EFFECT OF INTERCROPPING ON THE GROWTH AND YIELD OF ROSELLE (*Hibiscus sabdariffa var. sabdariffa L.*)

By

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DEDICATION

To:

My Parents ,,,, ,,, ,, ,

My Family ,,,, ,,, ,, ,

My Friends ,,,, ,,,, ,,, ,, ,

Gratitude and Love.

ACKNOWLEDGMENT

I wish to express my sincere gratitude to Dr. Tag El-Din El-Deikh Musa Hago, for his guidance, assistance and providing all the facilities during the course of investigation.

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My pest wishes, sincere to my brothers and sisters for their keen interest in the execution of this experiment.

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ABSTRACT

A field experiment was carried out for one season (2003-2004) in the Experimental Farm of the Faculty of Agriculture at Shambat to study the effect of intercropping on the growth and yield of roselle under irrigation.

The Experiment was laid out in Randomized Complete Block Design with four replicates. Treatments were sole roselle (R), sole pigeonpea (P), sole cowpea (C) and three planting patterns of roselle intercropped with each of the two legumes: alternate holes (RP1, RC1), the same hole (RP2, RC2) and alternate rows (RP3, RC3) respectively.

The results showed that intercropping tended to reduce vegetative growth of roselle some times significantly. Moreover intercropping roselle with pigeonpea resulted in significant reduction in yield and yield components of roselle, particularly with same hole (RP2) treatment. On the other hand intercropping roselle with cowpea significantly increased yield and yield components of roselle especially with alternate holes and alternate rows treatments. Hay yield of roselle showed significant reduction with both legume combinations.

Intercropped pigeonpea showed insignificant reduction in all yield components, except hay yield which showed significant reduction especially with the same hole (RP2) treatment. Intercropped cowpea exhibited insignificant reduction in all yield components, except the number of pods per plant and hay yield which showed significant reduction particularly with the same hole (RC2) treatment.

Calyx protein content of roselle was significantly increased by intercropping with pigeonpea, whereas intercropping with cowpea caused significant decrease. Anthocynin and citric acid content of

intercropped roselle showed insignificant increase, whereas oxalic acid content showed significant increase with intercropping.

The land equivalent ratio (LER) for the different intercropping systems was found to be more than one. Roselle/ legumes intercropping showed highest LER with cowpea than with pigeonpea treatments. Generally alternate rows treatments were the most productive system.

ملخص الأطروحة

أجريت ربة حقلية خلال موسم (2003-2004) ا قل التجرب لكلية الزراعة، بـات. لدراسة اثر الزراعة ا تداخلة على صول الكركدى مع صنفان من البقوليات (اللوبيا العدسى و اللوبيـا ا لو) على و و انتاجية كل صول ت ظروف الرى.

صممت التجربة بواسطة القطاعات كاملة العشوائية باربعة مكررات. لت ا عاملات شاهد لكل من صول الكركدى(R) و اللوبيا عدسى (P) اللوبيا حلو (C) مع ثلاثة ا اط من الزراعة ا تداخلـة للكركدى مع كل من البقوليات: حفرة بعد حفرة (RP1, RC1) و نفـس ا فـرة (RP2, RC2) و سرابة بعد سرابة (RP3, RC3).

اظهرت النتائج بان الزراعة البينية أدت إ نقصان النمو ا ضري للكركدي وكـان النقـصان معنويا بعض الاحيان. زراعة الكركدى مع العدسى أدت ا نقصان معنوي الكوؤس والوزن الرطب وا اف للكأس و إنتاجية العلف. من جهة اخرى زراعة الكركدى مع اللوبيا حلو ادت ا زيـادة عـدد الثمار النبات وانتاجية الكوؤس الرطبة وا افة.

زراعة اللوبيا العدسى مع الكركدي اظهرت تاث ا سلبا ولكن غ معنوي علـى عـددالقرون النبات و عدد البذور القرن ووزن ا ئة حبة اما انتاجية النبات الواحد فقد اظهرت تاث ا ا ابيا. و بالنسبة للوبيا حلو كان التأث سالبا ومعنويا على عدد القرون النبات وا ابا علي انتاجية العلف.

