EFFECTS OF INTERCROPPING AND PLANT DENSITY ON GROWTH, DEVELOPMENT AND YIELD OF PIGEONPEAS (*Cajanus cajan* (L.) Millsp.) AND MAIZE (*Zea mays* L.). UNDER SEMI-ARID CONDITIONS OF KENYA.

BY

WINIFRIDA KOKUHIRWA RWAMUGIRA

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DECLARATION

This thesis is my original work and has not been submitted for a degree in any other University.

Date 29.7.88 W.Rwamugira

WINIFRIDA KOKUHIRWA RWAMUGIRA

This thesis has been submitted for examination with our approval as University supervisors.

Date 1/8/1988 P.M. Kimani

DR. P.M. KIMANI

Date 1/8/88 D.R. Basiime

DR. D.R. BASIIME

DEDICATION

To my daughters,

Eunice Zawadi and Joyce Upendo

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ABSTRACT

In semi-arid areas of Kenya 95% and 70% of pigeonpeas and maize, respectively are intercropped annually. This study was designed to determine the effects of intercropping pigeonpeas and maize at variable plant densities and also to determine the appropriate intercropping ratio or combination for optimum economic yield.

Two pigeonpea cultivars were intercropped with Katumani maize at three plant densities in Kabete, Thika and Kiboko during the 1986/87 cropping season. The experimental design was a split-split plot with three replications at each location. Results indicated that intercropping and plant density reduced leaf area and shoot dry weight of both pigeonpeas and maize. Plant height of pigeonpeas was reduced by intercropping while that of maize was increased. In pigeonpeas number of mature pods and grain yield per plant were reduced by both intercropping and high plant density. Reduction in 100 seed weight varied with location suggesting an environmental influence. For maize, number of cobs and grain yield per plant were also reduced by intercropping and high plant density.

Generally, yield per hectare of a species in intercrop was lower than in monocrop, but total yield of intercrops (pigeonpea + maize) gave higher yield advantage over monocrops. Land equivalent ratio (LER) values indicated that all intercrop ratios were superior to monocropping. At all the experimental sites best intercrop combination was attained when a row of pigeonpea alternated with a row of maize. Each crop at an interrow spacing of 105 cm.

CHAPTER 1

1.0 INTRODUCTION

Arable land shortage is becoming critical in most countries, Kenya being no exception. This has been a consequence of rapid increase in farm population and the dwindling availability of new lands for cultivation. In view of this, researchers should now look for ways of exploiting land resources for the maximum farm production. Intercropping is one among many alternatives of improving and stabilising food crop yields in subsistence agriculture.

Intercropping is a polyculture cropping system in which two or more crops are grown simultaneously on the same area of ground. The crops might be grown at different times but are usually growing simultaneously for a significant part of their growing season (Andrews and Kassam,1976, Willey,1979 and Gomez, 1983). Generally there is interaction during either all or part of crop growth (Andrews and Kassam, 1976).

In a broad sense intercropping is a multiple cropping system which is related to several other cropping systems practised under subsistence agriculture.

These include:-

(1) Mixed cropping which is growing two or more crops simultaneously with no distinct row arrangement.

(2) Row intercropping is growing two or more crops simultaneously when one or more crops are planted in rows.

(3) Strip intercropping is growing two or more crops simultaneously in different strips, wide enough to permit independent cultivation but narrow enough for the crops to interact agronomically.

(c) Relay intercropping involves growing two or more crops simultaneously during part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage of growth but before it is ready for harvest (Andrews and Kassam, 1976).

Therefore, intercropping is the opposite of sole or monocropping which refer to a crop component being grown alone at optimum population and spacing

(Willey, 1979).

Intercropping is an old practice used by subsistence farmers especially under rainfed conditions in parts of Asia, Africa and Latin America (Francis, 1978; Willey,1979; Nadar,1980 and Gomez 1983).

Advantages associated with intercropping include:-

(1) Greater stability of yield over different seasons as influenced by environmental and economic fluctuations.

(2) Higher yields in a given season than in monocropping.

(3) Better use of scarce growth resources (water, nutrients and light).

(4) Better control of weeds, insect pests and diseases.

(5) A continuous leaf cover may give better protection against soil erosion and

(6) Dependability of gross return (Norman 1974; Trenbath 1974; Francis 1978;

Willey,1979; Nadar,1980 and Gomez, 1983). These advantages have justified the continued practice of intercropping in subsistence farming.

There are however, disadvantages associated with intercropping which include:-

(1) Yield decrease of component crops because of adverse competition effects and;

(2) The difficulties concerned with practical management of intercropping especially where mechanisation is required or where component crops have different fertilizer, herbicide or pesticide requirement (Norman,1974; Willey,1979 and Nadar,1980).

In an intercropping system, the following consideration should be made:-

(a) The component crops of a cropping pattern must be planned and implemented jointly because the management of one component crop influences productivity of other(s).

(b) The appropriate management for the same crop species may change depending upon the position of the crop in the pattern, and

(c) The management practice for a component crop in the pattern is chosen not to maximise production of that particular crop but rather to maximise production of the whole pattern (Gomez and Gomez, 1983).

More often intercropping legumes with non-legume crops is a traditional practice among peasant farmers in subtropical and tropical countries (Mongi et al, 1976). Practised on small farms, intercropping system mostly involves cereal + legume mixtures which provide a source of income as well as a balanced diet for the farm family.

In Machakos district (Kenya) 95% and 70% of pigeonpeas and maize are intercropped, respectively. Usually cereal + legume intercrops are planted during the short rains which normally occur between late October and December annually. Among the cereals commonly intercropped are maize and sorghum while legumes include beans, pigeonpeas, and cowpeas (Muhammed et al, 1985).

Pigeonpeas are short-lived perennials often cultivated as annuals. Due to their very strong, deep tap root, they are drought tolerant. Its production is widespread in India, Tropical Africa and West Indies, parts of Central and South America, Northern Australia, Hawaii and Mauritius (Gooding, 1962). It is sensitive to waterlogging and frost. Pigeonpea ranks fifth in total world production among grain legumes. The declining order being dry beans, garden peas, chickpeas and broadbeans (Nambi, 1981). In Kenya, it ranks third in importance among other pulses and it covers an area of 110,000 hectares annually. In the marginal areas of Kenya, pigeonpeas rank first and are produced in the Eastern Province and drier parts of Central and Coast provinces (Onim, 1977).

In Eastern Africa yields are low ranging between 400 - 850 kg/ha (F.A.O., 1983) but yields of up to 2.6 tonnes/ha have been obtained in farmer's fields growing the new cultivars in Kitui and

Machakos districts in Kenya (Pigeonpea Improvement Programme, 1986).

Maize (*Zea mays* L.) is a stout annual grass usually with a single stem,1-4 m tall. The stem is solid with clearly defined nodes and internodes. Maize is the third most important cereal in the world (Purseglove, 1972) and is found in tropical, subtropical and warm temperate countries of the world.

In Kenya, maize is the most important cereal crop both in high potential and medium potential areas (Chui, 1987). Total area under maize production is estimated at one million hectares of which 50% is in high potential areas, 15% in the medium potential and 35% in the low potential areas. However farmers' yields are low (average of 1.9 tons per hectare) due to rainfall fluctuations, low soil fertility, damage by pest and poor husbandry (Onyango, 1987).

One of the difficulties confronting researchers working with crop mixtures is the almost infinite number of crop varieties' proportions and arrangement within the intercropping system. Spacing of the component crops determine the proportions of each crop per unit area. It is therefore a function of plant density (population).

Plant density has two types of biological relationships:-

(1) An asymptotic one in which an increase in density results in increase in yield until it reaches a maximum and becomes relatively constant and

(2) A parabolic one whereby yield increases to a maximum but then declines at high densities (Willey and Heath 1969). For reproductive form of yield (grains, seed) the parabolic relationship should be obtained in order to know at what plant population density one should operate.

There is a need to determine the optimum spacings of component crops in an intercropping pattern which will lead to maximum yield advantage for a small farmer who practises intercropping.

As a result of breeding work on pigeonpea initiated at the University of Nairobi (Pigeonpea Project) a variety (NPP 670) has been released to farmers in Machakos, Kitui, Embu, Muranga and Baringo districts (Kimani 1985). However little agronomic behaviour of the variety is known. Although some agronomic studies were conducted during 1985 short rains at Thika (Muranga district); limited technology has reached the subsistence farming sector.

In view of the fact that pigeonpeas are usually grown in combination with other crops (especially maize), a general lack of information on the nature of such interaction and how productivity of such system could be optimised, this study was designed

(1) To determine the effect of intercropping on growth and development of maize and pigeonpeas.

(2) To determine the appropriate pigeonpea: maize intercropping ratio for optimum economic yield.

(3) To determine the effect of plant density and intercropping on yield and yield components of both maize and pigeonpeas.

(4) To determine if food output per unit area could be improved by intercropping pigeonpeas with maize.

CHAPTER II

2.0 LITERATURE REVIEW

2.1 Effects of cereal-legume intercropping on growth of component crops.

Okigbo (1979) evaluated plant interactions and productivity in complex mixtures and found that intercropping affected leaf area but effects varied with crop.

The relative growth rate (RGR) increased with the age of the plant. Net assimilation rate (NAR) was highest at early stages of growth and was dependent on intercropping pattern as well as number of crops in a mixture. Total dry matter was reduced by intercropping and dry weight of yield of different parts of the crop were significantly affected by intercropping, the extent of reduction increased with the increase in number of crops in mixtures.

Edje and Laing (1980) reported that total dry matter of beans (either in monoculture or in association with maize) increased almost linearly with time until 86 days after planting (DAP) and declined thereafter. At 58 DAP, total dry matter of maize in monoculture was 1.6 times higher than that of maize and bean associates. At 53 DAP, light interception was lower in intercrops than in monocultures. Stem diameter was 22.7% thinner in association than in monoculture.

Experiments involving groundnut+ maize intercrops showed that growing maize in association with groundnuts reduced leaf area index by 50% but had no significant effect on specific leaf area and specific leaf weight (Edje, 1980).

Enyi (1973) at Morogoro, Tanzania, observed that intercropping maize or sorghum with cowpeas or beans led to a reduction in leaf area of both cereal crops. Cowpeas reduced leaf area of maize by 49.7% while beans reduced it by 36.4%. The gross yield of grain (cereal and legume crops) was greater in maize than sorghum-intercrop plots. Total (gross) grain yield of maize + cowpeas was 65.5 tonnes/ha whereas that of sorghum + cowpeas was 63.0 tonnes/ha.

Gardner and Craker (1979) studied the competitive effects on bean alone or in combination with three population levels of corn. It was found that intercropping beans with corn decreased total dry matter (TDM) of beans mainly due to effects on the number of pods per plant. Leaf and stem dry weight remained constant.

Natarajan and Willey (1979) at ICRISAT reported that in an intercropping pattern of 2 rows sorghum: 1 row pigeonpea, seed yield of pigeonpea intercrop was 70% of the sole crop.

In intercropping systems of maize + beans; maize + pigeonpea and maize + cowpeas in marginal areas of Kenya, Nadar (1980) found that maize inhibited vegetative growth of pigeonpeas in comparison to monocultural pigeonpea. This resulted in delayed flowering and reaching maturity three weeks later.

Kimani (1985) studied the response of pigeonpea to intercropping either with a cereal or another legume. Results showed that intercropping pigeonpea with either beans or cowpeas reduced plant height of pigeonpeas but same trait was not affected by intercropping pigeonpeas with either maize or sorghum.

2.2. <u>Effects of intercropping on yield of component crops.</u>

Fisher (1977 and 1979) working at Kabete Field Station in Kenya, conducted productivity studies of maize + bean and maize + potato mixtures in alternate rows and at different plant population densities in four cropping seasons. He concluded that (i) in seasons of low rainfall, yield from mixtures fell short of that from pure stand resulting in large reductions of maize yield due to competition from the potato or bean; (ii) in exceptionally wet season a yield advantage was found in maize + bean mixtures which could have been attributed to more efficient exploitation of the soil resources due to different rooting habits (iii) although mixtures gave an apparent yield advantage over pure stand this was attributable to increased populations in mixture.

Evans (1960) at Ilonga and Mwanhala Tanzania, observed that intercropping of maize or sorghum with groundnuts generally led to a greater overall crop production per unit area than by growing the crops in pure stands. This was found in two areas of contrasting levels of soil fertility and different rainfall patterns. Similar results were later reported by Evans and Sreedharan (1962) who intercropped castor bean with groundnut or soyabean.

Work done in Uganda by Osiru and Willey (1972) involved mixtures of dwarf sorghum and beans (*Phaseolus vulgaris*) under intensive farming conditions. Results showed that yields of mixtures were up to 55% higher than could be achieved by growing the crops separately. It was concluded that this yield increase must have been due to a greater utilization of environmental resources due to different rooting depths of the two crops and their different growth cycles.

De Groot (1980) interplanted beans (*Phaseolus vulgaris*) with maize (*Zea mays*) at various research stations in Kenya to determine the most suitable densities of component crops. He observed that land equivalent ratio (LER) for intercrops was greater than 1, indicating that for the same yield more land would have been required when grown in pure stand. Further observations indicated that for dry beans grown in Eastern Province of Kenya, intercropping one row of beans between two rows of maize increased bean yield by 50% over those of pure stand. However maize yield in that intercrop was reduced by 65%.

Intercropping maize with nine different legumes was studied by Agboola and Fayemi (1971) in the rain forest zone of Nigeria. Results indicated that cowpeas (*Vigna sinensis*) and green grams (*Phaseolus aureus*) had much less effect on maize than popondo (*Phaseolus lunatus*) and mucuna (*Mucuna utilis*).

Crookston and Hill (1974) observed that although corn yields were significantly increased in some combinations, the accompanying soyabean yields were always reduced.

Trenbath (1974), reported that most binary mixtures have been recorded as yielding at a level between the yields of the component monoculture. This was termed as "non-transresssive yielding". On the other hand a minority of binary mixtures were recorded as yielding "transgressively" i.e. they yielded beyond the range defined by the yields of the component crops grown in monoculture.

Francis (1978) in his studies on multiple cropping potentials of beans and maize, observed that planting dates could be critical for yields. He reported that yield of maize planted before or simultaneously with beans was not affected. When beans were planted before maize, the latter suffered from early competition and yields were reduced by 30 - 50% or more depending on growth habit of variety and days to maturity. He also reported that planting pattern of the maize and legume did not affect the yield of maize.

In a study of cropping systems involving millet, sorghum and cowpeas in Nigeria, Andrews (1972) observed that relay cropping and simultaneous intercropping gave 59 and 80% more return respectively than a sole crop of sorghum. It was suggested that in order to attain increased returns from intercropping (1) the intercrop competition must be less than intracrop competition and (ii) the effect of competition between/among crops could be alleviated when their maximum demands from the environment occurred at different times. This could be achieved by selecting crops with different growth cycles.

Cordero and McCollum (1979) in their study on yield potentials of interplanted food crops, found that intercropping soyabean or sorghum with maize caused maize yield reduction of 5-10%. Land equivalent ratio of 1.20 - 1.40 was obtained thus suggesting 20 - 40% increase in total production by intercropping.

Natarajan and Willey (1980c) studied the effects of moisture availability in groundnuts, millet and sorghum in their mono and intercrops at ICRISAT, India. They reported that intercropping may give relative yield advantage under conditions of moisture stress but little or none under no stress conditions. It was further noted that the effects of moisture stress were very complex and varied with crop combination and row arrangement within a combination.

Dalal (1974) reported that intercropping maize with pigeonpea in a mixed stand or in alternate row significantly increased the grain yield of maize but not of pigeonpeas. Maize monoculture produced 3130, mixed stand 3735 and alternate rows 4460 kg/ha. Pigeonpea monoculture produced 1871, mixed stand 1710 and alternate rows 1854 kg/ha.

Nadar (1980) reported that although intercropping delayed flowering and reduced leaf area of pigeonpeas, it did not reduce grain yield of the crop.

Kimani (1985) reported that intercropping pigeonpeas with either sorghum or maize depressed 100 seed weight and seeds per pod of pigeonpeas. The depression was dependent on row arrangement and ratio of each species. Yield reduction in pigeonpeas was 52.7% and 50.5% when grown with maize and sorghum respectively. Maize yield reduction in intercrop was 12.4%. Land equivalent ratio values indicated that in all cases intercropping was superior to monocropping. It was concluded that alternating two rows of pigeonpea with two rows of maize gave the most efficient use of land.

2.3. Effect of intercropping on nutrient uptake

Dalal (1974) reported that maize grown in alternate rows with pigeonpeas absorbed relatively higher amounts of potassium (1.64), calcium (0.28) and magnessium (0.31) kg/ha/week than monocultural maize. However pigeonpeas grown in pure stand absorbed minimum amounts of same nutrients (0.73, 0.23 and 0.17 kg/ha/week of K, Mg and Ca respectively). Inspite of the increase in mineral N due to fixation, pigeonpea still responded to fertilizer N giving maximum production with 20 kg N/ha.

Willey (1979) showed that pigeonpea may nodulate better where the roots intermingled with those of intercropped sorghum. He attributed it to the fact that sorghum depleted nitrogen thereby stimulating pigeonpea to fix nitrogen. He also suggested that component crops may exploit different soil layers and hence in combination they may exploit a greater volume of soil.

2.4 Effects of plant density

2.4.1 General observations

In a study on multiple cropping potentials of beans and maize, Francis (1978) found that densities of crops in association were more specific to locations than to other agronomic variables. He suggested that recommendations could be made for a wide range of temperature and soil conditions.

Baker (1979) reported that within polyculture systems there were two broad classification of mixtures:-

(1) Replacement mixture wherein one genotype replaced a proportion of another

genotype and;

(2) Superimposed or additive mixture, where one genotype was added to the other(s) so that the final plant population was considerably higher than had either genotype grown alone. He suggested that in a cereal and non-cereal mixture, the yield of cereal remained constant but yield from non-cereal was reduced. Branching of non-cereal was reduced and even suppressed resulting in different "shape" of plants.

Singh and Kush (1980) studied the effects of plant density on growth and yielding ability of pigeonpeas. They observed that cultivars differed in response to plant population.

2.4.2. Effects of plant population on growth of component crops.

Willey and Osiru (1972) working on beans and maize intercrops suggested that because of height differences of the two crops, an increased utilization of light was probably a major contributing factor to higher yields of intercrops. They observed that the need for high population in mixtures was indicated partly because the mixtures required a high population pressure to produce their maximum yield. Maize was reported to have higher competitive ability than beans as plant population was increased.

In another study on effects of plant population on growth and yield of pigeonpea, Ogombe (1978) reported that increasing plant density reduced number of flowers initiated and number of mature pods but increased flower and pod abscission. It was also reported that different plant density levels reduced number of pods per plant resulting into reduced seed yield/plant.

Talhalkar and Rao (1979) studied the genoytype - plant density interaction on the development of an optimum sorghum + pigeonpea interoropping systems. High recovery of sorghum yield (92% of its sole crop yield) was possible when intercropped with pigeonpea at a density of 27,000 plants/ha than at its optimum sole crop density of 55,000 plants per hectare. Erect variety of pigeonpea was more suitable for intercropping with sorghum than the bushy variety.

Natarajan and Willey (1979) reported that growth and yield of sorghum in an intercropping pattern of 2 rows sorghum: 1 row pigeonpea was similar to that of sole sorghum. The pigeonpea intercrop experienced considerable competition from sorghum but after the sorghum harvest, it compensated for the initial growth and produced yield equivalent of 70% of the sole crop. Increased pigeonpeas population produced higher leaf area. There was a positive response in total LER with an increase in pigeonpea population and a negative one with an increase in sorghum population.

Natarajan and Willey (1980a) conducted an intercropping experiment with three plant population levels of early sorghum (82 days) combined with three plant population levels of late-maturing pigeonpea (173 days) in a 2 sorghum: 1 pigeonpea row arrangement. Results showed that total dry matter and leaf area of sorghum showed some increase with increase in sorghum density in the early stages of growth (20 - 50 days after emergence). Increase in pigeonpea density increased both dry-matter yield and leaf area of pigeonpea. These effects were reflected in final stalk and seed yield with highest population (100,000 plants/ha) having highest stalk and grain yield of 1673 and 732 kg/ha, respectively.

Singh and Kush (1980) working with 10 cultivars of pigeonpea spaced at 150 and 50 cm between rows, observed that crop growth decreased with 50 cm row spacing than 150 cm row spacing in all cultivars. Plant population levels had no differential effect on node number. The response of dry matter yield per hectare to plant population was not significantly different at all densities. It was 37.5 tonnes/ha at density of 100,000 plants/ha and 40.0 tonnes/ha at density of 20,000 plants/ha.

In a plant population study of pigeonpea cultivars planted at four plant population levels, Kimani (1985) reported that NPP 670 (an early maturing variety) showed little response to increasing plant population but Kioko (a late maturing cutivar) plant height decreased as plant density increased. Results indicated that cultivars differ in their response to increasing plant density.

2.4.3. Effect of plant population on yield of component crops.

Fisher (1977) studied the population pressure in maize and bean mixtures at Kabete, Kenya. Results obtained indicated that the apparent yield advantage of mixtures over pure stand, was due to an increase in plant population per unit area. In the sorghum-pigeonpea mixtures, Osiru and Kibira (1979) achieved land equivalent ratio of 1.7 at ratios of $\frac{1}{2}$ sorghum: $\frac{1}{2}$ pigeonpea and $\frac{1}{4}$ sorghum: $\frac{3}{4}$ pigeonpea. They suggested that crop mixtures are likely to give yield advantages where the component crops are of different growth patterns.

Lima and Lopes (1979) studied plant population and spatial arrangement effects on maize + bean intercrop. Results showed that the best yield advantage occurred at higher plant population levels with 1 row of maize: 3 rows of beans. However percentage of lodging rose with increase in plant population in maize reaching 97%. Grain yield of monocultural maize decreased with an increase in plant population while bean yield remained unchanged with an increase in plant density.

Singh and Kush (1980) reported that grain yield of pigeonpeas was severely reduced at high plant population (100,000 plants/ha) because of combined influence of decreased number of primary branches, pod bearing and stem length. The length of the reproductive zone was drastically reduced at high population level, thus indicating the inverse relationship between the development of yield attributes and plant population.

In an experiment conducted by Kimani (1985) to determine the effect of plant density on yield and yield components of pigeonpeas planted at four plant population levels, results indicated that increase in plant population decreased pods per plant, and grain yield per plant. The decrease in 100 seed weight, number of seeds per pod and grain yield per hectare were cultivar dependent.

2.5 Pigeonpea cropping systems

In Kenya (Machakos district) 95% of pigeonpea is intercropped with cereals mainly maize or sorghum (Muhammed et al; 1985).

Reddy et al; (1986) reported that pigeonpea grown in monoculture is relatively slow in utilisation of resources because of its slow initial growth rate. When it is intercropped with more rapid growing crops such as cereals, it can give substantial yield advantage. They suggested that prolonged slow growth of pigeonpea and its adjustability to wide row spacings provided an excellent opportunity for growing early maturing intercrops so that early season resources could be used efficiently. Three categories of pigeonpea intercrop systems were advocated. They included:-

(1) pigeonpea with cereals

(2) pigeonpea with other legumes and;

(3) pigeonpea with long season annuals (castor, cotton or cassava).

Among the three systems, pigeonpea + cereal combination showed yield advantage (65%) because cereal had rapid growth hence was harvested before the reproductive stage of pigeonpeas. In pigeonpea and other legume (groundnut) mixture, high yields of groundnut were obtained; whereas in the pigeonpea + castor intercrop results indicated little or no yield advantage because long season annuals occupied similar agro-ecological riches.

Similar results were reported by Kimani (1985) working on pigeonpea + maize or sorghum intercrop and pigeonpea + cowpea or bean intercrop. Results indicated that alternating two rows of pigeonpea with two rows of maize gave the most efficient use of land (LER = 1.75). LER values of pigeonpea + bean or cowpea intercrop showed that legume + legume intercrop did not improved land use efficiency.

