CROP PHENOLOGY AND PRODUCTIVITY OF UPLAND RICE/LEGUME INTERCROPPING SYSTEMS

BY

MOHAMED DAYIB SH. ABDURAHMAN
B.Sc(Ag)

Thesis Submitted to the
ANDHRA PRADESH AGRICULTURAL UNIVERSITY
in Partial Fulfilment of the Requirements
for the Award of the Degree of
MASTER OF SCIENCE
in the Faculty of Agricultural Science

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Cropping Systems Unit
Resource Management Program
ICRISAT, Patancheru
A.P. 502 324,
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CERTIFICATE

This is to certify that the thesis entitled:

"Crop Phenology and Productivity of Upland Rice/Legume Intercropping Systems", submitted in partial fulfillment of the requirements for the degree of Master of Science in Agriculture of the Andhra Pradesh Agricultural University, Hyderabad, is a record of the bonafide research work carried out by Mr. MOHAMED DAYIB SH. ABDURAHMAN under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigations have been duly acknowledged by the author of the thesis.

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Mr. MOHAMED DAYIB SH. ABDURAHMAN has satisfactorily prosecuted the course of research and that the thesis entitled "Crop Phenology and Productivity of Upland Rice/Legume Intercropping Systems" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

Mustafa H m

Date: 26.11.1991

Dr. Mir Mustafa Husain
Chairman of the Advisory Committee

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ABSTRACT

The experiment was conducted at ICRISAT Center (India) **during** 1990 rainy season. The experiment was laid out in split **plot design** with planting patterns (ratios) in the main plots **and cultivars** of rice, soybean or pigeonpea in the sub-plots.

In general the season was good and the crop stand of the **sole** and intercrop of rice and soybean were fairly good, but **the** stand of the sole and the intercrop pigeonpea were low due the wilt disease. The rice crop did not show any significant difference between the sole and the intercrop in most of the parameters tested, whereas with soybean and the pigeonpea there was a significant difference between the sole and the intercrop in most of the parameters tested.

Sole and intercrop rice had almost similar leaf, stem, and total dry matter, indicating that planting pattern did not affect the biomass production of the crop. The sole soybean and the sole pigeonpea produced higher dry matter than that of their respective intercrops, because of a higher LAI and consequently higher light interception.

Yield of the rice was relatively poor. The sole rice gave slightly higher yield than the intercrop. The sole soybean and sole pigeonpea also gave higher yields than their respective intercrops.

Intercropped pigeonpea in the (3:1) ratio gave highest partial LER (0.98). The intercrop of rice with pigeonpea in the (5:1) ratio gave highest total LER (1.53) indicating a yield advantage of (53%) over the sole crop.

When comparing root length of the crops, the intercropped rice with soybean gave highest partial LER (0.98). The intercrop of rice and soybean gave a total LER of (1.88), indicating 88% of root growth advantage over the sole crop.

INTRODUCTION

CHAPTER I

INTRODUCTION

Upland rice, refers to rice directly seeded on both flat and sloping fields that are not bunded, and which depends on rainfall for moisture (De Datta and Vergara 1975).

Upland rice is grown on three continents, mostly by small or subsistence farmers in the poorest regions of the world. Grain yields are generally low, ranging from 0.5 to 1.5 t ha^{-1} in Asia; about 0.5 t ha^{-1} in Africa; and from 1 to 4 t ha^{-1} in Latin America. But the area planted in upland rice is so large (nearly a sixth of the world's total rice land) that even a small increase in yield will substantially influence total production.

Upland rice is grown under a wide range of conditions from shifting cultivation in Malaysia, the Philippines, West Africa, and Peru, to highly mechanized systems in parts of Latin America. Soil types vary from infertile acid in West Africa to Oxisol in the Llanos Orientales region of south America to fertile acid soil from volcanic tuff in the Philippines to saline soil in the coastal areas of India.

In India upland rice is usually raised during the kharif (wet) season under rainfed conditions in the highlands. Fields may or may not be bunded. Because of topography and high porosity, soils may be waterlogged for short periods of 2-3 days. Upland rice is also called autumn rice because the crop is direct seeded under dry conditions in May-June and remains in the field until harvest in September to early October (Maurya and Vaish 1984).

Upland rice is cultivated in areas with kharif rainfall ranging from less than 1000 to more than 2000 mm. In many areas the rainy season may be interrupted by a short dry spell, that can cause severe drought stress to upland rice. Land forms of upland rice growing areas vary from low lying valley bottoms (with occasional high water tables) to undulating and steep sloping lands with high runoff and lateral water movement. Upland rice is grown on deep soils of high water-holding capacity as well as shallow soils of low water-holding capacity (Oldeman 1975a).

Moisture for sustained plant growth of upland rice depends on the distribution and amount of the rainfall. Daily rainfall is actually more critical than monthly or annual rainfall. High variability of rainfall distribution is indicated by the high coefficient of variation (60-100%) in most of India with the exception of the west coast, northeast region, and Assam. More than 75% of total rainfall occurs during June-September. The onset of the monsoon and its cessation varies in most areas (National Commission on Agriculture Report 1976).

Improved technologies for upland rice have been given less attention compared to those of lowland rice. However, recently evolved management practices have shown considerable potential for increasing upland rice yields (Mahapatra 1987).

One approach is to increase the intensity of cropping by intercropping with short season legumes. Many crops can be intercropped with upland rice, depending on the length of the growing period and farmer's preference. Investigations at the Central Rice Research Institute (CRRI), Cuttack, revealed that intercropping of legumes (green gram and groundnut), with upland rice resulted in increased yield, land equivalent ratio, and monetary returns per hectare compared to sole cropping of rice both under wet and drought conditions (Rao *et al* 1982).

In areas where sequence cropping is not feasible due to inadequate rainfall in months of October and November an intercropping of short duration rice with long duration pigeonpea (4 or 5 rows of rice followed by one row of pigeonpea) has been recommended. In this system, rice grows vigorously during the early stages and covers the land while pigeonpea grows at a relatively slower rate. Once rice is harvested, pigeonpea recovers rapidly to utilize the residual moisture and space left after rice. This ensure an optimal utilization of soil moisture at deeper depths and rabi (postrainy) rainfall (Natarajan and Willey 1979).

Intercropping of upland rice and a legume crop is advantageous because of better utilization of resources partly because of the difference in canopy formation and in rooting habit. Rice roots are mostly in the upper layers (30 cm) whereas roots of some of the legumes can reach up to more than 2 m.

The objectives of our experiment were :

a) To produce a full crop of upland rice and to select pigeonpea and soybean genotypes which are compatible with upland rice.

b) To measure the light interception and root growth by upland rice and legume intercropping system.

c) To identify the most renumerative and feasible intercropping system of upland rice.

CHAPTER II

REVIEW OF LITERATURE

2.1. ENVIRONMENTS OF UPLAND RICE

2.1.1. Rainfall:

Availability of water is more uncertain for upland rice than for lowland rice because upland fields are not bunded or irrigated. Because upland rice depends entirely on rainfall for its moisture supply, both the amount and distribution of rainfall are important (Jana and De Datta 1971). Usually the lower the rainfall during the growing season, the lower is the grain yield of upland rice (Jana and De Datta 1971). Distribution of rainfall is also a major influence on yields, even in areas with high rainfall of 2,000 mm annual rainfall (Jana and De Datta 1971; De Datta *et al.* 1974a).

In India upland rice is grown under areas of heavy rainfall in Assam, West Bengal, and along the coastal areas of Kerala. It grows under low rainfall conditions in Madhya Pradesh. The growing season is extremely short and rainfall is highly variable in eastern Uttar Pradesh. The upland areas of Bangladesh are similar to those of eastern India.

In upland rice areas of northern Sri Lanka, 875 to 1,000 mm precipitation is received in a short period of 3 to 4 months. In upland areas of Burma, rainfall from May to November can be as low as 500 mm or as high as 2,000 mm (De

Datta and Vergara 1975).

In areas where the rainy season is very short and the rainfall is unevenly distributed like the eastern regions of Indonesia, varieties with growth duration of 90 to 135 days are highly desirable (De Datta and Vergara 1975).

In the Philippines the average yield of 0.66 t ha^{-1} of upland rice were obtained in the low rainfall areas, where rainfall is well distributed but with a maximum period of period of 4 to 5 months. Average yields of upland rice reach 1.1 t ha^{-1} in high rainfall areas where rainfall is evenly distributed throughout the season, but with 3 dry months (De Datta 1974b).

In Western Africa the rainy season may be continuous, or it may be interrupted, depending on the latitude but rain usually begins from March to July. Rainfall distribution is unimodal (having one peak) in areas with short rainy seasons, but in areas with long rainy seasons it is bimodal (having two peaks) in areas with a 1-2 month break from July to August. The region of bimodal rainfall includes south-eastern Ivory Coast, southern Ghana, southern Togo and Benin, and southern Nigeria, up to a maximum latitude of $7^{o}N$. Less important areas of bimodal distribution include south-eastern Guinea and northern Liberia (FAO Inventory Mission 1970).

Considering the rainfall amount and distribution there is a need to develop varieties with wide ranges of maturity and develop cultural practices that suit the rainfall distribution patterns.

For Latin America, Brown (1969) reported that 1,000 mm of annual rainfall, with 200 mm monthly rainfall during the growing season, is adequate for growing upland rice.

Brazil which has by far, the largest upland rice area in Latin America, has rainfall ranging from 1,300 to 1,800 mm; 70 to 80 percent of the rain falls during the upland rice growing season (de Souza 1973).

Rainfall in Peru ranges from 2,000 to 4,000 mm annually, far more than enough to grow one upland rice crop (Sanchez 1972). Kawano *et al.* (1972) reported yields of more than 4 t ha^{-1} in Peru's Amazon basin, with rainfall averaging 200 mm $month^{-1}$, during the growing season.

The daily rainfall is actually more critical than the monthly or annual rainfall. Moisture stress can damage or even kill plants in area which receives as much as 200 mm of rainfall in one day, and then receives no rainfall for the next 20 days. A precipitation of 100 mm $month^{-1}$, distributed evenly, is preferable to 200 mm $month^{-1}$ which falls in 2 or 3 days (De Datta and Vergara 1975).

Tropical cyclones (typhoons and hurricanes) usually occur during the monsoon season, when upland rice is planted. The strong winds may cause lodging in upland rice areas of the northern Philippines, south east Vietnam, Burma, and some parts of India.

2.1.2. Soils of upland rice:

Upland rice soils differ in their nature, soil texture varies from sand to clay; pH varies from 3 to 10; organic matter content varies from 1 to 50 percent; salt content for almost 0 to 1 percent; and nutrient availability, from acute deficiency to surplus (Ponnamperuma and Castro 1972).

Soil texture is one of the most important factors which affect upland rice growth when moisture and mineral nutrients are in adequate amounts (Moorman and Dudal 1965). Soil texture affects the moisture status of the soil and is particularly important in upland rice fields which have no bunds to hold moisture.

The textural profile includes not only the surface layers but also the layers below. If the sub-soil has sufficient clay content, the importance of the surface soil texture diminishes. In a clayey profile, a surface horizon that is of medium texture may be the most favorable rice soil, possibly because of greater pore space (Grant 1960). A surface soil of medium texture can also be easily worked. Less water is necessary for initial rice growth because less water is lost through cracks than from a soil with a clayey surface (De Datta and Feuer 1975). Hydromorphic soils (soils in which ground water is shallow or at the surface during the growth cycle) are considered suitable for upland rice. Research at the International Institute of Tropical Agriculture shows a marked correlation between the depth of ground water and the growth and production of upland rice (Moorman 1973). OS6, an upland variety from West Africa, was more tolerant of drought than was IR20 when the depth of ground water was about 80 cm.

Moorman and Dudal (1965) and Higgins (1964) also found satisfactory correlations between yield levels and textures of the soil in northern Nigeria; coarse textured soils produced the lowest yields.

Upland rice soils vary in their textures. For example, loamy and sandy soils are typical of the slightly elevated areas of Thailand's foothills and flat lands, but most upland rice in the hills is cultivated on clayey and clay loam soils (Brady 1974). In Batangas, Philippines, where upland rice is grown in alfisols, the soil texture varies from clay loam to loam (Buol *et al.* 1973).

Soil surface structures may develop under dry conditions, depending on the soil texture and the nature of clay minerals found in the soil. The surface structure of dry sandy soils is usually weak and crumbly, and that of medium-textured soils may be slightly more crumbly or granular. Polygonal cracks may form upon drying of soils which have sufficient clay of the shrinking-swelling types. The crumbly and granular structures are common in upland rice soils, although the highest yields are generally obtained on clayey soils (Aubert and Tavernier 1972; United States Department of

Agriculture 1967).

Oxisols cover minor upland rice areas in South-East Asia. They are found in the lower areas in Sarawak, Malaysia, the mountainous Ban Me Thuot area of South Vietnam (Tung 1973).

The soil is acidic in many upland rice areas of Southeast Asia. Ultisols are much more common in Sumatra and Kalimantan, Indonesia and in Thailand. Alfisols are more common in very dry zones and developed from base materials, on geomorphically young landscapes (United States Department of Agriculture 1966).

In West Africa, both the capacity of the soil to hold water and rainfall distribution help determine the success or failure of upland rice. Most upland rice soils in West Africa have low capacities to hold available water, so even short period of dry spells reduce grain yields. Some upland rice varieties can withstand such dry spells, although prolonged drought would kill the plants or cause low yields (Moorman 1973).

In case of lower slopes, the land forms offer better edaphic conditions for growing rice. In the dryer parts of West Africa, these may be the only areas suitable for rainfed rice culture (Moorman 1973). The small quantities of water from runoff, however, can seldom avert moisture stress damage to the rice crop during prolonged drought.

Soil structure helps determine a soils capacity to hold moisture, as well as the plant's capacity to develop roots. Soils which are prepared dry do not lose their structure.

2.2. YIELD POTENTIAL AND ITS COMPONENTS

Several seasons of testing on well-drained upland fields at International Rice Research Institute (IRRI), Los Banos, Philippines have shown that the average yields of traditional upland varieties, are limited to about 3 t ha^{-1}, while short-statured lowland varieties, such as IR8, IR5 can often produce yields slightly more than 4 t ha^{-1} (Chang *et al.* 1972; IRRI 1972, 1973). Under the most favorable climatic and soil conditions in the Philippines, about 4 t ha^{-1} seems to be the upper limit for most traditional upland varieties, while IRRI varieties may yield nearly 7 t ha^{-1} with high rates of nitrogen (Jana and De Datta 1971; De Datta and Beachell 1972; IRRI 1973, 1974). Similarly semidwarfs grown under upland conditions in the Peruvian jungle have produced up to 6 t ha^{-1} in seasons of heavy rainfall with high fertilization (Kawano *et al.* 1972).

Under drought conditions, however, all rice varieties yield poorly despite heavy fertilization and effective weed control (Jana and De Datta 1971; IRRI 1971, 1972, 1973). So, absolute grain yields reflect some degree of drought avoidance more than drought tolerance, particularly if the crop is harvested before water stress ends (Levitt 1972). But when drought ends before harvest, grain yield depends more on the ability to recover from drought.

The low tillering capacity of most upland varieties is the main restraint to higher yields (IRRI 1971; Ono 1971; Jana and De Datta 1971; Abifarin *et al.* 1972; Chang *et al.*1972; De Datta and Beachall 1972; Kawano *et al.* 1972). But the upland varieties produce heavy panicles of well-filled grain in spite of drought (Jana and De Datta 1971; IRRI 1973; Chang *et al.* 1974). Yields of Japanese upland varieties are also low because of their tall stature and susceptibility to lodging (Ono 1971), and diseases like sheath blight, Helminthosporium leaf spot, and stem maggots.

High tillering capacity is a desirable feature to increase the yield potential of upland varieties. Trials in Nigeria (IITA 1973), Peru (Kawano *et al.* 1972), and the Philippines (Jana and De Datta 1971; De Datta and Beachall 1972; IRRI 1974) generally indicate that when rainfall is plentiful and soil has good water-holding capacity, the high tillering and short statured varieties definitely respond better to nitrogen, giving higher yield than the taller types.

Tiller number and panicle number are positively and closely correlated. A high panicle number, such as is found among semidwarfs, is desirable for high yields. On the other hand, the moderate panicle number of the traditional upland varieties may be partially compensated by the higher number of heavy grains on each panicle.

Late tillering should be avoided in upland rice, because plants that tiller late produce small panicles or none at all leading to inefficient use of soil moisture (De Datta and Beachall 1972).

Although high tillering capacity is the principal means to higher yield potential, a balance between shoot growth and root development is essential for tolerance to prolonged drought.

2.3. CONCEPTS OF INTERCROPPING

Intercropping can be defined as the growing of two or more crops simultaneously in the same area of land (Willey 1979). It has only recently been shown to more efficient than the sole crops in exploiting the natural resources such as light and water.

There are several benefits of intercropping upland rice. Kass (1976), summarized the following advantages of intercropping, which he described as simultaneous polyculture:

- reduces insect pest and disease incidence,
- is adapted to local environmental variability,
- is adapted to crop-specific light requirements,
- provides a continuous and varied supply of fresh food,
- provides good soil cover,
- reduces labor for land preparation and generally provides for economic labor use,

- provides agronomic benefits like reduced lodging and improved stand establishment,
- associated crops may tolerate drought better than pure stands,
- uses land more effectively than single cropping,
- reduces intraplant competition, and
- increases yield stability.

Additionally, if animals are used in the system, intercropping may provide a more balanced and uniform source of feed (University of the Philippines at Los Banos (UPLB) 1977).

Yield stability across seasons is the most important reason for the wide popularity of intercropping in subsistence or near-subsistence agriculture (Willey 1979); if one crop fails or grows poorly, the component crop or crops compensate for lost yield. With a stable intercrop, yield in a given season, field, and with certain level of management can be reliably predicted.

Another advantage of intercropping is increased productivity of complementary component crops. Well designed intercropping combines component crops that use growth resources more fully than would single crops. Intercrop competition is less usually than intracrop competition (Willey 1979).

There are two kinds of intercrop complementarity.

- **Temporal complementarity** is when growth patterns of component crops have high resource demands at different time. Rice + maize have temporal complementarity. Early maize matures in 75-90 days and rice takes 120-150 days.

Spatial complementarity is when combined leaf canopy makes the best use of water and nutrients. This complementarity is less understood than and may impossible to differentiate from temporal complementarity (Willey 1979).

Willey (1979) reviewed the reasons for yield advantages in intercropping and found that intercropping maximized use of natural resources such as light, water, and nutrients. Sometimes, component crops may benefit from the nitrogen fixed by a companion legume crop.

Intercropping studies, [Andrews (1972); Harwood (1974); Rao (1984); and Krantz *et al.* (1976)], generally indicate substantial (50% or more) yield advantage from various combinations of alternative row intercropping over those of two separate sole crop cultures. The yield advantages from intercrops resulted from an efficient use of available moisture, solar energy, nutrients, and space and also from the possibility of increasing the total population per unit area of the crops involved (Osiru and Willey 1972; Venkateswarlu 1977). Since intercropping system provides a more complete canopy, either in space or in time than sole cropping the weeds are better controlled (Moody 1978;

Rao and Shetty 1976). In many instances pest and diseases are better controlled in intercropping (Aiyer 1949; Raheja 1977; and Alteri *et al* 1978). Higher and more dependable per hectare gross returns from intercropping than sole crops were reported by Mathur (1963); Norman (1974); Norman and Pryor (1978). Intercropping could ensure a greater and more even spread of labour employment (Mathur 1963). Other possible causes of yield advantages may be important in certain situations like one of the crops may provide physical support for another (Aiyer 1949). One may provide shelter for another (Rathke and Hegstron 1975), or a more continuous leaf cover may give better protection against erosion (Dennison 1956; Siddoway and Bonnett 1975).

It is important that the peak period of growth of the two crops should not coincide. Crops of varying maturity durations need to be chosen so that a quick maturing crop completes its life cycle before the start of grand period of growth of the other crop (Saxena 1972).

It must be also be appreciated that there can be some disadvantages of intercropping. These can take the form of a yield decrease because of adverse competition effects (Ahlgrenad and Aamodt 1939; Donald 1963; Risser 1969), although such effects are likely to be rare. A more serious disadvantages is often thought to be the difficulties concerned with practical management of intercropping, especially where there is a high degree of mechanization or the component crops have differential input requirement like fertilizers, herbicides and pesticides. These difficulties are typically associated with more developed agriculture.

2.3.1. Evaluating intercropping:

The productivity of intercropping can be evaluated by biological yield, economic yield, land equivalent ratio (LER), crop performance ratio (CPR), cash return/input, or labor and cash return/unit area. Willey (1979) gave three basic criteria for assessing yield advantages in intercropping.

- Intercropping must give full yield of a main crop and some second crops yield.
- Yields of intercropped component crops must exceed the sole crop yield.
- The combined intercrop yield must exceed the combined sole crop yield.

The first and third criteria are most important for intercropping with upland rice. The first is applicable where upland rice is the secondary crop, as when it is grown between sugarcane rows or between rubber or other plantation crops. The third situation is more common where the farmer's interest is in all the component crops, which may include maize + rice, rice + peanut, or rice + maize + cassava.

2.3.2. Land equivalent ratio (LER):

There are several ways of evaluating intercropping efficiency (Elemo 1980; Kass 1976; Willey 1979), but LER is preferred because it is simple, easy to compute, and not affected by market value of crops and inputs. Moreover, all the component crops, irrespective of type and yield, are considered on a relative and directly comparable basis (Choudury 1979; Willey 1979).

LER is the relative land area under sole crops that is necessary to produce at an equal management level the yields achieved from intercropping. LER is expressed as:

$$LER = \frac{Xi}{Xs} + \frac{Yi}{Ys}$$

Where Xi and Yi are the yields of intercropped component crops, and Xs and Ys are yields of the crops in sole.

LER was designed for intercropping, but it can be used to assess the performance of component crops intercropping. LER for intercropping is the sum of LER of the component crops. LER below 1 indicates a negative effect of intercropping. If LER is higher than 1, there is a positive benefit to the crop combinations. LER of 1.2 indicates a 20% yield advantage in intercropping over sole cropping.

Because LER is independent of crop yields and does not indicate the economic benefit of yield levels, it may not always meaningful (Choudhary 1979; Elemo 1980). In practice, farmers never compare pure stand of sole crops and mixtures of component crops. Therefore, LER is theoretical and unrelated to practical field conditions. Nevertheless, it provides relative comparisons of different crop combinations in intercropping systems.

As an index of combined yield, LER provides a quantitative evaluation of the yield advantage due to intercropping (Willey 1979). LER could be used either as an index of biological efficiency to evaluate the effects of various agronomic variables (e.g. fertility levels, density and spacing, comparison of cultivar performance, relative time of sowing, and crop combinations) on an intercrop system in a locality or as an index of systems (Chetty and Reddy 1987).

The partial LER values give an indication of the relative competitive abilities of the components of intercrop systems. In the intercropping system, the species with a higher partial LER is considered to be more competitive for growth limiting factors than the species with lower partial LER (Willey 1979).

Some of the disadvantages of LER are that LER is based on land area only and does not take the duration of component crops into consideration. However, crop production is a function of both crop duration (time) and land area because land occupancy by a given intercrop system is frequently of longer duration than are of the sole crops.

Several methods have been suggested in the literature for calculating LER using different sole crop values as standardization factors.

As an index of biological efficiency, LER is based on harvested products and not on desired yield proportions of the component crops predetermined at sowing (Mead and Stern 1980; Mead and Willey, 1980). This is overcome by the 'effective LER' proposed by Mead and Stern (1980), as alternative to LER for evaluating the biological efficiency of a given required proportion of component crops in an intercrop system.

2.3.3. Crop performance ratio (CPR):

The expected performance of a component of an intercrop is based upon its actual performance in the sole stand. Thus expected performance is calculated as the value per unit in the sole stand multiplied by the sown proportion of that component in the intercrop (Harris *et al.* 1987).

To assess the advantage of the intercrop in terms of the dry weight of harvested material, the yield per unit area of a component of the intercrop, I, should be divided by the proportion, P, of that component in the intercrop to give the yield per unit area sown to that component crop, I/P.

In their studies of intercropping upland rice with pigeonpea and cowpea, Ramakrishna and Ong (1991) expressed this quantity as a fraction of the same component in sole plot, S, to give Crop Performance Ratio (CPR) of $I_r/(P_r\ S_r)$ for rice, $I_p/(P_p\ S_p)$ for pigeonpea, and $I_c/(P_c\ S_c)$ for cowpea. The corresponding ratio for the whole intercrop a

Total Crop Performance Ratio (TCPR) is given by

$$TCPR = (I_r + I_p)/(P_r S_r + P_p S_p)$$

a value of CPR exceeding 1 implies that a component yielded more dry matter per unit sown area in the intercrop treatment than in the sole plot, and thus performed better than 'expected' based on sole crop yields. Values of TCPR exceeding 1 imply that the intercrop plot yielded more than sole plots, with the area for each component identical to the corresponding area in the intercrop plot.

Based on their results, Ramakrishna and Ong (1990) suggested that CPR and TCPR are more appropriate bases for calculating the biological advantage of an intercrop than the more conventional Land Equivalent Ratio (LER), because they attempted to compare the 'efficiency' with which sole crops and intercrops use intercepted radiation to produce dry matter.

Economic analysis such as cash return per unit area or per unit input also are used to compare intercropping systems. However, economic analysis has drawbacks. It is highly dependent on price fluctuations of inputs and outputs, and intercropping is practiced by farmers who farm for family consumption and have little surplus for markets. Economic analysis of input-output relationships may not be very useful for subsistence farmers (Choudhury 1979).

2.4. INTERCROPPING UPLAND RICE + CEREALS

Most subsistence farmers in south-east Asia intercrop upland rice. Many crops are intercropped with upland rice, depending on length of the growing season and farmers preference. Common systems include rice + maize, rice + maize + cassava, rice + cowpea, rice + peanut, rice + sesamum, rice + soybean, rice + mungbean, rice + pigeonpea, rice + sugar cane + rice, rice + capsicum sp.+ Solanum sp.+ beans + maize + banana + cassava, and rice + cassava + maize + okra + pepper (Choudhury 1979; Elemo 1980; Effendi *et al.* 1982)

Rice + maize is one of the most popular cropping systems of Asian uplands, particularly in south-east Asia. The growth patterns of both crops are complementary. Rice and maize are planted at the same time; the seeding rate of maize depends on farmer needs (Carangal 1983; McIntosh *et al.* 1982; McIntosh *et al.* 1984). Maize grows more rapidly than rice and is harvested before rice heads. The maize canopy does not develop until after rice tillers.

