and Hunt et al. (1977) explained the observed trend of plant height and internode length with increasing population to competition for light. The trend observed for leaves and branches per plant with increasing maize population agrees with findings of Wahua (1985) from his study on maize/melon intercrop system. Wahua (1985) reported that increasing the population of the taller maize component in

the intercrop system affected most vegetative characters of the associated melon crop. Plants produce more leaves and branches when they have adequate supplies of light, nutrient and soil moisture. The trend observed in the study may therefore be attributed to competition for these factors.

The effect of maize variety on stem girth of cassava 8WAP and internode length 4MAP (at maize harvest) gives an interesting trend for study. Cassava intercropped with the late maturing maize varieties had larger stems at this period and may be explained as being due to the fact that late maturing maize varieties were not exploiting their environment maximally at this time compared to the early maturing varieties thus allowing the cassava plants optimum use of growth factors for growth. The effect of maize variety on internode length agrees with the observation of Wahua et al. (1981)

Elliot and Miller, cited by Wahua et al. (1981) have indicated that the stem of peas like most plants elongate according to the degree of shading imposed on them. Internode length observed in the study indicated that cassava plants intercropped with the tall maize varieties had longer internode lengths. The non-significant difference observed between 1K84A-2135 and 1B84A-203 on one hand and 1B84A-203 and the late maturing varieties on the other suggest that all the maize varieties in the study imposed some amount of shade on the low growing cassava below their canopies but the intensity and duration of the effect was greater under the tall late maturing varieties.

The period, seven months after planting which is about three months after maize harvesting indicates a period of recovery by cassava from the effect of maize. Cassava appeared to have recovered from the effect of the maize varieties. Contrarily, the effect of maize population was still evident suggesting that cassava was yet to recover from this factor. This observation suggests that maize population may be a more important factor than maize variety in a cassava/maize intercrop system at higher maize population densities.

Root yield per hectare, number of roots per plant, average root weight and root yield per plant were related to maize population in the intercrop. Top dry weight, root dry weight and harvest index also decreased with increasing maize population in the intercrop. Kang and Wilson (1981) and Ezumah and Lawson (1982) have reported that increasing maize population in a cassava/maize intercrop from 30,000 to 60,000 plants/ha depressed root yield of cassava. Enyi (1973) also observed a similar trend of decreasing root yield and related characters with increasing plant population. Hunt et al. (1977) explained that stem and internode elongation caused by increasing plant populations as under shaded conditions require considerable energy for tissue synthesis. The sites of elongation serve as sizeable sinks for available carbohydrates within the plant and so could reduce carbohydrate supply to the roots. Such changes affect root number which is determined in the early stages of growth and thus have a significant effect on

yield. Using the 10,000 plants/ha maize population level in the intercrop as a baseline for comparison, root yield in the study was depressed by 28.4 percent when the maize population in the intercrop was increased to 40,000 plants/ha, and 50 percent when increased to 160,000 plants/ha.

Rao and Willey (1980) presented LER values of individual crops to indicate competitive effects and total LER to assess productivity. In this study, the LER for cassava at the different maize population densities was unusually low. This observation may be attributed to the high yield of the cassava monocrop. The short, early maize variety IK84A-2135 produced LER greater than unity at both 80,000 and 160,000 plants/ha giving indications that it was less affected by competition due to increasing maize population compared with the other varieties which had LERs less than one. Again, on the basis of individual LER comparisons the tall, early maturing IB84A-203, also demonstrated its superiority over the tall, late maturing varieties. In general, competitive effects of maize varieties in the intercrop increased with increasing maize population and with increasing maturity period.

Total LERs obtained gave indications that a cassava/maize mixed cropping system is a highly productive system as reported by Kang and Wilson (1981) and Guttrino (1984). Based on plant height, cassava intercropped with the shorter maize variety IK84A-2135, gave a consistently higher productivity than the other combinations between maize

populations of 40,000 to 160,000 plants/ha while the other varieties except IB84A-203 showed slight or no advantage for intercropping. With regards to maturity differences, the early maturing varieties IK84A-2135 and IB84A-203 gave the highest LERs at a maize population of 80,000 plants/ha. There was no consistent trend among LER values that could be related to the canopy characteristics of the maize varieties used.