2.6 Methods of evaluating intercrop yield advantages

Several criteria have been suggested for evaluating yield advantages of intercropping. They include:-

(1) Land equivalent ratio (LER) - is the sum of the ratios of dry weight yields of each crop in a mixture over its yield in pure culture. It is a measure of the area of pure stand required to produce the same yields as the intercrop under the same management (Okigbo, 1979). LER index essentially compares productivity in intercropping with that of monocrop, with values >1 indicating the advantage of intercropping (Gomez and Gomez

1983). It is calculated as follows:-

$$LER = \sum_{i=1}^{n} (xi/yi). \quad \text{(Gomez and Gomez, 1983)}$$

where xi is the yield of crop i in intercropping

yi is the yield of crop i in pure stand

(2) Monetary index - this is based on market prices of inputs used to produce some amount of output.

Monetary index = ax -b (Gomez and Gomez, 1983) where a is value of product (using market price)

x is the yield of crop components

b is the cost of production of component crops (using prevailing labour price)

It's meaning is easily understood but prices of agricultural products vary widely over locations and time.

(3) Calorie equivalent in which the index is expressed as an energy unit. It is based on the inherent character of the product itself but it is not easily understood nor easily appreciated by farmers. A high calorific value is generally not directly related to profi-

tability. It is calculated as follows:-

Calorie index = a'x - b' (Gomez and Gomez 1983)

where a' is value of total product in calories
x is the total yield of component crops
b' is the cost of production in calories.

(4) Relative crowding coefficient (RCC) is the ratio of the yield per area of component crops in a mixture over their yields in pure stand at standard density (Okigbo, 1979). It assumes that mixture treatments assume replacement series. Each species has its coefficient (k).

It's general formula is:-

$$kab = \frac{Y_{ab} \times Z_{ba}}{(Y_{aa} - Y_{ab}) \times Z_{ab}} \quad \text{[Willey, 1979]}$$

where k_{ab} = relative crowding coefficient

Y_{ab} = mixture yield of species a (in combination with b).

Z_{ab} = sown proportions of species a (in mixture with b).

Y_{aa} = pure stand yield of species a

Z_{ba} = sown proportions of species b (in mixture with a)

If a species has a coefficient less than, equal to or greater than 1, it means that it has produced less yield, the same yield or more yield than "expected" respectively.

(5) Relative yield (RY) is the ratio of the yield of a species in mixtures to its yield in pure stand. It is beneficial to intercrop when the sum of the RY of any two crops is >1.

Hilderbrand (1976) and Flinn (1978) suggested that criteria for the choice of productivity index should be:-

(a) Common to all products and inputs and must provide means of comparing different cropping patterns,

(b) Relatively easy to measure,

(c) Capable of reflecting quality differences between the products,

(d) Meaningful to the farmer in such a way that it helps him to allocate his resources between competing uses and

(e) Meaningful to researcher so that new technologies can be compared with existing ones.

Okigbo (1979) suggested that among the indices used, land equivalent ratio,monetary index, relative yield and calorie equivalent would be reliably used to select efficient mixtures for relay and simultaneous intercropping.

CHAPTER III

3.0 MATERIALS AND METHODS

The study was conducted at three locations, Nairobi, Muranga and Machakos districts in the Republic of Kenya. The reason for choice of these locations was the variation in agro-ecological zones characterised by soils, temperature and moisture availability.

3.1 LOCATIONS

3.1.1 Kabete - Experiment (I) was laid at Kabete Field station (Nairobi district) on latitude 1° 14' 20"S, longitude 36° 45'E and an altitude of 1820 metres above sea level (MASL).

On the average Kabete receives about 1046 mm of rainfall per annum with mean temperatures of 23.4° and 12.6°C (maximum and minimum respectively). The soils are deep, friable, clay soils resistant to soil erosion (Keya and Mukunya, 1979).

3.1.2 Thika - Experiment (II) was conducted at the National Horticultural Research station Thika (Muranga district) 01° 01' S, longitude 37° 04' E and an altitude of 1600 MASL. The station receives an average rainfall of 1018 mm per annum with mean temperatures of 26.4° and 13.3°C (maximum and minimum respectively). The soils are well drained, extremely deep, dusty red to dark reddish brown, friable clay with moderate fertility (Jaetsold and Schmidt, 1983B).

3.1.3 Kiboko - Experiment (III) was set at Kiboko, a sub-station of National Dryland Research station Katumani (Machakos district). Kiboko receives an average rainfall of 595 mm per annum with mean temperatures of 28.8° and 16.4° (maximum and minimum respectively). It is found on latitude 02°S, longitude 37°E and altitude of 975 MASL. The soils are well drained, deep dark red to strong brown, friable sandy clay to clay soils with moderate to low fertility (Jaetzold and Schmidt, 1983 C).

3.2 PLANT MATERIAL AND EXPERIMENTAL DESIGN

A split-split plot design was used with three replications at each location.

3.2.1 Main plots

Main plot treatments were two cultivars of pigeonpea. Pigeonpea cultivar NPP 670 (Nairobi Pigeonpea Project) and Katheka were used. The cultivar NPP 670 is determinate, high yielding, drought tolerant, maturing in about 5 - 6½ months after planting (Kimani, 1985). Katheka is a local, late maturing variety (9 - 10 months) but well adapted to semi-arid areas of Kenya. The maize cultivar was Katumani composite (B) which has been specifically bred for semi-arid areas and is therefore widely grown. It matures in about 120 days after planting

3.2.2. Sub-plots

Inter-row spacings of 75, 90 and 105 cm were the sub-plot treatment. These variable inter-row spacings were a function of plant population per hectare.

3.2.3 Sub sub plots

Cropping pattern/system and row arrangement were the sub sub plot. The cropping system was either monocultural or intercropped pigeonpeas and maize as shown on the following page. Treatment codes were used to differentiate the cropping pattern as shown on page 37.

Plant densities per hectare and crop combinations at three row spacings

Interrow spacing (cm)	Treatment code (no)	Crop combination	Plant density/hectare PP* (no)	M** (no)	Total (no)	Ratios
75	1	Pigeonpea pure stand	44444	-	44444	-
"	2	Maize pure stand	-	53333	53333	-
"	3	1 row PP + 1 row M	44444	53333	97777	1:1
"	4	1 row PP + 1 row M	44444	79999	124443	1:1.75
"	5	1 row PP + 1 row M	44444	106666	151110	1:2
90	1	Pigeonpea pure stand	37037	-	37037	-
"	2	Maize pure stand	-	44444	44444	-
"	3	1 row PP + 1 row M	37037	44444	81481	1:1
"	4	1 row PP + 1 row M	37037	66666	103703	1:1.75
"	5	1 row PP + 1 row M	37037	88888	125925	1:2
105	1	Pigeonpea pure stand	31746	-	31746	-
"	2	Maize pure stand	-	38095	38095	-
"	3	1 row PP + 1 row M	31746	38095	69841	1:1
"	4	1 row PP + 1 row M	31746	57142	88888	1:1.75
"	5	1 row PP + 1 row M	31746	76190	107936	1:2

PP* Pigeonpeas

M** Maize

Treatment code	Treatment combination
1	Pigeonpea pure stand
2	Maize pure stand
3	1 row pigeonpea + 1 row maize each planted at 1 plant per hill.
4	1 row of pigeonpea + 1 row maize (for maize 2 and 1 plant were alternated per hill).
5	1 row of pigeonpea + 1 row maize (for maize 2 plants per hill were planted).

3.2.4 Gross plot size. This was defined as the entire area of the plot excluding paths and alleys. The areas were as follows:-

Main plots	= 24.5 m x 11 m	($269.5m^2$)
Sub plot	= 24.5 m x 3 m	($73.5m^2$)
Sub sub plots	= 4.5 m x 3 m	($13.5m^2$)

3.2.5 Net experimental plot size. This was defined as the area from which final harvesting was done. It excluded guard rows, sampling rows and guard plants. In this study the net experimental plot for sub sub plot was $8m^2$.

3.3 PLANT POPULATION (PLANT DENSITY)

Pigeonpea in pure stand was planted at three interrow spacings of 75, 90 and 105 giving plant densities of 44444, 37037 and 31746 plants per hectare, respectively. Intra-row spacing was constant at 30 cm between plants. Similarly, maize in pure stand had variable interrow spacings of 75, 90 and 105 cm giving plant densities of 53333, 44444 and 38095 plants per hectare. Intra row spacing was constant at 25 cm between plants. Spacing between any two pigeonpea or maize rows was either 75, 90 or 105 cm.

In intercropped plots i.e. treatments 3, 4 and 5; one row of maize was planted halfway between two rows of pigeonpea as indicated in 3.2.3. In this pattern, plant population per hectare (for maize) increased giving ratios of pigeonpea: maize as 1:1, 1:1.75 and 1:2.

3.4. TIME OF PLANTING

Pigeonpeas are usually planted during the short rains which normally occur between October and November each year (Appendix Figure 1).

At Kabete the experiment was planted on October 24, 1986; at Thika on October 29, 1986 and at Kiboko on November 13, 1986. Time of planting was dependent on the onset of rains.

3.5 CROP MANAGEMENT

All plots received uniform rate of fertilizer at 100 kg diammonium phosphate (18% N, 21 - 23% P) per hectare. All applied at time of planting.

Thinning of maize was done at 2 weeks after germination while that of pigeonpea was done one month after germination at all locations.

Hand weeding was done throughout the cropping season so that crops were weed-free at all times. At Kabete and Thika, six weedings at each location were done while at Kiboko only four weedings were done.

Pests and diseases were kept at low levels by spraying schedules. For maize spraying was against stalk borers (*Busseola fusca*, *Sesamia calamistris* and *Chilo partellus*). For pigeonpeas main pests were pod fly (*Melanogromyza chalcosoma*) and pod borers (*Heliothis* spp. and *Maruca testulalis*). Diseases for pigeonpea included leaf spot (*Mycorellosiella cajani*) and Fusarium wilt (*Fusarium udum*).

Before flowering of pigeonpeas 25 ml Rogor + 60 g Dithane M45 in 20 l of water were sprayed at monthly intervals. At flowering and podding of pigeonpeas, 30 ml Rogor + 60 g Dithane M45 in 20 l water were sprayed fortinightly until pod filling was complete.

3.6 DATA COLLECTION

3.6.1 Pigeonpea data collected during growth and development

(a) Leaf area (LA) per plant. This was determined by using leaf area meter. Leaves of five plants (randomly selected from a plot) were passed through the meter individually and a reading was recorded in square centimetres. Leaf area per plant was therefore calculated as mean of the reading from five plants. Only a single row from a plot was sampled at 5, 10 and 12½ weeks after germination for Thika and Kiboko.

At Kabete, sampling for the same parameter was done at 5, 10 and 15 weeks after germination.

(b) Shoot dry matter. Five randomly selected plants were uprooted from a sampling row at same time as in (a) above. Plants were separated into leaves and stems (roots exclusively) and were oven dried at 60°C to constant weights. Dry matter per plant was mean weight of five plants.

(c) Plant height. This was determined by measuring height of five randomly selected plants from each plot by using the central axis. Height per plant was a mean value in centimetres of the five plants. This was done twice during the cropping season (at 12½ W.A.G.$^+$ at Thika and Kiboko and 15 W.A.G.$^+$ at Kabete as well as at harvesting for all sites).

3.6.2 Pigeonpea data collected at harvesting

Data of yield components were recorded from the harvest area (net experimental plot). Four three, and two rows were harvested for the 75, 90 and 105 cm spaced plots, respectively. In each row, two end plants were left as guard plants.

(a) Number of primary branches. Branches of five randomly selected plants from the harvest area were counted and mean number of primary branches calculated.

(b) Pods per plant was determined by counting pods of random sample of five plants from the harvest area and a mean number was pods per plant.

(c) Seeds per pod. Ten pods were selected at random from each sample of five plants. A mean of that was recorded as the number of seeds per pod.

(d) Seed-size was determined by weighing 100 dry seeds taken randomly from each sample.

(e) Grain yield per plant. From the harvest area, number of plants were counted before harvesting. Weight of dry grain obtained per harvest area was divided into the number of plants that were harvested thus giving grain yield per plant.

(f) Grain yield per hectare. It was calculated by multiplying grain yield per plant x expected plant density per hectare.

3.6.3 Maize data recorded during growth and development phases.

(a) Leaf area per plant. This was determined as for pigeonpeas and at the same time.

(b) Shoot dry matter - same procedure as for pigeonpeas was followed. Weight of leaves, stems and cobs were obtained after drying the materials at 80°C to constant weights. Shoot dry matter per plant was mean combined weights obtained from leaves, stems and cobs.

(c) Plant height. It was determined as height measured from soil level to the base of a tassel. Five plants were randomly selected from the harvest area and a mean height in centimeters gave plant height per plant. This measurement was done at tasselling time and harvesting at each location.

3.6.4 Maize data recorded at harvesting

Data of yield components were recorded from the harvest area as pigeonpeas. Four, three and two rows were harvested for the 75, 90 and 105 cm spaced plots, respectively. In each row, two end plants were left as guard plants.

(a) Cobs per plant. Number of plants in the harvest area were counted prior to harvesting. Cobs per plant were determined by dividing harvested cobs into the number of plants harvested in each plot.

(b) Rows per cob. Ten cobs were selected randomly from each plot sample, then rows of each cob were counted. Rows per cob were determined as a mean number of rows from ten cobs.

(c) Kernels per row. Ten cobs were selected randomly from each plot sample. The number of kernels in each row for ten cobs were counted and a mean value calculated.

(d) Grain yield per plant was determined by dividing the total dry weight of kernel obtained from a plot by the number of plants harvested.

(e) Kernel weight was determined by weighing 100 dry kernels taken at random from each plot sample.

(f) Grain yield per hectare. It was calculated by multiplying grain yield per plant by expected plant density per hectare.

3.6.5 Meteorological data

Weather condition information regarding rainfall and atmospheric temperature during cropping time were obtained from meteorological stations near the experimental sites.

Information on rainfall and temperature was recorded throughout the cropping season and is presented in the Appendices 1, 2, 3, 4 and 5.

3.7 ANALYSIS OF DATA

Data were subjected to statistical analysis

3.7.1 Analysis of variance (ANOVA)

Procedure for split-split plot design as described by Steel and Torrie (1960) was followed. Means of those traits which showed significant differences were further analysed using the least significant difference (LSD) multiple test whose formular is:-

$$LSD = t_{\frac{\alpha}{2}} \sqrt{2 \frac{MES}{r}}$$

where MES is mean square for error

α - percent level of probability

r - is sample size or number of replication

t - is cumulative t distribution value tabulated according to degrees of freedom.

3.7.2 Land Equivalent Ratio (LER)

LER is an index used to evaluate yield advantage of an intercropping over monocropping technology. This index is easy to use and satisfies most of the conditions given by Hilderbrand (1976) and Flinn(1978).

It was computed using the following formula:-

$$LER = \sum_{i=1}^{n} (X_i/Y_i)$$

Where $\sum_{i=1}^{n}$ is the summation of all values

X_i is the yield of crop i in intercrop

Y_i is the yield of crop i in pure stand.

3.7.3 Coefficient of variation - the relative variation in the experimental variables was estimated by using the coefficient of variation, calculated by using the following formula:

$$CV = \frac{\sqrt{\text{Mean square for Error}}}{\text{Grand mean}} (100)$$

CHAPTER IV

4.0 RESULTS

4.1 EXPERIMENT (I). KABETE

4.1.1 General weather condition

Rainfall and temperature conditions are presented in Appendices 1 and 4. During the period of this study total rainfall at Kabete was 1082 mm. Mean temperatures were 23.7°C and 12.5°C (maximum and minimum, respectively). The rainfall pattern was bimodal with highest records in November, 1986 for short rains and April, 1987 for long rains.

4.1.2 Effect of intercropping and plant density on growth and development of component crops on:

(a) Duration of flowering. Neither intercropping nor plant density affected the duration to 50% flowering of component crops. However there were differences in duration to flowering between pigeonpea cultivars.

NPP 670 being an early maturing variety, had two flushes of flowering. The first one was observed on 20th February, 1987 irrespective of the treatments. Flowers aborted due to pod fly infestation and dry spell that was prevailing. Consequently there was no first crop of NPP 670. Second flush occurred two months later. Therefore, NPP 670 had first flush within 120 days after planting.

Katheka (a late maturing cultivar) had the first flush of flowers within 160 days after planting. In maize, tasselling occurred 60 days after planting.

(b) <u>Time to maturity</u>

NPP 670 was expected to have matured by April, 1987 had the flowers not aborted. After second flowering maturity of NPP 670 was reached within 45 - 50 days irrespective of plant density or intercropping pattern. Katheka matured within 270 - 280 days after planting while maize reached maturity within 120 days after planting without the effect of plant density or intercropping pattern.

(c) Leaf area per plant

Table 1 and 2 show the effect of intercropping and plant density on leaf area of pigeonpea cultivars at 5, 10 and 15 weeks after germination (W.A.G.$^{+}$). Cultivars of pigeonpea did not differ significantly in leaf area during this time. However this trait was affected by both plant density and intercropping.

Plant density reduced leaf area per plant in pigeonpeas. At 5 and 15 W.A.G.$^{+}$ plant densities of 44444 and 37037 plants/ha reduced leaf area by 22-27%. Highest leaf area per plant was observed in plots with plant density of 31746 plants/ha. This illustrated an inverse relationship between plant density and leaf area i.e. as plant density increased leaf area per plant decreased.

Intercropped plots had significantly lower leaf area than pure pigeonpea plots (Figure 1). Leaf area reduction due to intercropping varied from 40 to 80%. In general, leaf area per plant

Table 1. Effect of intercropping and plant density on leaf area of pigeonpeas planted during the short rains, 1986 at Kabete.

Crop combination	Intercrop Ratio PP*:M**	Plant population (plants/ha)			Leaf area (cm^2/plant) at		
		Pigeonpea	Maize	Total	5 W.	10 A.	15 G.+
NPP 670 pure stand	-	44444	-	44444	35.3	372.0	7572.0
		37037	-	37037	24.3	242.3	7135.7
		31746	-	31746	35.5	345.3	7939.3
NPP 670 + Maize	1:1	44444	53333	97777	30.0	213.0	3278.3
		37037	44444	81481	22.6	212.7	4034.3
		31746	38095	69841	28.7	306.7	5171.3
NPP 670 + Maize	1:1.75	44444	79999	124443	24.7	191.7	2543.0
		37037	66666	103703	20.7	145.0	3648.3
		31746	57142	88888	26.7	299.0	4558.0
NPP 670 + Maize	1:2	44444	106666	151110	23.0	130.3	1515.3
		37037	88888	125925	19.7	105.0	1873.0
		31746	76190	107936	24.0	287.0	2695.7
Katheka pure stand	-	44444	-	44444	50.0	431.3	8227.3
		37037	-	37037	44.0	384.0	7930.0
		31746	-	31746	38.0	321.7	12708.3
Katheka + Maize	1:1	44444	53333	97777	46.0	264.3	3372.7
		37037	44444	81481	39.3	361.0	4502.7
		31746	38095	69841	26.0	289.0	4740.3
Katheka + Maize	1:1.75	44444	79999	124443	40.0	264.7	2594.7
		37037	66666	103703	33.7	314.7	2436.7
		31746	57142	88888	25.7	253.7	2306.0
Katheka + Maize	1:2	44444	106666	151110	35.7	224.0	1681.3
		37037	88888	125925	27.0	250.7	1575.3
		31746	76190	107936	24.0	242.0	1983.7
		LSD (0.05)	Main plot				
			Sub plot		5.22		1035.20
			Sub sub plot		5.71	81.11	929.32

PP* = Pigeonpea
M** = Maize
W.A.G.+ = Weeks after germination

Table 2. Mean squares of leaf area of two pigeonpea cultivars planted at three densities and three intercrop combinations. Short rains 1986 at Kabete.

Source of variation	DF	Leaf area (cm^2/plant) at 5 W.A.G.+	10 W.A.G.+	15 W.A.G.+
Blocks	2	126.05	56124.25	4941184.0
Cultivars	1	1634.01	63249.50	497536.0
Main plot $error_1$	2	320.88	66028.75	292096.0
Plant density	2	376.67*	9315.25	13460670.0*
Cultivar x Plant density	2	430.59*	46043.0	303168.0
Subplot $error_2$	8	61.41	21904.63	2418368.0
Crop combination	3	501.27*	61176.50*	153947600.0*
Cultivar x crop combination	3	24.56	158.83	8135595.0*
Plant density x crop combination	6	14.88	8830.00	2248661.0
Cultivar x density x crop combination	6	14.09	864.91	3556821.0
Sub subplot $error_3$	36	71.81	14495.15	1903026.0
	$CV_{(1)}$	57.7	95.6	10.5
	$CV_{(2)}$	25.2	55.1	30.1
	$CV_{(3)}$	27.3	44.8	26.7

W.A.G.+ = Weeks after germination

* Significant at 5% level ;

CVs are in percentages and are high due to sampling technique

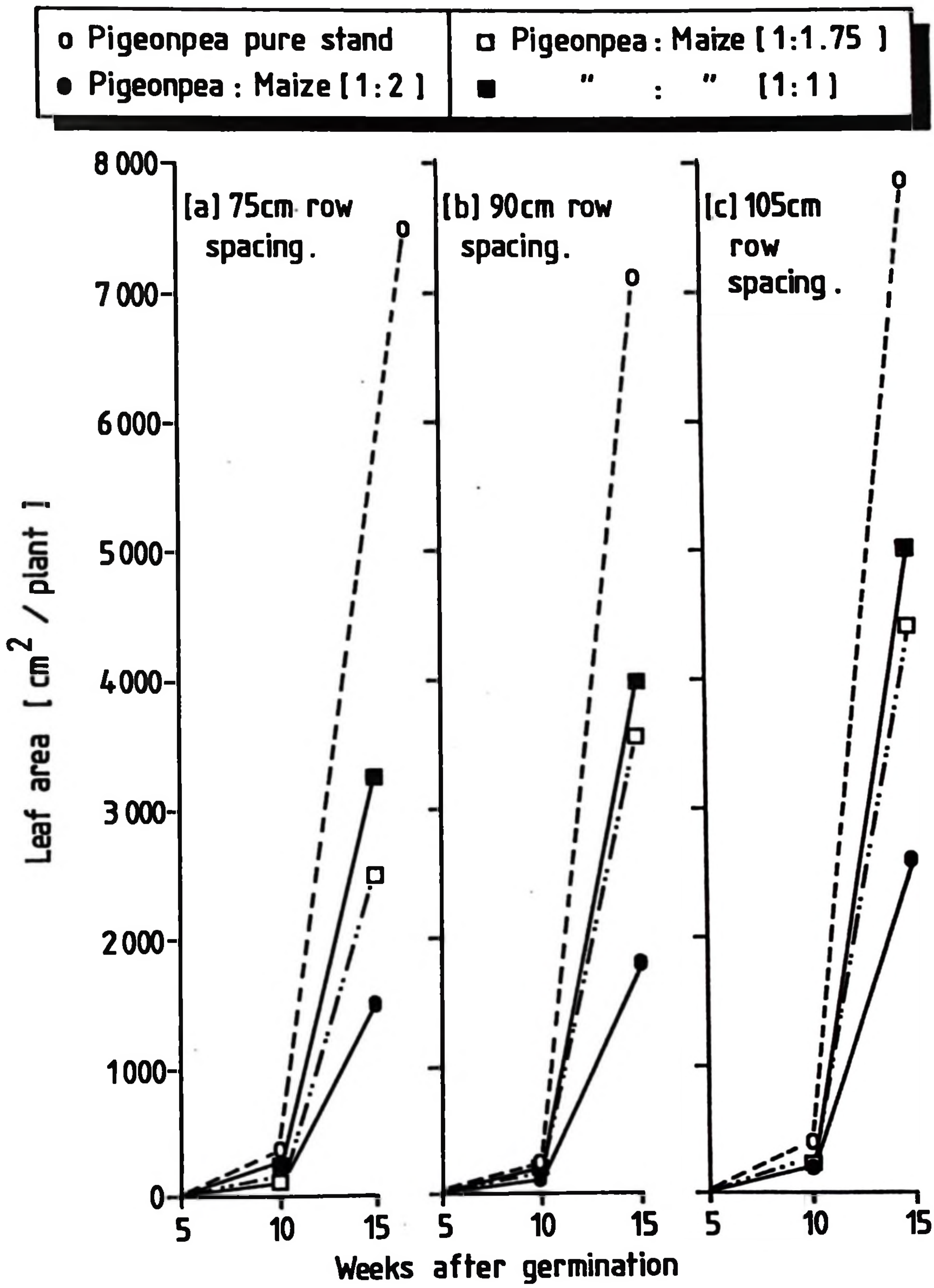

Fig. 1. Effect of crop combination, intercrop ratios and row spacings on leaf area of pigeonpea, short rains, 1986 at Kabete.

decreased as the intercrop ratio increased. However leaf area reduction due to intercropping was dependent on cultivar.