In Indonesia, Sierra Leone, Brazil, and Peru, cassava is an important component crop with upland rice + maize (Kass 1976; McIntosh *et al.* 1982; McIntosh *et al.* 1984; Okigbo and Greenland 1976; Wade and Sanchez 1976). Cassava is generally planted after rice and maize are established, and may be relay-planted in maize rows so that when maize is harvested it occupies the same space (IRRI 1983; Wade *et al.* 1976). After rice is harvested, groundnut can be planted in its place, and when groundnut is harvested cowpea can be grown, thus allowing 5 crops in one year (McIntosh *et al.* 1982; Wade *et al.* 1976). In West Africa, spices and beans are grown in the main intercrop of upland rice + maize + cassava (Das Gupta 1983; Okigbo *et al.* 1976).

Rice is a cereal, and thus supplies primarily carbohydrates to human diets. Often, legumes are preferred food crops because they have a high protein content and enrich the soil by fixing nitrogen. Two to three rows of rice at 20-25 cm spacing are planted between two rows of mungbean, cowpea, peanut, pigeonpea, and soybean in many parts of India, Philippines, Brazil, and West Africa (Choudhury 1979; Das Gupta 1983; Elemo 1980; Harson 1981; IRRI 1983; Rao *et al.* 1982).

Generally, individual crop yields are slightly less when intercropped, but combined productivity of both crops is higher than in monoculture. Total dry matter production is closely related to leaf area and the dry matter accumulation per unit leaf area of intercropped maize and rice.

Maize + rice is a highly productive combination because of increased leaf area duration (LAD) of the intercrop during the assimilation period. Maize + rice accumulated more nitrogen than either maize or rice in monoculture with zero or 180 kg N ha^{-1} (McIntosh 1982).

Elemo and Mabbayad (1980) found that upland rice and peanut yielded less when intercropped is a row arrangement 1:1 than in monoculture (based on a hectare of intercrop), but that absolute yield (based on a hectare of component crop in the intercrop) of component rice and peanut was higher than yields of the sole crops. LER was highest (1.21) when both were planted together.

Intercropping mungbean and groundnut with rice at Cuttack, India, improved grain yield and LER (1.42). Higher grain yields were attributed to symbiotic association of legumes with rice (Rao *et al.* 1982). Intercropping upland rice with pigeonpea was studied at Ranchi, India. Two to three rows of upland rice were intercropped with pigeonpea. The intercrop yielded more than monocropped pigeonpea or rice. LER ranged from 1.41-1.64, indicating that intercropping was 41-64% more productive than monocropping (Choudhury 1979).

There have been some studies on competition in upland rice + maize intercropping (IRRI 1976; Lahoni and Zandstra 1977; Lahoni and Zandstra 1977; Sooksathan and Harwood 1974). The compatibility of rice + maize depends on avoiding overlapping reproductive growth stages. Yield of intercropped rice is positively correlated with the number of days of rice growth after maize is harvested (Lahoni and Zandstra 1977). If rice grows for more than 45 days after maize harvest, yield is similar to that of sole rice.

Another important factor for the compatibility of maize

+ rice is the difference in the phenology of the two crops, the early rapid growth of maize and the high productivity of rice late in the season. Maize reaches maximum leaf area index (LAI) 6 weeks after planting, whereas rice reaches maximum LAI 12 weeks after seeding and after maize is harvested (IRRI 1976).

Photosynthetic efficiency, measured by net assimilation rate 6 to 8 weeks of planting, was higher (48 $g.m^{-2}.wk^{-1}$), in intercropping than sole cropping. The net assimilation rate for maize + rice (maize at 1-m row, 40,000 plant ha^{-1}) was 43 $g.m^{-2}.wk^{-1}$. Maize had relatively low leaf area duration (LAD) and accumulated little dry matter. Maize + rice had high LAD and high dry matter accumulation. Rice alone had considerably higher LAD than maize + rice, but produced less dry matter, because of slow initial growth rate.

2.5. INTERCROPPING WITH PIGEONPEA

Saraf *et al.* (1975) observed that pigeonpea (redgram) grain yield and its components and dry matter production were not affected significantly when intercropped with greengram, (mungbean), soybean and groundnut. Similar findings were reported by Kaul *et al.* (1975); Singh and Singh (1976).

Kaul and Sekhan (1974) reported that pigeonpea grain yield was increased by intercropping with short duration (75-80 days) greengram and blackgram but pigeonpea yield was reduced by longer duration (112-130 days) soybean and groundnut. Gajendragiri and Rajat De (1978) reported from a

3-year study that plant height, number of branches per plant, total dry matter production, pods per plant and 1000 grain weight of redgram were not influenced significantly when intercropped with greengram or blackgram in alternate rows at 50 cm distance in 1:1 population ratio.

Intercropping pigeonpea with sorghum, pearl millet, did not significantly reduce the total nutrient content of pigeonpea per unit area (Palaniappane *et al.* 1984).

Reddy *et al.*(1984) tested the possibility of taking an intercrop in the rabi (postrainy) season, under residual soil moisture on a deep clay loamy soil. The intercrops were wheat + redgram and safflower + redgram. Wheat gave the highest grain yield (1514 kg ha^{-1}) followed by safflower (849 kg ha^{-1}). Since wheat and safflower are winter crops, their growth was very fast and profuse which suppressed the growth of intercropped redgram leading to poor yields of 250 kg ha^{-1} in redgram + wheat and 540 kg ha^{-1} in redgram + safflower system.

Patra and Chatterjee (1986) in their experiment conducted during rainy seasons of at Kalyani found that soybean and redgram intercropped in 1:1 row proportions spaced at 30 cm apart gave 35 to 45 per cent yield advantage and about Rs 2700 to Rs 2900 more per hectare monetary return over sole cropping.

2.6. FERTILIZER MANAGEMENT IN INTERCROPPING

The fertilizer and management requirements of component crops affect intercrop management. Research at International Rice Research Institute (IRRI) compared nutrient uptake by rice + maize with that of sole rice and sole maize (IRRI, 1976; Palada and Harwood, 1974; Suryatna and Harwood, 1976). Increasing applied N from 0 to 180 kg ha^{-1} increased NPK uptake of the intercrop. Nutrient uptake was higher than for the crops in sole. Increasing N from 180 to 240 kg ha^{-1} did not increase N uptake of rice + maize.

Increasing applied N from 0 to 180 kg ha^{-1} increased intercrop yield from 2.0 to 6.2 t ha^{-1}. However, LER dropped from 1.60 to 1.45, indicating that intercropping was 60% more productive at 0 applied N and 45% more productive at 180 kg N ha^{-1} than rice or maize n sole (IRRI 1976). In another study, LER was not increased by increasing fertilizer from 180 to 240 kg N ha^{-1}. LER was maximum (1.50) with 180 kg N applied to rice + maize (Palada and Harwood, 1974).

Wade and Sanchez (1976) studied a maize + rice + cassava + peanut + cowpea system at Yurimaguas, Peru. Tall crops were planted at 1, 2, or 3 m spacing and with 0, 45, 90, or 180 kg N ha^{-1} per year in equal splits at planting and 60 days after planting. Nitrogen was not applied to legumes or to later growth stages of cassava. Before maize and rice were planted, fields receive 1 tone lime, 49 kg P and 40 kg K ha^{-1}. Rice in sole responded up to 45 kg applied N ha^{-1}, and maize in sole responded up to 180 kg N ha^{-1}. Cassava, peanut, and cowpea did not respond to applied N.

Maize + rice yielded 30-60% more than when planted in sole. LER was highest at 0 N. At 0 N, 1 m maize row spacing was most efficient LER (1.62), but yield was only 2.4 t ha^{-1}. At 180 kg N ha^{-1} 2 m spacing yielded poorly because of the wet year. No cowpea was grown at 1 m spacing because of the dense cassava canopy. Peanut yields were 50% of those in sole. The intercrop yielded 300% more than the crops planted in sole.

2.7. ECONOMICS OF INTERCROPPING:

In a three year study, John *et al* (1943) reported that groundnut + pigeonpea in 8:1 row arrangements was Rs 435 more profitable than sole crop of groundnut. Arrangement of groundnut and pigeonpea of 6:1 ratio was more economical than 8:1. Groundnut gave 99% of its sole crop yield and pigeonpea 37% (Veerswam *et al.* 1974; Appadurai and Selvaraj 1974). Ramadoss *et al.* (1980) worked out the economics of different crop combinations and reported that intercropping groundnut with pigeonpea was the most remunerative with a net income of Rs 3095 per hectare compared to pure crop of pigeonpea as well as other crop combinations of greengram, soybean and sorghum.

Baker (1978) reported that groundnut intercropped with maize, sorghum, gave an average of 27.7 per cent more monetary returns than sole cropping. Reddy *et al.* (1965) stated that growing castor mixed with groundnut was better than raising a pure crop of castor and monetary returns were 61.9 per cent higher than pure castor. Kalyan *et al.* (1978) observed that the highest net profit was obtained when blackgram was intercropped with redgram. Andrews (1972) reported 82% more returns from sorghum + cowpea than a sole crop of sorghum.

Jha and Satpathy (1973) indicated that in red soils of Bhubaneswar, redgram + finger millet intercropping gave the highest return compared to that obtained by growing as a pure crop.

Studies on intercropping proportions by All India Coordinated Research Project for Dryland Agriculture at Anantapur during 1978 showed that growing redgram and groundnut in 1:8 ratio gave the maximum gross monetary returns compared to other proportions. In another experiment redgram + groundnut in 3:12 proportion gave maximum gross returns (Rs 2722 per hectare) followed by 3:6 proportion (Rs 2,604 per hectare). From Tirupati higher monetary returns (Rs 3,153 per hectare) were achieved by growing groundnut + redgram in 7:1 ratio under rainfed conditions.

Ramadoss and Thirumurugan (1983) stated that intercropping 2 rows of greengram in between paired rows of redgram recorded higher net returns per hectare.

There is little economic information on upland rice intercropping because it is usually a subsistence system.

In Yurimaguas, Peru, Wade and Sanchez (1976) found that intercropping upland rice + maize + cassava + peanut + cowpea yielded $ 500 (30%) more profitable than growing them in 2 monoculture strips. Choudhury (1979) found that growing upland rice + pigeonpea was more profitable than growing them in monoculture. Similarly, maize + rice was found more profitable (Loheni and Zandstra 1977) in Philippines. In Lampung, Indonesia, maize + upland rice + cassava + peanut was more profitable than the traditional maize + rice + cassava (McIntosh 1984).

In northeastern Brazil, Seguy (1984) found that rice + maize + cassava followed by cowpea was more profitable at low and high input levels than the traditional, small farm system. Mean daily return was $ 4.50 to $ 4.70 for the new system versus $ 1.80 for the traditional system. Rao *et al.* (1982) found that rice + mungbean returned 25% more than rice alone. However, rice + groundnut returned only 5% more than rice alone.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

3.1. EXPERIMENTAL SITE

3.1.1. Location:

The experiment was conducted at ICRISAT Center (India) during the 1990 rainy season. The site is located at 18° N, 78° E, in Patancheru village, 26 km northwest of Hyderabad (State of Andhra Pradesh) at an altitude of 545 m above sea level (ICRISAT, 1985).

3.1.2. Climate:

The climate of ICRISAT Center is typical of Semi-Arid Tropical environment characterized by a short rainy season (3-4 months) and a prolonged dry weather (8-9 months).

Three distinct seasons characterize this environments :

Kharif or monsoon season, usually begins in June and extends into early October during which more than 80% of the total annual rainfall (760 mm) is received. In this season rainfed crops are raised (ICRISAT, 1989).

Rabi or the postrainy season (mid-October through January), is dry and relatively cool, and days are short. During this period, crops can be grown on vertisols using stored soil moisture.

Summer, the hot season begins in February and lasts until rains begin in June; crops grown in this season require irrigation.

The mean annual maximum temperature is 35.5°C and the minimum is 18°C. The average daily pan evaporation varies from 3.8 to 12.3 mm.

3.1.3. Soil:

The field used was medium-deep black soil with pH of 8.5 and EC of 0.58 m. mhos/cm and OC of 0.4%.

3.2. EXPERIMENTAL DETAILS

3.2.1. Treatments:

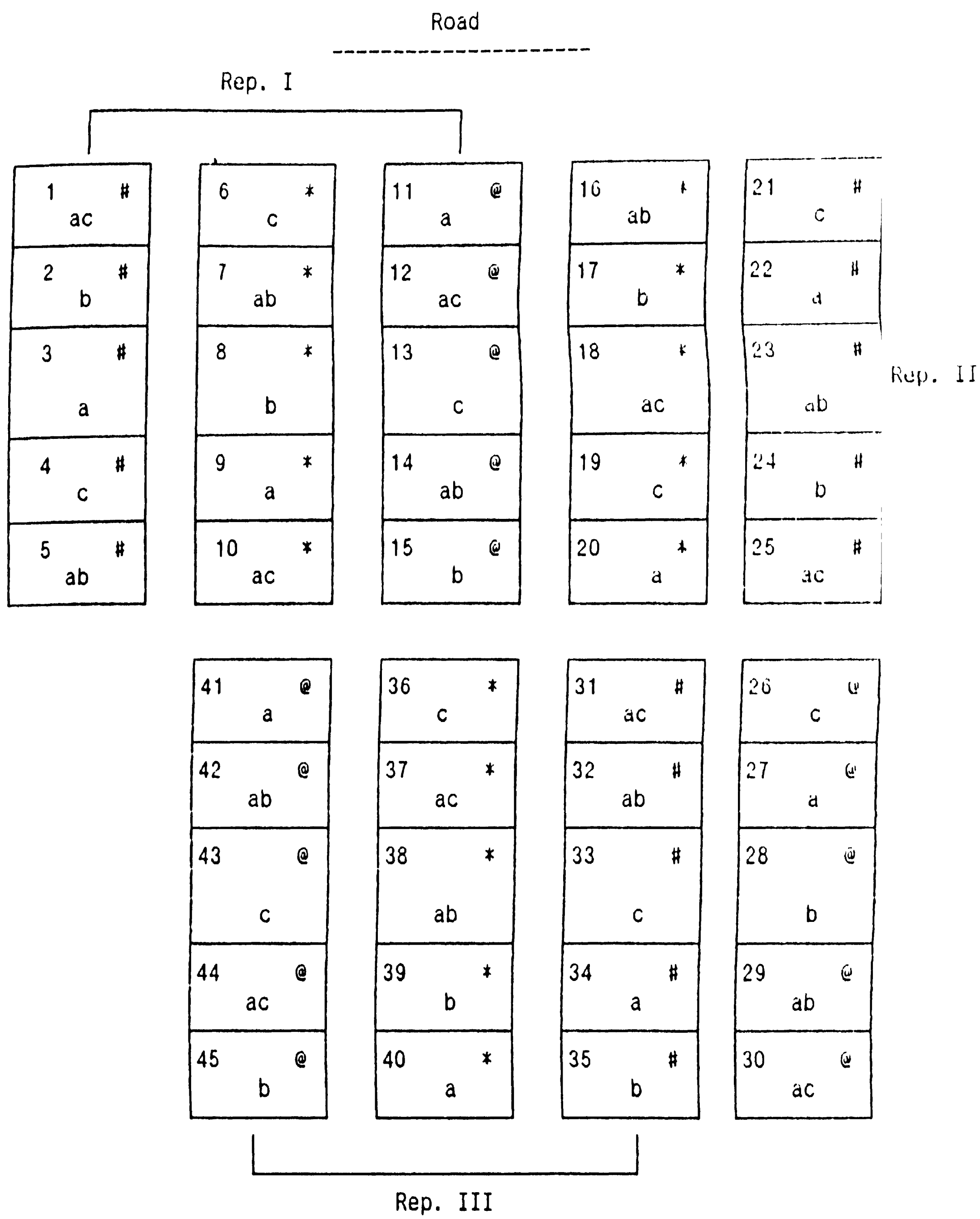
Three cropping patterns were taken, and the spacing between the rows was 20 cm.

The patterns were:

1. 3:1 (3 rows upland rice : 1 row legume crop) row arrangement
2. 4:1 (4 rows upland rice : 1 row legume crop)
3. 5:1 (5 rows upland rice : 1 row legume crop)

The species were :

1. Rice cv. IET 9225 a dwarf variety, fine grain, duration 100-110 days.
2. Pigeonpea cv. ICP 1-6, a medium,spreading, brown-seeded variety.
3. Soybean cv. Hardee a medium duration variety, erect, brown seeded variety.



Field layout of the experiment at BP12-B during Kharif Season 1990.

1-45 = Plot numbers
a = Sole rice
b = Sole soybean
c = Sole pigeonpea
ab = Rice + Soybean
ac = Rice + Pigeonpea

* = 3:1 pattern
@ = 4:1 pattern
# = 5:1 pattern

Sowing dates were :

1. Rice : 11.7.90
2. Pigeonpea : 25.8.90
3. Soybean : 25.8.90

3.2.2. Experimental Design and Layout:

The treatments were arranged in a split plot design with 3 replications. Main plot treatments consisted of three sowing patterns and subplot treatments consisted of the 5 cropping systems.

Each plot was 7.2 X 5 m. Total experimental area was 0.162 ha^{-1} . The crops were grown under rainfed conditions but due to dry spells, it has been irrigated two times using a sprinkler irrigation system.

Before sowing, a basal dose of 100 kg ha^{-1} of diammonium phosphate and 80 kg N ha^{-1} top dressing was applied. Hand weeding was carried out on 25-30, 60, and 90 DAS to keep the plot weed-free. Pigeonpea was sprayed four times against *Helicoverpa armigera*.

3.3. OBSERVATIONS AND MEASUREMENTS

3.3.1. Phenology:

- Days to 50% flowering: Number of days from sowing until 50% of the plants in the net plot had flowered.

Days to maturity: Number of days from sowing to maturity when more than 85% of the pods (in case of legumes) or panicles (in case of rice) were dried.

Length of reproductive period: Total days from 50% flowering to physiological maturity.

3.3.2. Plant Growth Analysis:

The first sampling was done four weeks after sowing and subsequently at weekly intervals. Plants were cut at the base of stem. Roots were not included in calculating total biomass.

3.3.3. Plant Height and Number of Branches or Tillers:

Plant height, number of branches (legumes), tillers (rice) of each crops were measured in both sole and intercrop plots at weekly intervals.

3.3.4. Leaf Area:

From destructive samples, leaves were separated and the 10 g as a sub-sample was taken, then the total leaf area for the sample was calculated accordingly for determining leaf area by using a LI-COR LI 3100 leaf area meter.

3.3.5. Total Dry Matter:

The dry matter (DM) of leaves, stems, and reproductive structures were measured separately. The dry masses were recorded after drying the samples in a hot air oven at 80°C until constant weight.

3.3.6. Root length measurement:

Root depth was measured by taking the soil cores at five depths (0-10, 10-20, 20-30, 30-40, 40-50 cm) at final harvest. Roots were taken from the 3:1 pattern in which it was considered that it is the best pattern from the pattern tested to study the depth and the interaction between rice and the legumes. Samples were taken in the rice intercropped with soybean plot, and the rice intercropped with pigeonpea plot, the sole crop plots of the three varieties. Soil cores were taken to the laboratory for washing and extracting the roots. Total root length in each sample and for each crop was measured by using the Comair root length scanner.

3.3.7. Light interception:

Canopy interception of photosynthetically active radiation (PAR) intercepted (F) was measured with using a "Mouse Sensor" for light interception measurement as described by Matthews *et al.* (1987).

3.3.8. Oxygen in the Soil:

The amount of oxygen in the soil was measured by placing glass tubes in the soil at 5, 10, and 15 to measure the status of the air in the soil mainly in the upper root zone. Tubes were placed in the soybean and pigeonpea plots. The glass tubes were taking to the laboratory, and then the air in each tube was carefully sampled by a syringe and fed in to the oxygen analyzer (Toray oxygen analyzer LC 700F), which indicates the percentage of oxygen in the sample.

3.3.9. Total Dry Matter and Grain Yield:

A half square meter was harvested. Number of plants in each sample was counted and total fresh weight recorded. The fresh weight of (10) randomly selected plants from this sample was collected. This sub-sample was oven dried at 80°C to a constant weight. TDM in the net area was then calculated. For grain yield, harvesting of pods and panicles was done by hand. Grain yield was estimated in the net plot which were:

1. 5:1 pattern (4m wide and 3 patterns)
2. 4:1 pattern (4m wide and 4 patterns)
3. 3:1 pattern (4m wide and 5 patterns)

3.3.10. Yield Components:

The ten (10) plants from the sub-samples, which were taken at random for calculating TDM were also used for estimating yield components.

The parameters measured were :

- Number of pods plant^{-1}
- Number of panicles plant^{-1}
- Pod weight (g m^{-2})
- Panicle weight (g m^{-2})
- Panicle length (cm)

3.4. STATISTICAL ANALYSIS

The data of the experiments were subjected to the analysis of variance (ANOVA) using a standard split plot design analysis of GENSTAT packages in the VAX mainframe computer system at ICRISAT, Patancheru, and as mentioned in Gomez and Gomez (1984).

The comparisons of the treatments were made by using orthogonal single degree analysis in the SYSTAT program and SAS program in the VAX mainframe.

RESULTS

CHAPTER IV

RESULTS

4.1. CLIMATE

Meteorological data during the experimental period at ICRISAT center are shown as Appendix 1. Total rainfall during the cropping period was 607.7 mm, maximum received during week 33 (22.4% of the total rainfall). There was no drought stress in the early stages of the crop growth, but there was a short drought period towards the end of the year 1990, and during the first week of 1991, and the crop was given two irrigations.

Daily maximum and minimum atmospheric temperatures were recorded for all the weeks of the experimental period (Fig. 1).

4.2. NUMBER OF PLANTS m^{-2}

Data of the number of rice plants were taken at weekly intervals, the difference of the number of plants between the different rice treatments were not significant. The expected number of plants m^{-2} was 100. The sole plot had 156-210 plants m^{-2}, whereas the intercrops ranged from 130-145 plants m^{-2}. The intercropped rice plots did not show significant difference between them in the number of plants (Table 1).

The number of soybean plants m^{-2} in the sole and the intercrop plots were significantly different. The expected number of plants m^{-2} was 50 plants. The sole crop had 45-50

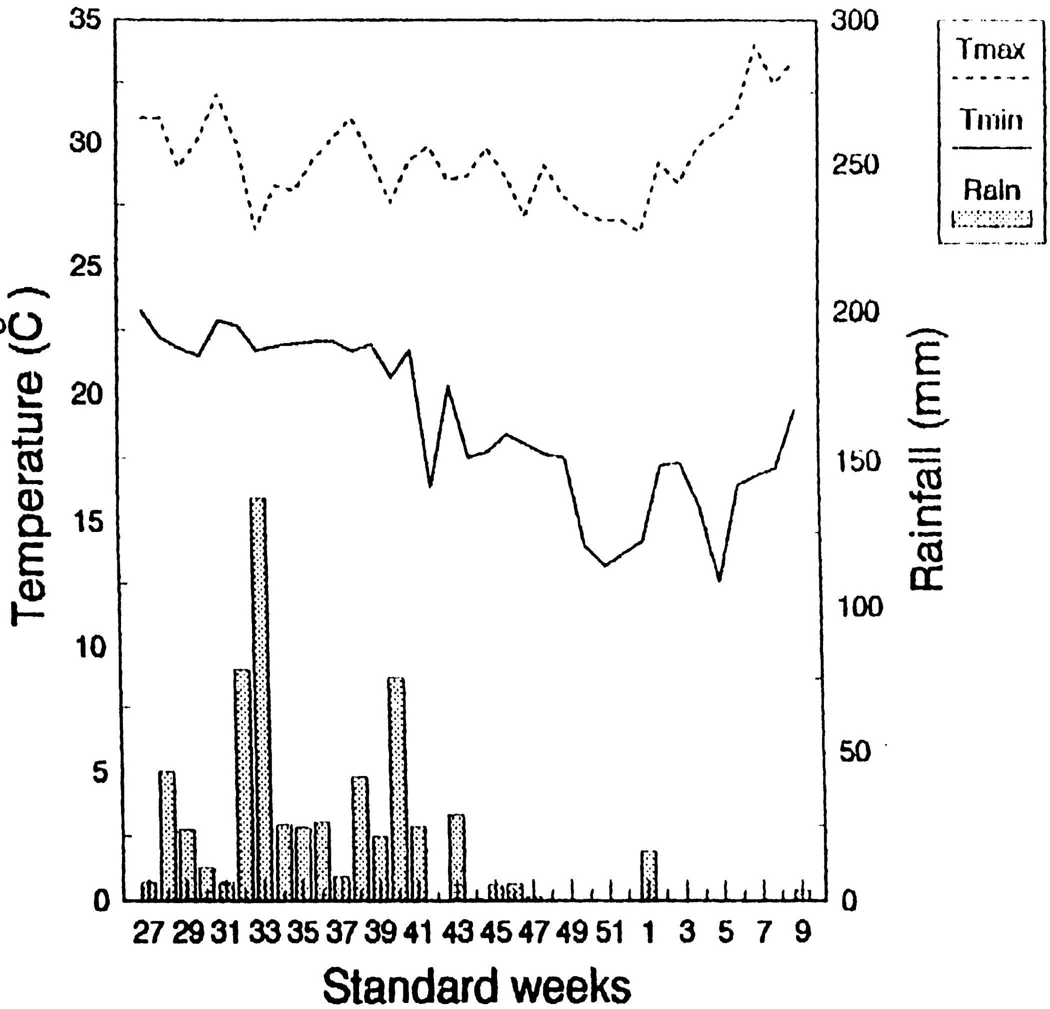


Fig.1: Rainfall and temperature during growing season at ICRISAT Center (Kharif Season 1990).

Table 1. Number of plants m^{-2} of the sole and intercrop rice.