الزراعة البينية ادت معنويا ا زيادة توى ال وت و ض الاكساليك الكوؤس بينما كانت الزيادة غ معنوية ض الستريك و صبغة الانثوسيان بعض ا عاملات. اما نسبة ال وت بـذور البقوليات فقد اظهرت زيادة غ معنوية . اظهرت الدراسة ان نـسبة مكـافئ الارض (LER) كـل معاملات الزراعة البينية اك من الرقم واحد حيث وجدت اك قيم عند الزراعة مع اللوبيا ا لـو وقـد انعكس ذلك على انتاجية افضل خاصة عند الزراعة صفوف متبادلة.

CHAPTER ONE
INTRODUCTION

Roselle “karkade” *(Hibiscus sabdariffa.var. sabdariffa L.)* is a member of the family Malvaceae. It occurs wild in tropical and subtropical regions. The center of origin is thought to be West Africa (Mclean 1973 and Perry 1980). The short stemmed and branched type of roselle is grown mainly for its fleshy calyces. Other types of long stemmed and non-branched roselle are used for fiber production. The short stemmed has a red stem and flowers with fleshy red calyces and its fruits are distributed throughout the main stem. The fruit consists of a calyx (bracts plus sepals), which surrounds a capsule containing varying number of seeds depending on the cultivar. The calyx contains 84.5% water, 1.9% protein 0.1% fat, 12.3% fibre, 0.12% ash in addition to high amounts of citric acid and anthocyanin (Duke 1984).

The calyx extract is used as a natural colouring material for drugs and many other products. It is also used as cold or hot refreshing drink and in traditional medicine, especially for the treatment of cough.

Sudan is the largest producing country of roselle (Marczell 1982). Other producing countries include China, Thailand, Mexico, Pakistan, India, Indonesia, Jamaica and Guatemala. Moreover Sudan ranks first as an exporter. In the world markets “El-rahad” variety from Sudan is considered as superior to all other varieties.

Despite the importance of roselle as a cash crop in the Sudan, both in the domestic and foreign markets, there is a paucity of information concerning improved management practices, such as time and method of sowing, irrigation, fertilizer application, time and method of harvesting and mode of drying and storage of calyces. The crop is still produced by traditional methods under rainfed conditions. The great risks inherent in the traditional sector, chief among which is the uncertainty and fluctuation of rainfall, discourage the adoption of modern production techniques due to the high cost involved. Due to these conditions, roselle yields in the Sudan are still far below the potential of this crop (El Saeed 1964).

Recently, however, roselle cultivation expanded to the irrigated sector, which offers greater prospects for the use of improved production practices to increase yield, such as use of fertilizers. However, fertilizers are very expensive, especially in the developing counties where most fertilizers are imported.

In Sudan, the addition of nitrogen fertilizer is very important because, the level of combined nitrogen in most of Sudanese soils is very low (Mustafa and Gamar 1981). However this will add to the cost of production, therefore, it is of great importance to look for cheaper sources that can provide this important plant nutrient. In the traditional rainfed areas of roselle production in Sudan cheaper means of improving soil fertility are more feasible due to uncertainty and fluctuation of rainfall.

Intercropping involving legumes is one of the cheapest means of improving soil fertility. It is also accessible to small farmers with limited financial resource. In addition it provides the farmer with more crops including food and forage crops. Ahmed and Gunaseng (1979) showed a positive response to nitrogen in the non-legume crops under mono and intercropped systems. Yield depression of intercropped legumes at higher nitrogen rates could be related to the possible shading effect of the non- legumes or the adverse effect of combined nitrogen on nodulation and nitrogen fixation.

The objectives of the present experiment are to investigate the effects of intercropping roselle (*Hibiscus sabdariffa. Var. sabdariffa L.*) with two legumes: pigeonpea (*Cajanus Cajan L. Mill spp*) and cowpea (*Vigna unguiculata L.Walp*). The study will look into the effects of the treatments on the growth and yield of roselle as well as the other crops in the mixture. The information obtained may help in evaluating the advantages of intercropping as a cheap means of improving yield and quality of roselle.