The advantage gained by cassava under the late maturing maize varieties at 8WAP and 4MAP could not be translated into a higher root yield compared to those under the early maturing ones which appeared suppressed at the growth stages. This is manifested by the fact that LER values arising from cassava/late maturing maize combinations were lesser than those obtained for cassava/early and short maize combinations even though late maturing maize varieties had higher yields.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

Cassava planted at two spacings, 100 x 100cm and 100 x 67cm was interplanted with five maize varieties to identify some maize plant characters which should be incorporated in maize plants intended for use in cassava/maize intercropping systems. Maize population within the intercrop was varied systematically from 10,000 to 160,000 plants/ha to examine the feasibility of intercropping cassava with high populations of maize to increase overall yield.

On the basis of the results obtained from one cropping year, under the prevailing climatic and soil conditions over the period, the following conclusions may be drawn.

Cassava spacing at the level used did not show adverse effect on maize yield nor on cassava yield but its interaction with maize variety or maize population affected some agronomic characteristics of maize.

Inconsistent correlation coefficients between grain yield and agronomic characteristics were obtained for maize varieties. Some of these agronomic characteristics did not reflect the characteristics of the varieties as described by the breeders. Thus some of the characters of maize varieties in a sole cropping may differ in a mixed cropping system. It was possible in the study to relate differences in agronomic characteristics of cassava at various periods to some of the morphological and physiological characteristics of the maize varieties.

Increasing maize populations in the intercrop had a pronounced effect on both agronomic characteristics of maize and cassava. Root yield of cassava decreased with increasing maize population. At extremely high maize populations, maize yields also decreased.

Results from this exploratory trial, indicated a high productivity of cassava/maize intercrop system. Higher productivity is achievable with early maturing and short of maize varieties at higher maize populations. Best total productivity can be realized by intercropping a cassava population of 10,000 to 15,000 plants/ha with 80,000 plants/ha of short and early maturing maize varieties. At the same range of cassava population, up to 40,000 plants/ha of the other maize varieties could be used. These results, having been obtained at the geographical location of Ibadan, seems to be appropriate for the derived savannah and the northern limits of the lowland forest zones of the tropical rain forest. The recommendation given regarding the level of maize population in the intercrop is only applicable if native fertility of the soil is supplemented with recommended rates of fertilizers. Similar studies expanded to include different rates of fertilizer levels need to be conducted in the pure savannah and high rainfall zones to determine appropriate maize population densities and fertilizer management in such intercrop systems in these areas.

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APPENDIX 1

Mean Squares Arising From Analysis of Variance of
Grain Yield Per Hectare, Grain Yield Per Plant, Ear
Weight and 1000-Grain Weight

Source of Variation	Degrees of Freedom	Mean Squares			
		GH	GP	EWT	TGWT
Rep	2	438945	53.6	0.004759	1182.4
Cassava Spacing (CS)	1	110026ns	26.0ns	0.000000ns	304.2ns
Error (a)	2	3937995	3085.0	0.0035021	1191.1
Maize variety (MV)	4	2402704ns	1526.5*	0.0024288ns	4805.2*
Error (b)	8	741281	385.4	0.0011431	1020.5
CSxMV	4	668797ns	434.4ns	0.0009714ns	622.2ns
Error (c)	8	773891	750.1	0.0014478	637.5
Maize population (M)	4	9073814**	21706.1**	0.0288689**	7089.1**
CSxMP	4	202578ns	618.5ns	0.0007175ns	278.6
MVxMP	16	414340ns	751.1ns	0.0011862ns	149.4ns
CSxMVxMP	16	146307ns	357.1ns	0.0007284ns	95.0ns
Error (d)	80	243425	460.2	0.0006946	119.7

Where: *. ** - Significant at the 0.05 and 0.01 levels respectively.

ns - non-significant

GH - maize grain yield/ha

GP - maize grain yield/plant

EWT - Ear weight

TGWT - 1000-grain weight.