	Days after sowing						
	70	77	84	98	105	112	119
Sole rice	196	201	197	208	213	212	214
R IC SB							
3:1	164	165	175	160	210	213	203
4:1	195	167	180	178	157	174	164
5:1	145	134	143	172	169	171	175
R IC PPEA							
3:1	175	176	181	178	222	232	219
4:1	172	170	162	207	190	195	194
5:1	182	150	144	173	147	163	164
SE(±)	30						
CV %	15 %						

R IC SB= rice intercropped with soybean
R IC PPEA= rice intercropped with pigeonpea

SEM (+) = 30

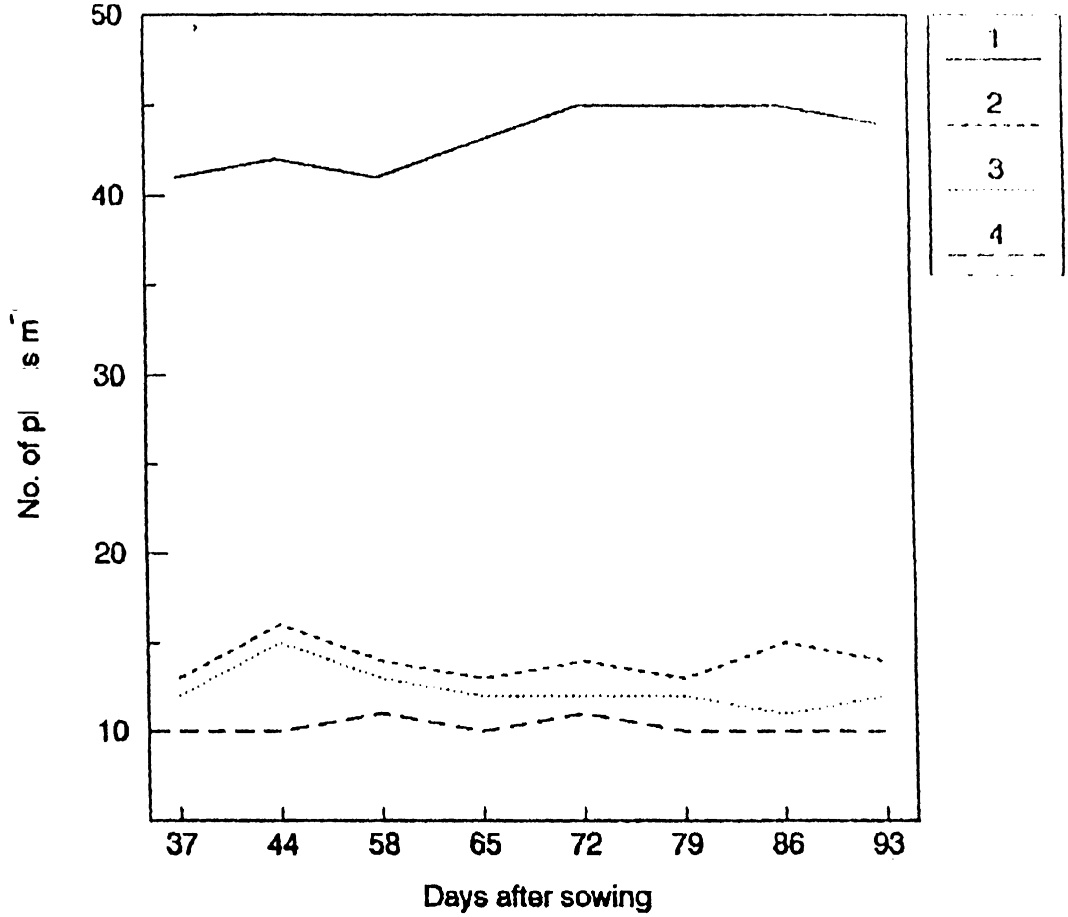


Fig.2a: Number of plants m^{-2} of the sole and intercrop soybean.

1 = Sole Soybean
2 = Soybean intercropped with rice in the (3:1) ratio.
3 = Soybean intercropped with rice in the (4:1) ratio.
4 = Soybean intercropped with rice in the (5:1) ratio.

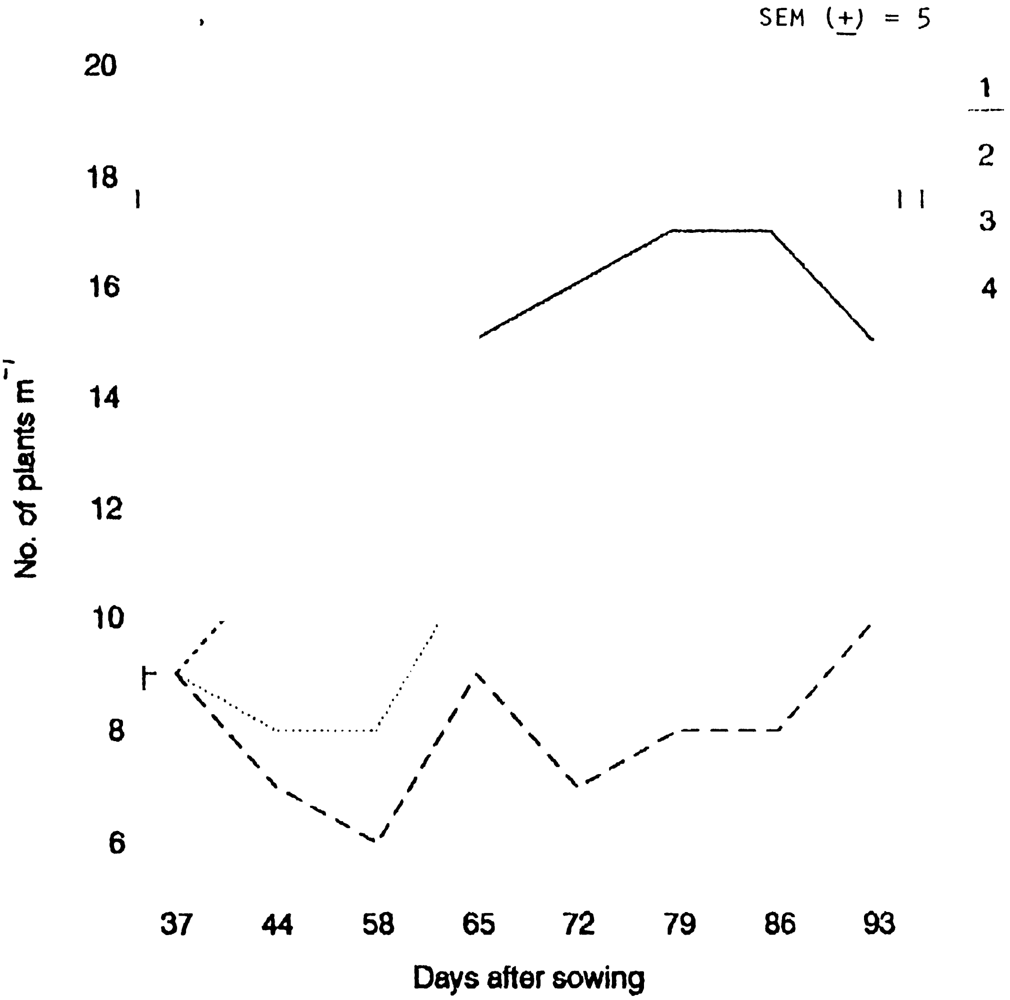


Fig.2b: Number of plants m^{-2} of the sole and intercrop pigeonpea.

1 = Sole Pigeonpea.
2 = Pigeonpea intercropped with rice in the (3:1) ratio.
3 = Pigeonpea intercropped with rice in the (4:1) ratio.
4 = Pigeonpea intercropped with rice in the (5:1) ratio.

plants m^{-2}. The intercrop had 12-15 plants m^{-2}. The intercrop soybean did not show any significant difference between them in the number of plants (Fig. 2a).

The number of pigeonpea plants m^{-2} in the sole and in the intercrop did not show any significant difference. The expected number of plants were 20 plants m^{-2}. The sole had 15-18 plants m^{-2}, whereas the intercrops had 10-15 plants m^{-2}. The intercrops did not show any significant difference between them in the number of plants. Most of the pigeonpea plants were dying due to wilt disease which caused low plant population (Fig. 2b).

4.3. NUMBER OF TILLERS PLANT^{-1} (RICE)

There was no significant difference in the number of tillers between the sole rice and the intercrop rice. When number of tillers was counted at 70 DAS there were 3 tillers plant^{-1} in the sole rice and the intercrop rice. The number of tillers did not increase much. At 119 DAS when counted again it was found that the sole rice and the intercrop rice both had 4 tillers plant^{-1} (Table 2).

When compared between the different intercrops, it was found that there was no significant difference between the intercrops in the different ratios. This indicated that the intercrop it self as well as the planting ratio did not affect the tillering of the rice.

Table 2. Number of tillers plant^{-1} of the sole and intercrop rice

	Days after sowing						
	70	77	84	98	105	112	119
Sole rice	3.0	4.0	4.0	4.0	4.0	5.0	5.0
R IC SB							
3:1	3.0	4.0	4.0	4.0	4.0	4.0	4.0
4:1	3.0	4.0	4.0	4.0	4.0	4.0	4.0
5:1	3.0	3.0	4.0	4.0	4.0	4.0	4.0
R IC PPEA							
3:1	3.0	3.0	4.0	4.0	4.0	4.0	4.0
4:1	3.0	4.0	4.0	4.0	4.0	4.0	5.0
5:1	3.0	3.0	4.0	4.0	4.0	4.0	4.0
SE(±)	1.0						
CV %	5 %						

R IC SB= rice intercropped with soybean
R IC PPEA= rice intercropped with pigeonpea

4.4. NUMBER OF BRANCHES PLANT^{-1} (LEGUMES)

The number of branches plant^{-1} in the sole soybean and in the intercrop soybean were significantly different. At 58 DAS the number of branches plant^{-1} in the sole soybean and the intercrops were same 1 branch plant^{-1}, but after that the sole had lower number of branches than the intercrops. At harvest of the soybean the plants in the sole had 5 branches plant^{-1}, the soybean intercropped with rice in the 3:1 and 4:1 ratio both had 7 branches plant^{-1}, and the soybean intercropped with rice in the 5:1 ratio had 6 branches plant^{-1} (Fig. 3a).

The plants in the intercrop soybean in the three ratios tested did not show any difference between them in the number of branches plant^{-1}.

The difference in the number of branches plant^{-1} of the sole pigeonpea and the intercrop pigeonpea was not significant at the early stages of the growth. At the later stages of the growth the difference was significant. The intercrop pigeonpea had higher number of branches than the sole. At harvest the sole had 3 branches plant^{-1}. The intercropped pigeonpea in the 3:1 and 4:1 ratio had 5 branches plant^{-1}, and 4 branches plant^{-1} in the 5:1 ratio (Fig. 3b).

The trend of increase of the number of branches of the soybean and the pigeonpea were different from each other. The growth of the soybean was faster than that of the pigeonpea in the early stages that the number of branches of the pigeonpea were low at the beginning compared to the soybean.

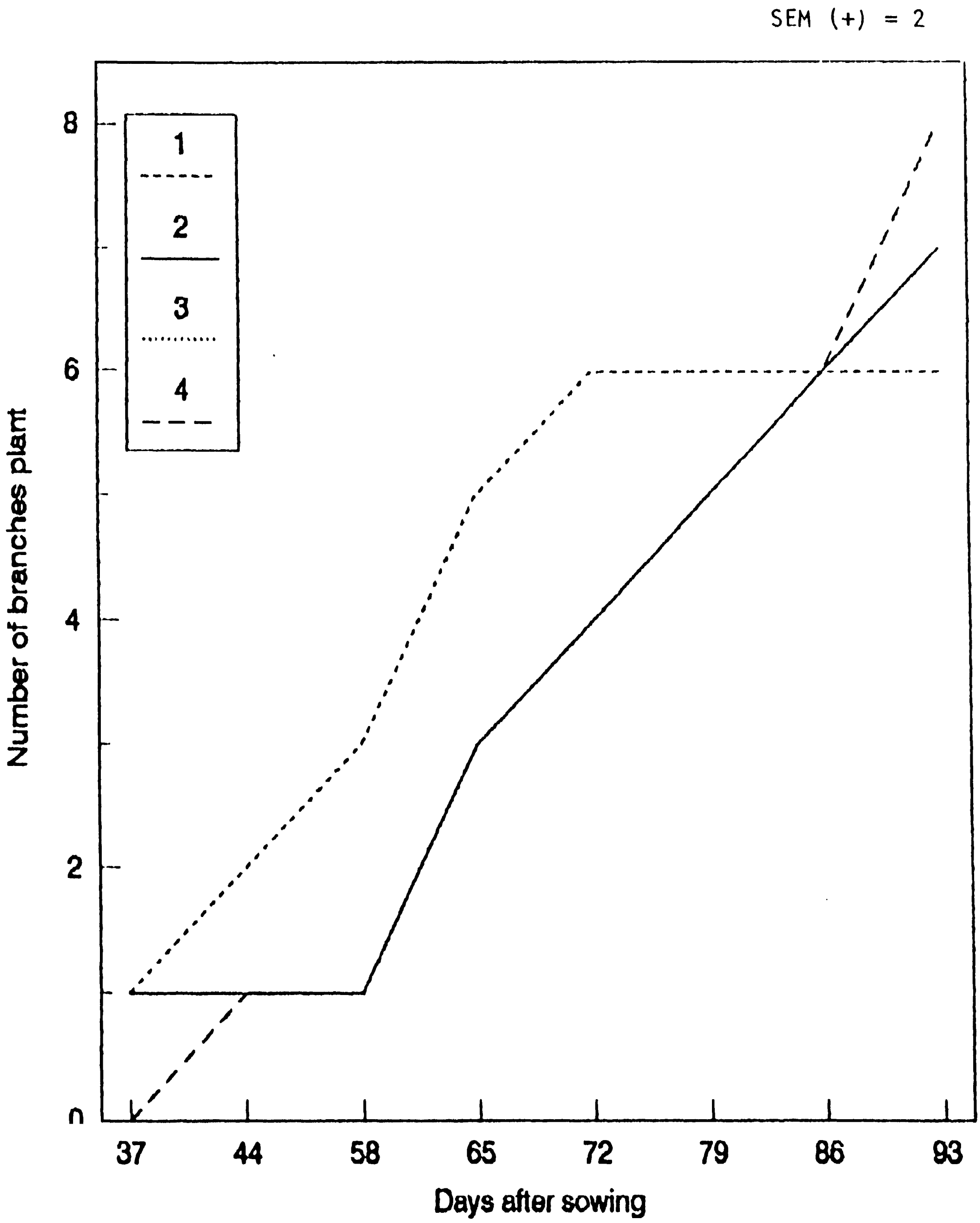


Fig.3a: Number of branches plant^{-1} of the sole and intercrop Soybean.

1 = Sole Soybean.
2 = Soybean intercropped with rice in the (3:1) ratio.
3 = Soybean intercropped with rice in the (4:1) ratio.
4 = Soybean intercropped with rice in the (5:1) ratio.

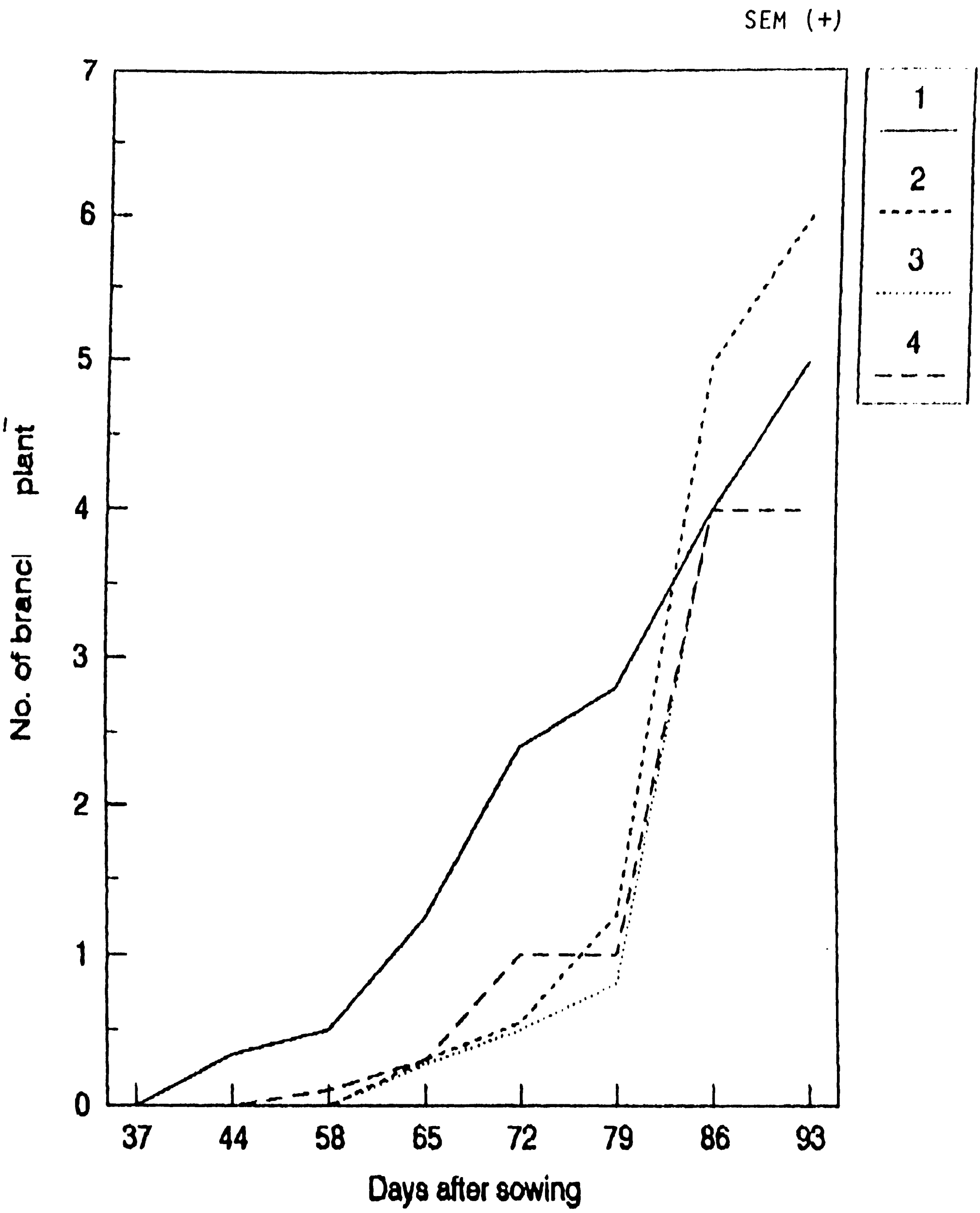


Fig3b: Number of branches plant^{-1} of the sole and intercrop pigeonpea.

1 = Sole Pigeonpea.
2 = Pigeonpea intercropped with rice in the (3:1) ratio.
3 = Pigeonpea intercropped with rice in the (4:1) ratio.
4 = Pigeonpea intercropped with rice in the (5:1) ratio.

4.5. LEAF AREA AND LEAF AREA INDEX (LAI)

The difference in the LAI of the sole rice and the intercrops was not significant. Some of the treatments show some difference at the later stages of the growth. AT 70 DAS the sole rice had LAI of 2.0. The rice intercropped with soybean had a LAI of 2.43, 2.54, and 2.0 in the 3:1, 4:1, and 5:1 ratios respectively. The rice intercropped with pigeonpea had a LAI of 2.63, 2.22, and 2.1 in the 3:1, 4:1, and the 5:1 ratios respectively. At 119 DAS there was some difference in the leaf area and LAI between the sole and the intercrops, due to the maturity of the crop and the drying of the leaves. At that time the sole had a LAI of 3, the rice intercropped with soybean had a LAI of 3.25, 2.20 and 2.0 in the 3:1, 4:1 and 5:1 ratios respectively (Table 3).

The rice plants reached the maximum leaf area and LAI at 105 DAS, where the sole recorded a LAI of 5.0, the rice intercropped with soybean had a LAI of 5.8, 4.3, and 4.4 in the 3:1, 4:1 and 5:1 ratios respectively. The rice intercropped with pigeonpea had a LAI of 6.41, 4.44 and 3.28 in the 3:1, 4:1 and 5:1 ratios respectively. After that the leaf area reduced due to the maturity of the crop and drying of the leaves.

There was no significant difference in the leaf area and LAI between the rice intercropped with soybean and the rice intercropped with pigeonpea in the three ratio tested.

Table 3. Leaf area index (LAI) of the sole and intercrop rice

	Days after sowing						
	70	77	84	98	105	112	119
Sole rice	2.03	2.50	3.07	3.50	5.04	4.03	3.24
R IC SB							
3:1	2.43	2.69	3.0	3.53	5.80	3.94	3.24
4:1	2.54	2.65	2.81	3.51	4.27	3.19	2.19
5:1	1.82	2.00	2.99	3.37	4.35	2.70	2.04
R IC PPEA							
3:1	2.62	2.74	3.26	3.40	6.4	3.97	3.31
4:1	2.21	2.43	2.83	3.56	4.44	3.26	2.62
5:1	2.09	2.19	2.84	3.40	3.28	2.68	2.51
SE(±)	2.22						
CV %	7 %						

R IC SB= rice intercropped with soybean
R IC PPEA= rice intercropped with pigeonpea

There was a significant difference in the leaf area and LAI between the sole soybean and the soybean intercropped with rice in the three ratios. At 37 DAS the sole soybean had a LAI of 1.25, the soybean intercropped with rice in the 3:1 ratio had a LAI of 0.3, 0.28 for the soybean intercropped with rice in the 4:1 ratio, and the soybean intercropped with rice in the 5:1 ratio had a LAI of 0.3 (Fig. 4a).

The soybean reached maximum LAI at 79 DAS when the sole soybean recorded a LAI of 4.45, 2.33 for the intercropped soybean in the 3:1 ratio, 2.51 for the intercropped soybean in the 4:1 ratio and the intercropped soybean in the 5:1 ratio had a LAI of 1.98. At later stages the LAI declined due to the maturity of the crop and consequent drying of the leaves (Fig. 4a).

There was no significant difference in the leaf area and LAI between the sole pigeonpea and the intercropped pigeonpea in the three ratio. At 37 DAS the sole pigeonpea had a LAI of 0.97, whereas the intercropped pigeonpea in the 3:1 ratio had a LAI of 0.56, 0.51 for the pigeonpea intercropped with rice in the 4:1 ratio and 0.50 for the intercropped pigeonpea in the 5:1 ratio. The leaf area and LAI of the pigeonpea were increased up to 93 DAS but due to the mortality of many plants and subsequent reduction of the sampling area, it has been suggested to stop the sampling and leave sufficient area for yield assessment (Fig 4b).

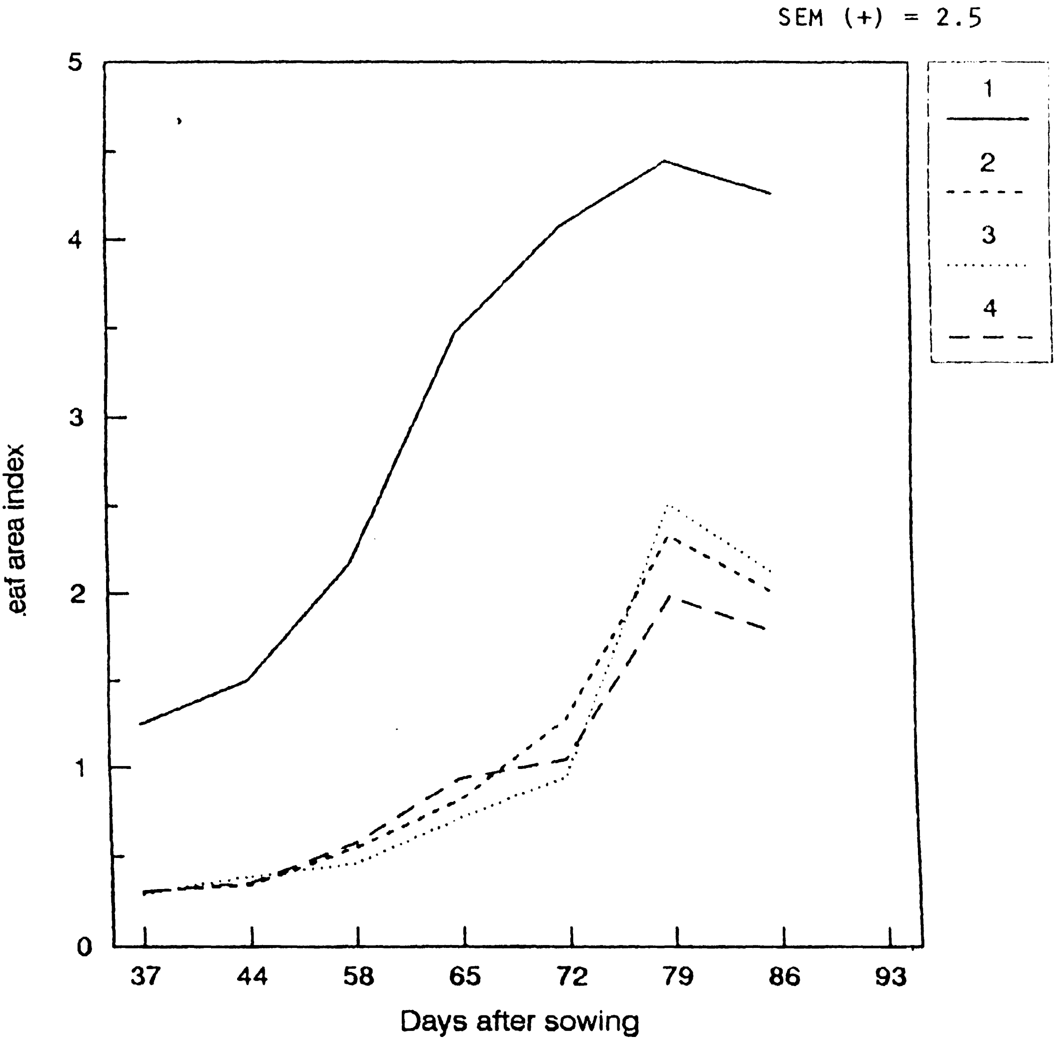


Fig.4a: Leaf area index (LAI) of the sole and intercrop soybean.

1 = Sole Soybean.
2 = Soybean intercropped with rice in the (3:1) ratio.
3 = Soybean intercropped with rice in the (4:1) ratio.
4 = Soybean intercropped with rice in the (5:1) ratio.