In maize, leaf area per plant was only affected by intercropping as shown in Table 3. Intercrop ratio of 2:1 (maize: pigeonpea, respectively) had the lowest leaf area per plant. However maize leaf area in pure stand was not significantly higher than maize at an intercrop ratio of 1:1 (maize:pigeonpea).

(d) <u>Shoot dry weight per plant</u>

Table 4 shows the effect of both intercropping and plant density on shoot dry weight of pigeonpea. At 5 and 10 W.A.G.$^{+}$ pigeonpea cultivars did not differ significantly in shoot dry weight. However at 15 W.A.G.$^{+}$, Katheka had higher dry weight per plant than NPP 670. Katheka had a mean dry weight of 24.1 g while NPP 670 had 12.8 g per plant.

Dry weight was reduced as density increased. Although a density of 31746 plants/ha had the highest dry weight it was not significantly different from that of 37037 plants/ha.

Figure 2 shows the response of dry weight to intercropping ratios and three interrow spacings. Monocropped pigeonpea had significantly higher dry weight per plant than intercropped pigeonpea. Dry weight per plant decreased consistently as intercrop ratios increased i.e. an intercrop ratio of 1:1 (pigeonpea:maize) had higher dry weight per plant than other ratios. At close row spacing (75 cm) dry weight per plant was 35% lower than at wide spacing (105 cm).

Table 5 shows the effect of plant density and intercropping on shoot dry weight in maize. Results were generally similar to those of pigeonpeas; for example at 5 and 10 W.A.G.+ plant density did not significantly affect shoot dry weight. However at 15 W.A.G.+ low plant density (interrow spacing 105 cm) had significantly higher shoot dry weight than interrow spacing of either 90 or 75 cm.

In maize, dry weight per plant was reduced by intercropping. Pure stand maize had significantly higher shoot dry weight per plant than intercropped maize. Shoot dry weight per plant decreased with an increase in the intercrop ratios and this reduction accounted for 20 - 30%.

(e) Plant height

Plant height of both pigeonpea and maize at different stages are shown in Table 6.

Pigeonpea cultivars differed significantly in plant height. Katheka had taller plants than NPP 670 at all sampling stages. Plant density did not affect this trait. Intercropping reduced plant height of pigeonpea, at 15 W.A.G.[+] and this reduction in plant height varied between 18 and 28%. At harvesting however, intercropped pigeon peas had taller plants than monocultural pigeonpeas and the increase in height varied between 2 and 8%.

Generally similar results to those of pigeonpeas were observed in maize at harvesting. Intercropped maize had 1% to 7% taller plants than maize in pure stand.

Table 4. Effect of intercropping on dry weight per plant for two cultivars of pigeonpeas planted at three densities. Short rains 1986 at Kabete.

Crop combination	Inter-crop Ratio PP*:M**	Plant population (plants/ha)			DRY MATTER (grams/plant)								
					5 W.A.G.+			10 W.A.G.+			15 W.A.G.+		
		Pigeonpea	Maize	Total	Leaves	Stem	Total	Leaves	Stem	Total	Leaves	Stems	Total
NPP 670 pure stand		44444	-	44444	0.19	0.09	0.28	2.5	1.2	3.7	11.7	8.4	20.1
		37037	-	37037	0.10	0.05	0.15	1.3	0.9	2.2	13.5	10.0	23.5
		31746	-	31746	0.18	0.08	0.26	1.7	1.4	3.1	17.5	16.0	33.5
NPP 670 + Maize	1:1	44444	53333	97777	0.19	0.08	0.27	0.9	0.7	1.6	7.3	5.9	13.2
		37037	44444	81481	0.10	0.04	0.14	0.8	0.6	1.4	8.9	7.3	16.2
		31746	38095	69841	0.21	0.09	0.30	1.4	1.3	2.7	11.4	8.1	19.5
	1:1.75	44444	79999	124443	0.15	0.07	0.22	0.9	0.7	1.6	4.8	3.1	7.9
		37037	66666	103703	0.15	0.07	0.22	0.7	0.5	1.2	11.0	5.9	16.9
		31746	57142	88888	0.21	0.09	0.30	1.8	1.2	3.0	7.5	5.9	13.4
NPP 670 + Maize	1:2	44444	106666	151110	0.15	0.07	0.22	0.5	0.1	0.6	2.8	3.4	6.2
		37037	88888	125925	0.13	0.07	0.20	0.7	0.9	1.6	4.6	3.2	7.8
		31746	76190	107936	0.19	0.08	0.27	1.5	1.3	2.8	5.2	4.4	9.6
Katheka pure stand	-	44444	-	44444	0.22	0.10	0.32	2.1	2.0	4.1	22.4	24.4	46.8
		37037	-	37037	0.10	0.07	0.17	3.6	1.6	5.2	19.5	19.0	38.5
		31746	-	31746	0.21	0.09	0.30	2.4	1.4	3.8	36.2	36.6	72.8
Katheka + Maize	1:1	44444	53333	97777	0.25	0.13	0.38	1.4	1.1	2.5	7.9	6.6	14.8
		37037	44444	81481	0.20	0.10	0.30	1.6	1.4	3.0	11.2	11.3	22.5
		31746	38095	69841	0.15	0.09	0.24	1.7	1.3	3.0	11.5	11.1	22.6
Katheka + Maize	1:1.75	44444	79999	124443	0.24	0.12	0.36	1.3	2.0	3.3	6.6	5.9	12.5
		37037	66666	103703	0.28	0.09	0.37	1.7	1.4	3.1	6.6	5.8	12.4
		31746	57142	88888	0.23	0.12	0.35	1.3	1.2	2.5	6.5	5.2	11.7
Katheka + Maize	1:2	44444	106666	151110	0.27	0.12	0.39	1.2	1.3	2.5	4.6	3.7	8.3
		37037	88888	125925	0.20	0.09	0.29	1.1	1.0	2.1	9.3	7.3	16.6
		31746	76190	107936	0.29	0.17	0.46	1.2	1.0	2.2	5.4	4.2	9.6
			$LSD_{(0.05)}$	Main plot							3.31	4.99	
				Sub plot		0.014					2.48	3.28	
				Sub sub plot				0.472	0.305		2.37	2.24	

PP* - Pigeonpeas
M** - Maize
W.A.G.+ - Weeks after germination

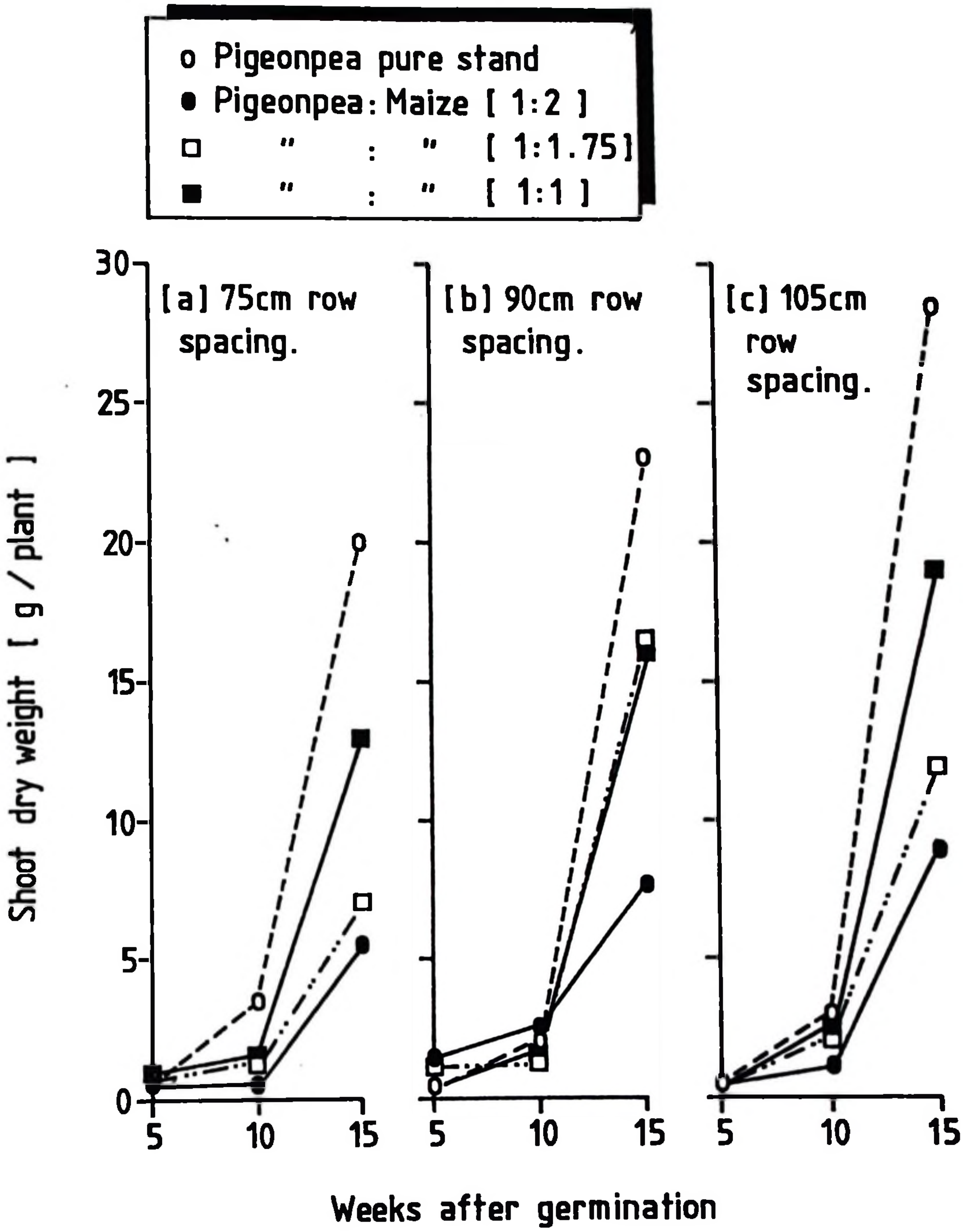

Fig. 2. Response of shoot dry weight of pigeonpeas to crop combination and intercrop ratios. Short rains, 1986 at Kabete.

Table 5. Effect of intercropping maize with two pigeonpea cultivars on dry weight of maize grown at Kabete 1986 (Short rains).

Crop combination	Inter-crop ratio P*:M**	Plant population			DRY MATTER (grams/plant)										
		Maize	Pigeonpea	Total	5 W.A.G.⁺			10 W.A.G.⁺				15 W.A.G.⁺			
					Leaves	Stem	Total	Leaves	Stem	Cob	Total	Leaves	Stem	Cob	Total
Maize pure stand	-	53333	-	53333	7.4	12.0	19.4	14.9	31.9	52.6	99.4	22.0	39.4	152.9	214.3
		44444	-	44444	7.9	10.3	18.2	18.7	33.5	64.1	116.1	26.2	48.3	163.2	237.7
		38095	-	38095	6.2	10.1	16.3	17.6	24.7	62.5	104.8	26.3	52.0	168.4	246.7
Maize + NPP 670	1:1	53333	44444	97777	7.2	11.6	18.8	16.7	47.9	64.6	129.2	21.3	40.1	174.2	235.6
		44444	37037	81481	8.3	11.2	19.5	13.1	31.7	48.1	92.9	18.3	39.9	165.2	223.4
		38095	31746	69841	5.9	10.2	16.1	16.4	33.6	64.7	114.7	23.3	50.7	176.9	250.9
Maize + NPP 670	1.75:1	79999	44444	124443	5.5	9.4	14.9	13.6	34.6	47.5	95.7	19.6	34.6	148.6	202.8
		66666	37037	103703	4.7	8.8	13.5	14.3	37.0	57.1	108.4	12.9	26.5	127.1	166.5
		57142	31746	88888	5.1	6.9	12.0	10.9	26.0	39.7	76.6	23.9	35.8	166.7	226.4
Maize + NPP 670	2:1	106666	44444	151110	4.8	7.1	11.9	14.5	36.9	37.3	88.7	15.8	27.6	109.1	152.5
		88888	37037	125925	4.8	7.1	11.9	15.0	29.0	39.4	83.4	15.9	31.3	142.9	190.1
		76190	31746	107936	5.9	8.7	14.6	16.0	40.7	62.6	119.3	19.6	35.8	174.8	230.2
Maize + Katheka	1:1	53333	44444	97777	7.6	10.2	17.8	20.2	46.7	99.0	165.9	20.3	46.7	177.4	244.4
		44444	37037	81481	7.3	9.1	16.4	18.9	44.1	71.4	134.4	19.4	40.5	158.1	218.0
		38095	31746	69841	7.7	12.7	20.4	17.8	47.9	56.6	122.3	21.4	30.5	171.1	223.0
Maize + Katheka	1.75:1	79999	44444	124443	5.6	10.5	16.1	14.1	31.7	48.0	93.8	24.0	31.6	156.9	212.5
		66666	37037	103703	7.3	11.7	19.0	15.2	49.3	41.4	105.9	19.8	38.0	153.9	211.7
		57142	31746	88888	8.6	11.7	20.3	15.8	37.0	37.6	90.4	17.8	29.9	146.3	194.0
Maize + Katheka	2:1	106666	44444	151110	7.3	9.7	17.0	19.3	54.9	43.5	117.7	16.0	31.2	127.7	176.5
		88888	37037	125925	6.0	8.2	14.2	12.8	32.8	51.4	97.0	23.5	38.6	161.8	223.9
		76190	31746	107936	4.9	8.1	13.0	10.8	25.7	37.4	73.9	18.6	43.2	153.7	215.5
$LSD_{(0.05)}$ Main plot														8.24	
$LSD_{(0.05)}$ Sub plot													2.85	18.21	
$LSD_{(0.05)}$ Sub sub plot					1.30	1.33		2.36		10.01		3.95	6.24	20.64	

P* = Pigeonpea
M** = Maize
W.A.G.⁺ = Weeks after germination

Table 6. Response of plant height to intercropping two pigeonpea cultivars with maize grown at three densities during 1986 short rains at Kabete.

Crop combination	Intercrop Ratio PP*:M**	Plant population (plants/ha) Pigeonpea	Maize	Total	Height per plant (cm) Pigeonpeas 15 WAG+	Pigeonpeas At harvest	Maize At tasse-lling	Maize At harvest
Maize pure stand	-		53333	53333			99.7	151.7
			44444	44444			105.3	171.7
			38095	38095			107.7	169.0
NPP 670 pure stand	-	44444		44444	72.7	84.3		
		37037		37037	89.3	91.7		
		31746		31746	89.7	92.3		
NPP 670 + Maize	1:1	44444	53333	97777	73.3	81.7	111.3	164.0
		37037	44444	81481	88.0	95.7	99.7	166.0
		31746	38095	69841	76.0	80.3	107.7	169.3
NPP 670 + Maize	1:1.75	44444	79999	124443	69.3	85.7	96.7	170.0
		37037	66666	103703	73.7	83.3	94.3	163.3
		31746	57142	88888	68.7	75.0	94.3	171.7
NPP 670 + Maize	1:2	44444	106666	151110	67.7	83.7	119.0	173.0
		37037	88888	125925	71.3	86.0	101.0	174.0
		31746	76190	107936	69.0	93.0	93.0	177.3
Katheka pure stand	-	44444		44444	155.3	195.0		
		37037		37037	159.3	205.0		
		31746		31746	157.0	203.3		
Katheka + Maize	1:1	44444	53333	97777	119.7	216.0	106.0	172.0
		37037	44444	81481	117.3	195.7	94.3	161.0
		31746	38095	69841	131.7	199.3	106.0	163.3
Katheka + Maize	1:1.75	44444	79999	124443	107.0	212.7	97.7	175.7
		37037	66666	103703	117.7	215.0	106.3	176.3
		31746	57142	88888	124.0	206.7	93.0	168.7
Katheka + Maize	1:2	44444	106666	151110	94.0	210.7	103.7	184.3
		37037	88888	125925	112.7	219.3	97.0	177.0
		31746	76190	107936	117.7	232.0	100.7	180.3
		$LSD_{(0.05)}$ Main plot			13.207	5.403		
		Sub plot						
		Sub sub plot			6.396	6.445	7.037	6.11

P* = Pigeonpea
M** = Maize
W.A.G.+ = Weeks after germination

4.1.3 Effect of intercropping and plant density on yield components of pigeonpea.

Table 7 and 8 show the effect of intercropping and plant density on yield components of pigeonpeas.

(a) Number of primary branches per plant

Pigeonpea cultivars differed significantly in this trait. Katheka had a higher number of branches per plant than NPP 670. On the average Katheka had 9.0 branches/ plant while NPP 670 had 6.5 branches/ plant. Neither intercropping nor plant density affected number of primary branches per plant at Kabete.

(b) Number of pods per plant

The two cultivars showed significant difference in number of pods per plant. Katheka had an average of 73.1 and NPP 670 had 28.1 pods per plant.

Plant density affected this trait significantly. At a density of 44444 plants/ ha the two cultivars had the lowest number of pods per plant and was highest at 31746 plant/ha. Reduction in number of pods per plant with increasing density varied from 16% to 35%.

Intercropping also reduced number of pods per plant. Monocultural pigeonpea had an average of 89.6 pods/plant whereas intercropped plots varied between 44.9 and 30.0 pods/plant. Reduction in number of pods per plant due to intercropping accounted for 51 - 67% with highest reduction corresponding to intercrop ratio of 1:2 (pigeonpea: maize). There was significant difference in cultivar x crop combination interaction indicating that as intercrop ratio increased, pods per plant decreased and the effect was significant between cultivars.

(c) Number of seeds per pod

The two cultivars differed in number of seeds per pod, with Katheka having an average number of 6.1 and NPP 670 had 4.9 seeds/pod.

Neither intercropping nor plant density affected number of seeds per pod significantly.

(d) 100-seed weight.

There were no significant differences among treatments for this trait, although 100 seed weight ranged from 20.3 g for NPP 670 to 21.6 g for Katheka.

(e) Grain yield per plant

The two cultivars differed significantly in grain yield per plant. Katheka had 79.9 g and NPP 670 produced 13.5 g/plant.

Plant density results revealed that high density reduced grain yield per plant. At a density of 44444 plants/ha grain yield was reduced by 39% as compared to a density of 31746 plants/ha. However grain yield per plant at density 31746 plants/ha was not significantly different from that of 37037 plants/ha. As plant density increased grain yield per plant decreased.

Intercropping reduced grain yield per plant significantly. It was observed that monocultural pigeonpea outyielded the intercropped plots. Intercropping reduced grain yield per plant by 37 to 44%. As intercrop ratio increased grain yield per plant

Table 7. Effect of intercropping and plant density on yield components of pigeonpeas planted at Kabete during the short rains, 1986.

Crop combination	Intercrop Ratio P*:M**	Plant density (plants/ha) Pigeonpeas	Maize	Total	Primary branches/ plant (no)	Pods/ plant (no)	Seeds/ pod (no)	Weight of 100 seed (g)	Grain yield/ plant (g)
NPP 670 monoculture	-	44444		44444	6.3	37.6	4.9	20.7	13.2
		37037		37037	6.7	36.9	4.6	20.8	14.0
		31746		31746	7.0	37.5	5.0	20.7	15.5
NPP 670 + Maize	1:1	44444	53333	97777	6.3	28.3	5.0	20.8	12.8
		37037	44444	81481	6.4	28.6	4.9	19.7	13.6
		31746	38095	69841	6.9	25.8	5.8	19.8	14.9
NPP 670 + Maize	1:1.75	44444	79999	124443	6.7	24.1	5.1	20.9	12.3
		37037	66666	103703	6.3	23.5	4.9	19.8	12.9
		31746	57142	88888	6.6	26.2	4.9	20.4	14.3
NPP 670 + Maize	1:2	44444	106666	151110	6.3	22.8	5.2	20.3	12.0
		37037	88888	125925	6.1	21.3	4.9	20.2	12.5
		31746	76190	107936	6.6	24.4	5.0	20.0	14.0
Katheka monoculture	-	44444		44444	9.1	110.9	6.0	21.8	71.5
		37037		37037	9.8	155.7	6.1	21.9	104.9
		31746		31746	10.6	159.2	6.1	21.5	101.7
Katheka + Maize	1:1	44444	53333	97777	9.3	35.6	6.1	21.5	54.7
		37037	44444	81481	10.4	75.8	6.2	21.6	90.6
		31746	38095	69841	10.9	75.6	6.1	21.3	97.2
Katheka + Maize	1:1.75	44444	79999	124443	9.2	26.6	6.0	21.9	46.7
		37037	66666	103703	10.5	58.7	6.2	21.4	88.8
		31746	57142	88888	10.0	68.1	6.1	21.7	90.2
Katheka + Maize	1:2	44444	106666	151110	9.0	21.9	6.1	21.4	43.6
		37037	88888	125925	9.6	40.3	6.2	21.8	80.9
		31746	76190	107936	9.8	49.1	6.1	21.5	88.2
		LSD (0.05)	Main plot		0.40	17.517	0.322		17.335
			Sub plot			11.529			5.199
			Sub sub plot			6.781			6.406

P* = Pigeonpea
M** = Maize

Table 8. Mean squares of yield components (plant traits) of two pigeonpea cultivars grown at three plant densities and three intercrop combinations. Short rains, 1986 at Kabete.

Source of variation	DF	Primary branches (no)	Pods/ plant (no)	Seeds/ pod (no)	Weight of 100 seed (g)	Grain yield/ plant (g)	Plant height at harvest (cm)
Blocks	2	3.76*	695.13	0.29*	1.59	127.32	90.81
Cultivars	1	201.33*	36503.99*	23.46*	28.87	79374.56*	280375.60*
Main plot $error_1$	2	0.09	298.30	0.10	1.76	72.51	28.37
Plant densities	2	3.77	2708.36*	0.03	0.70	3237.72*	14.87
Cultivars x Plant densities	2	1.41	2725.68*	0.08	0.49	2779.67*	45.43
Sub plot $error_2$	8	0.92	315.76	0.06	0.73	60.99	37.96
Crop combination	3	0.76	12855.78*	0.03	0.75	449.90*	492.62*
Cultivars x crop combinations	3	0.30	7402.48*	0.02	0.13	345.27*	279.87*
Plant densities x crop combination	6	0.25	67.56	0.03	0.40	20.93	214.41
Cultivar x density x crop combination	6	0.17	55.07	0.01	0.11	22.43	176.16
Sub sub plot $error_3$	36	0.57	101.33	0.06	1.15	90.41	91.53
CVs are in percentages	$CV_{(1)}$	10.1	34.1	5.7	6.3	18.2	3.6
* Significant at 5%.	$CV_{(2)}$	11.7	35.1	4.7	5.1	16.7	4.2
	$CV_{(3)}$	9.2	19.8	4.6	4.1	15.2	6.5

decreased. There was a significant difference in cultivar x crop combination interaction indicating that grain yield per plant decreased with an increase in intercrop ratio (Tables 7 and 8).

4.1.4 Effect of intercropping and plant density on yield components of maize.

Most of the maize yield components such as number of rows/cob, kernels/row and weight of 100 seed were not affected by either intercropping or plant density. Table 9 shows the trend for these traits.

(a) Number of cobs per plant

Only intercropping affected this trait. In maize pure stand, number of cobs were higher than intercropped plots of maize. However, pure stand plots of maize were not significantly different from an intercrop ratio of 1:1 (pigeonpea:maize). As intercrop ratio increased number of cobs per plant decreased significantly. Plots with intercrop ratio of 1:2 (pigeonpea: maize) had 18% less cobs/plant than monocultural plots.