APPENDIX 2

Mean Squares Arising from Analysis of Variance for
Percentage Barren Plants and Stover Dry Weight

Source of Variation	Degrees of Freedom	Mean Squares	
		SDW	BN
Rep	2	1720619	47.0
Cassava Spacing (CS)	1	236017ns	183.2ns
Error (a)	2	14906325	222.8
Maize variety (MV)	4	4343982ns	609.5ns
Error (b)	8	4574380	304.9
CSxMV	4	1553464ns	94.5
Error (c)	8	2110545	199.5
Maize population (MP)	4	112048608*	2968.6**
CSxMP	4	772730ns	162.6ns
MVxMP	16	738030ns	103.0ns
CSxMVxMP	16	349860ns	98.7ns
Error (d)	80	923569	109.5

Where *, ** - Significant at 0.05 and 0.01 levels respectively

ns - non-significant

BN - percentage barren plants

SDW - stover dry weight

APPENDIX 3

Mean Squares Arising from Analysis of Variance for
Plant Height at Tasselling' Plant Height at Harvest
and Ear Height

Source of Variation	Degrees of Freedom	Mean Squares		
		PHTSL	PHARV	EARHT
Rep	2	536.5	196.1	84.84
Cassava spacing (CS)	1	175.5ns	100.9ns	1.19ns
Error (a)	3	1710.1	3464.7	663.60
Maize variety (MV)	4	1320.4ns	8379.9**	1384.17**
Error (b)	8	511.1	342.5	108.70
CSxMV	4	943.4ns	1680.2ns	617.60ns
Error (c)	8	487.4	647.8	240.54
Maize population (MP)	4	929.0**	2424.0**	1813.83**
CSxMP	4	61.0ns	546.4ns	91.42ns
MVxMP	16	301.9ns	463.9ns	142.28ns
CSxMVxMP	16	128.6ns	269.8ns	47.65ns
Error (d)	80	225.1	402.3	83.76

Where: *, ** - Significant at 0.05 and 0.01 levels respectively

ns - non-significant

PHTSL - plant height at tasselling

PHARV - plant height at harvest

EARHT - ear height

APPENDIX 4

Mean Squares Arising From Analysis of Variance for
Silking Days, Leaf Area, Leaf Area Index and Stalk
Diameter

Source of Variation	Degrees of Freedom	Mean Squares			
		DS	LA	LAI	SD
Rep	2	0.960	4556114	2.2244	0.05946
Cassava spacing (CS)	1	8.167	579481ns	0.0090ns	0.00625
Error (a)	2	2.747	533332	0.0597	0.17929
Maize variety (MV)	4	63.907	10580077*	2.7357*	0.13423
Error (b)	8	8.827	1620746	0.4353	0.04430
CSxMV	4	0.667	1708167ns	0.7367	0.05755
Error (c)	8	1.447	1981728	0.7075	0.06355
Maize population (MP)	4	326.023	132163916**	132.2079**	2.27027**
CSxMP	4	4.582	943918	0.0965ns	0.03846
MVxMP	16	2.519	1607751**	0.7827**	0.02319
CSxMVxMP	16	2.021	250228ns	0.1888	0.01552
Error (d)	80	2.447	768639	0.3020	0.02858

Where: *, ** - Significant at 0.05 and 0.01 levels respectively.

ns - non-significant

DS - days for 50% plant to produce silks

LA - leaf area

LAI - leaf area index

SD - stalk diameter

APPENDIX 5

Mean Squares Arising from Analysis of Variance
for Leaf Angles

Source of Variation	Degrees of Freedom	Mean Square
Rep	2	534.34
Cassava spacing (CS)	1	0.00ns
Error (a)	2	72.72
Maize variety (MV)	4	830.82**
Error (b)	8	14.25
CSxMV	4	151.47ns
Error (c)	8	41.05
Maize population (MP)	4	539.98**
Leaf position (LP)	3	1884.11**
CSxMP	4	22.41ns
MVxMP	16	63.61ns
CSxLP	3	37.39ns
MVxLP	12	93.33*
MPxLP	12	63.52ns
CSxMVxMP	16	63.59ns
CSxMVxLP	12	41.52ns
CSxMPxLP	12	17.01ns
MVxMPxLP	48	19.23ns
Error (d)	428	46.16

Where: *, ** - significant at 0.05 and 0.01 levels respectively
ns - non-significant

APPENDIX 6

Mean Squares Arising from Analysis of Variance
for Maize Root and Stem Lodging

Source of Variation	Degrees of Freedom	Mean Squares			
		Root Lodging/ha		Stem Lodging/ha	
Rep	2	5.760E	6	5.510E	6
Cassava spacing (CS)	1	4.004E	7ns	9.375E	4ns
Error (a)	2	1.520E	7	2.066E	7
Maize variety (MV)	4	2.019E	7**	8.344E	6ns
Error (b)	8	2.779E	6	3.961	6
CSxMV	4	4.807E	6ns	5.625E	6ns
Error (c)	8	7.893E	6	8.742E	6
Maize population (MP)	4	2.788E	8**	1.764E	8*
CSxMP	4	1.460E	7**	1.813E	6ns
MVxMP	16	4.444E	6ns	2.829E	6ns
CSxMVxMP	16	2.184E	6ns	3.421E	6ns
Error (d)	80	4.503E	6	4.690E	6