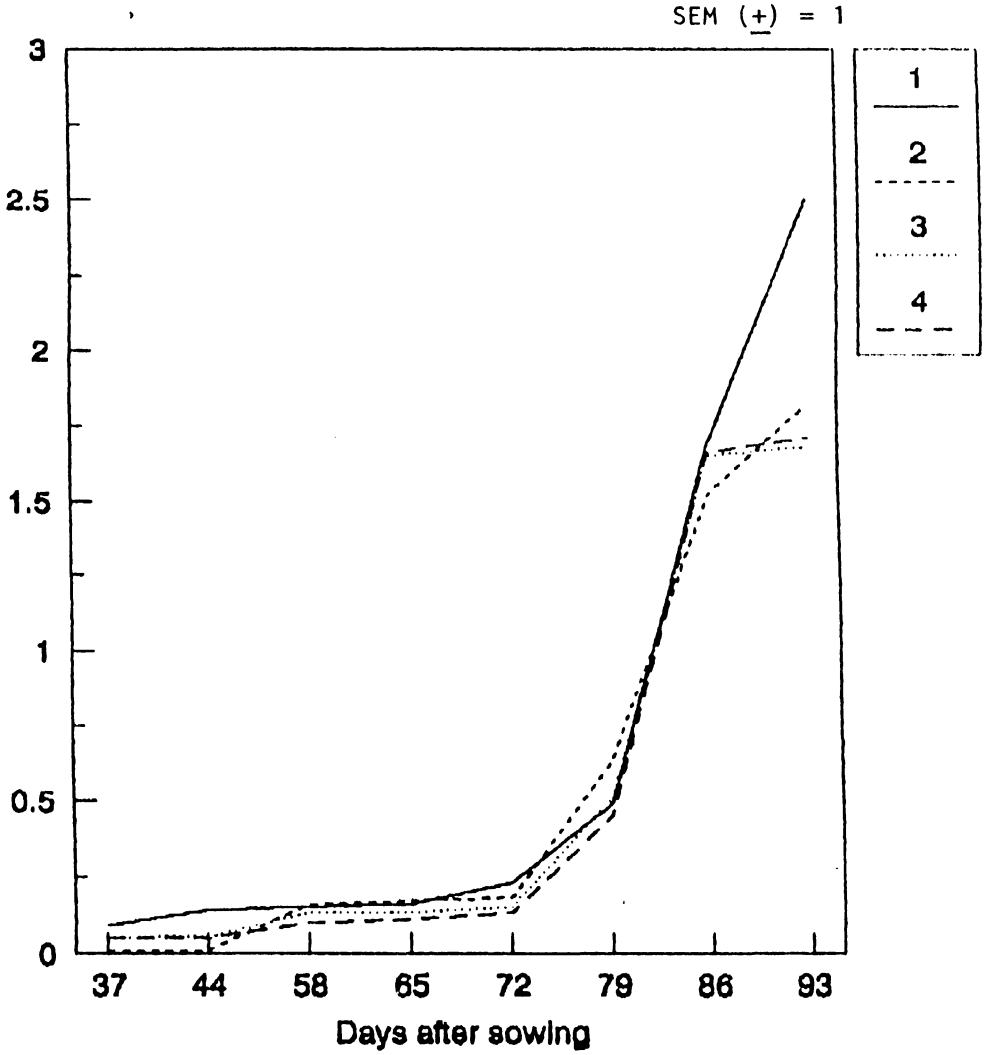


Fig.4b: Leaf area index (LAI) of the sole and intercrop pigeonpea.

1 = Sole pigeonpea.
2 = Pigeonpea intercropped with rice in the (3:1) ratio.
3 = Pigeonpea intercropped with rice in the (4:1) ratio.
4 = Pigeonpea intercropped with rice in the (5:1) ratio.

The soybean and the pigeonpea showed variation with regard to the leaf area and LAI. The growth rate of the pigeonpea in the early stages was low, and its growth started vigorously when the rice was harvested. However, there was no comparison between the soybean and the pigeonpea in this point due to their difference in the growth habits.

4.6. PLANT HEIGHT (CM)

The difference of the plant height between the sole rice and the intercrop rice was not significantly different. Likewise the difference of the plant height between the plants in the intercrops of the three ratios tested were not significant. At 70 DAS the mean height of the rice plants in the sole was 39 cm. The height of the rice plants intercropped with soybean in the 3:1 ratio was 39 cm, 37 cm for the rice plants intercropped with soybean in the 4:1 ratio, and the height of the intercrop rice in the 5:1 ratio was 38 cm. The height of the rice plants intercropped with pigeonpea in the 3:1 ratio was 36 cm, 38 cm for the rice intercropped with pigeonpea in the 4:1 ratio and 39 cm was the plant height of the rice intercropped with pigeonpea in the 5:1 ratio (Table 4).

Maximum height that the plants of the sole rice attained was 55 cm. The maximum height of the rice plants intercropped with soybean in the 3:1 ratio was 54 cm, 56 cm for the rice plants intercropped with soybean in the 4:1 ratio, and 54 cm was the maximum plant height for the 5:1 ratio.

Table 4. Plant height (cm) of the sole and intercrop rice.

	Days after sowing						
	70	77	84	98	105	112	119
Sole rice	39	44	48	51	54	54	55
R IC SB							
3:1	39	46	50	54	54	55	58
4:1	37	42	47	49	53	56	56
5:1	38	40	44	51	53	54	54
R IC PPEA							
3:1	36	38	44	47	52	55	55
4:1	38	43	47	51	53	54	55
5:1	39	41	50	50	53	53	57
SE(±)	6.5						
CV %	4 %						

R IC SB= rice intercropped with soybean
R IC PPEA= rice intercropped with pigeonpea

The height of the rice plants intercropped with soybean and the rice intercropped with pigeonpea were not significantly different. The plants of the rice intercropped with pigeonpea in the 3:1 and 4:1 ratio both had reached a maximum height of 53 cm, and the rice intercropped with pigeonpea in the 5:1 ratio had reached a maximum height of 56 cm (Table 4).

The trend of the increase in plant height of the legumes was different from that of the rice. There was no significant difference in the plant height between the sole soybean and the intercrop soybean, and also between the intercrop soybean. At 37 DAS the plants of the sole reached a height of 34 cm, 37 cm for the soybean intercropped with rice in the 3:1 ratio, 34 cm for the plants of the soybean intercropped with rice in the 4:1 ratio, and the soybean plants intercropped with rice in the 5:1 ratio had a height of 33 cm (Fig. 5a).

The height of the soybean plants increased and the maximum height that the plants in the sole reached was 69 cm, the soybean intercropped with rice in the 3:1 ratio reached 65 cm, 68 cm for the plants in the 4:1 ratio, and the maximum height that the plants of the soybean intercropped with rice in the 5:1 ratio was 65 cm (Fig 5a).

There was no significant difference in the plant height between the sole pigeonpea and the pigeonpea intercropped with rice in the three ratios tested. At 37 DAS the pigeonpea plants in the sole had a height of 25 cm, the pigeonpea plants

SEM (+) = 6

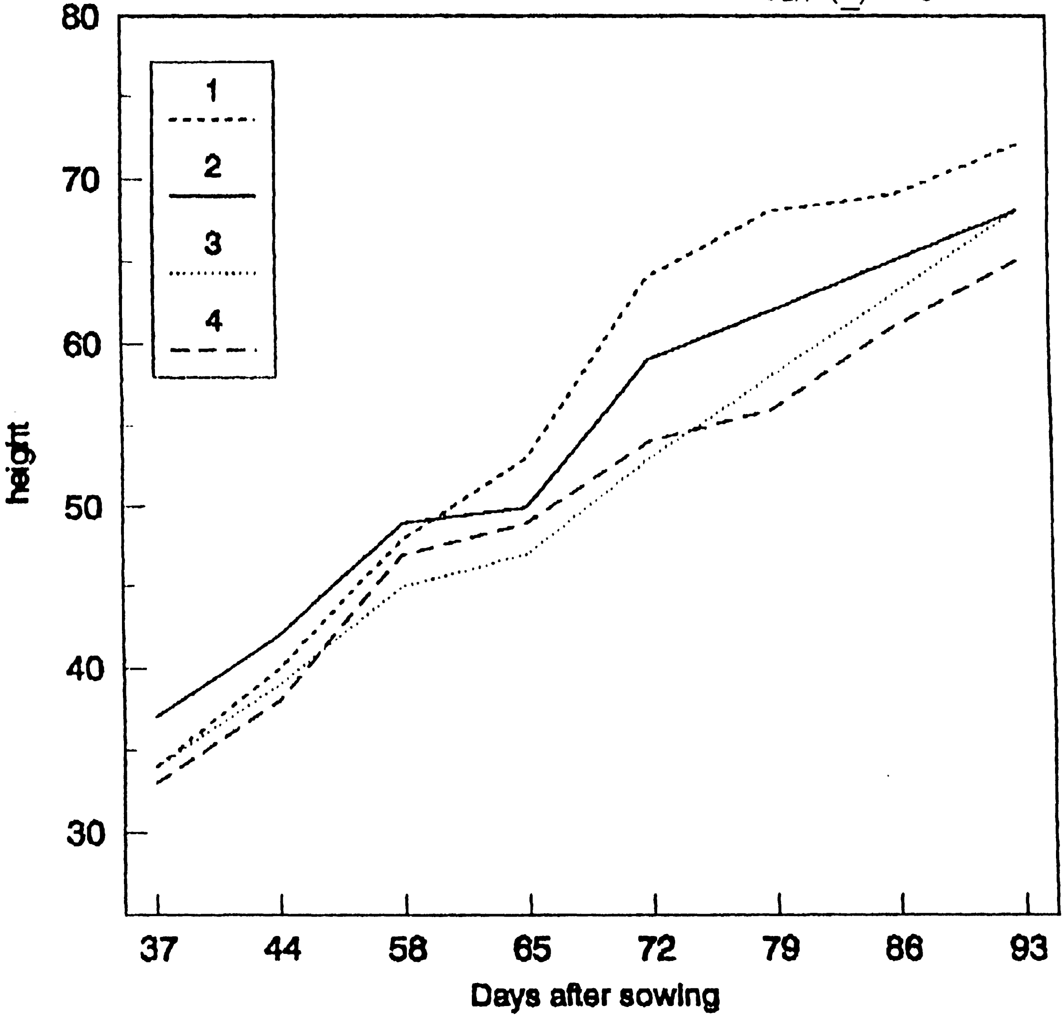


Fig.5a: Plant height (cm) of the sole and intercrop soybean.

1 = Sole soybean.
2 = Soybean intercropped with rice in the (3:1) ratio.
3 = Soybean intercropped with rice in the (4:1) ratio.
4 = Soybean intercropped with rice in the (5:1) ratio.

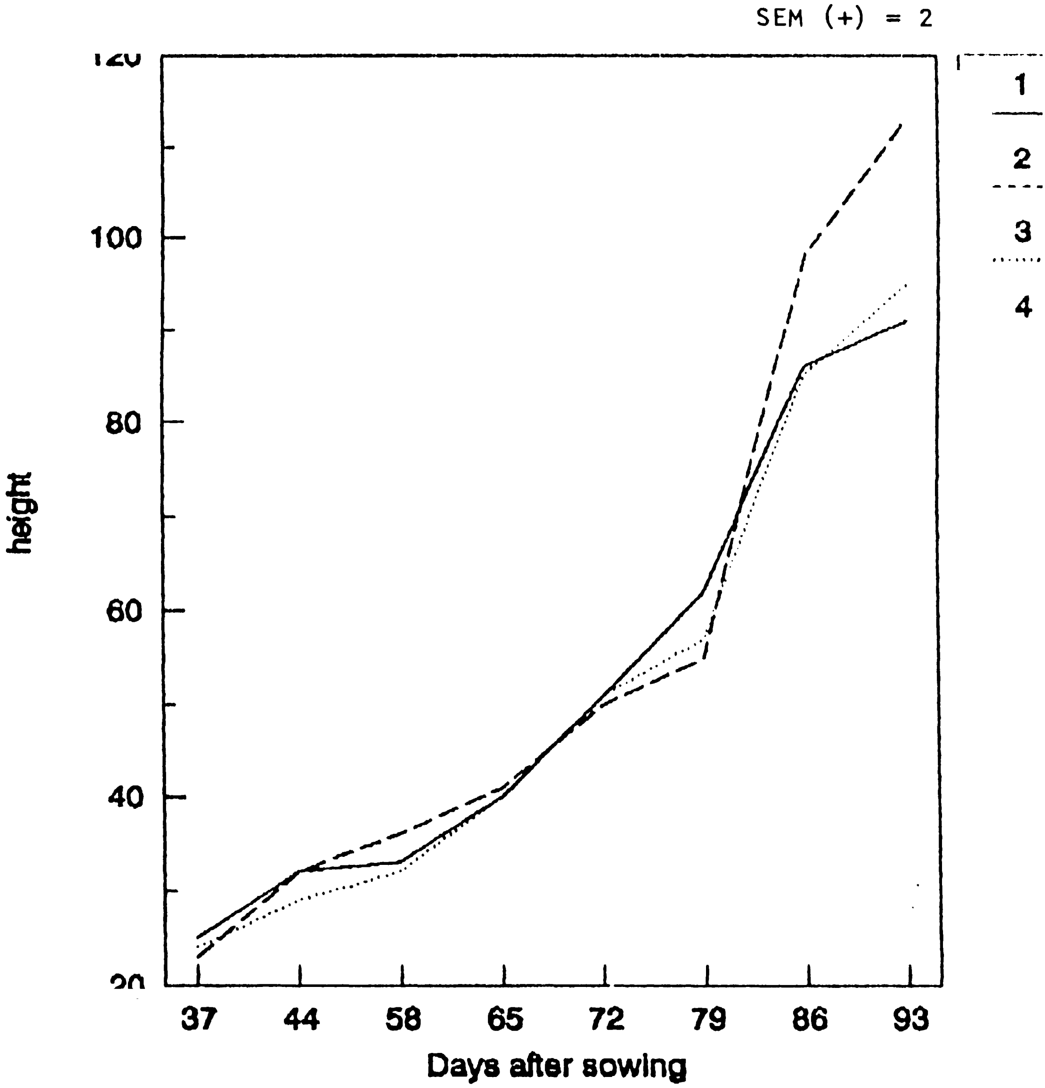


Fig.5b: Plant height (cm) of the sole and intercrop pigeonpea.

1 = Sole pigeonpea.
2 = Pigeonpea intercropped with rice in the (3:1) ratio.
3 = Pigeonpea intercropped with rice in the (4:1) ratio.
4 = Pigeonpea intercropped with rice in the (5:1) ratio.

intercropped with rice in the 3:1 ratio had a height of 23 cm, 24 cm for the pigeonpea intercropped with rice in the 4:1 ratio, and the plants of the pigeonpea intercropped with rice in the 5:1 ratio had a plant height of 23 cm. There was no significant difference in plant height between the plants in the three intercrop pigeonpea. The maximum height that the plants reached was 1.20 m (Fig. 5b).

4.7. LEAF DRY WEIGHT (g m^{-2})

There was no significant difference in the leaf dry weight between the sole rice and the intercrop rice. At 70 DAS the sole rice recorded a leaf dry weight of 221 g m^{-2}, whereas the rice intercropped with soybean in the 3:1 ratio recorded 257 g m^{-2}, 218 g m^{-2} for the rice intercropped with soybean in the 4:1 ratio, and the rice intercropped with soybean in the 5:1 ratio had a leaf dry weight of 176 g m^{-2}. The rice intercropped with pigeonpea in the 3:1 ratio had a leaf dry weight 208 g m^{-2}, 236 g m^{-2} for the rice intercropped with pigeonpea in the 4:1 ratio, and 192 g m^{-2} was the leaf dry weight of the rice intercropped with pigeonpea in the 5:1 ratio (Table 5).

At harvest of the rice, the sole rice recorded a leaf dry weight of 891 g m^{-2}. The rice intercropped with soybean in the 3:1 ratio had a leaf dry weight 865 g m^{-2}, 593 g m^{-2} for the rice intercropped with soybean in the 4:1 ratio, and the rice intercropped with soybean in the 5:1 ratio recorded a leaf dry weight of 738 g m^{-2}. The rice intercropped with pigeonpea in

Table 5. Leaf dry weight g m^{-2} of the sole and intercrop rice.

	Days after sowing						
	70	77	84	98	105	112	119
Sole rice	221	263	269	292	527	626	890
R IC SB							
3:1	257	271	282	373	600	830	864
4:1	218	229	250	272	534	557	593
5:1	176	182	193	230	514	638	707
R IC PPEA							
3:1	209	216	238	268	765	872	1043
4:1	236	254	257	301	350	533	781
5:1	193	194	216	220	423	556	670
SE(±)	28.20						
CV %	10 %						

R IC SB= rice intercropped with soybean
R IC PPEA= rice intercropped with pigeonpea

the 3:1 ratio had a leaf dry weight of 1043 g m^{-2}, 781 g m^{-2} for the rice intercropped with pigeonpea in the 4:1 ratio, and the rice intercropped with pigeonpea in the 5:1 ratio had a leaf dry weight of 670 g m^{-2} (Table 5).

There was no significant difference in leaf dry weight between the rice intercropped with soybean and the rice intercropped with pigeonpea in the three ratios tested. However, some of the intercrops showed slight difference in leaf dry weight between them, but that was not a significant difference throughout the experiment.

There was a significant difference in leaf dry weight between the sole soybean and the intercrop soybean. At 37 DAS the sole soybean had a leaf dry weight of 117 g m^{-2}, the soybean intercropped with rice in the 3:1 ratio had a leaf dry weight of 61 g m^{-2}, 65g m^{-2} for the soybean intercropped with rice in the 4:1 ratio, and the soybean intercropped with rice in the 5:1 ratio had a leaf dry weight of 59 g m^{-2}. The plants of the soybean intercropped with rice in the three ratios (3:1, 4:1, and 5:1) did not show any significant difference between them in leaf dry weight. At harvest of the soybean the plants in the sole had a leaf dry weight of 487 g m^{-2}. The soybean intercropped with rice in the 3:1 ratio had a leaf dry weight 400 g m^{-2}, 307 g m^{-2} for the soybean intercropped with rice in the 4:1 ratio, and the soybean intercropped with rice in the 5:1 ratio had a leaf dry weight of 282 g m^{-2} (Fig. 6a).

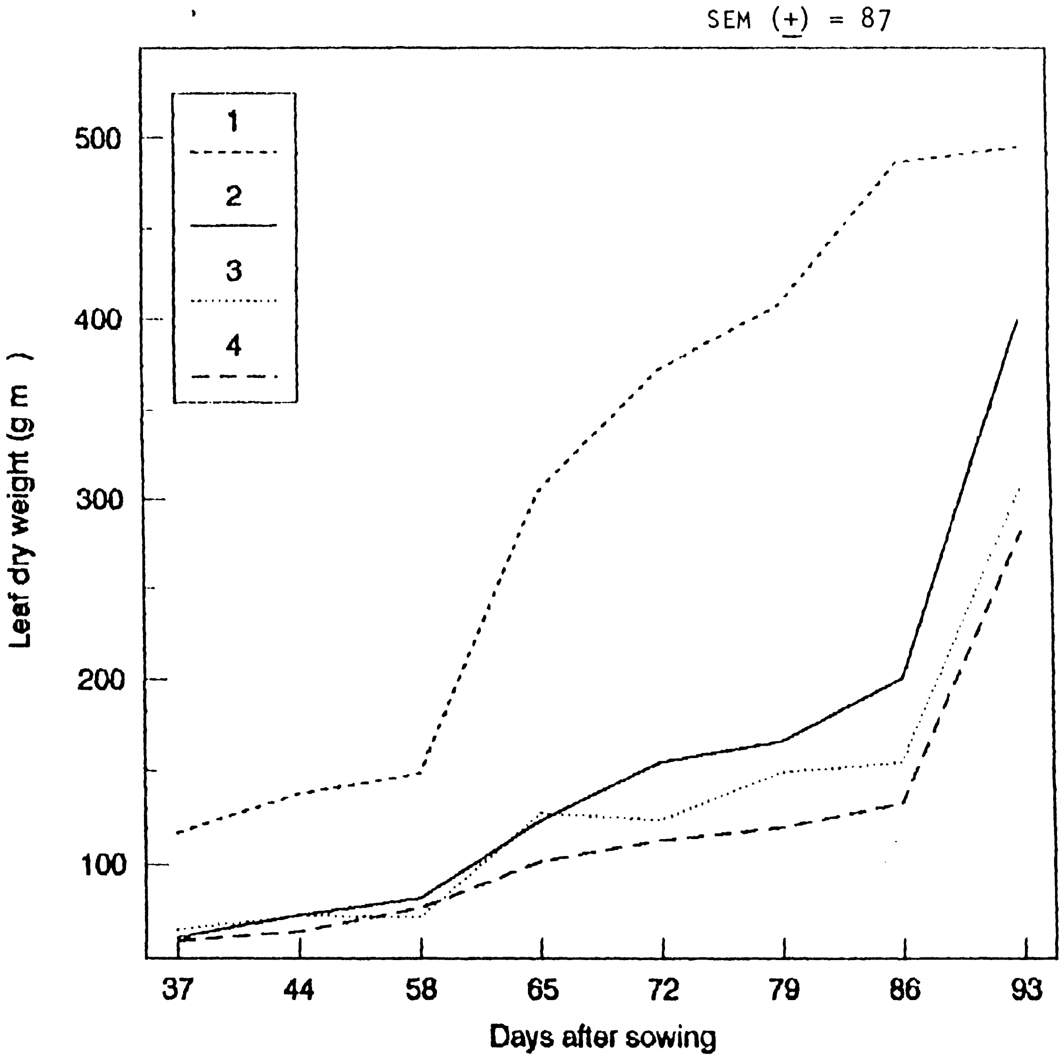


Fig.6a: Leaf dry weight (g m^{-2}) of the sole and intercrop soybean.

1 = Sole soybean.
2 = Soybean intercropped with rice in the (3:1) ratio.
3 = Soybean intercropped with rice in the (4:1) ratio.
4 = Soybean intercropped with rice in the (5:1) ratio.

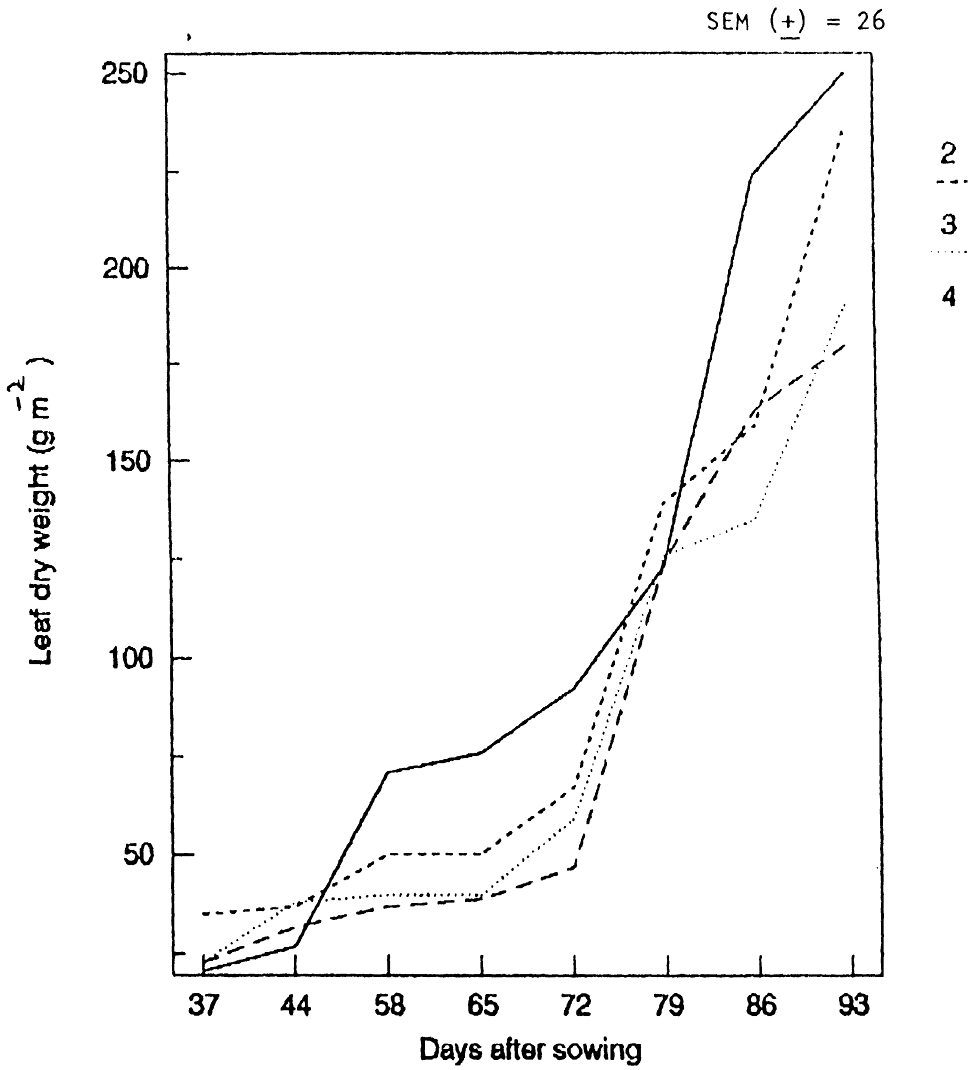


Fig.6b: Leaf dry weight (g m^{-2}) of the sole and intercrop pigeonpea.

1 = Sole pigeonpea.
2 = Pigeonpea intercropped with rice in the (3:1) ratio.
3 = Pigeonpea intercropped with rice in the (4:1) ratio.
4 = Pigeonpea intercropped with rice in the (5:1) ratio.

There was no significant difference in leaf dry weight between the sole and the pigeonpea intercropped with rice in the three ratios. At 37 DAS the sole pigeonpea had a leaf dry weight of 21 g m^{-2}. The pigeonpea intercropped with rice in the 3:1 ratio had a leaf dry weight of 35 g m^{-2}, 23 g m^{-2} for the pigeonpea intercropped with rice in the 4:1 ratio, and the pigeonpea intercropped with rice in the 5:1 ratio had a leaf dry weight of 24 g m^{-2}. The different intercrop pigeonpea did not show any difference between them in leaf dry weight (Fig. 6b).

4.8. STEM DRY WEIGHT (g m^{-2})

There was no significant difference in stem dry weight between the sole rice and the intercrop rice. At 70 DAS the sole rice recorded a stem dry weight of 209 g m^{-2}. The rice intercropped with soybean in the 3:1 ratio had a stem dry weight of 259 g m^{-2}, 231 g m^{-2} for the rice intercropped with soybean in the 4:1 ratio, and the rice intercropped with soybean in the 5:1 ratio had a stem dry weight of 196 g m^{-2}. The rice intercropped with pigeonpea in the 3:1 ratio recorded a stem dry weight of 232 g m^{-2}, 239 g m^{-2} for the 4:1 ratio, and the rice intercropped with pigeonpea had a stem dry weight of 205 g m^{-2} (Table 6).