CHAPTER TWO
LITERATURE REVIEW

2.1 Roselle.

Roselle (*Hibiscus sabdariffa var. sabdariffa L.*) belongs to the family Malvaceae .It is an annual, erect, bushy, herbaceous subshrub, 2-4m tall with smooth or nearly smooth, cylindrical, typically red stems. Leaves are alternate, green with reddish veins and long or short petioles. Flowers are borne singly in the leaf axil, yellow with rosy eyes.

Calyces are typically red consisting of 5 large sepals with epicalyx of 8-12 slim, pointed bracts around the base which begin to enlarge and become fleshy and juicy. The capsule is green when immature, with light-brown seeds. The capsule turns brown and splits open when mature and dry. The calyx, stems and leaves are acidic (Morton 1987).

Roselle is well adapted to tropical and subtropical climates. It grows between latitude 45° N and 30° S. The optimum climatic conditions for growth are a temperature range of 16-28° C and rainfall of 500-625 mm and a growing season of 3-4 months (Onwueme *et al* 1991). Roselle is a short day plant (Rhoden *et al* 1993) and exhibits marked photoperiodism and flowers at 11 hours day length.

Roselle is grown on a wide range of soils, but it thrives best on well-drained, rich and sandy loamy soils. The crop is drought resistant, but it can be successfully grown under irrigation (Onwueme *et al* 1991). In arid and semi arid regions, roselle is sown at the beginning of the rainy season, generally together with other crops (Romain 2001). Roselle throughout its growing regions is not usually fertilized (Onwueme *et al* 1991), but Rhoden *et al* (1993) mentioned that application of nitrogen is recommended for better vegetative growth of roselle.

2.2 Pigeonpea.

Pigeonpea (*Cajanus Cajan L.Mill spp*), also known as red garm, congo bean, tur, no-eye pea, and arhar is an important crop among the grain legumes. It belongs to the family Leguminoseae and sub-family Fabaceae (Onwueme *et al* 1991).

Pigeonpea is an ancient African grain legume, it has been cultivated in the Nile valley for more than 4000 years and they were taken to India in prehistoric times, and this region now constitutes the center of the greatest diversity of pigeonpea cultivars. The crop is now grown widely throughout the tropics and subtropics (Onwueme *et al* 1991).

Pigeonpeas are grown for mature and immature seeds and pods, and for forage also as a cover crop and wind break. It is a short-lived (3-4 years) perennial and bears seeds every year .It has a very deep tap root and a mass of lateral roots The main stem is thick and erect, 1-4m tall. Leaves are trifoliate and the petioles are short. The inflorescence is small; flowering extends over several months. The pods are straight, usually 4-5cm long, in each pod, 3-4 seeds are formed (Onwueme *et al* 1991).

Dry ripe seeds contain about 57.3% carbohydrate, 19.2%protein, 7.5% fat, 8.1% fibers, 3.8% ash and 10.1% water. Pigeonpea tolerates a wide range of soils, from sands to heavy black clays, and pH of 5-7. (Skerman 1988).

Pigeonpea Rhizobium is promiscuous and therefor seeds are not inoculated. Skerman (1988) found that nodules appeared on the roots three weeks after seeding, and that young nodules of pigeonpea were the most active in fixing nitrogen.

Pigeonpea is a useful crop in a rotation as its deep root system opens the lower layers of the soil, particularly when it follows an exhausting crop. In intercropping pigeonpeas may produce greater total yields than either crop grown alone, because of better utilization of soil moisture and nutrients (Onwueme *et al* 1991). In India and Uganda, it is usually sown in alternate rows with other crops (Romain 2001). Harvesting is based on the flowering behavior, when the plant is still green but most of the leaves have dried and are shed. Pods are picked, dried for few days and threshed. When pigeonpeas are grown as a sole crop the yield of dried seed ranges from 500-1100kg/ha. In mixture, yields of 250-800 kg/ha are obtained (Onwueme *et al* 1991).