Where: *, ** - significant at 0.05 and 0.01 levels respectively
ns - non-significant

APPENDIX 7

Mean Squares Arising from Analysis of Variance for
Agronomic Characteristics of Cassava 8WAP

Source of Variation	Degrees of Freedom	Mean Squares			
		PHT	STG	LEAFPLT	INTERLT
Rep	2	822.1	0.0041	635.59	18.395
Cassava spacing (CS)	1	1016.3ns	0.0031ns	48.17ns	0.168ns
Error (a)	2	270.2	1.2692	7.17	0.181
Maize variety (MV)	4	318.4ns	1.3102**	30.97ns	1.599ns
Error (b)	8	429.7	0.1357	64.57	1.953
CSxMV	4	125.7ns	0.0552ns	8.85ns	0.745ns
Error (c)	8	663.6	0.1445	18.05	0.867
Maize population (MP)	4	4117.0*	0.1536ns	46.35*	6.926**
CSxMP	4	623.7**	0.2693ns	24.75ns	0.964ns
MVxMP	16	105.3ns	0.1177ns	12.29ns	0.275ns
CSxMVxMP	16	169.2ns	0.1154ns	13.25ns	0.099ns
Error (d)	80	138.1	0.1669	16.59	0.388

Where: *, ** - Significant at 0.05 and 0.01 levels respectively.

ns - non-significant

PHT - plant height

STG - Stem girth

LEAFPLT - number of leaves per plant

INTERLT - internode length

APPENDIX 8

Mean Squares Arising from Analysis of Variance for
Agronomic Characteristics of Cassava 4MAP

Source of Variation	Degrees of Freedom	Mean Squares				
		PHT	STG	INTERLT	LEAVES	BRANCHES
Rep	2	1076.0	1.461	69.702	1591.9	50.257
Cassava spacing (CS)	1	140.5ns	0.001ns	36.260*	256.5ns	4.328ns
Error (a)	2	404.5	0.429	1.819	291.3	5.226
Maize variety (MV)	4	661.2ns	1.260ns	20.061*	562.3ns	10.102ns
Error (b)	8	729.8	0.367	5.062	460.0	11.548
CSxMV	4	197.1*	0.504**	16.831ns	149.5*	1.623ns
Error (c)	8	387.0	0.041	10.120	21.9	0.798
Maize population (MP)	4	2187.7**	0.458ns	446.837*	1526.9**	10.598**
CSxMP	4	127.9	0.311ns	12.772ns	106.8ns	1.102ns
MVxMP	16	123.2	0.266ns	5.009ns	254.9*	2.956ns
CSxMVxMP	16	261.6	0.304ns	4.152ns	195.2ns	2.348ns
Error (d)	80	187.9	0.222	4.576	119.1	1.852

Where: *, ** - Significant at 0.05 and 0.01 levels respectively.

ns - non-significant

PHT - plant height

STG - Stem girth

INTERLT - internode length

LEAVES - leaves per plant

BRANCHES - branches per plant

APPENDIX 9

Mean Squares Arising from Analysis of Variance for
Agonomic Characteristics of Cassava 7MAP

Source of Variation	Degrees of Freedom	Mean Squares				
		PHT	STG	INTERLT	BRANCHES	LEAVES
Rep	2	5870.5	0.7351	0.1459	205.5	9049.0
Cassava spacing (CS)	1	450.4ns	0.0668ns	0.2390ns	0.09ns	286.1ns
Error (a)	2	425.6	0.1114	0.1180	74.22	4867.8
Maize variety (MV)	4	1620.8ns	0.2158*	0.2405ns	94.38ns	5612.3ns
Error (b)	8	1118.3	0.1058	0.0676	39.17	1616.7
CSxMV	4	947.2ns	0.0355ns	0.0298ns	14.47ns	1692.6ns
Error (c)	8	480.5	0.0421	0.1032	12.15	1109.2
Maize population (MP)	4	2090.7**	0.0102*	1.1910**	108.28**	4697.3**
CSxMP	4	240.5ns	0.0194ns	0.0194ns	8.33ns	240.8ns
MVxMP	16	175.7ns	0.0157ns	0.0369ns	14.96ns	636.3ns
CSxMVxMP	16	313.5ns	0.0239ns	0.0285ns	17.19ns	819.4ns
Error (d)	80	292.9	0.0355	0.0431	10.38	774.4