Table 9. Effect of intercropping maize with pigeonpea at three densities on yield components of maize. 1986 short rains at Kabete

Crop combination	Intercrop ratio P*:M**	Plant density (Plants/ha)			Cobs/ plant (no)	Rows/ cob (no)	Grains/ row (no)	Weight of 100 seed (g)	Yield/ plant (g)
		Pigeonpea	Maize	Total					
Maize monoculture	-		53333	53333	1.03	10.93	29.5	37.7	109.8
			44444	44444	1.20	11.60	31.9	35.8	115.2
			38095	38095	1.10	11.90	30.2	36.9	109.2
NPP 670 + Maize	1.1	44444	53333	97777	1.00	12.13	28.7	35.6	111.6
		37037	44444	81481	0.97	11.90	29.5	38.2	102.9
		31746	38095	69841	1.03	10.90	28.7	39.1	96.1
NPP 670 + Maize	1:1.75	44444	79999	124443	1.03	11.73	27.5	37.6	100.6
		37037	66666	103703	0.93	11.50	30.1	38.5	95.6
		31746	57142	88888	1.13	11.30	28.0	39.1	111.2
NPP 670 + Maize	1:2	44444	106666	151110	0.90	11.73	28.7	34.4	83.3
		37037	88888	125925	0.93	11.90	29.3	38.3	83.1
		31746	76190	107936	1.10	11.70	31.3	39.2	85.4
Katheka + Maize	1:1	44444	53333	97777	1.00	11.2	29.9	38.5	93.5
		37037	44444	81481	1.00	11.9	29.7	37.7	98.4
		31746	38095	69841	1.30	11.3	30.2	37.6	88.9
Katheka + Maize	1:1.75	44444	79999	124443	0.97	12.0	30.1	38.6	108.6
		37037	66666	103703	0.97	10.7	30.5	38.5	104.1
		31746	57142	88888	1.10	12.0	28.5	38.7	93.8
Katheka + Maize	1:2	44444	106666	151110	0.97	12.1	29.3	37.4	85.3
		37037	88888	125925	0.93	11.9	28.9	35.3	98.6
		31746	76190	107936	0.77	11.7	27.1	38.2	99.4

$LSD_{(0.05)}$	Main plot		
	Sub plot		
	Sub sub plot	0.118	10.59

P* = Pigeonpea
M** = Maize

(b) Grain yield per plant

Intercropping reduced grain yield per plant. Maize in pure stand produced 113.7 g/plant while intercrops produced 102.3, 98.5 and 89.1 g/plant for intercrop ratios of 1:1.75, 1:1 and 1:2 respectively. Intercrop ratio of 1:1.75 did not differ significantly from 1:1 but ratio 1:2 had the lowest grain yield plant.

4.1.5 Land productivity

Land productivity was evaluated by using the land equivalent ratio (LER) index. Table 10 shows the land equivalent ratios obtained at different densities and intercrop combinations.

Results indicate that pigeonpea in intercropping yielded less than in monocropping at the equivalent plant density. This reduction in yield ranged between 4 - 5% in NPP 670 and 5 - 22% in Katheka.

However, intercropped maize had similar yields per hectare as in monocropping.

Cultivars responded differently to intercrop ratios. For NPP 670, land equivalent ratios increased with an increase in intercrop ratio to a maximum and declined thereafter. Thus at an intercrop ratio of 1:1 LER was small but as intercrop ratio was increased to 1:1.75 the LER reached a maximum (Table 10). At this ratio the LER was 2.58 and was attained at plant density of 31746 plants (pigeonpeas) + 57142 plants (maize) giving total density of 88888 plants per hectare. Yield advantage was therefore 158%.

Katheka had the lowest LER at intercrop ratio of 1:1 but increased linearly as the intercrop ratios increased. The highest LER of 3.01 was attained at plant density of 31746 plants (pigeonpea) + 76190 plants (maize) giving total plant density of 107936 plants/ha. Therefore intercropping Katheka + maize at 1:2 ratio had yield advantage of 201%.

It is however interesting to note that yields of maize were very high (7-8 tonnes/ha). This could have been due to the method used to convert the yields from grain yield plant^{-1} to grain yield hectare^{-1} basis by using the plant population factor.

Table 10. Effect of intercropping pigeonpea at three densities with maize on grain yield and land equivalent ratios (LER) at Kabete. Short rains, 1986.

Crop combination	Intercrop ratio P*:M**	Plant density (plants/ha)			Grain yield (kg/ha)[a]			
		Pigeonpea	Maize	Total	Pigeonpea	Maize	Total	LER
Maize (monoculture)			53333	53333		6015.0	6015.0	
			44444	44444		5287.9	5287.0	
			38095	38095		3341.7	3341.7	
Katheka (monoculture)	-	44444		44444	3177.7		3177.7	
		37037		37037	3885.2		3885.2	
		31746		31746	3216.9		3216.9	
NPP 670 (monoculture)	-	44444		44444	588.2		588.2	
		37037		37037	518.5		518.5	
		31746		31746	493.1		493.1	
1 row NPP 670 + 1 row maize planted at 1 plant/hill	1:1	44444	53333	97777	567.4	6569.6	7137.0	2.05
		37037	44444	81481	502.5	5368.4	5870.9	1.98
		31746	38095	69841	472.0	3997.5	4469.5	2.16
1 row NPP 670 + 1 row maize planted alternating 2 and 1 plant per hill	1:1.75	44444	79999	124443	545.2	8320.0	8865.2	2.30
		37037	66666	103703	476.6	6306.7	6783.3	2.11
		31746	57142	88888	454.0	5537.6	5991.6	2.58
1 row NPP 670 + 1 row maize planted at 2 plants per hill	1:2	44444	106666	151110	531.9	8837.4	9369.3	2.37
		37037	88888	125925	464.2	7907.9	8372.1	2.40
		31746	76190	107936	444.5	4920.5	5365.0	2.37
1 row Katheka + 1 row maize planted at 1 plant per hill	1:1	44444	53333	97777	1431.1	5628.0	8059.1	1.71
		37037	44444	81481	3356.8	5491.7	8848.5	1.90
		31746	38095	69841	3084.7	3452.1	6536.8	1.99
1 row Katheka + 1 row maize planted alternating 2 and 1 plant per hill	1:1.75	44444	79999	124443	2077.0	9071.8	11148.8	2.15
		37037	66666	103703	3290.1	7029.2	10319.3	2.17
		31746	57142	88888	2864.5	4663.3	7527.8	2.29
1 row Katheka + 1 row maize planted at 2 plants per hill	1:2	44444	106666	151110	1936.3	8655.9	10592.2	2.05
		37037	88888	125925	1997.3	7753.8	10751.1	2.24
		31746	76190	107936	2802.1	7158.4	9960.5	3.01

[a]Grain/plant converted into yield/ha by plant population factor

P* = Pigeonpea
M** = Maize

4.2 EXPERIMENT (II), THIKA

4.2.1 General weather condition

Rainfall and temperature data are presented in the Appendix 2.

Thika received total rainfall of 812.9 mm during the period of study, with highest rainfall in November, 1986 for short rains and April, 1987 for long rains. Mean temperatures were 25.8°C and 14.5°C for maximum and minimum, respectively.

4.2.2 Effect of intercropping and plant density on growth and development of component crops on:

(a) Time of flowering

Time of flowering was not affected by neither intercropping nor plant density because plants of the same genotype flowered about the same time irrespective of the treatment.

NPP 670 came into first flush on March 25th, 1987 (150 days after planting). Flowers aborted due to pest infestation and dry spell that was prevailing. However a second flush had developed by May

8th, 1987. Katheka flowered on 15th July, 1987 (about 210 days after planting. Tasselling in maize occurred within 50 days after planting.

(b) Time to maturity

As earlier mentioned, NPP 670 first flowers aborted hence there was no first crop. After the second flowering, maturity was attained within 80 days.

Katheka reached maturity within 300 days after planting irrespective of treatments. Maturity in maize was attained within 105 days after planting.

(c) Leaf area per plant

Effect of intercropping and plant density on leaf area of two pigeonpea cultivars is shown on Table 11. The two cultivars did not differ significantly in leaf area at all stages when sampling was done. Similarly, plant density did not affect leaf area per plant at 5 and 10 W.A.G.[+]. However, at 12½ W.A.G.[+] a density of 37037 plants/ha had the highest leaf area (2346.17 cm^2/plant) but was not significantly different from that of 31746 plants/ha. The highest density of 44444 plants per hectare (row spacing of 75 cm) had the lowest leaf area per plant (Figure 3).

Intercropping (crop combination) affected leaf area of pigeonpeas at all sampling stages. It was observed that as intercrop ratios increased leaf area was reduced. At 5 W.A.G.+ reduction in leaf area varied between 24% and 38%. At 10 W.A.G.+ the reduction in leaf area increased between 50% and 59% but stabilized thereafter. Monocultural pigeonpeas had significantly higher leaf area than intercropped pigeonpea.

Table 12 shows the mean squares of two cultivars of pigeonpeas as they were affected by intercropping and plant density. At 10 W.A.G.+ there was significant difference in plant density x crop combination interaction indicating that as intercrop ratio increased there was significant decrease in leaf area.

In maize significant differences were observed among intercrop ratios as shown in Table 13. At 5 W.A.G.+ monocultural maize had higher leaf area

Table 11. Effect of intercropping and plant density on leaf area of pigeonpeas planted during the short rains, 1986 at Thika.

Crop combination	Intercrop ratio PP*:M**	Plant density (plants/ha)			Leaf area (cm^2/plant) at		
		Pigeonpea	Maize	Total	5 W.	10 A.	12½ G.+
NPP 670 pure stand	-	44444		44444	122.0	756.7	2246.7
		37037		37037	103.7	475.0	5218.0
		31746		31746	82.7	384.3	2633.3
NPP 670 + Maize	1:1	44444	53333	97777	90.7	275.3	1446.0
		37037	44444	81481	94.0	257.7	1838.7
		31746	38095	69841	75.7	365.3	2048.3
NPP 670 + Maize	1:1.75	44444	79999	124443	84.3	189.3	1228.3
		37037	66666	103703	80.7	240.7	1352.3
		31746	57142	88888	72.7	279.7	1981.7
NPP 670 + Maize	1:2	44444	106666	151110	82.0	152.3	982.7
		37037	88888	125925	76.0	210.7	1328.3
		31746	76190	107936	60.7	238.3	1594.0
Katheka pure stand	-	44444		44444	109.3	926.7	2810.3
		37037		37037	198.7	394.0	3705.7
		31746		31746	125.0	325.0	2824.7
Katheka + Maize	1:1	44444	53333	97777	102.3	217.7	1463.3
		37037	44444	81481	92.3	211.7	1896.0
		31746	38095	69841	114.0	316.3	1584.3
Katheka + Maize	1:1.75	44444	79999	124443	82.0	179.3	1240.0
		37037	66666	103703	91.7	197.7	1862.3
		31746	57142	88888	91.0	250.7	1248.7
Katheka + Maize	1:2	44444	106666	151110	66.0	149.3	1161.0
		37037	88888	125925	86.0	192.7	1568.3
		31746	76190	107936	95.0	202.0	1237.3
		$LSD_{(0.05)}$	Main plot				
			Sub plot				578.624
			Sub sub plot		24.240	61.69	593.077

WAG+ = Weeks after germination

PP* = Pigeonpea

M** = Maize

Table 12. Mean squares of leaf area of two pigeonpea cultivars planted at three densities and three intercrop combinations. Short rains 1986 at Thika.

Source of variation	DF	Leaf area (cm^2/plant)		
		5 W.A.G.+	10 W.A.G.+	12½ W.A.G.+
Blocks	2	1296.84	24468.00	1052432.00*
Cultivars	1	4753.06	8022.00	214496.00
Main plot $error_1$	2	4709.65	7704.00	26448.00
Plant density	2	777.68	45506.75	3606224.00*
Cultivar x plant density	2	1019.56	9501.50	436528.00
Sub plot $error_2$	8	1992.37	13714.44	755536.00
Crop combination	3	6875.08*	467879.90*	14046040.00*
Cultivar x crop combination	3	1521.25	2867.00	59264.00
Plant density x crop combination	6	1111.91	33825.30*	1335488.00
Cultivar x density x crop combination	6	1393.82	6818.33	756373.30
Sub sub plot $error_3$	36	1294.70	8386.37	775054.30
	$CV_{(1)}$	72.2	43.3	8.3
	$CV_{(2)}$	47.0	38.1	44.8
	$CV_{(3)}$	37.0	29.7	45.4

*Significant at 5%.

W.A.G.+ = Weeks after germination.

CVs are in percentages but high due to sampling technique.

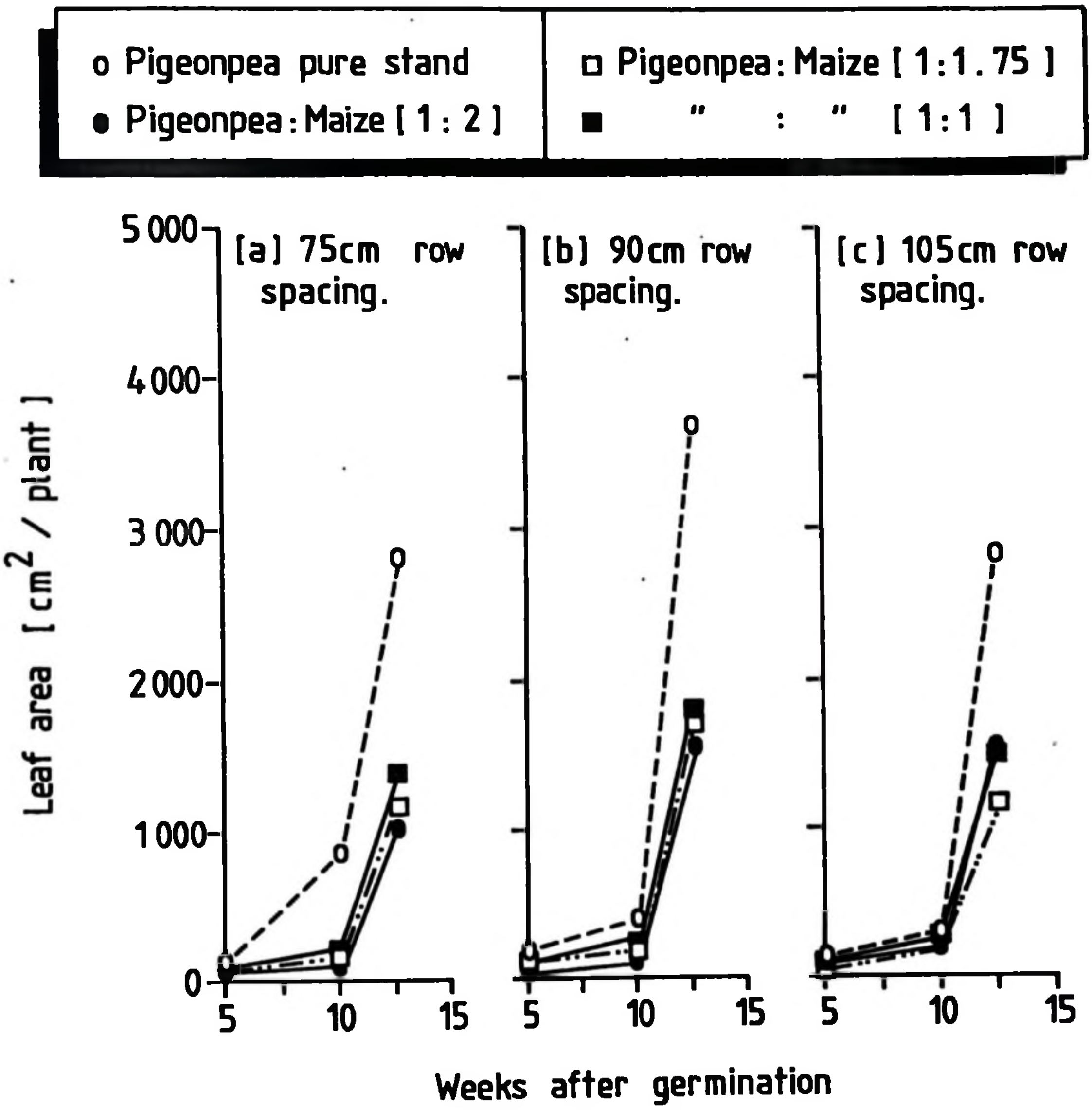

Fig. 3. Effect of intercrop ratios on leaf area of pigeonpea planted at three row spacings. Short rains 1986, at Thika.

Table 13. Effect of intercropping maize with two pigeonpea cultivars on leaf area of maize, short rains 1956 at Thika.

Crop combination	Intercrop ratio P*:M**	Plant density (plants/ha)			Leaf area (cm^2/plant) at	
		Pigeonpea	Maize	Total	5 W. A.	10 G+
Maize pure stand	-		53333	53333	2457.7	2456.7
			44444	44444	2370.0	2211.0
			38095	38095	2429.7	1752.0
Maize + NPP 670	1:1	44444	53333	97777	2309.0	1832.7
		37037	44444	81481	2281.3	1557.7
		31746	38095	69841	2274.0	1314.0
Maize + NPP 670	1.1:1.75	44444	79999	124443	2072.0	1698.3
		37037	66666	103703	2111.7	1390.7
		31746	57142	88888	1961.3	1122.3
Maize + NPP 670	1:2	44444	106666	151110	2026.3	1387.7
		37037	88888	125925	1905.3	1200.0
		31746	76190	107936	1731.7	1054.3
Maize + Katheka	1:1	44444	53333	97777	1565.7	1819.0
		37037	44444	81481	1856.3	1506.7
		31746	38095	69841	2425.0	1815.7
Maize + Katheka	1.:1.75	44444	79999	124443	1107.7	1548.7
		3707	66666	103703	1750.3	1357.7
		31746	57142	88888	2168.7	1355.3
Maize + Katheka	1:2	44444	106666	151110	1075.0	1534.0
		37037	88888	125925	1259.7	1211.0
		31746	76190	107936	2013.7	1137.0
		$LSD_{(0.05)}$	Main plot			
			Sub plot			255.071
			Sub sub plot		305.644	207.758

P* = Pigeonpea

M** = Maize

WAG+ = Weeks after germination

(2479.6 cm^2/plant) than intercropped maize. Leaf area was reduced as intercrop ratio was increased. This reduction in leaf area by intercropping varied between 15% and 33%.

At 10 W.A.G.+ there were similar observations that monocultural maize had significantly higher leaf area than intercropped maize. Reduction in leaf area induced by intercropping at this stage varied between 20% and 39%. An intercrop ratio of 1:2 (pigeonpea: maize) had the lowest leaf area per plant at all stages of growth.

(d) Shoot dry-weight per plant

Effects of intercropping and plant density on shoot dry weight of pigeonpeas are shown in Table 14. At all sampling stages cultivars did not differ significantly in shoot dry weight per plant. Statistically, plant density had no significant effects on dry weight but when dry matter values were plotted, 105 cm row spacing had the lowest dry weight (Figure 4).

Table 14. Effect of intercropping on dry weight for two cultivars of pigeonpeas planted at three densities. Short rains, 1986 at Thika.

Crop combination	Intercrop ratio P*:M**	Plant density (plants/ha)			DRY MATTER (grams per plant)								
					5 W. A. G.⁺			10 W. A. G.⁺			12½ W. A. G.⁺		
		Pigeonpea	Maize	Total	Leaves	Stem	Total	Leaves	Stem	Total	Leaves	Stem	Total
		44444		44444	0.8	0.5	1.3	2.8	1.8	4.6	8.1	6.5	14.6
NPP 670 pure stand	-	37037		37037	0.6	0.4	1.0	2.6	1.8	4.4	17.3	17.7	35.0
		31746		31746	0.5	0.3	0.8	2.1	1.1	3.2	9.0	8.8	17.8
		44444	53333	97777	0.5	0.3	0.8	1.2	0.7	1.9	5.6	4.9	10.5
NPP 670 + Maize	1:1	37037	44444	81481	0.7	0.4	1.1	0.9	0.6	1.5	6.9	9.0	15.9
		31746	38095	69841	0.5	0.3	0.8	1.8	1.0	2.8	6.6	7.9	14.5
		44444	79999	124443	0.5	0.2	0.7	1.0	0.5	1.5	6.9	4.8	11.7
NPP 670 + Maize	1:1.75	37037	66666	103703	0.4	0.3	0.7	0.8	0.7	1.5	6.9	4.8	11.7
		31746	57142	88888	0.7	0.7	1.4	2.5	1.8	4.3	6.6	8.3	14.9
		44444	106666	151110	0.7	0.3	1.0	0.8	0.5	1.3	2.5	2.4	4.9
NPP 670 + Maize	1:2	37037	88888	125925	0.5	0.3	0.8	1.3	0.5	1.8	7.5	7.1	14.6
		31746	76190	107936	0.5	0.3	0.8	1.7	1.1	2.8	5.3	6.3	11.6
		44444		44444	0.7	0.4	1.1	4.5	3.1	7.6	13.0	12.7	25.7
Katheka pure stand	-	37037		37037	1.4	1.0	2.4	2.9	1.3	4.2	14.1	12.3	26.4
		31746		31746	0.5	0.7	1.2	1.8	1.1	2.9	8.4	7.7	16.1
		44444	53333	97777	1.0	0.6	1.6	0.9	0.7	1.6	5.5	7.4	12.9
Katheka + Maize	1:1	37037	44444	81481	0.6	0.3	0.9	0.6	0.6	1.2	4.5	4.8	9.3
		31746	38095	69841	0.8	0.5	1.3	1.5	1.1	2.6	4.2	3.6	7.8
		44444	79999	124443	0.5	0.3	0.8	0.5	0.4	0.9	6.3	9.2	15.5
Katheka + Maize	1:1.75	37037	66666	103703	0.6	0.4	1.0	1.3	1.2	2.5	6.4	6.9	13.3
		31746	57142	88888	0.6	0.4	1.0	1.5	1.1	2.6	8.9	7.6	16.5
		44444	106666	151110	0.4	0.2	0.6	0.5	0.4	0.9	3.8	3.9	7.7
Katheka + Maize	1:2	37037	88888	125925	0.5	0.4	0.9	1.3	1.0	2.3	9.2	9.9	19.1
		31746	79190	107936	0.6	0.4	1.0	2.9	2.4	5.3	9.3	6.4	15.7
		$LSD_{(0.05)}$	Main plot										
			Sub plot										
			Sub sub plot					1.179	0.887		2.257	3.13	

P* = Pigeonpea
M** = Maize
WAG⁺ = Weeks after germination

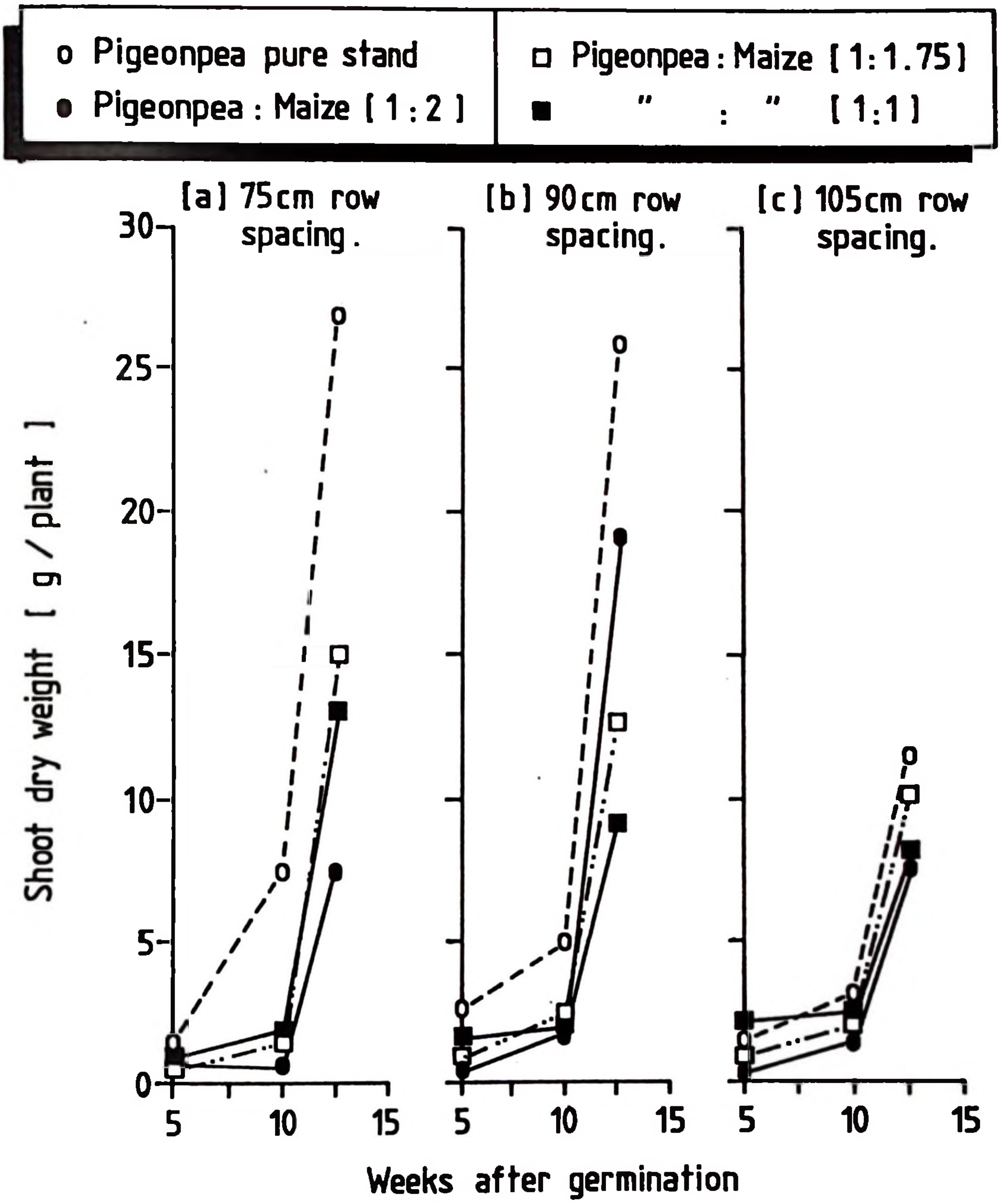

Fig. 4. Response of shoot dry weight of pigeonpea to intercrop ratios. Short rains 1986, at Thika.