At harvest of the rice, the sole rice recorded a stem dry weight 638 g m^{-2}. The rice intercropped with soybean in the 3:1 ratio had a stem dry weight of 745 g m^{-2}, 528 g m^{-2} for the rice intercropped with soybean in the 4:1 ratio, and the

Table 6. Stem dry weight g m^{-2} of the sole and intercrop rice.

	Days after sowing						
	70	77	84	98	105	112	119
Sole rice	209	253	274	307	486	604	638
R IC SB							
3:1	259	266	296	368	486	575	745
4:1	231	235	246	310	367	464	528
5:1	196	197	245	267	368	479	533
R IC PPEA							
3:1	232	237	267	303	472	603	793
4:1	239	252	255	292	414	525	545
5:1	205	213	231	262	342	453	460
SE(±)	32.28						
CV %	12 %						

R IC SB= rice intercropped with soybean
R IC PPEA= rice intercropped with pigeonpea

rice intercropped with soybean in the 5:1 ratio had a stem dry weight of 534 g m^{-2}. The rice intercropped with pigeonpea in the 3:1 ratio had a stem dry weight of 794 g m^{-2}, 546 g m^{-2} for the rice intercropped with pigeonpea in the 4:1 ratio, and the rice intercropped with pigeonpea in the 5:1 ratio had a stem dry weight of 460 g m^{-2} (Table 6).

There was no significant difference in stem dry weight between the rice intercropped with soybean and the rice intercropped with pigeonpea in the three ratios tested. Some of the rice treatments showed slight difference in stem dry weight between them but that was not statistically significant.

There was a significant difference in stem dry weight between the sole soybean and the soybean intercropped with rice in the three ratios tested. At 37 DAS the sole soybean had a stem dry weight of 79 g m^{-2}, the soybean intercropped with rice in the 3:1 and 4:1 ratio had a stem dry weight of 5 g m^{-2}. The soybean intercropped with rice in the 5:1 ratio recorded a stem dry weight of 4 g m^{-2} (Fig. 7a).

The soybean intercropped with rice in the three ratio did not show any significant difference between them in stem dry weight. At harvest of the soybean the plants in the sole had a stem dry weight of 539 g m^{-2}, 206 g m^{-2} for the 3:1 ratio, 156 g m^{-2} and the soybean intercropped with rice in the 5:1 ratio had a stem dry weight of 145 g m^{-2} (Fig. 7a).

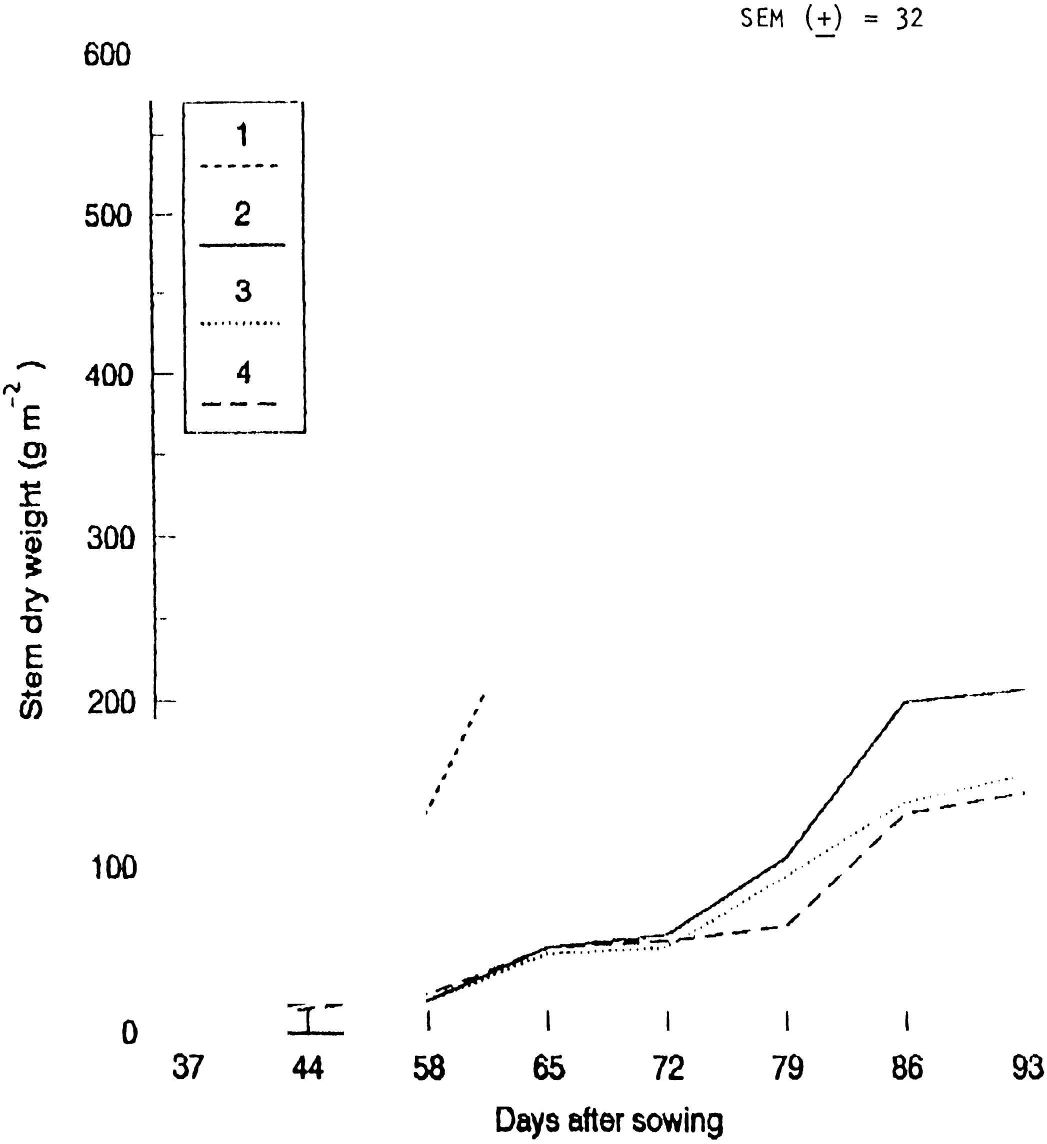


Fig.7a: Stem dry weight (g m^{-2}) of the sole and intercrop soybean.

1 = Sole soybean.
2 = Soybean intercropped with rice in the (3:1) ratio.
3 = Soybean intercropped with rice in the (4:1) ratio.
4 = Soybean intercropped with rice in the (5:1) ratio.

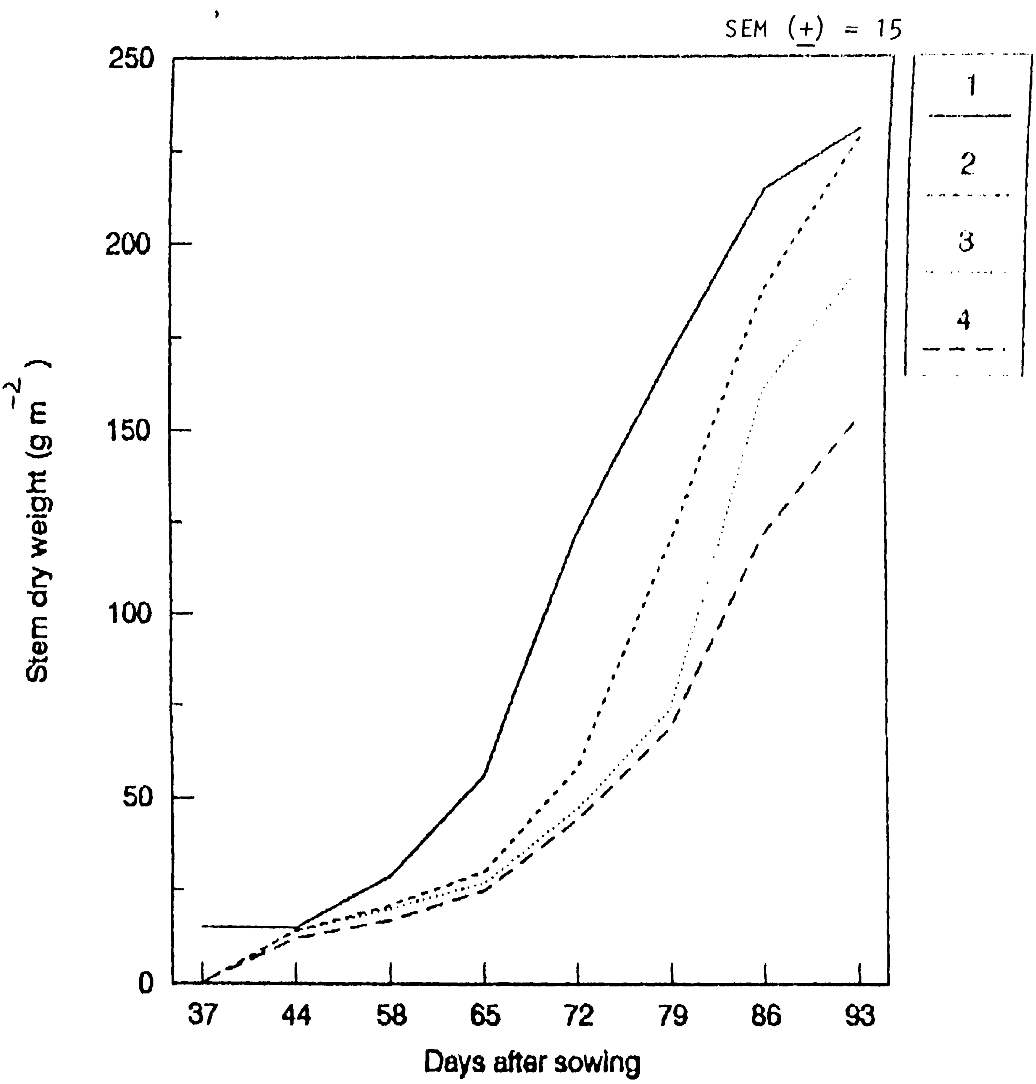


Fig.7b: Stem dry weight (g m^{-2}) of the sole and intercrop pigeonpea.

1 = Sole pigeonpea.
2 = Pigeonpea intercropped with rice in the (3:1) ratio.
3 = Pigeonpea intercropped with rice in the (4:1) ratio.
4 = Pigeonpea intercropped with rice in the (5:1) ratio.

There was no significant difference in stem dry weight between the sole pigeonpea and the intercrop pigeonpea in the three ratio. At 37 DAS the sole pigeonpea had a stem dry weight of 15 g m^{-2}, the pigeonpea intercropped with rice in the 3:1 ratio had a stem dry weight of 0.26 g m^{-2}, 0.25 g m^{-2} for the pigeonpea intercropped with rice in the 4:1 ratio, and the pigeonpea intercropped with rice in the 5:1 ratio recorded a stem dry weight of 0.45 g m^{-2}. The stem dry weight of the pigeonpea increased but due the mortality of many plants the data of the stem dry weight at harvest was not available (Fig. 7b).

4.9. TOTAL DRY MATTER (TDM) g m^{-2}

There was no significant difference in total dry matter between the sole rice and the intercrop rice, except there was a significant difference between the sole rice and the rice intercropped with pigeonpea in the 5:1 ratio. At 70 DAS the sole rice had a total dry matter of 622 g m^{-2}. The rice intercropped with soybean in the 3:1 ratio had a total dry matter of 642 g m^{-2}, 597 g m^{-2} for the rice intercropped with soybean in the 4:1 ratio, and the rice intercropped with soybean in the 5:1 ratio had a total dry matter of 479 g m^{-2}. The total dry matter of the rice intercropped with pigeonpea was not significantly different from that intercropped with soybean. The rice intercropped with pigeonpea in the 3:1 ratio recorded a total dry matter of 566 g m^{-2}, 587 g m^{-2} for the 4:1 ratio, and the rice intercropped with pigeonpea had a total dry matter of 520 g m^{-2} (Table 7).

Table 7. Total dry matter g m^{-2} of the sole and intercrop rice.

	Days after sowing						
	70	77	84	98	105	112	119
Sole rice	622	700	769	879	1314	1405	1590
R IC SB							
3:1	642	671	709	788	1263	1465	1659
4:1	597	616	683	763	1137	1249	1368
5:1	478	508	604	700	1083	1319	1418
R IC PPEA							
3:1	566	582	665	693	1317	1536	1881
4:1	587	655	685	786	961	1362	1369
5:1	520	559	679	683	1021	1121	1174
SE(±)	50.48						
CV %	16 %						

R IC SB= rice intercropped with soybean
R IC PPEA= rice intercropped with pigeonpea

The total dry matter of the rice crop increased with time and at harvest of the rice, the sole rice recorded a total dry matter of 1590 g m^{-2}. The rice intercropped with soybean in the 3:1 ratio had a total dry matter of 1659 g m^{-2}, 1168 g m^{-2} for the rice intercropped with soybean in the 4:1 ratio, and the rice intercropped with soybean in the 5:1 ratio had a total dry matter of 1418 g m^{-2}. The rice intercropped with pigeonpea in the 3:1 ratio had a total dry matter of 1881 g m^{-2}, 1370 g m^{-2} for the rice intercropped with pigeonpea in the 4:1 ratio, and the rice intercropped with pigeonpea in the 5:1 ratio had a total dry matter of 1174 g m^{-2} (Table 7).

There was a significant difference between the sole rice and the rice intercropped with pigeonpea in the 5:1 ratio. At harvest the sole rice had a total dry matter of 1590 g m^{-2}, whereas the rice intercropped with pigeonpea in the 5:1 ratio had a TDM of 1174 g m^{-2}.

There was a significant difference in total dry matter between the sole soybean and the soybean intercropped with rice in the three ratios tested. At 37 DAS the sole soybean had a total dry matter of 250 g m^{-2}, the soybean intercropped with rice in the 3:1 had a TDM of 65 g m^{-2}, the soybean intercropped with rice in the 4:1 ratio had a total dry matter of 69 g m^{-2}, and the soybean intercropped with rice in the 5:1 ratio recorded a total dry matter of 63 g m^{-2} (Fig. 8a).

The soybean intercropped with rice in the three ratio did not show any significant difference between them in total dry

SEM (+) = 71

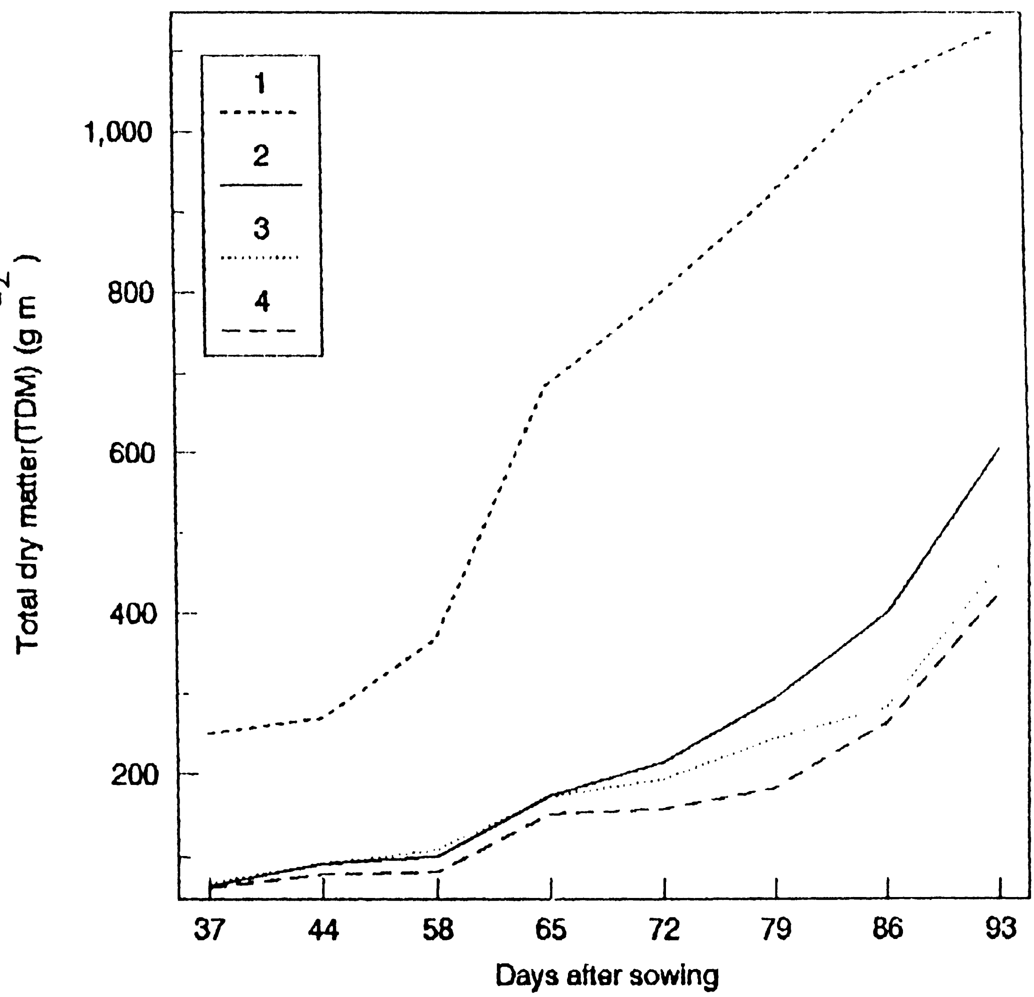


Fig.8a: Total dry matter (g m^{-2}) of the sole and intercrop soybean.

1 = Sole soybean.
2 = Soybean intercropped with rice in the (3:1) ratio.
3 = Soybean intercropped with rice in the (4:1) ratio.
4 = Soybean intercropped with rice in the (5:1) ratio.

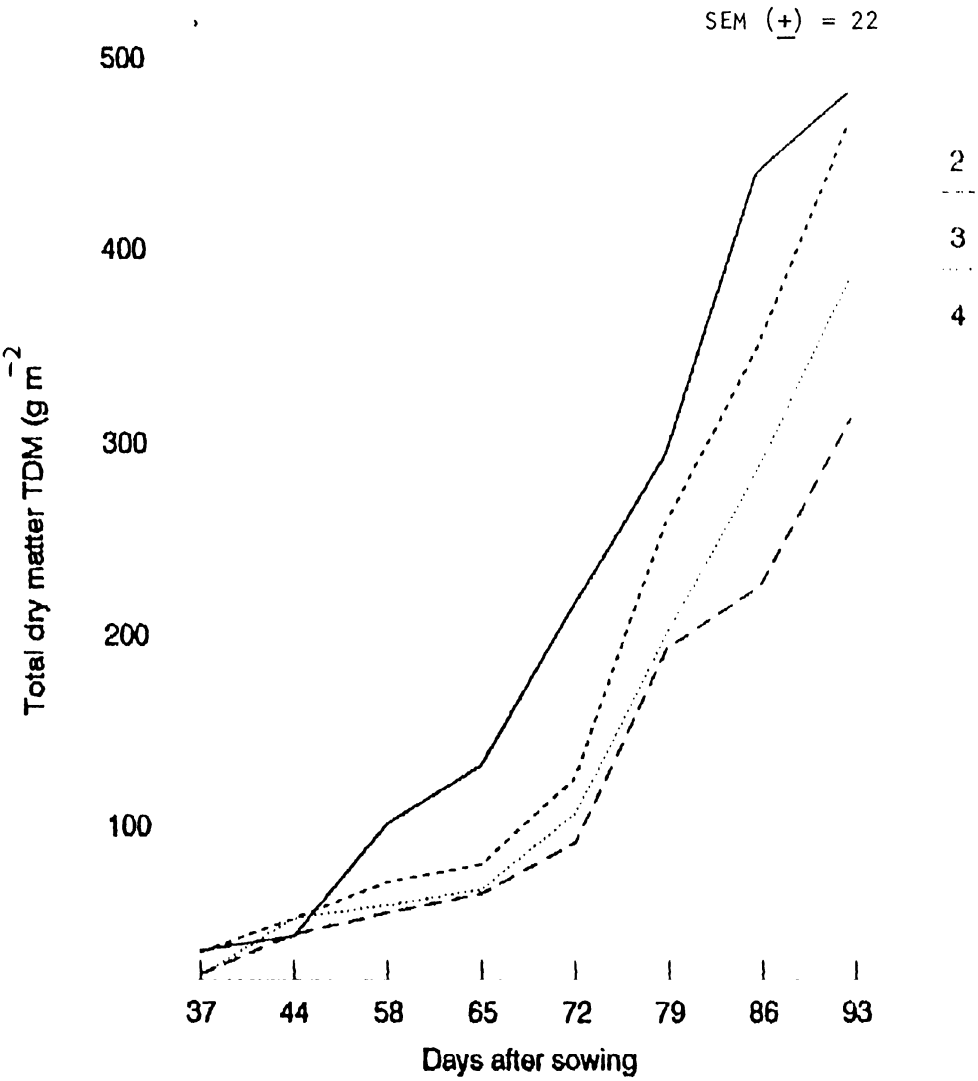


Fig.8b: Total dry matter (g m^{-2}) of the sole and intercrop pigeonpea.

1 = Sole pigeonpea.
2 = Pigeonpea intercropped with rice in the (3:1) ratio.
3 = Pigeonpea intercropped with rice in the (4:1) ratio.
4 = Pigeonpea intercropped with rice in the (5:1) ratio.

matter. At harvest of the soybean the sole had a total dry matter of 1062 g m^{-2}, 607 g m^{-2} for the soybean intercropped with rice in the 3:1 ratio, 463 g m^{-2} for the 4:1 ratio and the soybean intercropped with rice in the 5:1 ratio had a total dry matter of 428 g m^{-2} (Fig. 8a).

There was no significant difference in total dry matter between the sole pigeonpea and the intercrop pigeonpea in the three ratio. At 37 DAS the sole pigeonpea had a total dry matter of 36 g m^{-2}, the pigeonpea intercropped with rice in the 3:1 ratio had a total dry matter of 35 g m^{-2}, 23 g m^{-2} for the pigeonpea intercropped with rice in the 4:1 ratio, and the pigeonpea intercropped with rice in the 5:1 ratio recorded a total dry matter of 24 g m^{-2}. The stem dry weight of the pigeonpea increased but due the mortality of many plants the data of the stem dry weight at harvest was not available. At 93 DAS the sole pigeonpea had a TDM of 440 g m^{-2}, 466 g m^{-2} was the TDM of the pigeonpea intercropped with rice in the 3:1 ratio, 384 g m^{-2} for the 4:1 ratio, and the pigeonpea intercropped with rice in the 5:1 ratio had a TDM of 312 g m^{-2} (Fig. 8b).

4.10. NUMBER OF PANICLES PLANT^{-1} (RICE)

Observations on the number of panicles plant^{-1} have been recorded starting from 98 DAS. There was no significant difference in number of panicles plant^{-1} between the sole rice and the intercrop rice. The crop showed poor panicle initiation and at 98 DAS the rice plants in the sole had 2

Table 8. Number of panicles $plant^{-1}$ of the sole and intercrop ri

	Days after sowing			
	98	105	112	119
Sole rice	2.0	2.0	3.0	3.0
R IC SB				
3:1	2.0	3.0	3.0	3.0
4:1	2.0	3.0	3.0	3.0
5:1	2.0	3.0	3.0	3.0
R IC PPEA				
3:1	2.0	3.0	3.0	3.0
4:1	2.0	2.0	3.0	3.0
5:1	2.0	2.0	3.0	4.0
SE(±)	0.23			
CV %	7 %			

R IC SB= rice intercropped with soybean
R IC PPEA= rice intercropped with pigeonpea

panicles plant^{-1}, also the intercrop rice plants in the three ratios (3:1, 4:1, and 5:1) had 2 panicles plant^{-1} (Table 8).

There was no significant difference in number of panicles plant^{-1} between the sole rice and the intercrop rice. The rice intercropped with pigeonpea in the three ratios (3:1, 4:1, and 5:1) all of them had 2 panicles plant^{-1}. At harvest of the rice (119 DAS) the sole rice had 3 panicles plant^{-1}. All the intercrop rice with soybean and with pigeonpea in the three ratios tested had 3 panicles plant^{-1} (Table 8).

4.11. PANICLE LENGTH (cm)

The observations of the panicle length were recorded starting from 98 DAS. There was no any significant difference in the panicle length between the sole rice and the intercrop rice. At 98 DAS the sole rice had a panicle length of 16 cm. The rice intercropped with soybean in the 3:1 ratio had a panicle length of 16 cm, 15 cm for the rice intercropped with soybean in the 4:1 ratio, and the rice intercropped with soybean in the 5:1 ratio had a panicle length of 15 cm (Table 9).

The rice intercropped with pigeonpea in the 3:1 and 4:1 ratio had a panicle length of 15 cm, and the rice in the 4:1 had a panicle length of 16 cm.

At harvest of the rice when again measured the panicle length of the rice crop, the sole had a panicle length of 17 cm. The rice intercropped with soybean had a panicle length of

Table 9. Panicle length (cm) of the sole and intercrop rice

	Days after sowing			
	98	105	112	119
Sole rice	87	157	242	280
R IC SB				
3:1	88	185	332	461
4:1	81	132	248	285
5:1	89	140	240	325
R IC PPEA				
3:1	87	187	347	451
4:1	77	142	309	331
5:1	76	100	259	279
SE(±)	9.10			
CV %	10 %			

R IC SB= rice intercropped with soybean
R IC PPEA= rice intercropped with pigeonpea

18, 16, and 17 cm in the 3:1, 4:1, and the 5:1 ratio respectively. The rice intercropped with pigeonpea had a panicle length of 16, 18, and 17 cm in the 3:1, 4:1, and in the 5:1 ratios. There was no significant difference in the panicle length between the rice intercropped with soybean and the rice intercropped with pigeonpea in the three ratios tested (Table 9).

4.12. NUMBER OF PODS PLANT^{-1} (SOYBEAN)

The observations on the number of pods plant^{-1} have been recorded starting from 65 DAS. There was a significant difference in number of pods plant^{-1} between the sole soybean and the soybean intercropped with rice. At 65 DAS the sole soybean had 17 pods plant^{-1}. The soybean intercropped with rice in the 3:1 ratio,4:1, and 5:1 ratio had 4 pods plant^{-1} each (Fig. 9).

There was no significant difference between the different intercrop soybean in the number of pods plant^{-1}. At harvest of the soybean the sole soybean had 43 pods plant^{-1}, 35 pods plant^{-1} for the soybean intercropped with rice in the 3:1 ratio, 37 for the 4;1 ratio, and the soybean intercropped with rice in the 5:1 ratio had 35 pods plant^{-1} (Fig. 9).