Where: *, ** - Significant at 0.05 and 0.01 levels respectively.

ns - non-significant

PHT - plant height

STG - Stem girth

INTERLT - internode length

BRANCHES - branches per plant

LEAVES - leaves per plant

APPENDIX 10

Means Arising from Analysis of Variance for Cassava
Root Yield and Related Characters

Source of Variation	Degrees of Freedom	Mean Squares			
		RNB	RTSZ	RWP	RYHA
Rep	2	10.682	0.0239	2.0547	3.132E 8
Cassava spacing (CS)	1	15.499**	0.0515ns	0.0018ns	1.029E 8ns
Error (a)	2	0.081	0.0076	0.0076	4.502E 7
Maize variety (MV)	4	5.692ns	0.0090ns	0.0090ns	3.886E 7ns
Error (b)	8	3.227	0.008	0.4109	5.840E 7
CSxMV	4	3.059*	0.0025ns	0.1282	1.591E 7ns
Error (c)	8	0.774	0.0023	0.0524	8.104E 6
Maize population (MP)	4	4.684*	0.0334*	1.8322**	1.823E 8*
CSxMP	4	2.118ns	0.0017ns	0.0560	5.744E 6ns
MVxMP	16	2.108ns	0.0046ns	0.1509	1.481E 7ns
CSxMVxMP	16	1.058ns	0.0029ns	0.0472ns	4.524E 6ns
Error (d)	80	1.627	0.0031	0.1181	1.272E 7ns

Where: *, ** - Significant at 0.05 and 0.01 levels respectively.

ns - non-significant

RNB - number of roots per plant

RTSZ - average root weight

RWP - root weight per plant

RYHA - root yield per hectare

APPENDIX 11

Mean Squares Arising from Analysis of Variance for
Harvest Index, Top and Root Dry Weight

Source of Variation	Degrees of Freedom	Mean Squares		
		SDW	RDW	HI
Rep	2	2279224	38362016	0.0469
Cassava spacing (CS)	1	375375ns	12601658ns	0.0137ns
Error (a)	3	651118	5515030	0.0018
Maize variety (MV)	4	1990222ns	4760731ns	0.0160ns
Error (b)	8	2017331	7154577	0.0069
CSxMV	4	1161951**	1949158ns	0.0056ns
Error (c)	8	164893	992730	0.0054
Maize population (MP)	4	1083733*	22333418*	0.0478*
CSxMP	4	70441ns	703653ns	0.0067ns
MVxMP	16	429688ns	1813624ns	0.0038ns
CSxMVxMP	16	246403ns	554230ns	0.0022ns
Error (d)	80	274973	1557896	0.0032

Where: *, ** - Significant at 0.05 and 0.01 levels respectively

ns - non-significant

SDW - shoot dry weight per hectare

RDW - root dry weight per hectare

HI - harvest index

APPENDIX 12

Mean Squares Arising from Analysis of Variance for
Land Equivalent Ratios

Source of Variation	Degrees of Freedom	Mean Squares		
		LERM	LERC	LERT
Rep	2	0.0708	0.7829	0.5873
Cassava spacing (CS)	1	0.01440ns	0.0972ns	0.1513ns
Error (a)	3	0.9312	0.1126	0.4771
Maize variety (MV)	4	0.9409ns	0.0972*	1.1889ns
Error (b)	8	0.1639	0.1460	0.4304
CSxMV	4	0.1580ns	0.0398ns	0.3364ns
Error (c)	8	0.2115	0.0203	0.2333
Maize population (MP)	4	1.9180*	0.4558*	0.6287**
CSxMP	4	0.0423ns	0.0144ns	0.0286ns
MVxMP	16	0.1199ns	0.0370ns	0.2069*
CSxMVxMP	16	0.0338ns	0.01113ns	0.0609ns
Error (d)	80	0.0535	0.0318	0.0995

Where: *, ** - Significant at 0.05 and 0.01 levels respectively

ns - non-significant

LERM - land equivalent ratio for maize

LERC - land equivalent ratio for cassava

LERT - total land equivalent ratio