2.3 Cowpea.

Cowpea (*Vigna unguiculata L. walp*) is a member of the family Leguminoseae, subfamily Fabaceae. Common names are crowder pea, black-eye pea, southern pea, lubia and nieba. (Davis *et al* 1991).

Cowpea is an important grain legume throughout the tropics and subtropics, covering Asia, Africa and central and South America. Its value lies in its high protein content, its ability to tolerate drought, and the fact that it fixes atmospheric nitrogen with high efficiency, which allows it to grow on, and improve poor soils. It is shade tolerant and is therefor compatible as an intercrop with many crops (IITA 1997).

Cowpea is erect or semi erect, climbing, annual herbaceous legume. Growth habit ranges from indeterminate to fairly determinate (Davis *et al* 1991). Cowpea has a deep taproot, with many branches; nodules are smooth, large, and globular. Stem very variable, erect or semi-erect, height between 2-4m, leaves are trifoliate. Flowers are white, purple, with a standard petal 2-3cm across. The flowers occur in alternate pairs on a long axillary peduncle. Pods are smooth cylindrical and generally curved, contain 8-20 seeds (Cobley 1976). The dry seeds contain 24.8% protein, 1.9 % fat, 63.6% carbohydrate, 6.3% fiber (Bressani *et al* 1985).

Sowing date is between June and August. Under rain cowpea is grown alone or with other crops such as cereals and the average yield is about 475 kg/ha. Under irrigation cowpea is mainly grown with vegetables, sorghum or cotton and average yield is about 650 kg/ha (Mohamed 1984). Hand harvested-cowpea suffers less damage, but the harvest season may continue over one to three weeks period (Davis *et al* 1991).

Cowpea is used as a food crop and provides forage for livestock .It is also used as green manure, cover crop for maintaining soil productivity and it compensates for the loss of nitrogen removed by other crops when it is intercropped with them, (Onwueme *et al* 1991).

Dried seeds may be ground into meal or flour which is used in many ways.

2.4 Intercropping.

2.4.1 General.

Out of all the world's land resources available for agricultural production, only half of this area is in actual use (Anon 1992). With the world increasing population high priority must be given to adopting systems of agricultural production which will be efficient and sustainable. Environmental considerations also invoice a growing awareness of the need to reduce pollution and other undesirable effects from application of nitrogenous fertilizers and other agrochemicals.

The biological fixation of atmospheric nitrogen, particularly through the legume/rhizobium symbiosis has a central role to play in sustainable agriculture and maintaining the long- term fertility of soil in the tropics. Legumes contribute to increased productivity of other crops when incorporated into cropping systems as intercrops or crop rotations. In intercrops, the legume is generally contributing a direct agricultural product through maintenance and restoration of soil fertility adding its fixed N to the soil or by other pathways such as exudation from legume roots and via mycrorrhizal association between plants (Murray *et al* 1998).

Intercropping is a potentially beneficial system of crop production. It can be defined as the growing of two (or more) crops simultaneously on the same area of land. Crops are not necessarily sown at the same time and their harvest time may be quite different, but they are usually simultaneous for a significant part of their growing periods (Willey 1979). Intercropping can provide yield advantages compared to sole cropping. The forms of these advantages are yield stability, low input, higher yield, better use of growth resources and better control of weeds, pests and disease. Paul (1983) reported that planting several different species and different varieties of the same species in the same farm has the following benefits:

- Use of available soil moisture and plant nutrients is maximized.
- Spread of pests and diseases is minimized.
- Exposure of the soil to erosive rainfall is minimized.
- Suppression of weeds at later stages in the cropping sequence is achieved through competition by established crops approaching harvest.
- Plants with different growth characteristics and leafing patterns may be able to combine to maximize use of available sunlight, rather than the competition in denser stands.

- Risks of crop failure are minimized, because of different speeds of maturation and moisture requirements.