4.13. PANICLE DRY WEIGHT g m^{-2} (RICE)

Observations on the number of panicles plant^{-1} have been recorded starting from 98 DAS. There was no significant difference in panicle dry weight between the sole rice and the

SEM (±) = 14

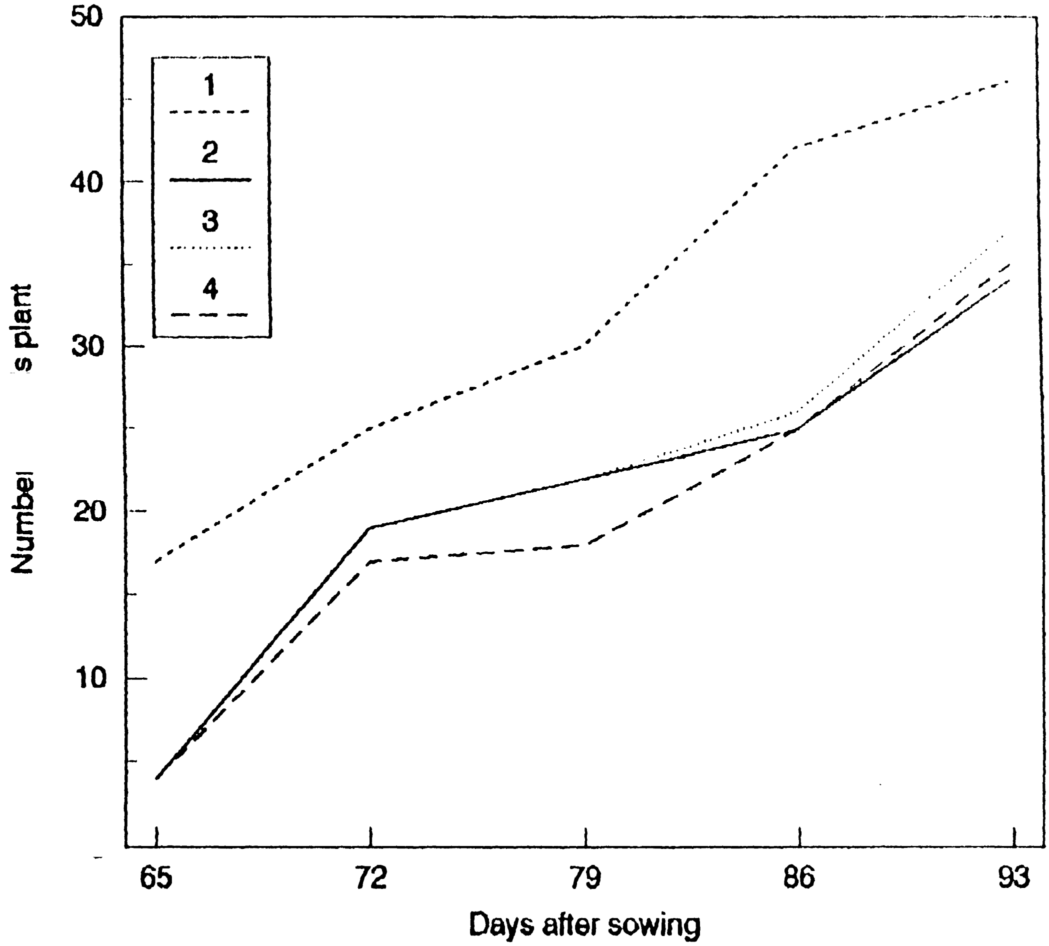


Fig.9: Number of pods plant^{-1} of the sole and intercrop soybean.

1 = Sole soybean.
2 = Soybean intercropped with rice in the (3:1) ratio.
3 = Soybean intercropped with rice in the (4:1) ratio.
4 = Soybean intercropped with rice in the (5:1) ratio.

intercrop rice, except the sole rice and the rice intercropped with soybean in the 3:1 ratio. There was also a significant difference in panicle dry weight between the rice intercropped with soybean in the 3:1 ratio and in the 4;1 ratio. There was also a significant difference in panicle dry weight between the rice intercropped with soybean in the 3:1 ratio and the rice intercropped with pigeonpea in the 5:1 ratio. At 98 DAS the sole rice had a panicle dry weight of 87 g m^{-2}. The rice intercropped with soybean in the 3:1 ratio had a panicle dry weight of 88 g m^{-2}, 81 g m^{-2} for the 4:1 ratio, and the rice intercropped with soybean in the 5:1 ratio had a panicle dry weight of 89 g m^{-2} (Table 10).

The rice intercropped with pigeonpea in the 3:1 ratio had a panicle dry weight of 87 g m^{-2}, the rice intercropped with pigeonpea in 4:1 ratio had a panicle dry weight of 77 g m^{-2}, and the rice intercropped with pigeonpea in the 5:1 ratio had a panicle dry weight of 76 g m^{-2} (Table 10).

The panicle dry weight of the rice increased, and at harvest of the rice (119 DAS) the sole rice had a panicle dry weight of 280 g m^{-2}. The rice intercropped with soybean in the 3:1 ratio had a panicle dry weight of 461 g m^{-2}, 285 g m^{-2} for the rice intercropped with soybean in the 4:1 ratio, and the rice intercropped with soybean in the 5:1 ratio had a panicle dry weight of 325 g m^{-2}.

There was no significant difference in panicle dry weight between most of the intercrops. At harvest of the rice the

Table 10. Panicle weight g m^{-2} of the sole and intercrop ri

	Days after sowing			
	98	105	112	119
Sole rice	87	157	242	280
R IC SB				
3:1	88	185	332	461
4:1	81	132	248	285
5:1	89	140	240	325
R IC PPEA				
3:1	87	187	347	451
4:1	77	142	309	331
5:1	76	100	259	279
SE(±)	9.10			
CV %	10 %			

R IC SB= rice intercropped with soybean
R IC PPEA= rice intercropped with pigeonpea

rice intercropped with pigeonpea in the 3:1 ratio had a panicle dry weight of 450 g m^{-2}, 301 g m^{-2} for the rice intercropped with pigeonpea in the 4:1 ratio, and the rice intercropped with pigeonpea in the 5:1 ratio had a panicle dry weight of 279 g m^{-2} (Table 10).

4.14. POD DRY WEIGHT g m^{-2} (SOYBEAN)

There was a significant difference in the pod dry weight between the sole soybean and the soybean intercropped with rice in the three ratios tested. The observations of the pod dry weight were recorded starting from 65 DAS in which the sole soybean had a pod dry weight of 69 g m^{-2}, 3 g m^{-2} for the soybean in the 3:1 ratio, 2 g m^{-2} for the 4:1 ratio, and the soybean intercropped with rice in the 5:1 ratio had a pod dry weight of 3 g m^{-2} (Fig. 10).

At harvest of the soybean (93 DAS) the sole soybean had a pod dry weight of 249 g m^{-2}, 136 g m^{-2} for the soybean in the 3:1 ratio, 103 and 83 g m^{-2} for the soybean intercropped with rice in the 4:1 and 5:1 ratios respectively. There was no significant difference between the different intercrops (Fig. 10).

4.15. LIGHT INTERCEPTION (%)

Fig. 11, illustrates the fraction of light interception (f) of the sole rice, and the intercropped rice. All the three crops (rice, soybean, pigeonpea) had markedly different rates of change of f with time. The sole rice recorded the

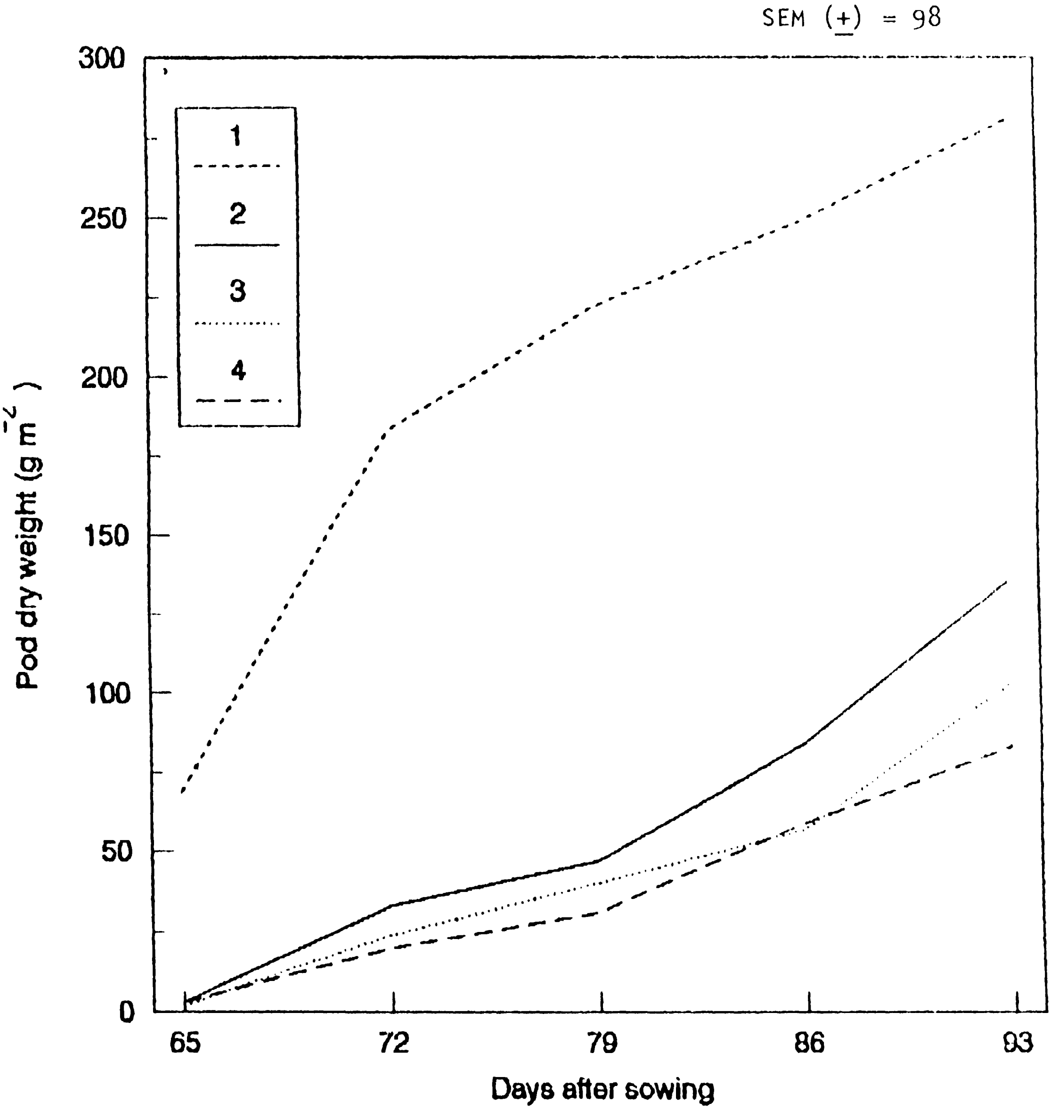


Fig.10: Pod dry weight (g m^{-2}) of the sole and intercrop soybean.

1 = Sole soybean.
2 = Soybean intercropped with rice in the (3:1) ratio.
3 = Soybean intercropped with rice in the (4:1) ratio.
4 = Soybean intercropped with rice in the (5:1) ratio.

highest light interception compared to the intercrops. Among the intercrops the rice intercropped with soybean in the 3:1 pattern intercepted more light than the other intercrops. Similarly the rice intercropped with pigeonpea in the 3:1 pattern intercepted more light compared to the rice in the same intercrop in the other two patterns. The rice intercropped with soybean in the 4:1 pattern had the lowest light interception. The sole rice recorded the highest light interception at 74 DAS (77%). All the intercrops recorded the lowest light interception at 68 DAS thenafter it increased. Rice intercropped with soybean and the rice intercropped with pigeonpea in the 3:1 pattern and 5:1 pattern had higher light interception than the rice intercropped with soybean or pigeonpea in the 4:1 pattern (Fig.11)

The soybean intercepted more light than the rice, specially in the early stages of the growth (Fig. 12). The intercrop soybean in the 3:1 pattern showed higher light interception, even more than the sole crop. The intercrop soybean in the 4:1 and 5:1 patterns recorded the lowest light interception in 68 DAS. All the intercrops recorded the highest light interception at 75 DAS, when the rice was harvested. The light interception of all the intercrops and the sole crop started reducing at 77 DAS due to the senescence of the leaves in the later stages of the growth and subsequent low LAI due to removal of rice (Fig. 12).

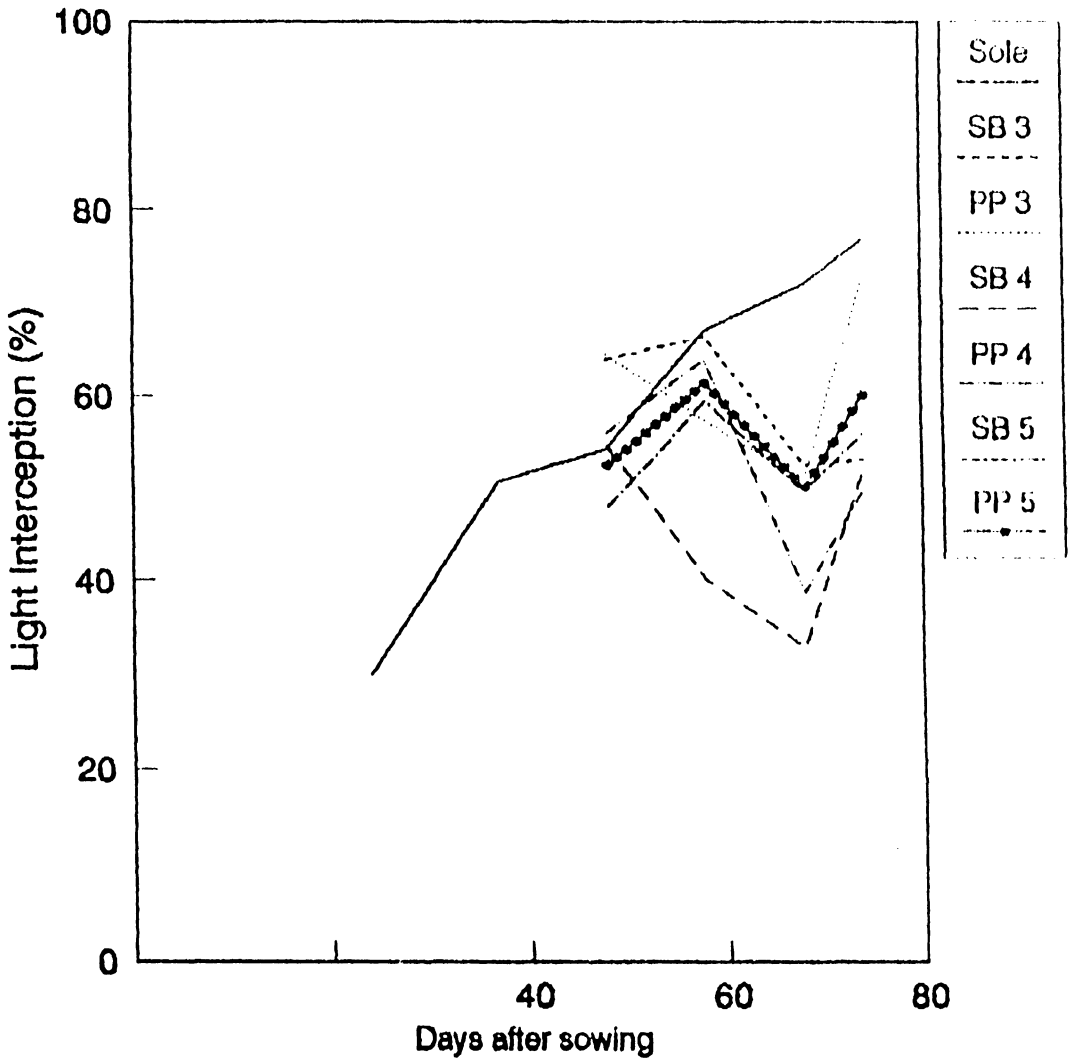


Fig.11: Light interception (%) of the rice crop.

Sole = Sole rice
SB3 = Rice intercropped with soybean in the (3:1) ratio.
SB4 = Rice intercropped with soybean in the (4:1) ratio.
SB5 = Rice intercropped with soybean in the (5:1) ratio.
PP3 = Rice intercropped with pigeonpea in the (3:1) ratio.
PP4 = Rice intercropped with pigeonpea in the (4:1) ratio.
PP5 = Rice intercropped with pigeonpea in the (5:1) ratio.

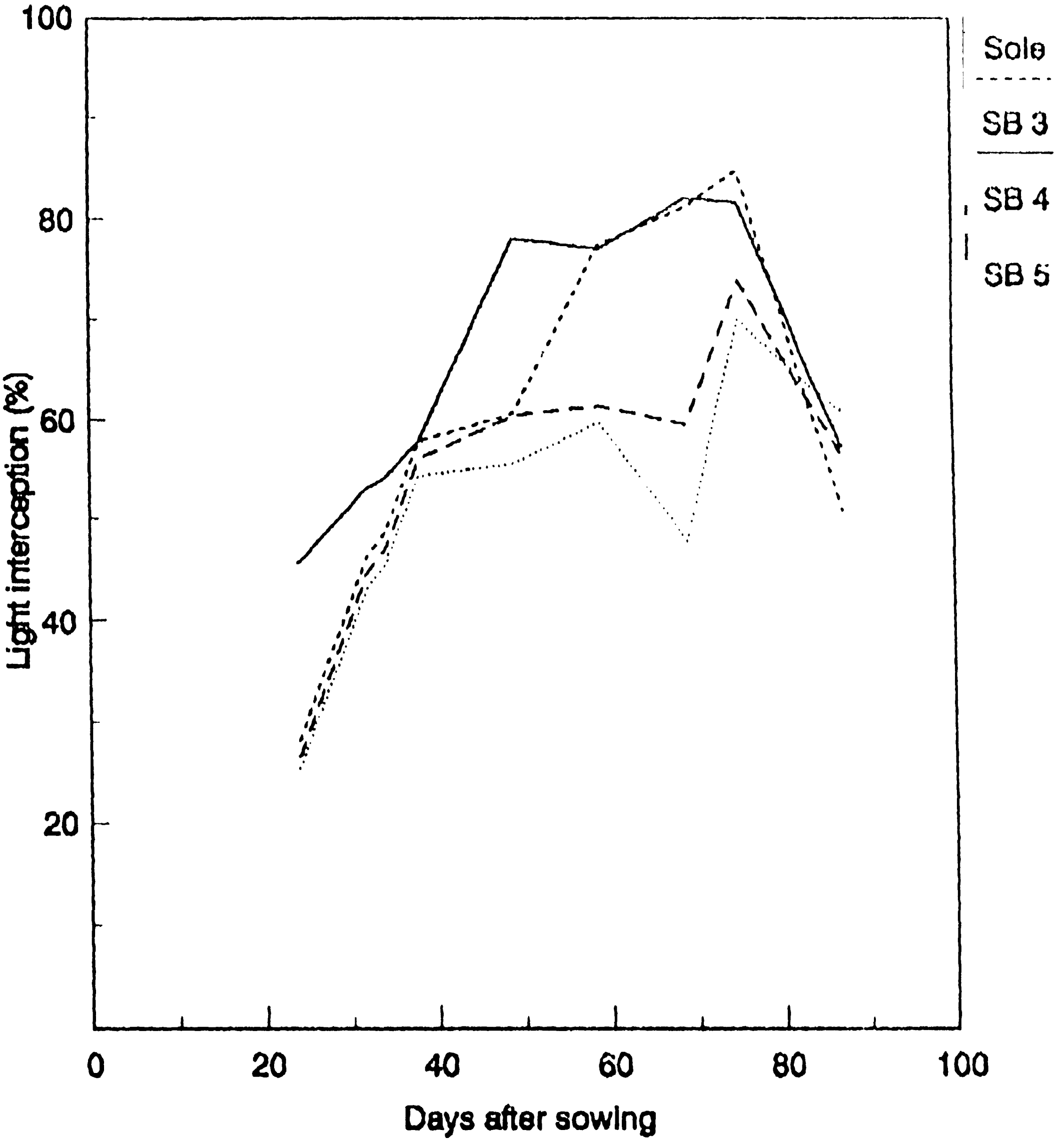


Fig.12: Light interception (%) of the soybean crop.

Sole = Sole soybean.
SB3 = Soybean intercropped with rice in the (3:1) ratio.
SB4 = Soybean intercropped with rice in the (4:1) ratio.
SB5 = Soybean intercropped with rice in the (5:1) ratio.

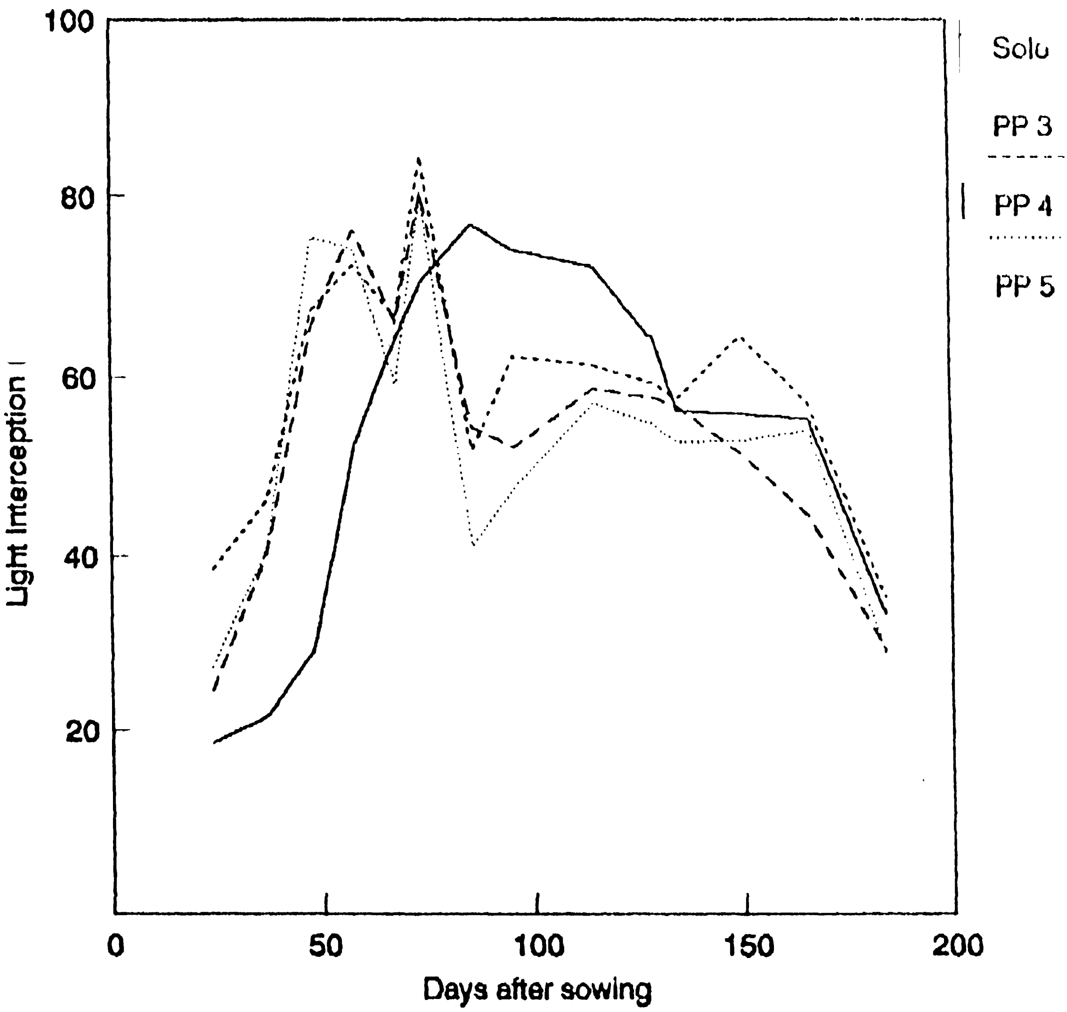


Fig.13: Light interception (%) of the pigeonpea crop.

Sole = Sole pigeonpea.
PP3 = Pigeonpea intercropped with rice in the (3:1) ratio.
PP4 = Pigeonpea intercropped with rice in the (4:1) ratio.
PP5 = Pigeonpea intercropped with rice in the (5:1) ratio.

The light interception of the pigeonpea was higher than that of soybean and rice (Fig. 13). All the intercrops had higher light interception than sole rice up to 74 DAS when the rice was harvested. Again here in the intercrop pigeonpea in the 3:1 pattern had higher light interception than the other intercrops through all the time and the sole crop sometimes. The light interception of all the components declined after 170 DAS due to reduction in the leaf area and the LAI (Fig. 13).

4.16. GRAIN YIELD kg ha^{-1}

There was a significant difference in yield between the sole rice and the intercrop rice. The sole rice gave a grain yield of 1942 kg ha^{-1}. The rice intercropped with soybean in the 3:1 gave a grain yield of 1096 kg ha^{-1}, 1009 for intercrop rice in the 4:1 ratio and the intercrop rice in the 5:1 ratios gave a yield of 1166 kg ha^{-1} (Fig. 14).

The rice intercropped with pigeonpea in the 3:1 ratio gave a grain yield of 1005 kg ha^{-1}, 943 kg ha^{-1} for the rice intercropped with pigeonpea in the 4:1 ratio, and the rice intercropped with pigeonpea in the 5:1 ratio gave a grain yield of 1156 kg ha. There was no significant difference in grain yield between the rice intercropped with soybean and the rice intercropped with pigeonpea (Fig. 14).