Intercropping revealed significant differences in shoot dry weight per plant except at 5 W.A.G.$^{+}$. Monocultural pigeonpea had higher dry weight at 10 W.A.G.$^{+}$ but all intercrop ratios did not differ from each other. At 12½ W.A.G.$^{+}$ there were similar observations and intercropping reduced shoot dry weight within range of 53% and 69%.

The effects of intercropping and plant density on shoot dry weight in maize are shown in Table 15. Results revealed that plant density did not affect shoot dry matter accumulation at all sampling stages.

Intercropping reduced dry matter accumulation at 5 and 10 W.A.G.$^{+}$. It was observed that at 5 W.A.G. pure stand maize had higher dry weight/plant. but was not significantly different from an intercrop ratio of 1:1 (maize: pigeonpea). Generally as intercrop ratio increased, shoot dry weight per plant decreased and the reduction varied between 36% and 39%.

(e) Plant height

Response of plant height to intercropping in both pigeonpea and maize is shown in Table 16. Results indicated that the two pigeonpea cultivars differed significantly in plant height at all sampling stages. At harvesting for example, Katheka plants were 254.3 cm while NPP 670 plants averaged to 107.3 cm.

Plant density did not significantly affect plant height of pigeonpea. At each sampling time, plant height was the same at all densities.

Intercropping reduced plant height of pigeonpeas. Monocultural pigeonpea had taller pigeonpea than intercrops. For example at harvesting pure stand of pigeonpea had plants averaging to 191.4 cm high while intercrop varied between 176.0 and 179.5 cm depending on intercrop ratio. Plant height among intercrop decreased with an increase in intercrop ratio but this reduction was not significant.

In maize the reverse was true. Intercropping increased plant height. The results showed that as intercrop ratio increased, plant height also increased thus a direct relationship between plant height and density in maize. Intercrop ratio of 1:2 (pigeonpea: maize) had the tallest plants averaging 144.2 cm and 189.7 cm (at tasselling and harvesting, respectively). Monocultural maize recorded 126.2 and 161.7 cm at the same time.

Table 15. Effect of intercropping maize with two pigeonpea cultivars on shoot dry weight of maize grown at Thika, short rains 1986.

Crop combination	Intercrop ratio P*:M**	Plant density (Plants/ha)			DRY MATTER (grams per plant)										
		Pigeonpea	Maize	Total	5 W. A. G.+			10 W. A. G.+				12½ W. A. G.+			
					Leaves	Stem	Total	Leaves	Stem	Cob	Total	Leaves	Stem	Cob	Total
Maize pure stand			53333	53333	18.3	56.2	74.5	15.7	49.8	78.4	143.9	15.0	38.2	126.6	179.8
			44444	44444	16.9	30.6	47.5	15.2	42.6	65.3	123.1	10.6	36.9	96.6	147.1
			38095	38095	20.1	38.8	58.9	12.4	32.9	61.6	106.9	19.0	47.9	127.2	194.1
Maize + NPP 670	1:1	44444	53333	97777	19.7	47.5	67.2	15.8	59.6	45.0	120.4	13.5	33.4	137.0	183.9
		37037	44444	81841	18.2	47.1	65.3	19.0	56.4	98.8	174.2	13.6	34.9	100.7	149.2
		31746	38095	69481	17.3	45.6	62.9	11.0	30.8	56.1	97.9	15.5	42.8	157.1	215.5
Maize + NPP 670	1:1.75	44444	79999	124443	12.5	35.7	48.2	13.7	48.2	52.1	114.0	17.1	38.3	122.7	178.1
		37037	66666	103703	13.2	32.8	46.0	11.1	35.9	27.8	74.8	15.3	29.0	97.0	141.3
		31746	57142	88888	12.1	31.8	43.9	12.9	37.6	46.4	96.9	14.5	39.9	120.3	174.7
Maize + NPP 670	1:2	44444	106666	151110	18.4	33.8	52.2	10.5	34.9	37.7	83.1	18.6	38.9	107.8	165.3
		37037	88888	125925	12.9	31.7	44.6	11.1	29.9	37.3	78.3	12.9	26.4	92.8	132.1
		31746	76190	107936	15.5	37.3	52.8	16.0	48.0	49.0	113.0	20.9	52.0	87.3	160.2
Maize + Katheka	1:1	44444	53333	97777	20.5	43.5	64.0	13.3	44.9	65.8	124.0	17.8	39.2	153.1	210.1
		37037	44444	81841	15.4	32.1	47.5	12.7	32.6	45.8	99.1	14.4	37.4	128.7	180.5
		31746	38095	69481	15.5	47.5	63.0	14.4	39.4	59.4	113.2	16.0	35.4	108.6	160.0
Maize + Katheka	1.1.75	44444	79999	124443	20.5	43.5	64.0	14.3	40.3	43.3	97.9	18.5	44.6	132.0	195.1
		37037	66666	103703	15.4	32.1	47.5	12.4	35.9	42.1	90.4	12.2	35.2	94.1	141.5
		31746	57142	88888	12.8	28.7	41.5	12.3	33.9	45.4	91.6	16.1	39.7	88.4	144.2
Maize + Katheka	1:2	44444	106666	151110	12.7	31.3	44.0	15.5	46.3	46.9	108.7	17.4	38.8	93.2	149.4
		37037	88888	125925	15.3	31.4	46.7	11.3	36.9	36.7	84.9	14.5	37.5	88.2	140.2
		31746	76190	107936	12.7	30.7	43.4	16.1	46.7	60.8	123.6	15.8	39.0	85.8	140.6
		$LSD_{(0.05)}$	Main plot												
			Sub plot												
			Sub sub plot		3.744	7.041				20.543					

W.A.G.+ - Weeks after germination

P* = Pigeonpea
M** = Maize

Table 16. Response of plant height to intercropping two pigeonpea cultivars with maize grown at three densities during short rains, 1986, at Thika.

Crop combination	Intercrop ratio PP*:M**	Plant density (plants/ha)			Height per plant (cm)			
					Pigeonpeas		Maize	
		Pigeonpea	Maize	Total	12½ W.A.G.	At harvest	At tasseling	At harvest
Maize pure stand	-		53333	53333			130.0	164.0
			44444	44444			125.7	154.3
			38095	38095			129.3	177.7
NPP 670 pure stand	-	44444		44444	75.6	97.7		
		37037		37037	73.7	113.7		
		31746		31746	67.7	115.7		
NPP 670 + Maize	1:1	44444	53333	97777	66.7	101.7	126.0	176.3
		37037	44444	81481	65.6	107.7	126.3	180.3
		31746	38095	69841	62.3	104.3	131.7	164.7
NPP 670 + Maize	1:1.75	44444	79999	124443	56.7	102.7	134.0	186.7
		37037	66666	103703	55.0	106.3	132.0	183.3
		31746	57142	88888	59.0	116.0	126.7	180.3
NPP 670 + Maize	1:2	44444	106666	151110	51.0	109.7	155.3	191.3
		37037	88888	125925	53.3	109.3	147.3	191.0
		31746	76190	107936	59.0	110.3	140.0	184.7
Katheka pure stand	-	44444		44444	92.3	275.0		
		37037		37037	88.7	284.7		
		31746		31746	82.0	263.0		
Katheka + Maize	1:1	44444	53333	97777	74.7	259.3	137.3	182.7
		37037	44444	81481	70.0	251.3	126.0	172.7
		31746	38095	69841	74.0	252.7	120.3	169.0
Katheka + Maize	1:1.75	44444	79999	124443	64.0	257.3	142.3	199.3
		37037	66666	103703	59.0	244.0	130.0	179.0
		31746	57142	88888	63.3	238.0	136.3	184.0
Katheka + Maize	1:2	44444	106666	151110	63.0	240.7	133.3	194.0
		37037	88888	125925	66.7	241.0	150.0	186.7
		31746	76190	107936	60.3	245.0	139.3	190.7
		$LSD_{(0.05)}$	Main plot		7.924	23.912		
			Sub plot					
			Sub sub plot		6.052	9.131	10.854	6.052

P* = Pigeonpea
M** = Maize
WAG+ = Weeks after germination

4.2.3 Effect of intercropping and plant density on yield components of pigeonpeas.

Table 17 shows the response of yield components of two pigeonpea cultivars to plant density and intercropping. Table 18 shows the mean squares for the same traits.

(a) Number of primary branches per plant

Pigeonpea cultivars showed significant differences in number of primary branches per plant. Katheka had more number of primary branches per plant than NPP 670. Katheka had an average of 8.1 branches while NPP 670 had an average of 7.3 branches per plant. The difference between cultivars could have influenced the interaction between cultivar x crop combination.

There were no significant differences for this trait among the three plant densities nor intercrop combinations.

(b) Number of pods per plant

Cultivars showed significant differences in number of pods per plant. On an average Katheka produced 104.9 pods per plant whereas NPP 670 had an average of 42.9 pods per plant.

Plant density and intercropping did not affect the number of pods per plant significantly.

(c) Number of seeds per pod

Although Katheka had an average of 6.0 seeds/pod and NPP 670 had 5.3 seeds/pod, the difference was not significant. Similarly, neither intercropping nor plant density affected this trait significantly.

(d) 100 seed weight

Hundred seed weight was neither affected by intercropping nor by plant density. This indicated that, there was no effect of intercropping on 100 seed weight. Katheka had an average weight of 22.4 g while NPP 670 was 21.9 g/plant but they were not significantly different.

Table 17. Effect of intercropping and plant density on yield components of pigeonpeas planted at Thika during the short rains, 1986.

Crop combination	Intercrop ratio PP*:M**	Plant density (plants/ha) Pigeonpea	Maize	Total	Primary branches/ plant (no)	Pods/ plant (no)	Seeds/ pod (no)	Weight of 100 seed (g)	Yields/ plant (g)
NPP 670 Monoculture	-	44444		44444	6.6	45.0	5.3	21.5	30.8
		37037		37037	6.9	47.7	5.5	21.8	31.6
		31746		31746	6.5	48.9	5.1	21.5	34.2
NPP 670 + Maize	1:1	44444	53333	97777	6.8	37.7	5.2	21.9	25.6
		37037	44444	81481	7.5	45.8	5.4	22.0	26.7
		31746	38095	69841	6.7	47.5	5.4	21.5	30.5
NPP 670 + Maize	1.1.75	44444	79999	124443	7.7	34.8	5.2	21.9	24.5
		37037	66666	103703	7.5	43.1	5.3	21.7	22.8
		31746	57142	88888	7.5	47.0	5.4	22.1	29.9
NPP 670 + Maize	1:2	44444	106666	151110	7.6	30.7	5.3	22.3	22.3
		37037	88888	125925	7.8	42.5	5.0	22.2	21.4
		31746	76190	107936	7.8	44.4	5.1	22.0	25.9
Katheka Monoculture	-	44444		44444	8.8	106.1	5.8	22.6	82.9
		37037		37037	8.3	111.8	6.0	22.9	78.1
		31746		31746	8.5	114.5	6.0	22.7	97.0
Katheka + Maize	1:1	44444	53333	97777	7.5	96.1	5.8	22.3	73.0
		37037	44444	81481	7.2	97.9	6.2	22.5	76.4
		31746	38095	69841	8.4	109.9	5.8	22.3	104.3
Katheka + Maize	1:1.75	44444	79999	124443	8.1	103.5	6.0	22.8	83.0
		37037	66666	103703	8.3	98.5	5.8	22.1	75.6
		31746	57142	88888	8.0	108.3	6.1	22.7	96.6
Katheka + Maize	1:2	44444	106666	151110	7.9	104.2	6.1	22.2	79.2
		37037	88888	129925	8.3	109.1	6.0	22.0	76.3
		31746	76190	107936	7.7	100.1	6.0	22.0	92.4
		$LSD_{(0.05)}$	Main plot		0.550	7.383	0.281		16.460
			Sub plot						
			Sub sub plot						

P* = Pigeonpea
M** = Maize

Table 18. Mean squares of yield components (plant traits) of two pigeonpea cultivars grown at three plant densities and three intercrop combinations. Short rains 1986, at Thika.

Source of variation	DF	Primary branches (no)	Pods/ plant (no)	Seeds/ pod (no)	Weight of 100 seed g)	Grain yield/ plant (g)	Plant height at harvest (cm)
Blocks	2	1.32	170.20	0.35	11.01	366.16	271.5
Cultivars	1	11.68*	69359.47*	8.89*	3.96	59265.53*	377146.00*
Main plot error,	2	0.29	52.98	7.70	5.60	263.39	555.87
Plant densities	2	0.03	371.48	3.40	0.03	1158.43	110.25
Cultivar x plant densities	2	0.29	53.48	0.14	0.06	468.50	226.12
Sub plot error$_2$	8	0.14	235.87	0.08	2.29	461.87	69.06
Crop combination	3	0.75	204.03	0.01	0.06	116.36	1116.33*
Cultivars x crop combination	3	2.29*	48.93	0.09	1.36	32.20	1161.08*
Plant densities x crop combination	6	0.17	42.41	0.09	0.28	37.00	85.91
Cultivars x densities x crop combination	6	0.49	60.43	0.03	0.09	29.09	111.50
Sub sub plot error$_3$	36	0.33	248.38	0.04	0.45	41.46	183.72
	$CV_{(1)}$	7.1	9.8	4.9	10.7	29.0	13.0
	$CV_{(2)}$	4.9	20.7	5.1	6.8	38.4	4.6
	$CV_{(3)}$	7.5	21.3	3.9	3.0	11.5	7.4

* Significant at 5%.
CVs are in percentages

(e) Grain yield per plant

Grain yield per plant differed between the two cultivars, with Katheka yielding higher than NPP 670. Katheka yielded an average of 84.6 g/plant and NPP 670 had an average yield of 27.2 g/plant. There was no general trend for either the effect of intercropping or plant density on this trait.

4.2.4. Effect of intercropping and plant density on yield components of maize.

Yield components of maize were not significantly affected by either intercropping or plant density at Thika. All yield components such as number of cobs/plant, rows/cob, kernels/row, 100-seed weight and grain yield per plant did not differ significantly under all treatments (Table 19).

4.2.5. Land productivity

Table 20 shows the values for land equivalent ratio (LER) which is an index for evaluating yield advantage of intercropping. Results indicate that generally intercrops of both maize and pigeonpea had lower yields than monocrops at equivalent densi-

Table 19. Effect of intercropping maize with pigeonpea at three densities on yield components of maize 1986 short rains, at Thika.

Crop combination	Intercrop ratio P*:M**	Plants density (Plants/ha)			Cobs/ plant (no)	Rows/ cob (no)	Grains/ row (no)	Weight of 100 seed(g)	Yield/ plant (g)
		Pigeonpea	Maize	Total					
Maize Monoculture			53333	53333	0.7	12.4	26.3	33.4	64.7
			44444	44444	0.8	10.9	26.2	35.0	72.5
			38095	38095	0.8	11.5	29.0	37.0	77.9
Maize + NPP 670	1:1	44444	53333	97777	0.7	11.7	27.5	34.4	64.8
		37037	44444	81481	0.8	11.9	26.9	35.6	76.1
		31746	38095	69841	0.7	11.0	26.7	37.5	65.0
Maize + NPP 670	1:1.75	44444	79999	124443	0.6	11.5	26.8	33.1	54.0
		37037	66666	103703	0.7	11.7	24.9	35.4	47.8
		31746	57142	88888	0.6	11.7	26.2	32.5	42.2
Maize + NPP 670	1:2	44444	106666	151110	0.7	10.9	25.8	32.0	49.2
		37037	88888	125925	0.7	11.3	26.1	30.0	52.7
		31746	76190	107936	0.8	11.5	26.5	33.1	57.6
Maize + Katheka	1:1	44444	53333	97777	0.9	11.8	28.5	31.7	74.7
		37037	44444	81481	0.7	11.9	24.9	30.5	43.6
		31746	38095	69841	0.8	11.3	25.1	30.1	46.1
Maize + Katheka	1:1.75	44444	79999	124443	0.8	10.9	28.3	30.2	51.1
		37037	66666	103703	0.7	11.9	25.3	32.2	46.7
		31746	57142	88888	0.7	11.5	25.6	31.5	50.9
Maize + Katheka	1:2	44444	106666	151110	0.7	11.0	24.2	30.0	39.9
		37037	88888	125925	0.7	11.7	25.9	31.6	49.9
		31746	79190	107936	0.8	12.1	23.4	31.3	45.6

P* = Pigeonpea
M** = Maize

ties. For NPP 670 the reduction in yield due to intercropping was within range of 11 to 18%, while for Katheka the reduction was between 3 and 12%. Maize showed a 2 to 18% yield reduction due to intercropping. However, there were cases where intercrops had higher yield than monocrops at equivalent densities. Although yields of intercrops were lower than monocrops the total yield per unit area was higher.

Table 20 shows that all intercrop combinations gave yield advantage. The two cultivars of pigeonpea had different trends when intercropped with maize. NPP 670 had increasing LER as intercrop ratio increased and reached the highest LER of 2.12 at an intercrop ratio of 1:2 (pigeonpea:maize). At this ratio plant density was 37037 plants (pigeonpea) + 88888 plants (maize) giving total density of 125925 plants/ha. The yield advantage was 112%.

Generally Katheka intercrop showed higher land equivalent ratio than NPP 670 intercrop but there was no obvious trend in Katheka corresponding to increasing intercrop ratios. However at an intercrop ratio of 1:1.75, Katheka attained its highest LER of 2.26. This LER was reached at plant density of 44444 plants pigeonpea were intercropped with 79999 plants (maize) giving a total density of

Table 20. Effect of intercropping two cultivars of pigeonpea at three densities and maize on grain yield and land equivalent ratios (LER). Short rains, 1986 at Thika.

Crop combination	Intercrop ratio PP*:M**	Plant density (Plants/ha)			Grain yield (kg/ha)[a]			
		Pigeonpea	Maize	Total	Pigeonpea	Maize	Total	LER
Maize (monoculture)	-		53333	53333		3432.9	3432.9	
			44444	44444		2663.3	2663.3	
			38095	38095		2438.8	2438.8	
Katheka (monoculture)	-	44444		44444	3685.9		3658.9	
		37037		37037	2891.4		2891.4	
		31746		31746	3076.3		3078.3	
NPP 670 (monoculture)	-	44444		44444	1371.8		1371.8	
		37037		37037	1171.6		1171.6	
		31746		31746	1085.7		1085.7	
1 row NPP 670 + 1 row maize planted at 1 plant per hill	1:1	44444	53333	97777	1136.4	3453.4	4589.7	1.84
		37037	44444	81481	990.1	2612.9	3603.0	1.82
		31746	38095	69841	968.2	1964.2	2932.4	1.70
1 row NPP 670 + 1 row maize planted alternating 2 and 1 plant per hill	1:1.75	44444	79999	124443	1088.8	3840.0	4928.4	1.91
		37037	66666	103703	843.2	2919.2	3762.4	1.82
		31746	57142	88888	949.2	1819.2	2768.4	1.62
1 row NPP 670 + 1 row maize planted at 2 plants per hill	1:2	44444	106666	151110	990.9	4341.7	5332.6	1.98
		37037	88888	125925	793.8	3847.5	4641.3	2.12
		31746	76190	107936	822.2	3060.0	3882.2	2.01
1 row Katheka + 1 row maize planted at 1 plant per hill	1:1	44444	53333	97777	3244.4	4560.0	7804.4	2.21
		37037	44444	81481	2828.4	1799.2	4627.6	1.65
		31746	38095	69841	3312.2	1571.3	4883.5	1.72
1 row Katheka + 1 row maize planted alternating 2 and 1 plant per hill	1:1.75	44444	79999	124443	3687.4	4320.5	8007.9	2.26
		37037	66666	103703	2800.0	2442.1	5242.1	1.89
		31746	57142	88888	3068.8	2240.5	5309.3	1.92
1 row Katheka + 1 row maize planted at 2 plants per hill	1:2	44444	106666	151110	3521.4	2897.9	6419.3	1.79
		37037	88888	125925	2828.4	3285.0	6113.4	2.21
		31746	76190	107936	2932.3	1746.7	4679.0	1.67

P* = pigeonpea
M** = maize

[a]Grain yield/plant converted into yield/ha by plant population factor.

124443 plants/ha. Yield advantage of intercropping Katheka and maize at that ratio was 126%.

4.3 EXPERIMENT (III), KIBOKO

4.3.1 General weather condition

Rainfall and temperature data are presented in the Appendix 3..

During the period of study, Kiboko received total rainfall of 590.4 mm. The highest rainfall for short rains was in November 1986, and for long rains, highest rainfall was recorded in April, 1987. Mean temperatures were 30.9°c and 16.2°C for maximum and minimum, respectively.

4.3.2 Effect of intercropping and plant density on growth and development of component crops on:

(a) Time of flowering

Fifty percent flowering in plots of the same genotype, was observed about the same time. Therefore neither intercropping nor plant density affected time of flowering.

NPP 670 had reached 50% flowering on March 13th, 1987 thus having a flowering time of about 120 days after planting. This first flush of flowers aborted probably due to insect infestation as well as drought. It however flowered again by May 20th, 1987.

Katheka had reached 50% flowering by July 20th, 1987. It's flowering time was therefore about 220 days after planting.

Maize flowered (tasselled) within 40 days after planting.

(b) Time to maturity

NPP 670 had serious flower abortion during the first flush of flowers and as a result, the first crop was not harvested. However, after the second flowering, maturity was reached within 70 days.

(c) Leaf area per plant

Table 21 shows the effect of intercropping two cultivars of pigeonpea at three densities with maize at various combinations. Results indicate that at 5 W.A.G.+ cultivars of pigeonpea had significant differences in leaf area per plant. On average NPP 670 had higher leaf area (423.9cm²/plant) than Katheka (329.6cm²/plant). However, the difference between cultivars was not observed both at 10 and 12½ W.A.G.⁺.