There was a significant difference in grain yield between the sole soybean and the intercropped soybean. The sole soybean gave a grain yield of 1913 kg ha^{-1}. The intercropped

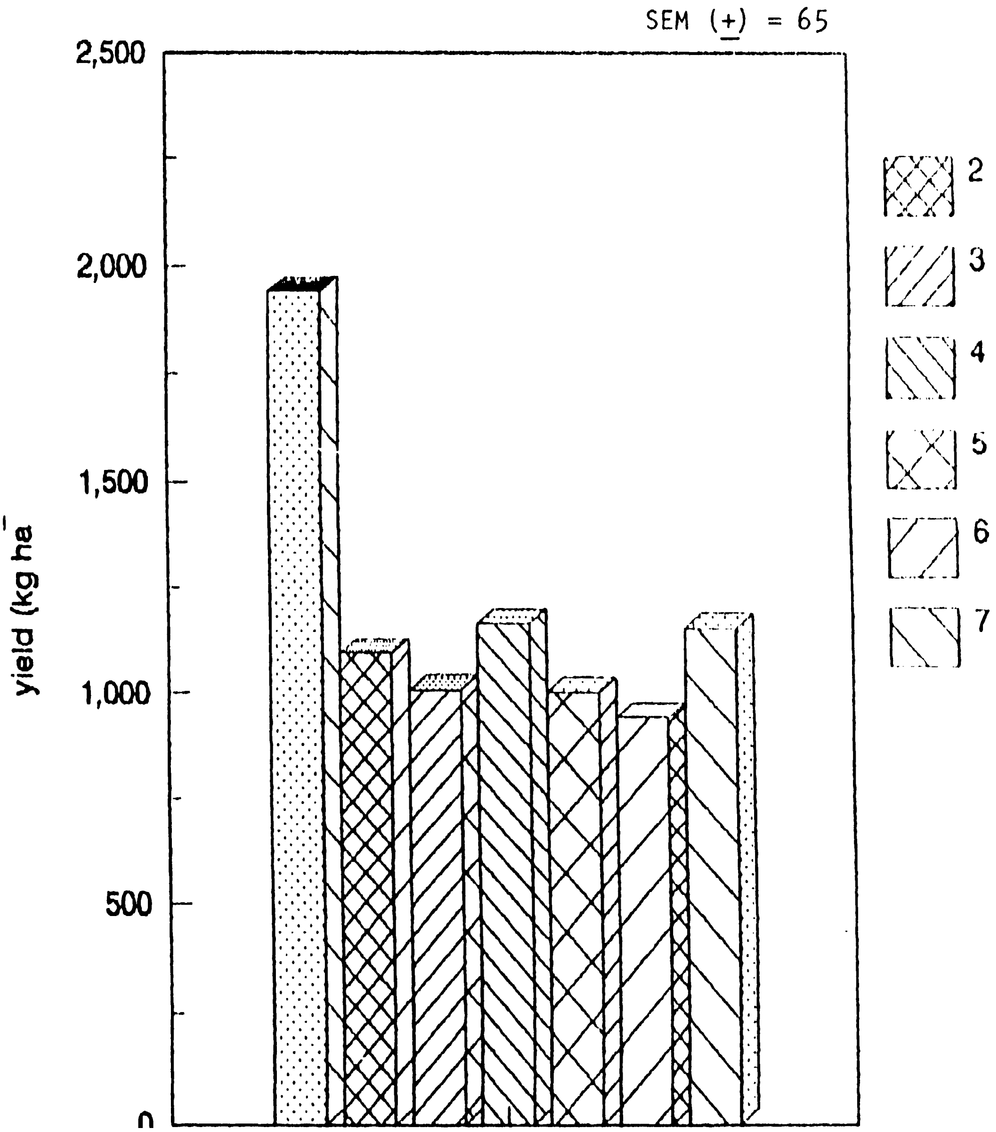


Fig.14: Comparison between the yield of the sole and intercrop rice.

1 = Sole rice.
2 = Rice intercropped with soybean in the (3:1) ratio.
3 = Rice intercropped with soybean in the (4:1) ratio.
4 = Rice intercropped with soybean in the (5:1) ratio.
5 = Rice intercropped with pigeonpea in the (3:1) ratio.
6 = Rice intercropped with pigeonpea in the (4:1) ratio.
7 = Rice intercropped with pigeonpea in the (5:1) ratio.

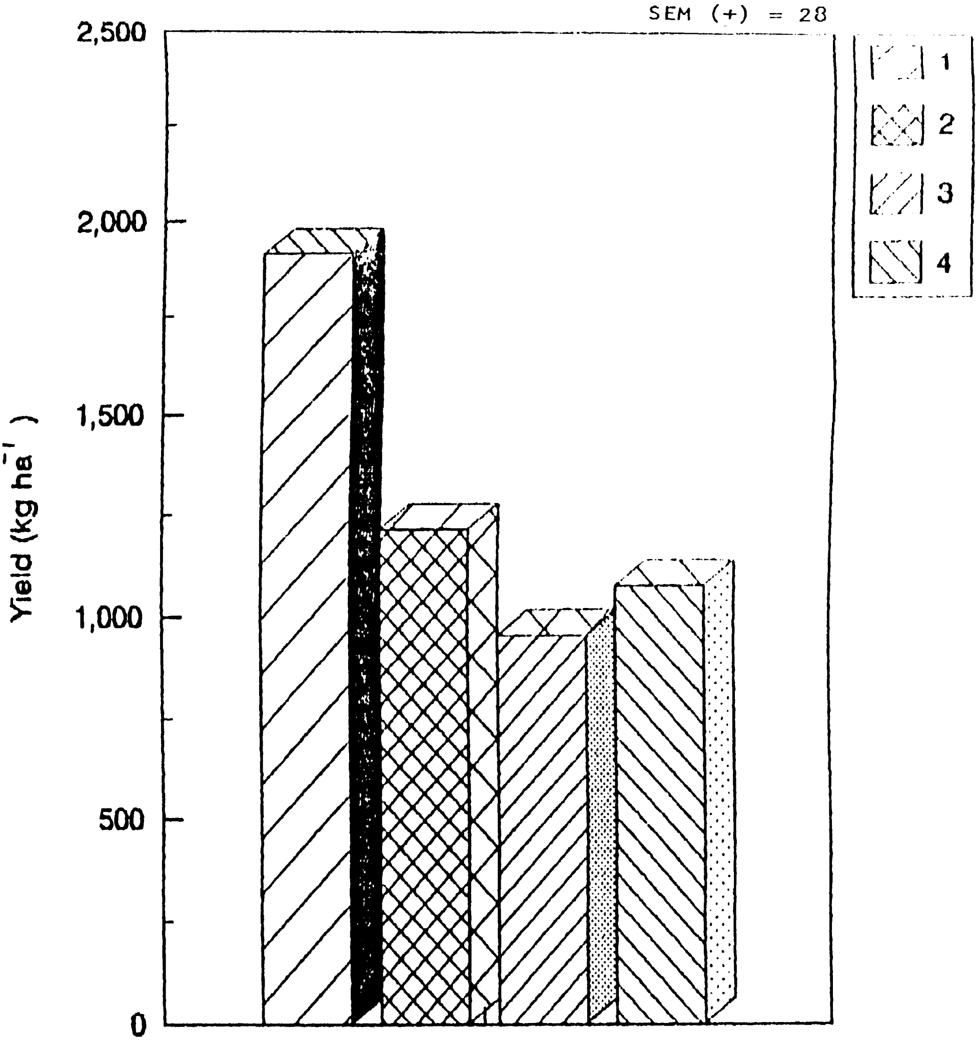


Fig.15: Comparison between the yield of the sole and intercrop soybean.

1 = Sole soybean.
2 = Soybean intercropped with rice in the (3:1) ratio.
3 = Soybean intercropped with rice in the (4:1) ratio.
4 = Soybean intercropped with rice in the (5:1) ratio.

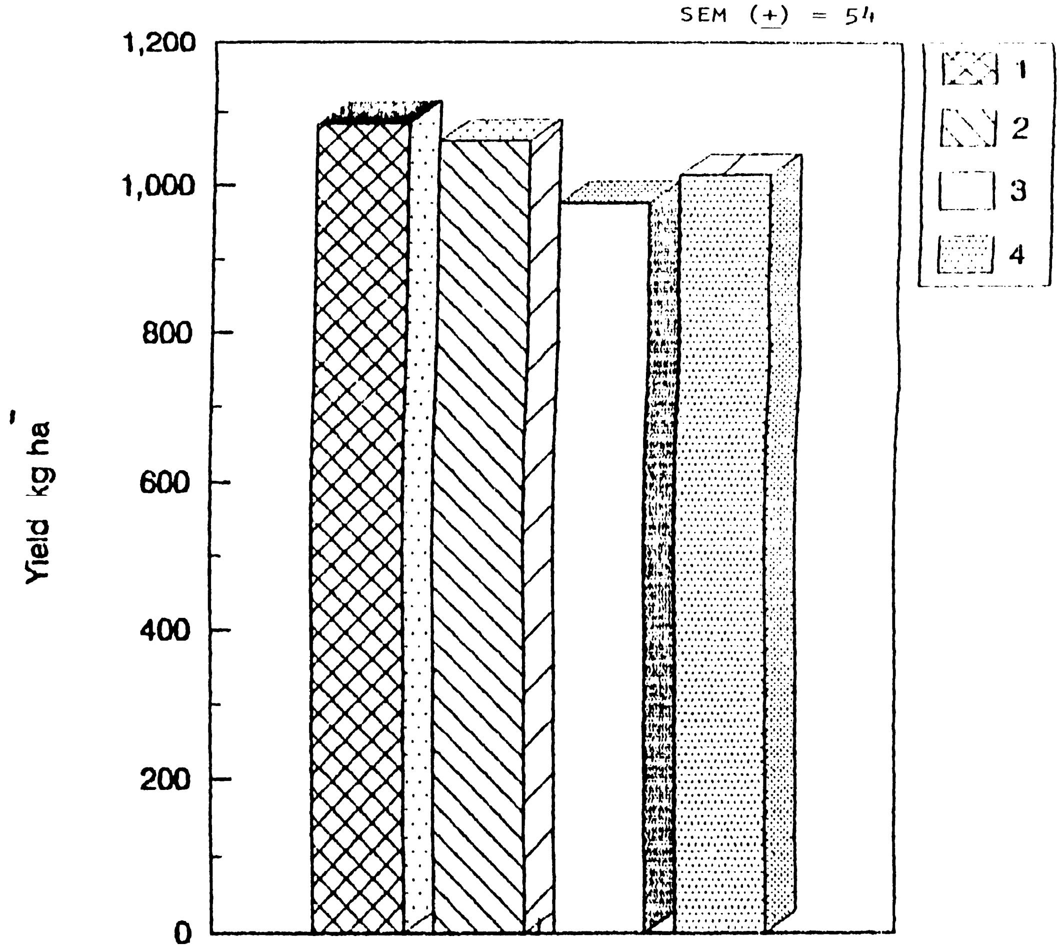


Fig.16: Comparison between the yield of the sole and intercrop pigeonpea.

1 = Sole pigeonpea.
2 = Pigeonpea intercropped with rice in the (3:1) ratio.
3 = Pigeonpea intercropped with rice in the (4:1) ratio.
4 = Pigeonpea intercropped with rice in the (5:1) ratio.

soybean in the 3:1 ratio gave a yield of 1212 kg ha^{-1}, 950 kg ha^{-1} was the yield of the intercropped soybean in the 4:1 ratio, and the intercropped soybean in the 5:1 ratio gave a yield of 1071 kg ha^{-1} (Fig. 15).

There was no significant difference in the yield between the sole pigeonpea and the intercropped pigeonpea. The sole pigeonpea gave a yield of 1084 kg ha^{-1}, the intercropped pigeonpea in the 3:1 ratio gave a yield of 1059 kg ha^{-1}, 973 kg ha^{-1} was the yield of the pigeonpea in the 4:1 ratio, and the intercropped pigeonpea in the 5:1 ratio gave a yield of 1010 kg ha^{-1} (Fig. 16).

4.17. TOTAL AND PARTIAL LAND EQUIVALENT RATIO (LER)

Table 11, shows the final yield of the three sole crops, their respective intercrop yields, partial LER's, and the total LER's. The intercrop pigeonpea recorded the highest partial LER (0.98) followed by the other intercrops which recorded almost similar partial LER's. The combination of rice intercropped with pigeonpea in the 5:1 ratio gave the highest total LER (1.53) indicating that there was an yield advantage of 53% over the sole. Rice intercropped with soybean gave a total LER of 1.19, 1.02, and 1.16 in the 3:1, 4:1, and 5:1 ratios respectively exhibiting yield advantage of 19%, 2%, and 16 % respectively over the sole crop (Table 11).

The LER of the roots also was calculated, the intercropped rice recorded the highest partial LER (0.98) and

Table 11. Total and partial land equivalent ratio (LER) of the yield of different crops

		Yield (kg ha^{-1})	Partial LER	Total LER
Sole crops				
Pigeonpea		1084	1.00	1.00
Soybean		1913	1.00	1.00
Rice		1942	1.00	1.00
Intercrops				
<u>(3:1) ratio</u>				
Rice+soybean	rice	1094	0.56	1.19
	soybean	1212	0.63	
Rice+pigeonpea	rice	1005	0.52	1.50
	pigeonpea	1059	0.98	
<u>(4:1) ratio</u>				
Rice+soybean	rice	1009	0.52	1.02
	soybean	950	0.50	
Rice+pigeonpea	rice	943	0.49	1.39
	pigeonpea	973	0.90	
<u>(5:1) ratio</u>				
Rice+soybean	rice	1166	0.60	1.16
	soybean	1071	0.56	
Rice+pigeonpea	rice	1156	0.60	1.53
	pigeonpea	1010	0.93	

the intercropped rice with pigeonpea recorded the lowest partial LER (0.78). The intercropped rice with soybean recorded the highest total LER (1.88) indicating a root growth advantage of 88% over the sole crop. The rice intercropped with pigeonpea gave a total LER of (1.65) indicating a root growth advantage of 65% over the sole (Table 12).

4.18. DAYS TO 50% FLOWERING AND DAYS TO MATURITY

The rice cultivar IET 9225 which was used in the experiment, reached 50% flowering at 80 DAS. Both the sole and the intercrop reached 50% flowering at the same time, this indicated that the intercrop did not affect the flowering of the crop. The length of the grain filling period was about 30 days. The crop took 110 days to come to maturity starting from the sowing day.

The soybean variety Hardee, reached 50% flowering at 47 DAS. The intercrop reached 50% flowering at 51 DAS. The growth of the crop was fast and it took 90 days to come to maturity. The length of the reproductive stage was about 37 days.

The pigeonpea variety ICP 1-6 reached 50% flowering at 130 DAS. The sole and the intercrop reached 50% flowering at the same time. The crop reached maturity at about 180 DAS. The length of the reproductive period was about 45 days.

4.19. OXYGEN IN THE SOIL

Glass tubes were placed in the field, in the plots of both soybean and pigeonpea, in three depths (5 cm, 10 cm, and

Table 12. Total and partial land equivalent ratio (LER) of the roots of different crops

		Root length	Partial LER	Total LER
Sole crops				
Rice		2.11	1.00	1.00
Soybean		2.39	1.00	1.00
Pigeonpea		3.53	1.00	1.00
Intercrops				
Rice+soybean	rice	2.07	0.98	1.88
	soybean	2.16	0.90	
Rice+pigeonpea	rice	1.65	0.78	1.65
	pigeonpea	3.07	0.87	

20 cm), to study the effect of waterlogging on the growth of these crops. The tubes were not put in the rice and pigeonpea plots because it was assumed that the crop is tolerant to low soil air and waterlogging. The glass tubes which were placed in the pigeonpea plots were unfortunately broken in the processes of the field work.

The sole soybean crop exhibited considerable tolerance to low soil air. Study of the rooting behavior revealed that the soybean roots were mostly placed at the upper 10-30 cm depth of the soil (Fig. 17a and b). Whenever the rainfall was high (Standard week 33 with 136.2 mm) oxygen level was zero at 20 cm soil depth and waterlogging prevailed and continued for 5 days, but still soybean crop was growing satisfactorily. This indicated that the crop was resistant to waterlogged condition. Even as an intercrop soybean had performed well under oxygen deficiency condition in the soil (Fig. 17a and b).

4.20. ROOT LENGTH AND DEPTH

The rice crop had higher root length in the upper 10 cm depth of the soil and it had about 5.96 m of root length. The root depth was reducing in the lower depths and the crop maintained 3.06 m in the 20 cm depth and 0.70 m in the 30 cm depth. This showed a considerable difference of the length of the rice roots in the different depths (Fig. 18a). The length of roots in the sole rice was not significantly different from the length of the roots of the intercrop rice

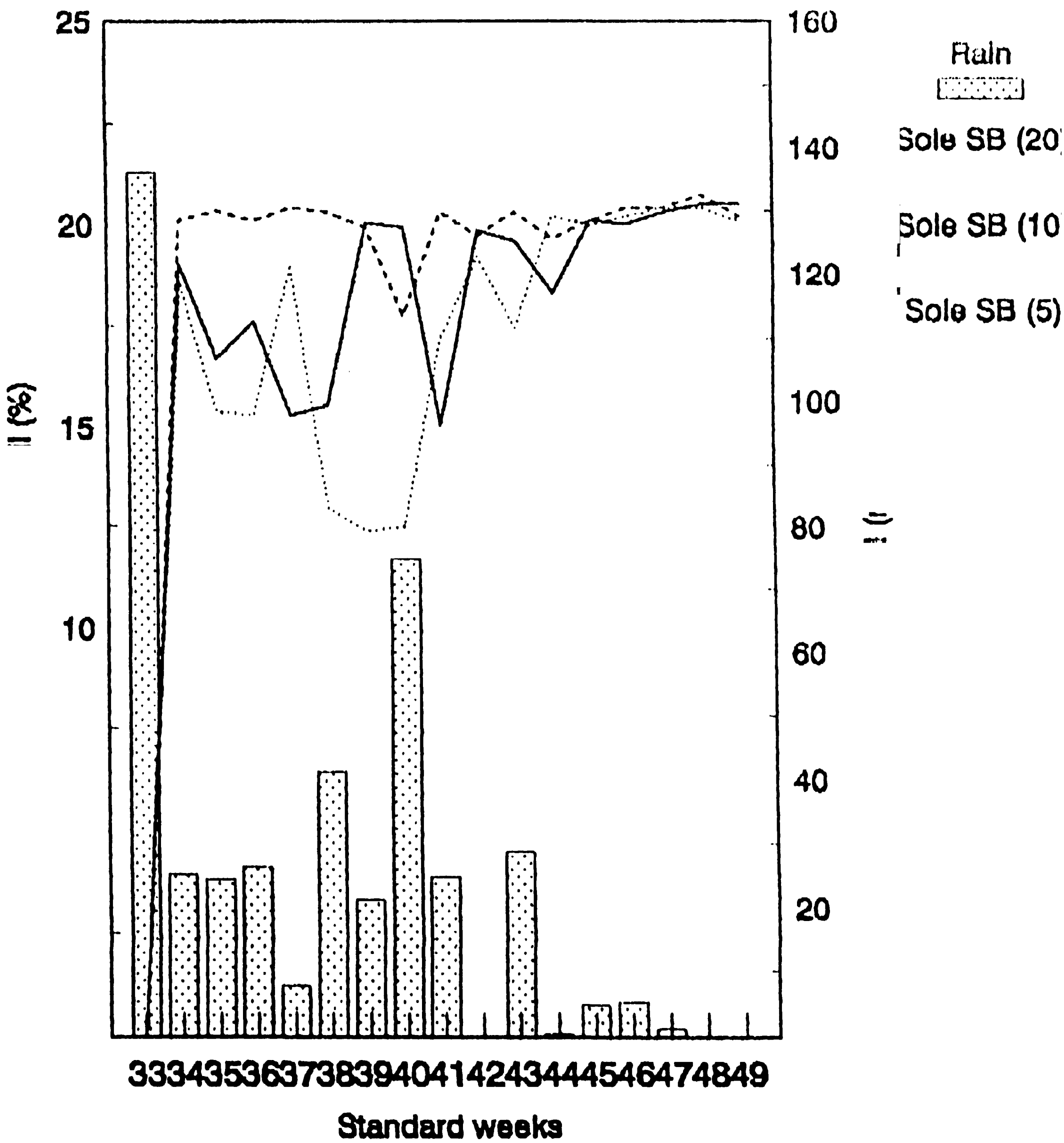


Fig.17a: Oxygen concentration (%) in the root zone of the sole soybean.

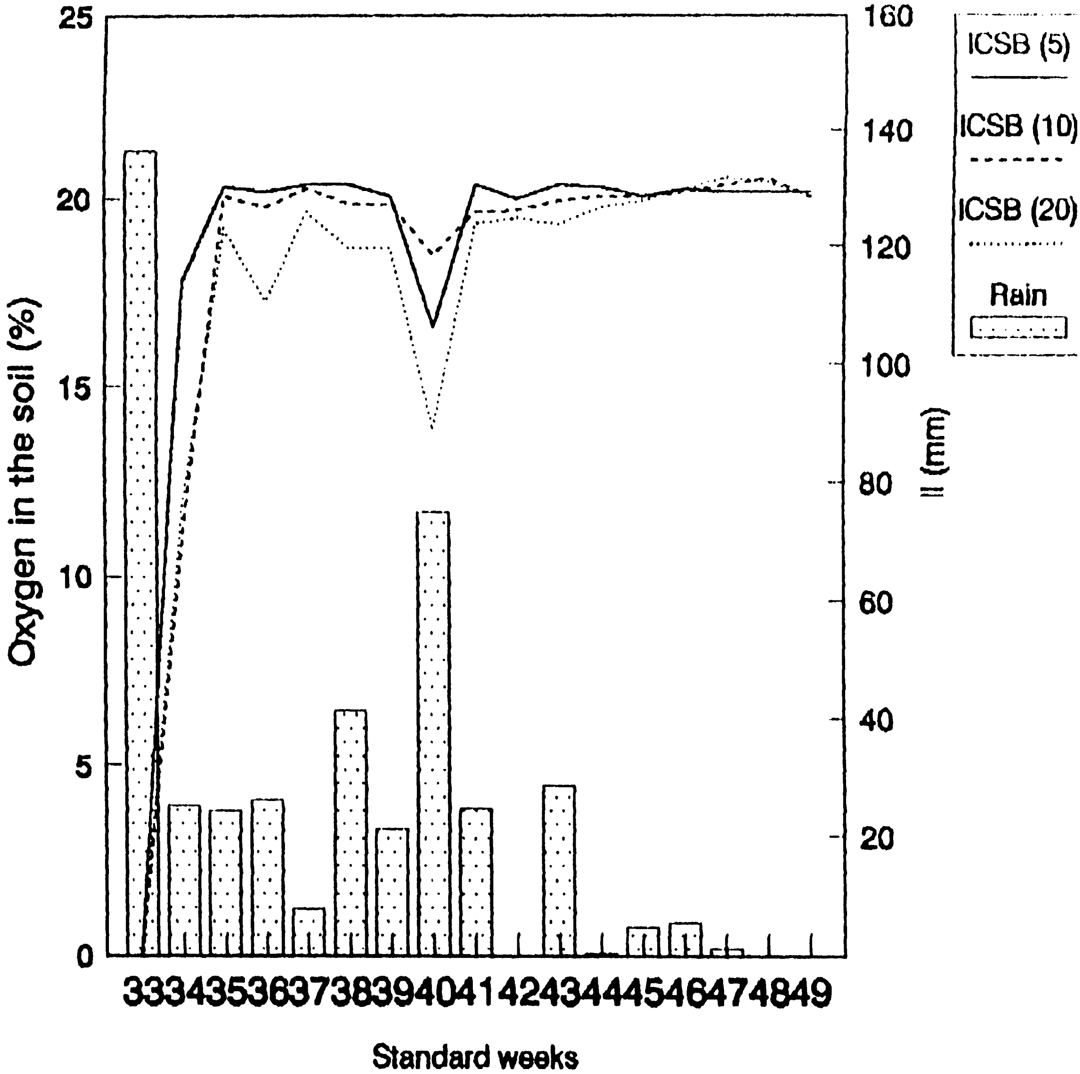


Fig.17b: Oxygen concentration (%) in the root zone of the intercrop soybean.

(Fig. 18b). The sole rice had root length of 2.11 m compared to 2.07 m for the rice intercropped with soybean, and 1.65 m for the rice intercropped with pigeonpea.

The soybean had deeper roots than those of the rice (Fig. 18c). However, the soybean also maintained most of its roots in the upper 10 cm (5.43 m), but it had also 0.60 m root length in the 40 cm depth. The sole soybean had slightly higher root length (2.39 m) than the intercrop soybean (2.16 m).

The pigeonpea had even deeper roots. The roots of the pigeonpea reached at 50 cm and had 1.13 m. The sole pigeonpea had root length of 3.53 m compared to 3.07 m for the intercrop (Fig. 18d).

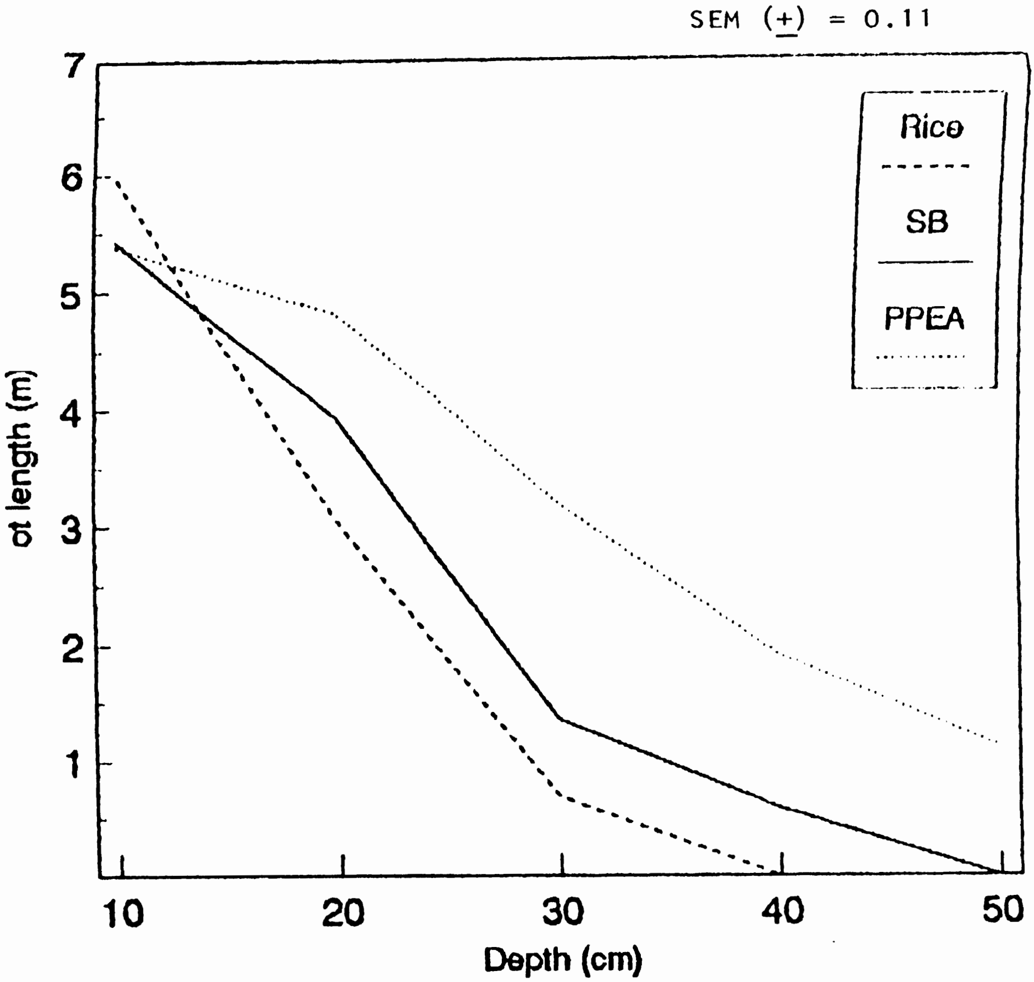


Fig.18a: Comparison between the root length of the various crops in the various depths.