Both cultivars were not affected by plant density for this trait because no significant differences were observed at any sampling time. The general trend was that, as plant density increased leaf area decreased but the reduction was not significant (Figure 5).

Mean squares for leaf area at different sampling times are shown in Table 22. Results indicate that intercropping affected leaf area significantly at all sampling dates. It was observed that as intercrop ratio increased, leaf area per plant decreased. At 5 W.A.G.⁺, leaf area reduction due to intercropping was between 22 and 39%, it increased to 54 and 61% at 10 W.A.G.⁺ and yet at 12½ W.A.G.⁺ the reduction rose up to 67%. Monocultural pigeonpea had significantly higher leaf area per plant throughout the growing season (Figure 5).

Table 21. Effect of intercropping and plant density on leaf area of pigeonpeas planted during the short rains, 1986 at Kiboko.

Crop combination	Intercrop ratio PP*:M**	Plant density (Plant/ha)			Leaf area (cm^2/plant) at		
		Pigeonpea	Maize	Total	5 W.	10 A.	12½ G.+
NPP 670 pure stand	-	44444		44444	663.7	3446.0	6912.7
		37037		37037	507.0	3459.0	5565.3
		31746		31746	505.3	3374.3	7290.7
NPP 670 + Maize	1:1	44444	53333	97777	348.0	1229.7	4827.7
		37037	44444	81481	454.0	1446.7	4041.0
		31746	38095	69841	491.7	1740.0	6476.0
NPP 670 + Maize	1:1.75	44444	79999	124443	333.3	1190.3	3244.7
		37037	66666	103703	365.7	1382.0	4005.0
		31746	57142	88888	411.0	1010.7	5145.3
NPP 670 + Maize	1:2	44444	106666	151110	323.0	1033.7	2165.3
		37037	88888	125925	322.3	1334.3	3955.3
		31746	76190	107936	361.3	1257.7	2914.3
Katheka pure stand	-	44444		44444	557.3	2735.0	8999.7
		37037		37037	381.7	1988.7	6779.0
		31746		31746	319.3	1512.7	6400.0
Katheka + Maize	1:1	44444	53333	97777	352.3	1264.0	2990.0
		37037	44444	81481	358.0	916.3	2933.7
		31746	38095	69841	309.3	1226.0	3538.7
Katheka + Maize	1:1.75	44444	79999	124443	281.3	947.0	2930.0
		37037	66666	103703	333.0	914.7	2933.7
		31746	57142	88888	267.7	1119.0	3503.0
Katheka + Maize	1:2	44444	106666	151110	276.0	865.7	3019.3
		37037	88888	125925	279.0	891.3	2883.7
		31746	76190	107936	240.0	1098.3	3390.7
		$LSD_{(0.05)}$		Main plot	48.90		
				Sub plot			
				Sub sub plot	42.01	478.50	1130.69

W.A.G.+ - Weeks after germination
P* = Pigeonpea
M** = Maize

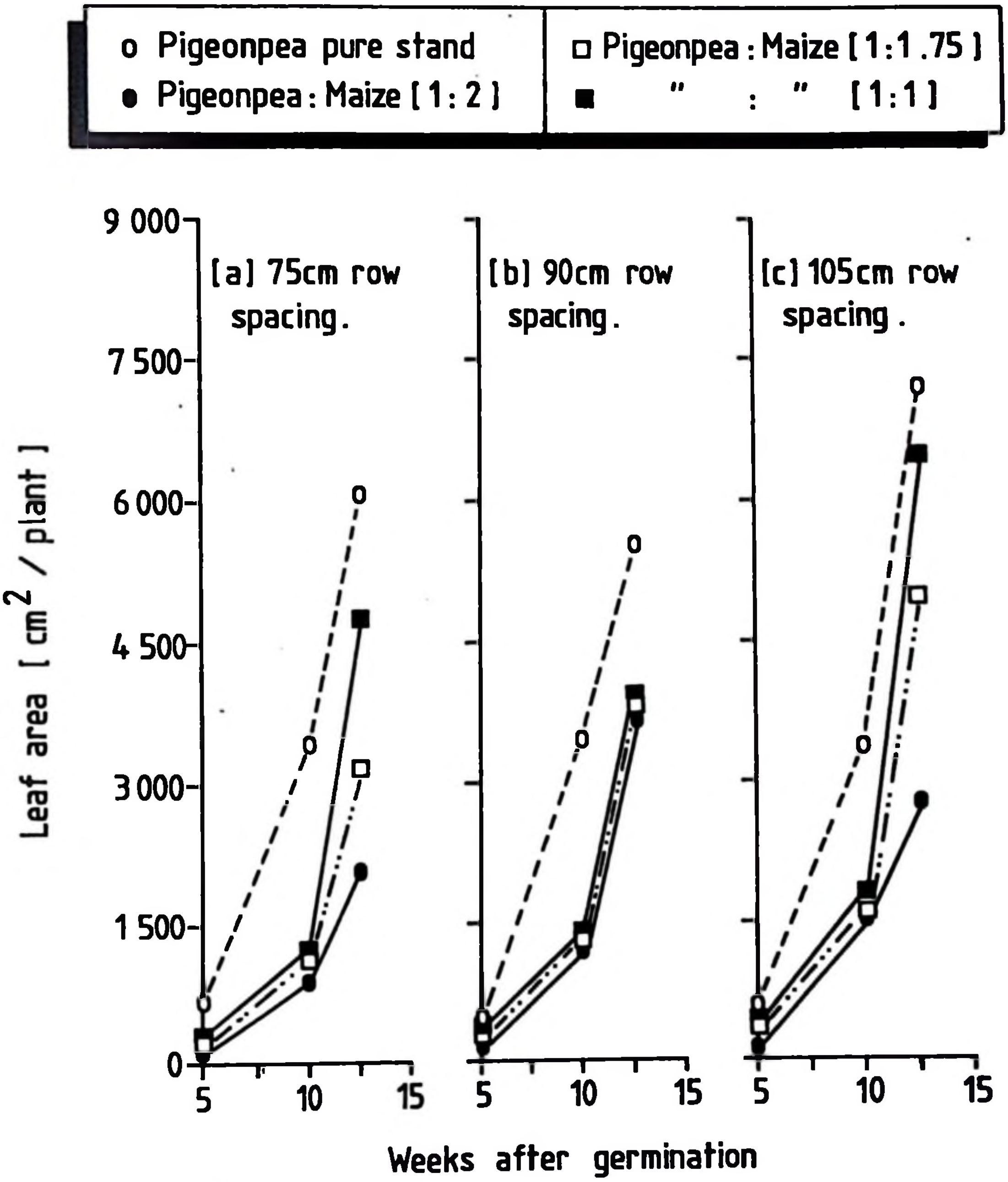

Fig. 5 . Effect of intercrop ratios on leaf area of pigeonpea grown during short rains 1986, at Kiboko.

Table 22. Mean squares of leaf area of two pigeonpea cultivars planted at three densities and intercrop combinations. Short rains, 1986 at Kiboko.

Source of variation	DF	Leaf area (cm^2/plant)		
		5 W. A. G.+	10 W. A. G.+	12½ W. A. G.+
Blocks	2	16965.00	3323128.00	3982720.00
Cultivars	1	114641.00*	6182304.00	4841728.00
Main plot error$_1$	2	2325.50	2765552.00	499840.00
Plant density	2	10836.50	32248.00	2956800.00
Cultivar x plant density	2	28591.00	440160.00	3137600.00
Sub plot error$_2$	8	10922.25	578494.00	2765744.00
Crop combination	3	84729.00*	110955300.0*	55075840.00*
Cultivar x Crop combination	3	277.33	1176208.0	6620416.00
Plant density x crop combination	6	35761.67	322893.40	3013504.00
Cultivar x density x crop combination	6	5230.66	97912.00	1300736.00
Sub sub plot error$_3$	36	3888.61	504514.20	2817106.00
	$CV_{(1)}$	12.8	95.0	15.8
	$CV_{(2)}$	27.7	48.0	37.3
	$CV_{(3)}$	16.6	44.8	37.6

*Significant at 5%

W.A.G.+ = Weeks after germination

CVs are in percentages but high due to sampling technique.

Table 23 shows the response of leaf area in maize as affected by intercropping. The results showed that at 10 W.A.G.+ maize intercropped with Katheka had less leaf area per plant than that intercropped with NPP 670. Monocultural maize had significantly higher leaf area than maize intercrop.

At 5 W.A.G.+ reduction in leaf area due to intercropping varied between 14 and 20% and at 10 W.A.G.+ intercropping reduced leaf area of maize by 37%. The highest reduction corresponded to an intercrop ratio of 1:2 (pigeonpea:maize).

(d) Shoot dry weight

Table 24 shows the effect of intercropping and plant density on shoot dry weight of pigeonpeas.

Results indicated that at all sampling dates, cultivars did not differ significantly in shoot dry weight. Similarly plant density did not affect shoot dry weight significantly.

However, plant density of 44444 had higher dry weight per plant than that of 31746 plants/ha i.e. 75 cm inter-row spacing had higher dry weight/plant than 105 cm inter-row spacing (Figure 6).

Intercropping reduced shoot dry weight. Pure stand pigeonpea had higher shoot dry weight than intercropped pigeonpea but intercrop ratios were not significantly different from each other throughout the sampling dates. Reduction in dry weight due to intercropping varied between 46 and 70%.

The effect of intercropping and plant density on maize shoot dry weight is shown in Table 25. Results indicated that plant density significantly affected dry weight of maize at 5 and 12½ W.A.G.$^+$. As density increased shoot dry weight decreased, thus indicating inverse relationship between plant density and shoot dry weight.

At 5 W.A.G.$^+$ intercrop ratio of 1:1 had the highest shoot dry weight per plant (56.2 g) but was not significantly different from pure stand maize (56.1 g/plant). At 10 W.A.G.$^+$ pure stand maize had significantly higher shoot dry weight than intercrop maize but all intercrop ratios did not differ

Table 23. Effect of intercropping maize with two pigeonpea cultivars on leaf area of maize. Short rains, 1986 at Kiboko.

Crop combination	Intercrop ratio P*: M**	Plant density (plants/ha)			Leaf area (cm^2/plant) at	
		Pigeonpea	Maize	Total	5 W.A.G.$^+$	10 W.A.G.$^+$
Maize pure stand			53333	53333	2663.7	2688.3
			44444	44444	2571.3	3089.3
			38095	38095	2728.0	2765.0
Maize + NPP 670	1:1	44444	53333	97777	2490.0	2662.7
		37037	44444	81481	2339.0	2429.6
		31746	38095	69841	1811.0	2516.0
Maize + NPP 670	1:1.75	44444	79999	124443	1593.7	1884.0
		37037	66666	103703	1407.3	2248.3
		31746	57142	88888	1650.0	1624.0
Maize + NPP 670	1:2	44444	106666	151110	1568.0	1831.7
		37037	88888	125925	1116.7	1881.0
		31746	76190	107936	1610.0	1436.0
Maize + Katheka	1:1	44444	53333	97777	2363.3	1965.0
		37037	44444	81481	2176.0	2313.0
		31746	38095	69841	2076.3	2402.0
Maize + Katheka	1:1.75	44444	79999	124443	2114.0	1422.0
		37037	66666	103703	1780.0	1600.3
		31746	57142	88888	1806.7	1889.0
Maize + Katheka	1:2	44444	106666	151110	2050.0	1148.7
		37037	88888	125925	1643.0	1591.3
		31746	76190	107936	1198.0	1878.0
		$LSD_{(0.05)}$	Main plot			306.37
			Sub plot			234.44
			Sub sub plot		253.54	

P* = Pigeonpea
M** = Maize
W.A.G.$^+$ = Weeks after germination

Table 24. Effect of intercropping on shoot dry weight of two cultivars of pigeonpeas planted at three densities. Short rains 1986, at Kiboko.

Crop combination	Intercrop ratio P*:M**	Plant density (plants/ha) Pigeonpea	Maize	Total	DRY MATTER (grams per plant) 5 W. A. G.+ Leaves	Stem	Total	10 W. A. G.+ Leaves	Stem	Total	12 W. A. G.+ Leaves	Stem	Total
NPP 670 monoculture	-	44444		44444	3.1	1.6	4.7	9.9	10.4	20.3	16.9	22.7	39.6
		37037	-	37037	2.7	1.2	3.9	8.7	8.6	17.3	12.0	16.2	28.2
		31746		31746	2.4	1.3	3.7	7.7	11.0	18.7	20.2	29.1	49.2
NPP 670 + Maize	1:1	44444	53333	97777	1.4	0.7	2.1	3.2	2.5	5.7	10.9	14.3	25.2
		37037	44444	81481	2.2	1.3	3.5	3.0	2.8	5.8	9.4	12.9	22.3
		31746	38095	69841	2.4	1.3	3.7	5.4	4.5	9.9	15.9	23.4	39.3
NPP 670 + Maize	1:1.75	44444	79999	124443	1.4	0.7	2.1	2.9	3.1	6.0	8.7	13.3	22.0
		37037	66666	103703	1.1	1.0	2.1	3.1	2.7	5.8	11.7	16.0	27.7
		31746	57142	88888	1.7	0.9	2.6	3.9	4.2	8.1	13.3	26.7	40.0
NPP 670 + Maize	1:2	44444	106666	151110	1.4	0.7	2.1	3.0	2.2	5.2	5.5	7.2	12.7
		37037	88888	125925	1.1	1.0	2.1	3.3	2.5	5.8	11.4	13.3	24.7
		31746	76190	107936	2.5	1.3	3.8	2.8	2.3	5.1	6.2	10.0	16.2
Katheka monoculture	-	44444		44444	3.1	1.6	4.7	8.1	10.1	18.2	21.2	42.9	64.1
		37037		37037	1.9	1.1	3.0	6.4	5.4	11.7	17.6	33.1	50.7
		31746		31746	1.8	0.8	2.6	7.2	8.2	15.4	15.0	27.5	42.5
Katheka + Maize	1:1	44444	53333	97777	1.1	0.9	2.0	2.9	2.6	5.5	7.7	11.7	19.5
		37037	44444	81481	1.5	0.9	2.4	2.3	1.9	4.2	7.9	11.9	19.8
		31746	38095	69841	1.2	0.6	1.8	3.0	2.5	5.5	10.0	14.8	24.8
Katheka + Maize	1:1.75	44444	79999	124443	1.2	0.7	1.9	2.0	1.9	3.9	7.4	10.0	17.4
		37037	66666	103703	1.8	1.1	2.9	2.3	2.3	4.6	8.6	12.9	21.5
		31746	57142	88888	2.2	1.2	3.4	2.7	2.3	5.0	9.9	14.5	24.4
Katheka + Maize	1:2	44444	106666	151110	1.8	0.9	2.8	2.7	2.8	5.5	11.4	19.4	30.8
		37037	88888	125925	1.2	0.7	1.9	2.1	2.2	4.3	8.9	13.1	22.8
		31746	79190	107936	1.3	0.7	2.0	2.9	2.7	5.6	11.8	18.5	30.3
	$LSD_{(0.05)}$		Main plot										
			Sub plot										
			Sub sub plot		0.29	0.21		1.44	1.97		2.76	6.59	

P* = Pigeonpea
M** = Maize
W.A.G.+ = Weeks after germination

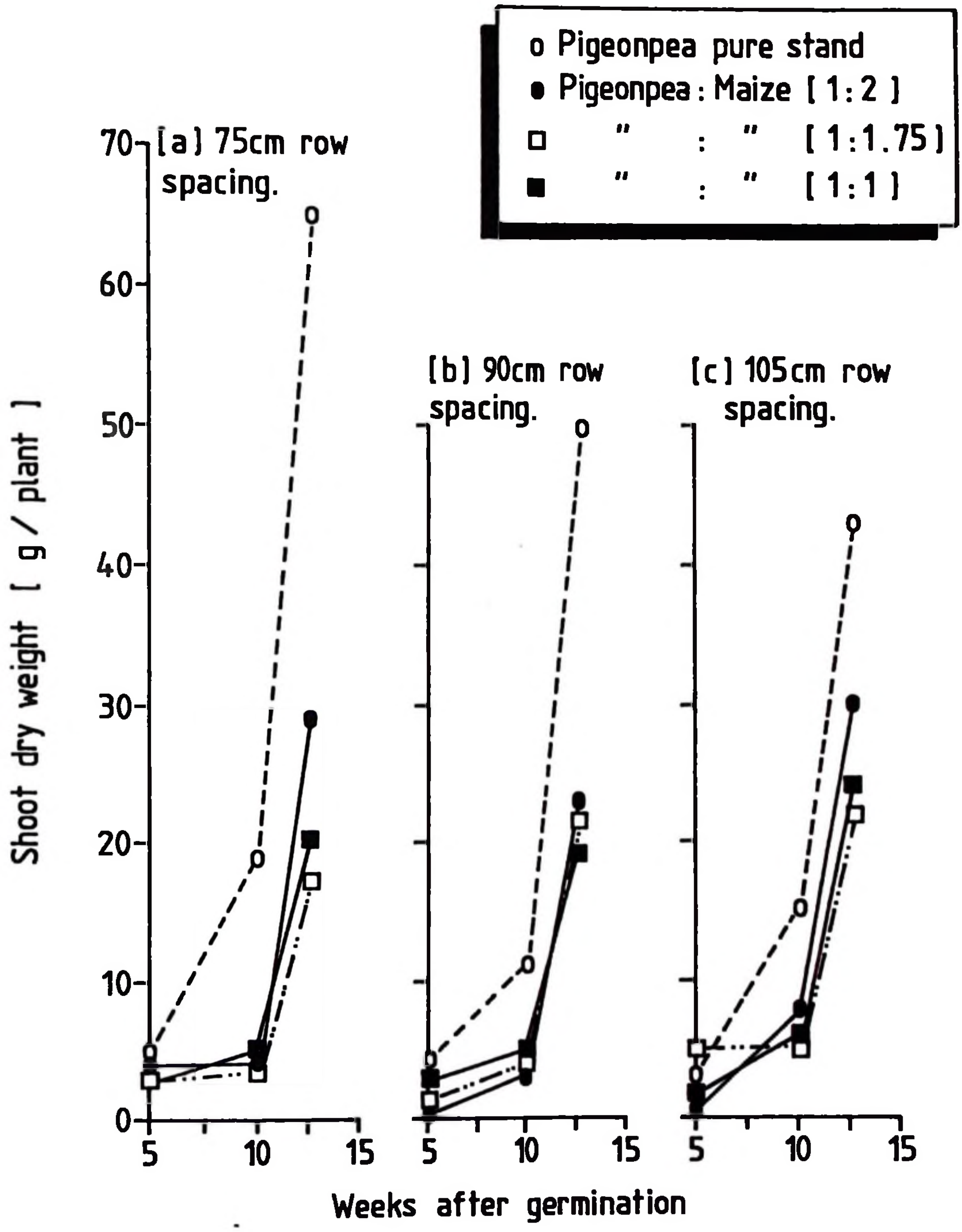

Fig. 6 . Response of shoot dry weight in pigeonpea to intercrop ratios. Short rains 1986, at Kiboko.

Table 25. Effect of intercropping maize with two pigeonpea cultivars on shoot dry weight of maize. Short rains 1986, at Kiboko.

Crop combination	Intercrop ratio P*:M**	Plant density (plant/ha)			DRY MATTER (grams per plant)										
					5 W. A. G.+			10 W. A. G.+				12½ W. A. G.+			
		Pigeonpea	Maize	Total	Leaves	Stem	Total	Leaves	Stem	Cob	Total	Leaves	Stem	Cob	Total
Maize pure stand	-		53333	53333	12.7	39.4	52.1	16.0	48.0	83.3	147.3	10.2	26.9	102.9	140.0
			44444	44444	10.9	36.6	47.5	20.1	57.7	118.9	196.7	13.9	28.6	141.6	184.1
			38095	38095	16.1	52.7	68.8	18.3	53.6	134.7	206.6	16.0	39.5	149.5	205.0
Maize + NPP 670	1:1	44444	53333	97777	13.4	37.4	50.6	16.2	42.3	69.7	128.2	11.5	23.7	114.5	149.7
		37037	44444	81481	14.7	49.5	64.2	16.7	35.1	108.5	160.3	13.4	32.6	150.6	196.6
		31746	38095	69841	10.0	32.7	42.7	19.9	61.9	114.1	195.9	8.5	30.2	114.2	152.9
Maize + NPP 670	1:.75	44444	79999	124443	9.1	28.0	37.1	11.3	33.4	66.2	110.9	13.9	32.6	123.0	169.5
		37037	66666	103703	9.7	22.2	29.9	12.2	31.9	72.4	116.8	15.3	24.2	107.4	146.9
		31746	57142	88888	7.2	27.9	35.1	8.8	25.2	55.8	89.8	12.1	19.7	93.8	125.6
Maize + NPP 670	1:2	44444	106666	151110	11.6	35.0	46.6	11.3	24.6	56.3	92.2	16.7	29.8	96.9	143.4
		37037	88888	125925	9.5	28.7	38.2	11.3	30.3	53.9	95.5	15.6	31.4	111.5	158.5
		31746	76190	107936	8.1	23.1	31.1	10.5	28.4	69.3	108.2	14.2	31.0	113.1	158.3
Maize + Katheka	1:1	44444	53333	97777	17.7	55.8	73.5	16.5	30.3	80.0	126.8	17.9	44.0	65.6	127.5
		37037	44444	81481	11.4	44.0	55.4	15.7	43.9	87.0	146.6	8.5	44.5	147.1	200.1
		31746	38095	69841	12.0	38.5	50.5	12.2	34.7	66.1	113.0	3.8	24.7	84.1	127.6
Maize + Katheka	1:1.75	44444	79999	124443	13.3	41.9	55.2	12.9	36.6	63.5	113.0	10.1	34.6	80.6	125.3
		37037	66666	103703	9.4	27.4	36.8	9.6	22.2	56.2	88.0	16.6	31.5	107.8	155.9
		31746	57142	88888	8.3	24.3	32.6	11.4	28.1	62.2	101.7	15.5	28.0	117.8	161.6
Maize + Katheka	1:2	44444	106666	151110	13.6	43.7	57.3	9.6	22.8	46.1	78.5	15.9	24.4	96.9	137.2
		37037	88888	125925	8.8	24.4	33.2	12.5	28.0	54.4	94.9	14.1	30.9	122.7	167.7
		31746	76190	107936	11.5	32.7	44.2	11.4	26.3	60.4	98.1	12.1	23.1	115.3	150.5
	$LSD_{(0.05)}$	Main plot													
		Sub plot			2.31	3.57								2.31	
		Sub sub plot			2.02	9.92		2.69	8.66	2.021					

P* = Pigeonpea
M** = Maize
W.A.G.+ = Weeks after germination

significantly. Reduction in shoot dry weight due to intercropping varied between 34 and 42%.

(d) Plant height

Table 26 shows the response of plant height of both pigeonpea and maize to plant density and intercropping.

At 12½ W.A.G.+ pigeonpea cultivar did not differ significantly in plant height. However at harvesting there were significant differences in plant height between pigeonpea cultivars. Katheka had taller plants than NPP 670 (300.0 and 162.9 cm respectively).

Plant density did not affect this trait significantly at all sampling dates and no general trend was observed. Intercropping however affected plant height significantly. Intercropping reduced plant height. As intercrop ratio increased plant height decreased and this reduction in plant height due to intercropping was within range of 8 and 26% with highest reduction corresponding to intercrop ratio of 1:2 (pigeonpea:maize).

Maize plant height was not affected by plant density but was affected by intercropping. Intercropped maize had taller plants than pure stand maize. For example at harvesting intercropped maize had an average height of 213.8 cm, while pure stand maize was 198.2 cm. It was observed that as intercrop ratio increased, plant height also increased. This increase in plant height due to intercropping was about 8%.

4.3.3 Effect of intercropping and plant density on yield components of pigeonpeas.

Tables 27 and 28 show yield components of two pigeonpea cultivars and their response to intercropping and plant density.

(a) Number of primary branches per plant

The two cultivars differed significantly in number of primary branches per plant. NPP 670 had significantly more branches than Katheka (6.8 and 5.5, respectively).

Plant density and intercropping did not affect number of primary branches per plant and no trend was observed in these variables.

(b) Number of pods per plant

Cultivars had significant differences in number of pods/plant. It was observed that NPP 670 had an average of 61.64 pods/plant and Katheka averaged to 48.62 pods/plant. Although the general trend indicated that high plant density reduced number of pods/plant the effect was not significant.

Intercropping affected this trait significantly. From the results it can be observed that as intercrop ratio increased, number of pods per plant decreased. Intercrop ratio of 1:1 had significantly higher number of pods/plant than intercrop ratio of 1:2 (Table 27).

(c) Number of seeds per pod

Seeds per pod were higher for Katheka than NPP 670 (5.5 and 5.1 respectively) but this variation was not significant. Both intercropping and plant density did not affect the number of seeds per pod significantly.

(d) 100-seed weight

Seed weight was different between the two pigeonpea cultivars. Hundred seed weight for Katheka was 22.9 g compared to 20.2 g for NPP 670.

Plant density however did not affect this trait and no general trend was observed as plant density was varied. Difference in 100-seed weight was observed among intercrop combinations. It was observed that pure stand pigeonpeas had heavier seeds (22.3 g) than intercropped pigeonpea (21.2 g) ($LSD_{.05}$= 0.47). As intercrop ratio increased, seed size decreased and the reduction in seed size varied between 3 and 17%.

(e) Grain yield per plant

The two cultivars of pigeonpea did not show significant yield difference. NPP 670 yielded an average of 31.3 g and Katheka 28.7 g/plant.

Only intercropping affected this trait. In pure stand pigeonpea yield per plant was higher than intercropped plots and yield decreased with an

Table 26. Response of plant height to incercropping of two pigeonpea cultivars with maize grown at three densities during short rains, 1986 at Kiboko.

Crop combination	Intercrop ratio PP*:M**	Plant density (plants/ha)			Height per plant (cm)			
					Pigeonpeas		Maize	
		Pigeonpea	Maize	Total	12½ W.A.G.[+]	At harvest	At tasselling	At harvest
Maize pure stand	-		53333	53333			163.0	215.7
			44444	44444			160.3	175.3
			38095	38095			159.0	203.0
NPP 670 pure stand	-	44444		44444	161.7	170.0		
		37037		37037	156.7	172.0		
		31746		31746	164.9	169.0		
NPP 670 + Maize	1:1	44444	53333	97777	143.0	157.3	153.3	186.8
		37037	44444	81481	142.8	161.3	169.3	204.6
		31746	38095	69841	149.7	161.0	163.0	196.2
NPP 670 + Maize	1:1.75	44444	79999	124443	122.0	158.3	168.0	217.3
		37037	66666	103703	140.3	168.0	160.0	221.5
		31746	57142	88888	149.7	163.3	163.0	211.3
NPP 670 + Maize	1:2	44444	106666	151110	146.0	162.7	183.7	224.7
		37037	88888	125925	128.7	154.7	160.3	205.3
		31746	76190	107936	132.0	158.3	169.0	220.3
Katheka pure stand	-	44444		44444	198.3	330.3		
		37037		37037	208.7	300.0		
		31746		31746	180.3	310.0		
Katheka + Maize	1:1	44444	53333	97777	149.8	286.3	174.7	223.0
		37037	44444	81481	177.1	287.3	155.0	214.0
		31746	38095	69841	155.3	308.3	169.7	207.8
Katheka + Maize	1:1.75	44444	79999	124443	149.3	302.7	160.7	235.0
		37037	66666	103703	157.0	301.3	174.0	215.6
		31746	57142	88888	113.3	303.7	159.3	217.3
Katheka + Maize	1:2	44444	106666	151110	131.7	285.0	180.3	208.7
		37037	88888	125925	151.7	286.3	181.3	222.6
		31746	76190	107936	109.3	300.7	176.3	220.0
		$LSD_{(0.05)}$	Main plot			55.24		
			Sub plot					
			Sub sub plot		10.6	6.69	8.21	13.03

PP* = Pigeonpeas

M** = Maize

W.A.G.[+] = Weeks after germination

Table 27. Effect of intercropping and plant density on yield components of pigeonpeas planted at Kiboko during the short rains, 1986.

Crop combination	Intercrop ratio PP*:M**	Plants density (plants/ha) Pigeonpea	Maize	Total	Primary branches/ plant (no)	Pods/ plant (no)	Seeds/ pod (no)	Weight of 100 seed (no)	Yield/ plant (g)
		44444		44444	6.4	70.8	5.0	20.8	35.5
NPP 670 monoculture	-	37037		37037	7,0	71.4	5.1	21.0	41.5
		31746		31746	7.3	75.9	4.9	21.7	45.1
		44444	53333	97777	6.5	58.9	5.1	19.9	34.1
NPP 670 + Maize	1:1	37037	44444	81481	7.1	63.0	5.3	20.0	36.7
		31737	38095	69841	7.1	64.1	5.0	20.7	37.9
		44444	79999	124443	6.6	54.9	5.3	19.2	29.0
NPP 670 + Maize	1:1.75	37037	66666	103703	6.8	59.2	5.0	20.0	32.5
		31746	57142	88888	7.1	60.8	5.0	20.4	33.4
		44444	106666	151110	6.2	51.8	5.2	19.1	27.5
NPP 670 + Maize	1:2	37037	88888	125925	6.6	54.9	5.2	19.3	31.6
		31746	76190	107936	6.7	54.0	5.0	19.6	31.6
		44444		44444	5.1	62.1	5.6	23.7	28.7
Katheka monoculture	-	37037		37037	5.2	75.8	5.7	23.7	38.1
		31746		31746	5.9	84,4	5,6	23.0	31.4
		44444	53333	97777	5.2	46.5	5.6	22.9	25.8
Katheka + Maize		37037	44444	81481	5.8	46.9	5.4	23.7	29.1
		31746	38095	69841	6,1	45.8	5,5	23,2	26,2
		44444	79999	124443	5.3	36.7	5.6	22.2	26.0
Katheka + Maize	1:1.75	37037	66666	103703	5.4	38.2	5.5	22.5	32.1
		31746	57142	88888	5.5	34.8	5.5	22.2	26.0
		44444	106666	151110	5.3	39.7	5.4	22.1	23.9
Katheka + Maize	1:2	37037	88888	125925	5.2	35.8	5.6	22.6	30.1
		31746	76190	107936	5.8	36.7	5.4	22.5	27.3
		$LSD_{(0.05)}$	Main plot		0.79	5.59		1.69	
			Sub plot						
			Sub sub plot			5.95		0.47	5.39

PP* - Pigeonpeas
M** - Maize

Table 28. Mean squares of yield components (plant traits) of two pigeonpea cultivars grown at three plant densities and three intercrop combinations. Short rains 1986, at Kiboko.

Source of variation	DF	Primary branches (no)	Pods/ plant (no)	Seeds/ pod	Weight of 100 seed (g)	Grain yield/ plant (g)	Plant height at harvest (cm)
Blocks	2	0.14	402.42	0.01	0.35	279.67	1891.50
Cultivars	1	30.16*	3049.81*	3.42	131.75*	643.81	338801.80*
Main plot error$_1$	2	0.6	30.46	0.21	2.81	92.18	2966.25
Plant density	2	2.38	119.47	0.12	1.27	167.09	176.00
Cultivar x plant density	2	0.15	0.31	0.01	1.66	56.17	269.75
Sub plot error$_2$	8	0.64	31.59	0.05	0.64	43.01	1576.12
Crop combination	3	0.32	2925.96*	0.02	7.67*	226.23*	1061.33*
Cultivar x crop combination	3	0.16	446.86*	0.07	0.81	42.33	114.33
Plant density x crop combination	6	0.12	62.34	0.03	0.08	7.76	190.66
Cultivar x density x crop combination	6	0.04	59.14	0.03	0.22	4.53	177.66
Sub sub plot error$_3$	36	0.46	77.97	0.03	0.47	64.21	206.97
* Significant at 5%	$CV_{(1)}$	12.8	10.0	8.7	7.7	30.2	23.5
CVs are in percentages	$CV_{(2)}$	13.1	10.2	4.5	3.7	20.6	17.1
	$CV_{(3)}$	11.1	16.0	3.5	3.2	25.3	6.2

increase in intercrop ratio. This reduction in yield due to intercropping was within range of 14 - 22%.

4.3.4. Effect of intercropping and plant density on yield components of maize.

Table 29 shows how yield components of maize were affected by intercropping and plant density. Yield components such as rows/cob, kernel/row and 100 seed weight were not affected by either intercropping or plant density. Significant differences were not observed among treatments for these traits.

(a) Number of cobs per plant

Intercropping reduced number of cobs per plant. Plots with pure stand maize had more cobs per plant than intercrop maize. However, cobs/plant in pure stand maize was not significantly different from intercrop ratios of 1:1 and 1:1.75. Intercrop ratio of 1:2 had 17% less cobs/plant than monocultural maize. Plant density did not affect number of cobs/plant.

(b) Kernel yield per plant

Yield per plant was affected by intercropping but not by plant density. It was observed that maize in pure stand plots had significantly higher yield/plant than intercropped maize. Yield/plant in pure stand plots was 110.8 g and it decreased as intercrop ratio increased. Yield reduction varied between 22 and 39%, the highest reduction corresponding to an intercrop ratio of 1:2 (pigeonpea:maize).

4.3.5 Land productivity

Table 30 shows land equivalent ratio (LER). Generally intercropping pigeonpea + maize reduced yield of pigeonpea per unit area but increased maize yield per unit area at all plant densities compared to pure stands. Yield reduction in pigeonpea by intercropping was 5 to 16% for NPP 670 and 11 to 24% for Katheka. Although the yield of pigeonpea per unit area in intercropping was less than in pure stand, total grain yield (pigeonpea + maize) for the equivalent area was higher.

The two pigeonpea cultivars showed different trends when intercropped. NPP 670 had the least

LER for intercrop ratio of 1:1 but increased with increase in intercrop ratio reaching a maximum at a ratio of 1:1.75 and declined thereafter. The highest LER of 2.22 was attained when 31746 plants (pigeonpea) were intercropped with 57142 plants (maize) giving a total density of 88888 plant/ha. A yield advantage of 122% was realized.

For Katheka LER increased with an increase in intercrop ratio, reaching a maximum at an intercrop ratio of 1:2. At this ratio LER was 2.52 and 31746 plants (pigeonpea) were intercropped with 76190 plants (maize) giving a total density of 107936 plants/ha and a yield advantage of 152% was realized.

Table 29. Effect of intercropping maize with pigeonpea at three densities on yield components of maize. Short rains 1986, at Kiboko.

Crop combination	Intercrop ratio PP*:M**	Plant density (plants/ha) Pigeonpea	Maize	Total	Cobs/plant (no)	Rows/cob (no)	Grains/row (no)	Weight of 100 seed (g)	Yield/plant (g)
Maize monoculture	-		53333	53333	1.0	12.7	29.5	32.1	92.2
			44444	44444	1.1	12.1	30.5	31.6	105.7
			38095	38095	1.2	12.7	29.2	36.1	132.7
Maize + NPP 670	1:1	44444	53333	97777	1.2	11.7	27.1	31.6	105.9
		37037	44444	81481	0.8	12.1	31.3	31.4	81.5
		31746	38095	69841	1.1	12.5	29.7	33.8	101.2
Maize + NPP 670	1:1.75	44444	79999	124443	1.0	12.7	28.3	28.3	80.0
		37037	66666	103703	0.9	11.3	29.5	35.2	76.8
		31746	57142	88888	0.9	11.3	26.7	31.6	81.6
Maize + NPP 670	1:2	44444	106666	151110	0.9	11.7	29.1	30.5	71.1
		37037	88888	125925	0.9	12.7	28.2	30.3	65.8
		31746	76190	107936	0.9	12.3	28.5	31.3	76.2
Maize + Katheka	1:1	44444	53333	97777	1.1	12.0	31.6	30.9	105.6
		37037	44444	81481	1.2	12.5	28.3	27.9	104.7
		31746	38095	69841	0.8	13.2	31.6	33.9	86.3
Maize + Katheka	1:1.75	44444	79999	124443	0.9	12.3	28.8	30.8	79.2
		37037	66666	103703	1.0	12.0	30.6	28.9	69.5
		31746	57142	88888	0.9	11.5	26.5	32.7	77.1
Maize + Maize	1:2	44444	106666	151110	0.8	12.0	26.7	28.4	41.4
		37037	88888	125925	0.9	12.4	28.5	28.7	64.2
		31746	76190	107936	1.0	12.5	28.0	30.5	91.4
		$LSD_{(0.05)}$	Main plot						
			Sub plot						
			Sub sub plot		0.12				16.02

PP* = Pigeonpea
M* = Maize

Table 30. Effect of intercropping two cultivars of pigeonpea at three densities and maize on grain yield and land equivalent ratios (LER). Short rains 1986 at Kiboko.

Crop combination	Intercrop ratio PP*:M**	Plant density (plants/ha)			Grain yield (kg/ha) [a]			
		Pigeonpea	Maize	Total	Pigeonpea	Maize	Total	LER
Maize monoculture			53333	53333		4142.9	4142.9	
			44444	44444		3346.3	3346.3	
			38095	38095		2619.6	2619.6	
Katheka monoculture	-	44444		44444	1277.0		1277.0	
		37037		37037	1409.8		1409.8	
		31746		31746	996.9		996.9	
NPP 670 monoculture	-	44444		44444	1577.8		1577.8	
		37037		37037	1538.3		1538.3	
		31746		31746	1430.7		1430.7	
1 row NPP 670 + 1 row maize planted at 1 plant per hill	1:1	44444	53333	97777	1514.1	4414.2	5928.3	2.03
		37037	44444	81481	1360.5	3406.7	4767.1	1.90
		31746	38095	69841	1204.2	3480.9	4685.1	2.17
1 row NPP 670 + 1 row maize planted alternating 2 and 1 plant per hill	1:1.75	44444	79999	124443	1288.9	4984.6	6273.5	2.02
		37037	66666	103703	1204.9	4450.9	5655.8	2.11
		31746	57142	88888	1061.4	3876.7	4938.1	2.22
1 row NPP 670 + 1 row maize planted at 2 plants per hill	1:2	44444	106666	151110	1223.7	5632.5	6856.2	2.14
		37037	88888	125925	1169.1	4705.9	5875.0	2.17
		31746	76190	107936	1044.2	3631.7	4675.9	2.12
1 row Katheka + 1 row maize planted at 1 plant per hill	1:1	44444	53333	97777	1146.7	5145.0	6291.7	2.14
		37037	44444	81481	1076.5	4079.2	5155.7	1.98
		31746	38095	69841	831.8	2837.5	3669.3	1.91
1 row Katheka + 1 row maize planted alternating 2 and 1 plant per hill	1:1.75	44444	79999	124443	1155.5	5766.7	6922.2	2.29
		37037	66666	103703	1190.1	3817.1	5007.2	1.98
		31746	57142	88888	826.5	2879.2	3705.7	1.93
1 row Katheka + 1 row maize planted at 2 plants per hill	1:2	44444	106666	151110	1062.2	3961.7	5023.9	1.79
		37037	88888	125925	1116.0	4692.5	5808.5	2.19
		31746	76190	107936	866.7	4311.7	5178.4	2.52

PP* - Pigeonpeas
M** - Maize

[a]Grain yield/plant converted into yield/ha by plant population factor.

CHAPTER V

5.0 DISCUSSION

5.1 Effects of intercropping and plant density on growth and development of pigeonpea and maize

(a) Time to flowering and maturity

Intercropping and plant density did not influence time of flowering and maturity at the three locations. Variability in days to flower and maturity were attributed to the inherent characters of the cultivars used for this study as well as temperature.

It was observed that NPP 670 flowered and matured earlier than Katheka. NPP 670 being an early maturing cultivar flowered within 120 - 150 days after planting (first flush). Katheka flowered within range of 160 - 220 days after planting. However, locational differences were observed such that plants at Kabete which is at 1820 metres above sea level (MASL) flowered earlier than those at Thika and Kiboko (1600 and 875 MASL, respectively). This is in agreement with Sheldrake (1984) who reported that cultivars he observed did not flower at 500 MASL but flowered under cooler conditions of 2000 MASL. Flower initiation and development was possibly influenced by temperature because the higher the altitude, the lower the temperature. Kabete had a mean daily temperature of 23.7°C compared to 25.9°C and 30.9°C for Thika and Kiboko respectively. Turnbull et al; (1980) reported that floral initiation of pigeonpea occurred soonest in day temperature regime close to 24°C and was delayed by increasing either day or night temperature, however increased temperature promoted the development of the flower buds once they had been initiated. Since pigeonpeas are short day plants,effect of temperature on flowering seems to be the reduction in requirement for short days under relatively cool conditions.

For maize the reverse was true. Maize at Kiboko (warm conditions) flowered 10 and 20 days earlier than at Thika and Kabete, respectively. This observation agrees with that of Duncan (1975) who reported that environments with lower temperature have slower development rates of maize and suggested that the rate of development of maize from planting to anthesis is a function of temperature rather than photosynthesis.

Time to flowering and maturity was not affected by either intercropping or plant density but was influenced by temperature regimes. These observations do not concur with those of Nadar (1980), who reported that pigeonpeas intercropped with maize had delayed flowering and reached maturity three weeks later than the pigeonpea in pure stand. This discrepancy could be due to the genotypes and the environmental conditions under which they were grown.

(b) Leaf area

In pigeonpea cultivars, leaf area was reduced by the increase in plant density. Generally as plant density increased, leaf area decreased and the reduction varied between 20 and 27%. In the early stages of growth i.e. 5 W.A.G.$^+$, the reduction was lower than at 10 and 12½ W.A.G.$^+$ because competition from maize at 5 W.A.G.$^+$ was not yet high. When maize was in the reproductive stage, reduction in leaf area increased because maize was possibly using most of the assimilates for grain filling. These results are in contrast to those reported by Natarajan and Willey (1979) who reported that pigeonpeas grown at high density had high leaf area. This is because the leaf area reported in this work was based on a per plant basis whereas their work was based on per unit area. Leaf area of maize was not affected by plant density. This might explain better competitive ability of maize over pigeonpeas.

Intercropping reduced leaf area of both pigeonpea and maize. Either pigeonpea or maize in pure stand had higher leaf area than intercropped plots. The reduction in leaf area increased with an increase in intercrop ratio. An intercrop ratio of 1:2 had the lowest leaf area per plant.

Pigeonpea leaf area was severely reduced especially at 12½ W.A.G.[+] when the reduction ranged between 40 and 70%. This was the time when maize was at the grain filling stage. Maize leaf area reduction at the same time ranged between 15 and 35%. Okigbo (1979) reported that intercropping affected leaf area of intercrops but effects varied with crops. Enyi (1973) also reported that intercropping cereal + non-cereal led to a reduction in leaf area of both crops.

Duncan (1975) reported that leaf area produced on the main stem of maize plants does not decrease in inverse proportion to an increase in plant density. This could be explained by the fact that maize leaves are well separated on the stalk, ensuring ventilation within the canopy and a minimum close overlapping thus giving favourable light exposure. Maize therefore intercepted more light necessary for photosynthesis than the accompanying pigeonpea, resulting into less reduction in leaf area of the former than the latter.

Coefficient of variation values are very high suggesting that there were some experimental error probably due to sampling technique used.

(c) Shoot dry weight (matter)

Increase in plant density of pigeonpeas increased shoot dry matter at Thika and Kiboko but decreased it at Kabete. Although the reason is not apparent, it is possible that environmental differences (e.g. radiation) could have been the major contributing factor. However, these results agree with that of Natarajan and Willey (1980a) that an increase in pigeonpea density increased dry matter yield of pigeonpeas. Contrasting results were reported by Singh and Kush (1980) that pigeonpea dry matter yield was not significantly different at all densities they studied.

In maize plant density reduced shoot dry matter yield at Kabete and Kiboko but not at Thika. These results also suggest an environmental influence on shoot dry weight apart from the variation in plant density.

Intercropping reduced dry weight of both maize and pigeonpea without any significant locational differences. It was observed that as intercrop ratios increased, dry weight in both crops decreased consistently. In pigeonpeas dry weight reduction due to intercropping varied between 46 to 70% during the growth period. In maize the reduction was between 20 and 40%. The highest percent reduction corresponding to an intercrop ratio of 1:2 (pigeonpea: maize). These results agree with those reported by Okigbo (1979) who observed that total dry matter was reduced by intercropping and dry weight yield of different parts of the crop were significantly affected. Edge and Liang (1980) reported that total dry matter of maize in intercrop was 60% less than that of maize in pure stand.

Despite the genotypic and environmental variations, intercropping reduced dry weight of component crops but the reduction in pigeonpeas was higher than that in maize. This probably could be explained by the growth habit of the two crops. Maize having faster growth than pigeonpeas shaded the pigeonpeas thus inhibiting it from intercepting adequate light, resulting into adverse effects on pigeonpeas. This observation is supported by Duncan (1969) who reported that shaded plants gained weight more slowly than less shaded ones. He reported that a plant 10 cm shorter than those surrounding it would be deficient in the production of dry matter (at low population) by 20% and at high populations by almost 50%. In this study shoot dry weight decreased consistently as intercrop ratio was increased.

(d) Plant height

The early maturing cultivar i.e. NPP 670 was generally shorter than the late maturing cultivar, Katheka. This was due to the genotypic characteristic inherent within the cultivars. However, locational differences in plant height were observed. At harvesting time, NPP 670 Plants at Kiboko were taller (162.9 cm) than at Thika (107.3 cm) and Kabete (86.1 cm). At Kiboko, Thika and Kabete plant height for Katheka were 300.0, 254.3 and 209.2 cm, respectively. Ishizuka (1969) reported that cool temperatures retarded translocation of assimilates and as a result plants in cool places were shorter than those in warm places. Kimani (1985), reported that plants at Kiboko grew taller than at Thika and Kabete. This can solely be attributed to variation in temperature. Results suggest that cool temperature reduced plant height possibly due to retardation of translocation of assimilates while warm temperature hastened it.

Generally, intercropping reduced plant height of pigeonpeas. At Kiboko and Thika (at harvesting time) intercropped pigeonpeas were 26% shorter than pure stand pigeonpea. At Kabete, 15 W.A.G.[+], intercropped pigeonpeas were shorter than monocrop but the reverse was observed at harvesting time. Although the reason for this is not apparent, it could be attributed to competition induced by intercropping. Duncan (1969) reported that shaded plants had an increased shoot/root ratio i.e. the more shaded plant invests a decreased part of its resources in roots so that its root system is smaller and shallower than its more favoured neighbours.

However moisture and fertility stress could have added to the increase in probability of suppression.

Maize showed a different trend from that of pigeonpeas. Intercropped maize had plants that were 1 to 10% taller than monocultural maize. There were no locational differences. This observation is in agreement with Duncan (1969) who reported that the height of corn plants increased with increasing plant population. He termed it "cooperative competition". The possible reason could be competition for light due to increased plant population. Shaded plants elongate more rapidly than unshaded ones thus resulting into tall plants.

The contrasting observations i.e. increase in plant height of intercropped maize versus decrease in height of intercropped pigeonpeas suggest that crop species differ in their responses to intercropping. Maize having "cooperative competition" and favourable canopy structure grew taller than pigeonpeas in intercrops thus suppressing it and could be attributable to reduced leaf area and shoot dry weight of pigeonpeas.

5.2 Effect of intercropping and plant density on yield and yield components of pigeonpeas.

(a) Number of primary branches per plant

Results from the three locations indicated that cultivars differed in number of primary branches per plant. At Kabete and Thika, Katheka had more primary branches than NPP 670. Katheka had an average of 8.5 while NPP 670 averaged 6.5 branches/plant. In contrast, Katheka at Kiboko averaged 5.5 while NPP 670 maintained 6.5 branches/plant. The reason for this difference is not clear. However, the tallest plants at Kiboko would have used the resources to increase the height of plants instead of expanding sideways. This suggests a genotype x environment interaction for this trait.

Plant density and intercropping did not influence branching habits of pigeonpeas, suggesting that branching is highly heritable and only slightly influenced by environment.