SB = Soybean
PPEA = Pigeonpea

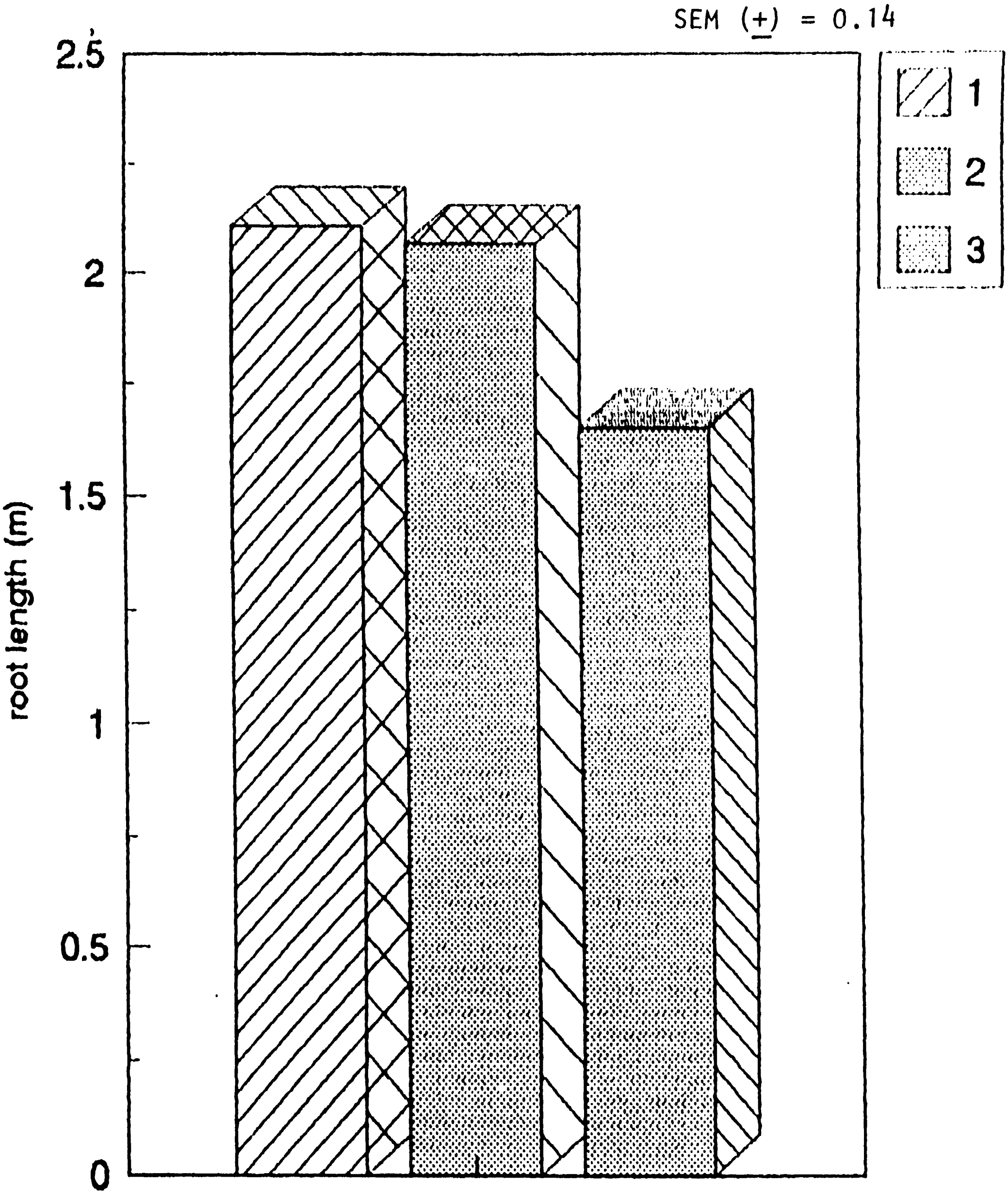


Fig.18b: Comparison between the root length of the sole and intercrop rice.

1 = Sole rice
2 = Rice intercropped with soybean.
3 = Rice intercropped with pigeonpea.

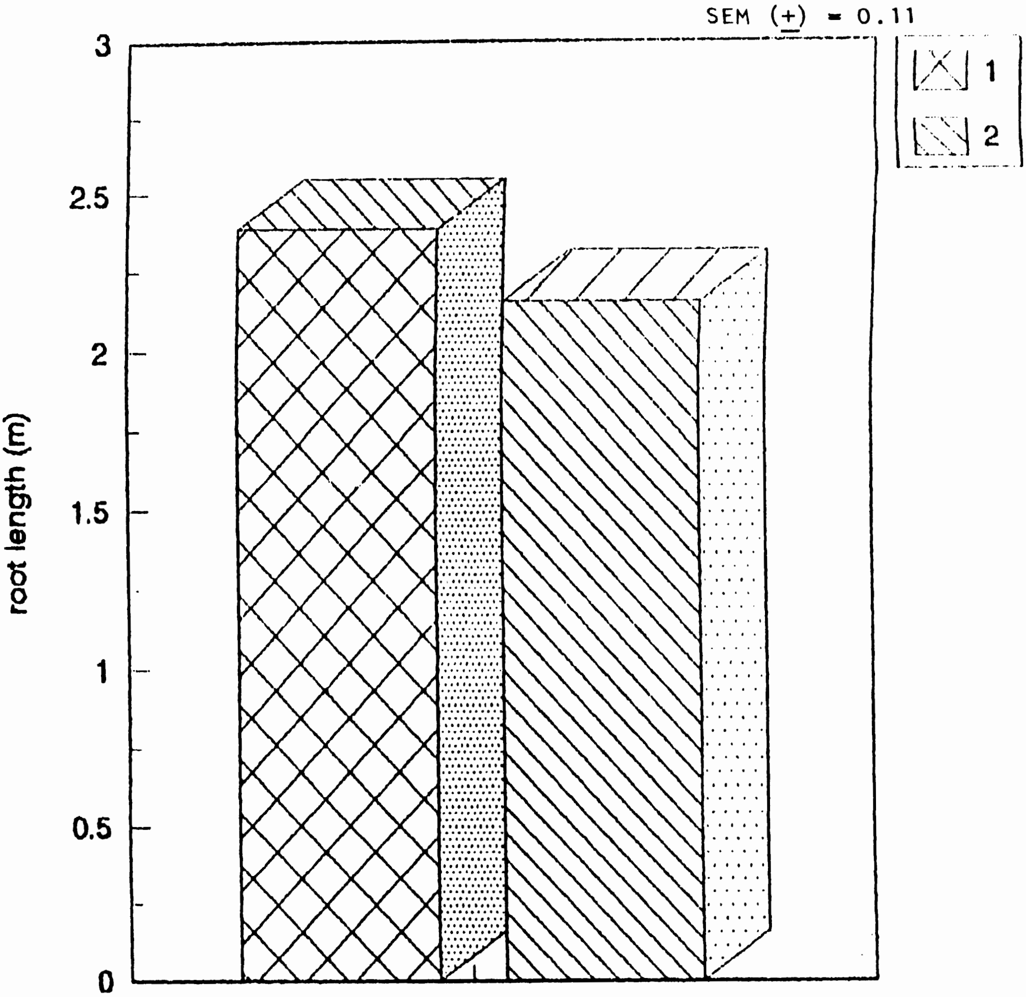


Fig.18c: Comparison between the root length of the sole and intercrop soybean.

1 = Sole soybean.
2 = Intercrop soybean.

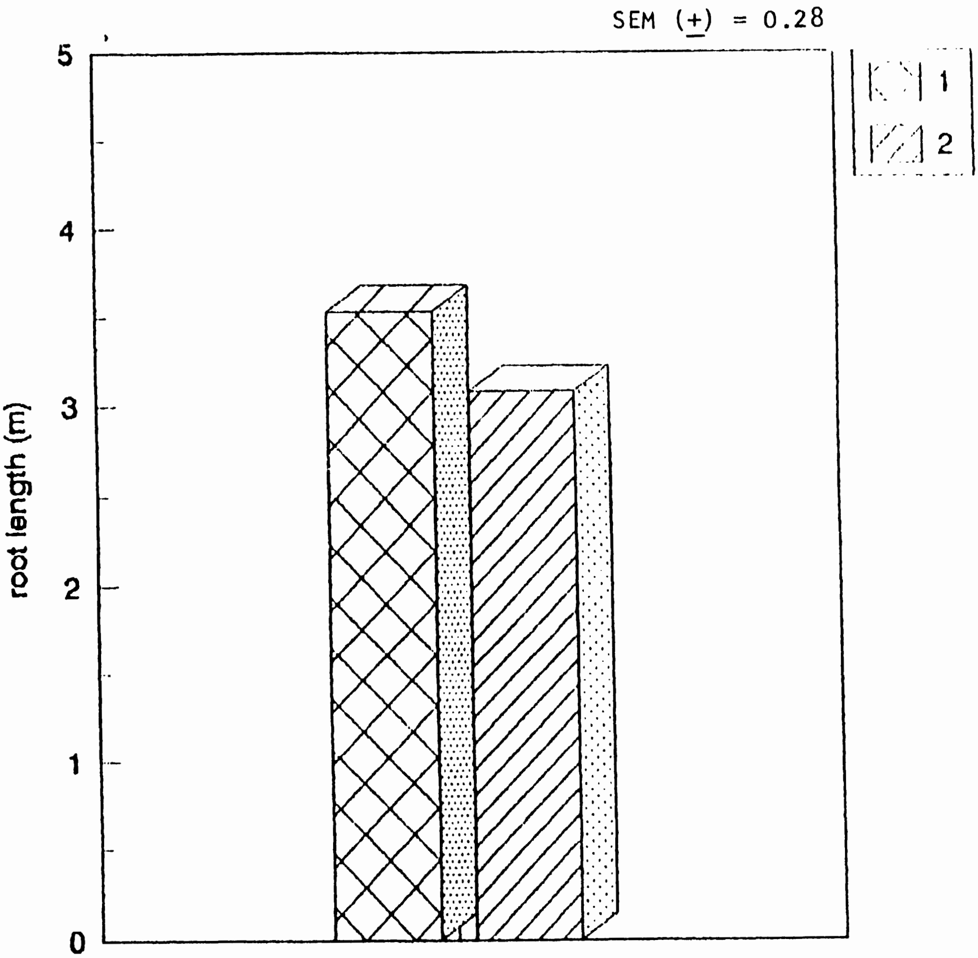


Fig.18d: Comparison between the root length of the sole and intercrop pigeonpea.

1 = Sole pigeonpea.
2 = Intercrop pigeonpea.

DISCUSSIONS

CHAPTER V

DISCUSSIONS

5.1. CROP GROWTH AND STAND

All the crops under study had established satisfactorily and the stand was normal even though rice was sown before the legumes.

Rainfall during the experimental period was adequate (607.7 mm), even though its distribution was erratic (24.4% of the total rainfall received in week 33). Because upland rice depends entirely on rainfall for its moisture supply, both the amount and distribution of rainfall are important (Jane *et al.* 1971).

There were more number of rice plants m^{-2} than expected, this could be due to some extra plants which emerged after the initial thinning. The soybean had the specified number of plants. The pigeonpea was lower than expected, due to the mortality caused by wilt disease and waterlogging.

The number of tillers of rice in both sole and intercrop treatments were almost same probably because the rice was established well before the legumes.

High tillering capacity is a desirable feature to increase the yield potential of upland rice varieties, because the low tillering capacity is restraint to higher yields in most of upland rice varieties (IRRI 1971; Ono 1971; Jana *et* *al.* 1971; Abifarin *et al.* 1972; chang *et al.* 1972; De Datta *et al.* 1972; Kawano *et al.* 1972). The tillering of the rice crop was late, probably this could be the reason of poor yield, this is in agreement of the findings of De Datta *et al.* (1972), when they reported that plants which tiller late produce small panicles or not at all leading to inefficient use of soil moisture and consequent yield reduction.

The number of branches plant^{-1} of the sole soybean was lower than the intercrop, because intercrop rice was less competitive than soybean in the early stages. This reflected in the light interception data which showed that soybean reached 50% interception at 25 DAS compared to 38 DAS by rice. Thus indicating that intercropping maximizes use of natural resources such as light (Willey 1979).

The branching of the pigeonpea showed the same trend as the soybean. In the early stages the sole and the intercrop were same but in the later stages the intercrops had higher number of branches plant^{-1}.

The sole rice and the intercrop rice had similar leaf area and LAI. Since the legume crops were only in one row, this indicates that the legumes had a minor affect the leaf area and LAI of the rice.

The trend of the leaf area development and the light interception were different for all those crops. The LAI of rice was reflecting unaffected by intercropping, this was in agreement with the findings of Ramakrishna and Ong (1991).

However the sole rice crop intercepted more light than the intercrop, and this could be due to the shading effect of the intercrop legume on the rice, especially in the early stages of growth due to their similar heights. LAI of the sole rice and the intercrop fell down at 105 DAS because of the senescence of the leaves, and the crop was approaching towards maturity.

The sole soybean had a higher LAI than the intercrops in different planting patterns, but had more or less similar light interception with intercrop soybean in the 3:1 pattern, this could be due to the compact canopy of the soybean crop, and the mutual shading of the leaves. This explains the efficient light interception of the 3:1 planting pattern canopy. In both sole and intercrop soybean LAI fell due to the senescence of the leaves after 79 DAS.

The pigeonpea leaf area development showed that at the early stages of growth LAI was low but later on it had increased. The trend of light interception of the pigeonpea was not clear due leave damage caused by Helicoverpa armigera.

Plant height of rice in both sole and intercrop were almost similar, and it was taller than those of soybean and pigeonpea in the early stages of growth. The sole soybean was slightly taller compared to intercrop soybean specially after 65 DAS, whereas, the height of pigeonpea was almost the same up to 93 DAS in both sole crop and intercrop. In this study differences in plant height of rice and legumes are therefore not important in determining competition between the component species although Ramakrishna *et al.* (1991) concluded that differences in competitive ability of pigeonpea is closely related to height. Charles (1977) related plant height with rooting density.

Sole rice and intercrop rice had almost similar leaf, stem, and total dry weight, indicating that planting pattern did not affect the biomass production of the rice crop.

These observations lend support to the findings made by Ramakrishna and Ong (1991), who reported that rice, as an intercrop with legumes, was able to intercept more light energy during early stages of its growth when the soil is saturated.

The trend of dry matter production in legumes was different to that of rice. The sole soybean produced higher dry matter than that intercrop; because of a higher LAI and consequently high light interception. The soybean gave a higher dry matter than the pigeonpea up to the time of the harvest of the former but the pigeonpea continued its growth up to 184 days.

5.2. YIELD

In both intercropping systems the yield of intercropped rice was reduced by 43-46% compared to the sole stand although the number of panicles per plant were unaffected. This evidence suggests that the reduction in rice yield occurred during the grain filling period, which may be a consequence of the delayed sowing of the legumes. Simultaneous sowing of the rice and legumes had resulted in a similar reduction in rice yield (Ramakrishna and Ong 1991). However, the intercropping of upland rice with grain legumes need not necessarily result a substantial reduction of the productivity of the intercrop rice in order to provide a high intercrop advantage. Recent work at ICRISAT shows that the selection of a suitable canopy structure is important and light extinction coefficient of 0.64 is suitable.

The intercrop pigeonpea had a partial LER of 0.98 which was the highest for the intercrops. Sahu *et al.* (1988) reported a partial LER of 0.88 from pigeonpea and Ramakrishna and Ong (1991) reported a partial LER of 0.94 from rice. The rice/pigeonpea system gave a total LER of 1.53 which closer to the LER reported by Choudhury (1979) which is (1.64) in the same system. By delaying the sowing of pigeonpea there was less overlap in the growth period of the two species compared to simultaneous sowing of both crops. In addition there is evidence from study that the root systems of rice and pigeonpeas were able to explore different parts of the soil profile for moisture and nutrients. This is particularly important during the post-rainy season when the top soil had dried out and the pigeonpea continued to grow using residual soil moisture. In the top 20 cm where most of the rice roots are located there was a substantial increase in root density but unlikely to influence competition during the rainy season when water and nutrient are not limiting growth. This is in agreement with the findings of (Charles 1977) which got similar results.

There is little economic information on upland rice intercropping because it is usually a subsistence system (Wade and Sanchez 1976). Choudhury (1979) found that growing upland rice + pigeonpea was more profitable than growing them in monoculture.

SUMMARY

CHAPTER VI

SUMMARY

Upland rice was grown on three continents, mostly by small or subsistence farmers in the poorest regions of the world. Grain yields are generally low, ranging from 0.5 to 1.5 t ha^{-1} in Asia; about 0.5 t ha^{-1} in Africa; and from 1 to 4 t ha^{-1} in Latin America. But the area planted in upland rice is so large (nearly a sixth of the world's total rice land) that even a small increase in yield will substantially influence total production.

Upland rice is grown under a wide range of conditions from shifting cultivation in Malaysia, the Philippines, West Africa, and Peru, to highly mechanized systems in parts of Latin America. Soil types vary from infertile acid in West Africa to Oxisol in the Llanos Orientales region of south America to fertile acid soil from volcanic tuff in the Philippines to saline soil in the coastal areas of India.

In India upland rice is usually raised during the kharif (wet) season under rainfed conditions in the highlands. Fields may or may not be bunded. Because of topography and high porosity, soils may be waterlogged for short periods of 2-3 days. Upland rice is also called autumn rice because the crop is direct seeded under dry conditions in May-June and remains in the field until harvest in September to early October (Maurya and Vanish 1984).

An experiment was laid out at ICRISAT Center (India) in a split plot design with three planting patterns (3:1, 4:1, 5:1) as a main plot and rice, soybean, and pigeonpea cultivars as a sub-plot.

Total rainfall at ICRISAT center during the experimental period was 607.7 mm. There was no drought stress in the early stages of the crop growth, but there was a short drought spell towards the end of the year 1990, and during the first week of 1991, and the crop was given two irrigations during that time.

Number of plants of the rice crop in both sole and intercrop were different from the expected due to the emergence of some plants after the initial thinning. The soybean had crop had almost the expected number of plants in both sole and the intercrop. The number of plants of the sole and intercrop pigeonpea were less than the expected number of plants due to the mortality of some plants due to wilt disease.

Number of tillers plant^{-1} of the sole and intercrop rice were same because the rice established well before the legumes. The number of branches plant of the sole soybean and pigeonpea were higher than their respective intercrops.

There was no significant difference in LAI between the sole and intercrop rice. LAI of the sole rice and the intercrop fell down at 105 DAS because of the senescence of the leaves, and crop was approaching towards maturity. Since the legume crops were only in one row, this indicates that the legumes had a minor effect on the leaf area development. The LAI of the sole soybean was higher than that of the intercrop, this is probably due to the mutual shading of the rice and the soybean. The sole pigeonpea had almost the same LAI of the intercrop.

There was no significant difference between the sole and intercrop rice in plant height. The sole soybean was slightly taller than the intercrop. The sole and the intercrop pigeonpea had almost similar plant height. In this study difference in plant height of rice and legumes are therefore not important in determining competition between the component species.

The sole and intercrop rice had almost similar leaf, stem, and total dry matter, indicating that planting pattern did not affect the biomass production of the rice crop.

The trend of dry matter production in legumes was different to that of rice. the sole soybean produced higher dry matter than that of the intercrop; because of a higher LAI and consequently high light interception. The soybean gave a higher dry matter than pigeonpea up to the time of the harvest of the former but pigeonpea continued its growth up to 184 days.

Number of panicles plant^{-1} of the sole and intercrop rice have been recorded starting from 98 DAS. There was no significant difference in number of panicles plant^{-1} between the sole and intercrop rice. the crop showed poor panicle initiation, and this could be a reason for the poor yield of the crop. There was no significant difference in the panicle length between the sole and the intercrop rice.

There was no significant difference in panicle dry weight between the sole rice and the intercrop. This indicates that the intercropping pattern and planting ratio did not affect the panicle dry weight of the rice.

The observations on the number of pods plant^{-1} have been recorded starting from 65 DAS. There was a significant difference in the number of pods plant^{-1} between the sole soybean and the intercrop. The sole soybean had higher number of pods plant^{-1} than the intercrop. Pod dry weight of the sole soybean was higher than that of the intercrop, this could be due to the intercropping of the soybean with the rice.

The sole rice crop intercepted more light than the intercrop, and this could be due to the shading effect of the intercrop legume on the rice, especially in the early stages of growth due to their similar heights.

The sole soybean had a higher LAI than the intercrops in different planting patterns, but more or less similar light interception with intercrop soybean in the 3:1 pattern, this could be due to compact canopy of the soybean crop, and the mutual shading of the leaves. This explains the efficient light interception of the 3:1 planting pattern canopy. In both sole and intercrop soybean LAI fell due to the senescence of the leaves after 79 DAS.

There was no significant difference in grain yield between sole and intercrop rice. In both intercropping systems the yield of the intercropped rice as reduced by 43-46% compared to the sole stand although the number of panicles per plant were unaffected. This evidence suggests that the reduction in the rice yield occurred during the grain filling period, which may be a consequence of the delayed sowing of the legume.

The intercrop pigeonpea had a partial LER of 0.98 which was the highest. By delaying the sowing of pigeonpea there was less overlap in the growth period of the two species compared to simultaneous sowing of both crops.

The study of the root systems of rice and pigeonpea show that they were able to explore different parts of the soil profile for moisture and nutrients. This is particularly important during the post-rainy season when the top soil had dried out and the pigeonpea continued to grow using the residual soil moisture.

The sole soybean crop exhibited considerable tolerance to low soil air and waterlogging. The study showed that the soybean roots were mostly placed at the upper 10-30 cm depth of the soil. At week 33 when the rainfall was high (136.2 mm) oxygen level was zero at the 20 cm soil depth and waterlogging prevailed and continued for 5 days, but still soybean crop was growing satisfactorily.

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Appendex 1. Meteorological data for the growing season at ICRISAT center (Rainy season 1990).

STD week	Rain mm	Evap. mm	T.max C°	T.min C°	RH07 %	RH14 %	Wind kphr	Sunshine hrs	Sol.Rad. $MJ/m^2/D$
27	5.8	43.7	31.0	23.3	87.1	58.1	16.7	3.3	15.7
28	42.8	43.5	31.0	22.2	90.3	55.6	18.0	4.1	15.8
29	23.4	30.7	29.0	21.8	92.3	67.3	15.7	1.2	11.8
30	10.8	42.6	30.1	21.5	91.0	62.4	16.9	6.8	19.6
31	5.7	45.4	32.0	22.9	83.4	49.3	11.7	6.7	20.0
32	77.7	35.2	30.8	22.7	95.0	61.0	8.6	6.1	17.8
33	136.2	21.5	26.5	21.7	94.0	85.3	20.0	1.9	7.6
34	25.0	27.5	28.3	21.9	91.9	71.4	17.4	4.3	13.2
35	24.2	25.6	28.1	22.0	93.3	69.0	13.6	3.0	15.6
36	26.2	29.2	29.3	22.1	93.3	66.3	11.4	3.1	14.9
37	7.9	33.6	30.2	22.1	92.7	65.3	7.7	7.2	18.4
38	41.1	36.2	31.0	21.7	92.4	53.6	6.7	8.5	20.1
39	21.2	27.4	29.5	22.0	95.4	68.9	6.4	5.6	14.7
40	75.0	21.3	27.6	20.7	96.1	76.1	10.2	3.9	13.0
41	24.6	21.0	29.3	21.8	94.9	75.7	4.1	5.2	15.3
42	0.0	38.2	29.9	16.4	88.1	37.9	4.9	9.8	21.5
43	28.6	31.5	28.5	20.4	94.9	65.9	8.8	5.7	15.9
44	0.4	32.2	28.7	17.6	92.9	47.3	6.4	8.5	18.4
45	4.8	32.5	29.8	17.6	93.9	42.3	5.4	8.9	17.5
46	5.4	28.8	28.7	18.5	92.6	52.3	6.6	7.7	15.7
47	1.2	22.3	27.1	18.1	94.6	62.9	6.4	5.1	12.3
48	0.0	30.8	29.1	17.7	92.3	47.7	7.3	8.8	17.0
49	0.0	28.7	27.9	17.6	94.9	49.3	8.0	8.2	15.3
50	0.0	29.0	27.2	14.1	92.6	42.0	6.6	9.3	16.3
51	0.0	27.2	26.9	13.3	91.3	39.0	4.9	8.6	15.1
52	0.0	33.2	26.9	13.8	93.3	38.6	7.6	8.9	16.8
1	16.2	26.2	26.4	14.3	87.7	48.6	8.1	7.7	15.4
2	0.0	28.3	29.2	17.3	95.1	45.6	8.5	7.8	15.5
3	0.0	33.0	28.4	17.4	94.9	44.9	9.6	8.7	16.6
4	0.0	35.0	29.9	15.6	92.6	37.1	6.0	9.1	17.1
5	0.0	42.4	30.5	12.7	79.6	20.9	6.8	10.3	19.5
6	0.0	42.2	31.2	16.5	85.0	28.9	7.2	9.9	19.2
7	0.0	47.3	34.0	16.9	68.1	20.6	6.3	9.8	20.3
8	0.0	57.9	32.5	17.2	79.1	24.3	10.1	10.3	21.5
9	3.5	53.0	33.3	19.5	87.3	27.4	10.4	9.3	20.5

* Rainfall and Evaporation data are totals and other data are mean values.