(b) Number of pods per plant

Pods per plant decreased with increasing plant density but the effect was not significant at

Thika and Kiboko. At Kabete however, plant density of 44444 plants/ha had 16 to 35% fewer pods than density of 31746 plants/ha. As mentioned earlier, this would possibly reflect the intra and inter plant competition for decreasing resources as plant density increased.

Monoculture plots had more pods per plant than intercropped plots of pigeonpeas. Intercropping therefore reduced number of pods per plant. The reduction varied with intercrop ratios. The higher the intercrop ratio, the fewer were the number of pods per plant. This suggests that under conditions of inadequate supply of growth resources, initiated flower buds would abort resulting into fewer mature pods per plant. Ogombe (1978), reported that plant density reduced number of flowers initiated and number of mature pods. Sheldrake (1984) reported that 90% of flowers in pigeonpeas shed without setting pods due to (a) pests damage (b) inadequate pollination (c) competition from other sinks within the plant for assimilates and (d) hormonal factors (intrinsic physiological mechanisms).

Cultivars also had significant differences in number of pods per plant. Kimani (1985) reported similar results. Katheka had more pods per plant than NPP 670 at Thika and Kabete. This could be attributed to high number of primary branches for Katheka at these two experimental sites. The interaction between cultivar and crop combination was significant suggesting that the effect of crop combination on number of pods per plant differed from one cultivar to another.

(c) Number of seeds per pod

Cultivars showed little response in number of seeds per pod to both plant density and intercropping; but there was variation in number of seeds per pod among locations. At Kabete and Thika, Katheka had more seeds per pod (6.1 and 5.9, respectively) than NPP 670 which had an average of 4.9 and 5.2 for Kabete and Thika, respectively. However at Kiboko, Katheka had 5.1 while NPP 670 had 5.5 seeds/pod but this difference was not significant. Sheldrake (1984) reported that seeds/pod of a cultivar is constant but these results suggest that they can be influenced by environment.

(d) Seed weight

There were no cultivar differences for seed weight at all experimental sites. Although Katheka had heavier seeds (21.5 g) than NPP 670 (20.5 g) this difference was not significant.

Locational differences were observed on the effect of intercropping on this trait. At Kiboko, intercropping significantly depressed seed weight but at Thika and Kabete, the reduction was not significant. The reduction in seed weight at Kiboko due to intercropping varied between 3 and 11% depending on the intercrop ratio. This agrees with Kimani (1985) who reported that 100-seed weight was decreased by intercropping and indicated that this reduction may explain the yield reduction in pigeonpeas intercropped with cereals.

The reduction in seed size of intercropped pigeonpea at Kiboko was probably due to water stress since Kabete and Thika had higher rainfall during the growing season than Kiboko (Appendix 4)
With increased population levels, plants competed for assimilates which were probably inadequate thus there was poor pod filling and consequently small seeds. Slatyer (1969) reported that water deficits reduced rates of organ development and cell enlargement since nutrient flow and protein and carbohydrate synthesis and metabolism are affected. After

flowering, water stress hastened rather than slowing maturations, hence pod filling time was shortened resulting into small seeds.

(e) Grain yield per plant

Plant density significantly affected grain yield per plant at Kabete but not at Thika and Kiboko. Results indicated that grain yield/plant decreased with an increase in plant density and the decrease was consistent especially at Kabete. This reduction was possibly due to competition for assimilates. Although Kabete has soils of medium fertility, there was higher rainfall than at the other two sites. In this aspect, nutrients could have leached beyond root-zone causing inadequate supply to the growing plants. Other factors could be radiation intensity and sunshine hours being less at Kabete than at Thika and Kiboko which could have reduced the photosynthetic ability of plants.

Intercropping depressed grain yield per plant. Pure stand pigeonpea had higher yield/plant than intercrop. Yield reduction at Kabete ranged between 37 and 44% while at Kiboko it was between 14 to 22%. Higher percent reduction corresponded to the highest intercrop ratio of 1:2 (pigeonpea:maize). This reduction was attributed to competition for assimilates as crop combination increased. The significant interaction between cultivar x crop combination at Kabete, suggested that grain yield per plant was reduced as intercrop ratio was increased. Reduction in grain yield/plant could however be compensated for by the fairly stable 100-seed weight and increased plant population per hectare.

5.3 Effect of intercropping and plant density on yield components of maize.

Maize yield components such as number of rows per cob, kernels per row and 100-seed weight were not influenced by either plant density or intercropping. This suggested that such attributes are highly heritable and may not be influenced by environment.

(a) Number of cobs per plant

Intercropping reduced number of cobs per plant at Kabete and Kiboko by 17 to 18%, and this reduction was dependent on intercrop ratio. As intercrop ratio increased, cobs per plant were reduced. This could be attributed to competition of component crops in intercropping. Higher plant populations result into suppressed, starved, spindly and barren plants.

(Duncan, 1969). As earlier mentioned that intercropping increased height of maize, this elongation of plant could have decreased stalk strength therefore causing lodging in intercropped plots.

However it is difficult to rule out that number of cobs per plant was reduced by competition induced by intercropping alone because at Thika, significant reduction in cobs/plant were not observed in intercrop maize. However, these results suggest that most of the resources competed for, were in adequate supply at Thika than either at Kabete or Kiboko.

(b) Grain yield per plant

Intercropped maize had lower grain yield per plant at Kabete and Kiboko but not at Thika. Pure stand maize produced 20 to 30% more grain than intercropped maize. Like in number of cobs/plant, grain yield reduction was dependent on the intercrop ratio. The reduction in grain yield/plant was more pronounced when yield was converted on hectare basis. As mentioned earlier, intercropping reduced dry matter accumulation in maize which might have resulted into grain yield decrease.

5.4 Land productivity

Intercropping maize and pigeonpeas reduced yield, especially that of pigeonpeas. Yield reduction per hectare in pigeopea varied from 5 to 25% whereas yield of maize intercrop compared well with that of pure stand. Agboola and Fayemi (1971) reported that in a cereal + legume intercrop, yield of legume was more depressed than that of a cereal. Dalal (1974) reported that growing maize with pigeonpeas increased grain yield of maize but not of pigeonpeas; while Kimani (1985) reported that yield reduction in pigeonpeas grown with maize was 52.7%.

The reason for yield depression in pigeonpea could be attributed to slow growth at early stages; hence less competitive ability. Maize with fast early growth, utilised the available growth resources and thus established itself faster than pigeonpeas. The reproductive stage of maize was reached when pigeonpeas had not yet induced severe competition to maize. Another factor would be the difference in growth pattern and canopy structures of the two crops. Maize plants have inclined leaves while pigeonpeas have horizontal leaves. The former intercept more light hence maintain a relatively constant rate of photosynthesis while in the latter, there is less photosynthetic activity due to self shading and overlapping of leaves. Similar results were reported by Evans (1975) and Duncan (1975).

Although maize was harvested before pigeonpeas had reached the reproductive stage, drought and pest infestation could have contributed to yield reduction. NPP 670 came into flower when there was no other host for flower pests. Most of the flowers were destroyed by the pod fly (Melanagromyza sp.). Secondly, pigeonpeas flowered during the dry spell (March, June and July). Moisture stress led to flower abortion/abscission resulting into fewer mature pods/plant. Coupled with these, is the inherent characteristic of 90% flower abortion in pigeonpea which consequently lead to poor pod set.

Despite the yield decrease of pigeonpea in intercrop, total yield of intercrop (pigeonpea + maize) per hectare was higher than for monocrops. All intercrop combinations showed positive land equivalent ratio values (>1) indicating that for similar yield of monocrop, more land would be required.

At Kabete and Kiboko, intercropping NPP 670 with maize at a ratio of 1:1.75, respectively gave highest LER of 2.58 for Kabete and 2.22 at Kiboko. For Katheka at same locations, highest LER were obtained at an intercrop ratio of 1:2 (Katheka:maize). At Kabete it was 3.01 while at Kiboko it was 2.52. The difference in LER at these two locations indicate that although plant population in the intercrops were the same at these locations, Kabete had higher yield advantage from intercropping than other sites probably due to different agro-ecological conditions.

At Thika, NPP 670 intercropped with maize gave the highest LER of 2.12 at an intercrop ratio of 1:2 (NPP 670:maize) and for Katheka, the highest LER of 2.26 was attained at an intercrop ratio of 1:1.75 (Katheka:maize, respectively). This agrees with Chui (1987) that maize intercropped at 2 plants/ hill with pigeonpea gave higher yields than at 1 plant/hill.

The varietal differences in optimum intercrop ratio for optimum LER suggest that each genotype has an optimal density at which it can be intercropped, thus attaining the highest yield advantage.

The locational difference in intercrop ratio and LER value were possibly due to environmental effects such as:-

(a) Difference in rainfall - Kabete had more rainfall during the cropping season than Thika and Kiboko (Appendix 4). implying that plants at Kabete had lower moisture stress compared to plants at the other two sites. This is reflected in higher LER values at Kabete than the other two sites.

(b) Difference in temperature - Kiboko had the highest temperature (Appendix 5) hence favouring vegetative growth at the expense of reproduction. This was reflected in plant height of pigeonpeas resulting into very tall plants, less number of primary branches and consequently lower yields than at Kabete and Thika.

(c) Nutrient supply - experimental locations had different soil types and fertility levels. Kabete soils although fertile, nutrients could have leached due to high rainfall, thus nutrient availability became a limiting factor. Thika soils have moderate fertility, coupled with medium rainfall, soils could support more plants/unit area than the other two sites. These results therefore suggest that Thika had more available environmental resources to nourish the plants better than either Kabete or Kiboko.

CHAPTER VI

6.0 CONCLUSIONS

6.1 Time to flowering and maturity is an inherent character of a genotype, therefore there are early, medium and late genotypes. However, this character is influenced by temperature.

Pigeonpea grown at high altitude where the temperatures are cool, flower and mature earlier than at low altitude where temperatures are warm. In contrast, high altitude and cool temperatures delay flowering and maturity of maize but warm temperatures and low altitude hasten time to flowering and maturity.

6.2 Intercropping and plant density depressed leaf area and shoot dry weight of both pigeonpea and maize. The depression in leaf area however was higher in pigeonpeas (40 to 70%) than in maize (15 to 35%). Shoot dry weight reduction was higher in pigeonpeas (46 to 70%) than in maize which was 20 to 49%.

It could therefore be concluded that intercropping and plant density reduced vegetative growth of both component crops, the reduction being higher in pigeonpeas than in maize. This was also reflected in grain yield of intercropped pigeonpeas compared to pure stand. Since there were little locational differences for these characters, it can be concluded that intercropping and plant density reduce leaf area and shoot dry weight of component crops with little or no environmental influence.

6.3 Plant height

Plant height is characteristic of a genotype. Early maturing cultivar, NPP 670 was shorter than the late maturing, Katheka at all the experimental sites. However, locational differences within cultivars were observed such that plants were the tallest at Kiboko, medium height at Thika and were the shortest at Kabete. This could be concluded as temperature effect on plant height. High temperature favour vegetative growth while cool temperature retard translocation of assimilates resulting into shorter plants than at warm temperature. Kiboko had the highest day temperature of 30.9°C, Thika was 25.9°C and Kabete was 23.9°C during the period of study.

In general intercropped pigeonpeas were shorter than in pure stand but maize had a reverse trend. These two crops had different interactions when intercropped. Maize had a "cooperative interaction" i.e. increase in plant height when intercropped. Pigeonpeas had "competitive interaction" when intercropped. This could be possibly due to canopy structure i.e. angled leaves of maize versus horizontal leaves of pigeonpeas.

6.4 Yield components of pigeonpoeas that were affected by either intercropping or plant density included:-

(a) Number of mature pods per plant

(b) Grain yield per plant

Reduction in 100-seed weight was both location and cultivar dependent. The reduction in 100-seed weight was probably due to moisture stress hence reduced rates of organ development and cell enlargement because of reduced nutrient inflow.

Reduction in number of mature pods and grain yield per plant could also be attributed to flower and pod suckers apart from moisture availability.

In general, Katheka had more branches, pods, grain yield and bigger seeds than NPP 670.

6.5 Yield components of maize affected by intercropping and plant density included:-

(a) Number of cobs per plant

(b) Grain yield per plant.

Increased plant population and intercropping resulted into starved, spindly and tall plants with weak stems which might have increased lodging and barreness. Reduction in these two traits contributed to the depression in yield of intercropped maize although the reduction in most cases was not significant. However compensation for these reductions probably came from fairly stable 100-seed weight.

6.6 Intercrop ratios and spatial arrangement.

Intercrop ratios that produced the highest yield advantages were 1:1.75 and 1:2 (pigeonpea:maize, respectively). Although LERs were highest at these intercrop ratios, yield per plant decreased due to increased plant population per unit area.

In view of this one would recommend intercropping of pigeonpeas with maize at an interrow spacing of 105 cm at all the experimental sites. Spatial arrangement would be planting one row of pigeonpea alternating with one row of maize giving an intercrop ratio of 1:1. Plant densities would be 31746 and 38095 for pigeonpea and maize respectively, giving total density of 69841 plants per hectare.

6.7 Land efficiency/productivity.

Land efficiency was increased by intercropping pigeonpea with maize suggested by land equivalent ratio (LER) values.

Results indicated that although yield of component crops in intercrop was lower than of monocrops, total yield per unit area was increased by intercropping. This was probably due to the increase in plant population per unit area in mixtures.

This study was conducted for only one year therefore it is not conclusive. However, from the results it can be concluded that there is high potential in intercropping pigeonpea with maize as it is commonly practised by farmers in semi-arid areas. Intercropping pigeonpea with maize in the arrangement that one row of pigeonpea is alternated with one row of maize at an interrow spacing of 105 cm would give the best intercrop ratio.

In conditions of moisture stress e.g. semi arid areas, NPP 670 is more tolerant to drought than Katheka as it was indicated by yield results from Kiboko (NPP 670 and higher yields than Katheka).

This study was conducted for only one year, therefore the results reported here are not conclusive. Further investigation should incorporate more variables like radiation intensity, soil fertility analysis, night temperature recording, percent lodging and barreness in maize and gross returns. These should be repeated over several locations and seasons so that one may come up with conclusive recommendations for different localities.

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APPENDICES

Appendix 1. Weather conditions during the planting season 1986/87 at Kabete.

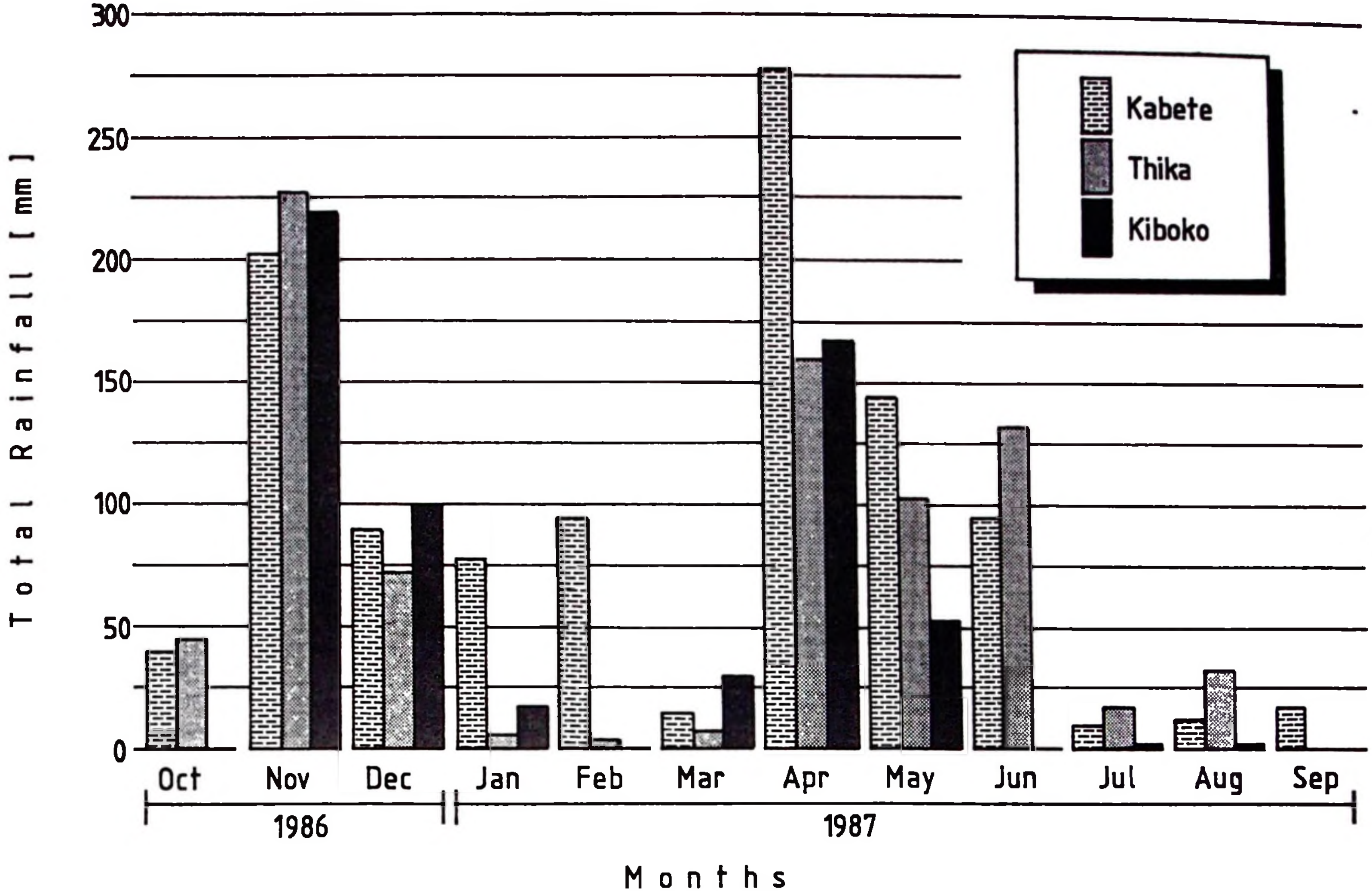
Year	Month	Total Rainfall (mm)	Mean atmospheric temperature (°C)	
			Max.	Min.
1986	October	40.4	25.1	13.1
"	November	202.0	21.8	13.5
"	December	91.5	22.8	12.5
1987	January	79.5	23.8	12.7
"	February	95.5	25.4	12.5
"	March	15.4	26.8	10.5
"	April	278.9	24.4	14.3
"	May	145.0	23.1	13.7
"	June	95.1	21.7	11.6
"	July	9.4	21.2	10.6
"	August	12.5	21.6	11.5
"	September	17.4	26.8	13.8
	TOTAL	1082.6	-	-
	MEAN	-	23.7	12.5

Appendix 2. Weather conditions during growing season at Thika (1986/87)

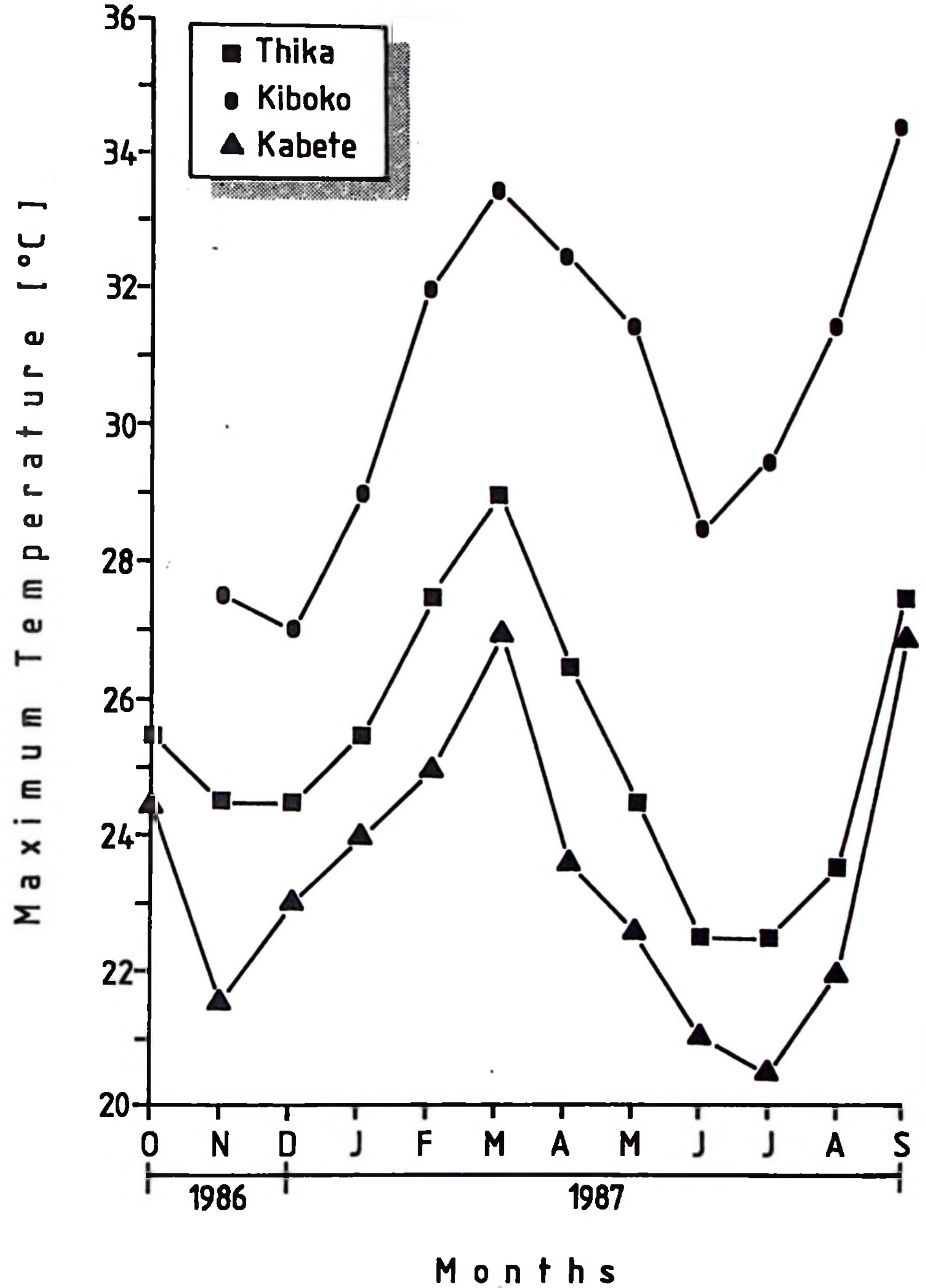
Year	Month	Total Rainfall (mm)	Mean atmospheric temperature (°C)	
			Max.	Min.
1986	October	44.5	27.0	14.9
"	November	227.3	24.5	15.3
"	December	73.1	24.3	14.6
1987	January	5.7	26.2	13.4
"	February	3.6	28.1	13.1
"	March	6.3	29.8	13.8
"	April	159.9	26.8	15.0
"	May	102.5	25.3	20.4
"	June	137.5	23.6	14.0
"	July	18.6	23.5	12.6
"	August	33.9	23.8	12.9
"	September	Nil	27.3	13.7
	TOTAL	812.9	-	-
	MEAN	-	25.9	14.5

Appendix 3. Weather conditions during the planting season 1986/87 at Kiboko.

Year	Month	Total Rainfall (mm)	Mean atmospheric temperature (°c)	
			Max.	Min.
1986	November	219.8	28.5	17.9
"	December	99.9	27.1	17.2
1987	January	17.0	28.8	16.4
"	February	Nil	31.9	16.6
"	March	29.8	33.7	18.4
"	April	168.2	32.8	18.7
"	May	52.0	31.2	16.8
"	June	Nil	29.3	14.6
"	July	1.0	29.8	13.4
"	August	2.7	31.8	13.2
"	September	Nil	34.8	14.9
	TOTAL	590.4	-	-
	MEAN	-	30.9	16.2



Appendix 4. Comparison of total rainfall at Kabete, Thika and Kiboko during the 1986/87 cropping season.



Appendix 5. Comparison of daily temperature (max) at Kabete, Thika and Kiboko during the 1986/87 cropping season.