Intercropping allows efficient use of both space and time to optimize beneficial effects (Potts *et al* 1990). It was reported as a means of risk reduction (Rao and Willey 1980). Intercropping through shading can enhance microclimate modification (Potts *et al* 1990). Campbell (1990) found that intercropping can promote diversification and allows greater flexibility in adjusting to short-and long-term changes in the production and marketing situation. Intercropping can provide better weed control and reduces pest and disease incidence (Finney 1990).

A High land equivalent ratio (LER) is an important advantage of intercropping as indicated by increased overall yield. LER was defined by Reddy *et al* (1989) as the proportional land area that would be required as sole crop to produce the yields achieved in intercropping. When two or more crops are growing together each must have adequate space to maximize cooperation and minimize competition between crops. To accomplish this, four requirements need to be considered as discussed by Sullivan (1998):

1-Spatial arrangement: It includes the following systems:

- Row intercropping: growing two or more crops with at least one crop planted in rows.
- Mixed intercropping: growing two or more crops together in no distinct row arrangement.
- Strip intercropping: growing two or more crops together in strips wide enough to permit separate crop production using machines.

- Relay intercropping: planting a second crop into a standing crop at a time when the standing crop is at its reproductive stage but before harvesting.

2-Plant density: To optimize plant density, the seeding rate of each crop in the mixture is adjusted below its optimum.

3-Plant architecture: Is allowing one member of the mixture to capture sunlight that would not otherwise be available to the others.

4-Maturity dates: Selection of crops or varieties with different maturity dates reduces the competition between the two crops. It can also assist in harvesting and separation of grain commodities.

Intercropping disadvantages is that the yields of each of the component crops are less than the corresponding sole crop yields (Ifenkwe *et al* 1989). They also appear in the difficulties involved in the practical management of the system and yield reduction may occur due to adverse competitive effects. Intercropping increased competition primarily for solar radiation and water (Midmore 1990).

Nitrogen fixation does not only provide N for the legume itself, but will also build up soil nitrogen, this depends on the proportion of the legume's N that is fixed (Giller *et al* 1995). Intercropping with legumes has been shown to give higher returns than single cropping, and increases the yield of the associated non-legumes under certain conditions (Roy 1990). Moreover, no difference exists in the legume yields between the intercrop and the same monocrop yield per plant, which indicates that intercropping had no beneficial effect on the individual legume plants and only contributed to higher yield reduction per hectare in the legume component (Keswani *et al* 1982).

2.4.2 Effect of intercropping on crops.

1. Growth attributes:

As legumes represent a source of nitrogen Snaydon and Haris (1981) reported that below ground interactions often give rise to yield advantage in intercropping, and it was largest in case of legume and non-legume intercrops and he attributed it to the atmospheric nitrogen fixed by legumes. Onuweme and Sinha (1991) stated that for proper plant growth, regular supply of plant nutrients is necessarily. Therefore nitrogen was found to increase plant height of many Malvaceae crops. El-shafie *et al* (1994) found that nitrogen fertilization had a highly significant effect on plant height of roselle. El -Gamal *et al.* (1984) found that nitrogen fertilizer increased plant weight of roselle. Bakar (1978) reported that cotton plants were always shorter when intersown than when grown sole. Intercropping significantly increased dry weight/ plant of sunflower (Azam Ali 1990).

2. Yield and yield components.

Waring and Gibson (1994) found that yield of roselle was increased when the crop followed legume crops, due to increase in nitrogen levels, and this was confirmed by Elgamal *et al* (1984) who found that calyx yield of roselle increased with increasing nitrogen levels. Intercropping did not affect number of roselle fruits/plant but reduced dry calyx yield when it was intercropped with cowpea (Mounke 2000).

As a related crop, cotton seed yield, in cotton/ cowpea/ maize intercrop, was higher in the spatial arrangement of single rows with cowpea and maize. This agrees with Bezerra (1991) who found that cotton seed yield in cotton/ cowpea/ sorghum intercrop was higher when single rows of cowpea and sorghum alternated with single rather than double rows of cotton. Association of groundnut with sunflower reduced the yield of sunflower compared with sole crop (Dayal and Reddy 1991a) and affected final seed yield of sole sunflower over other intercropping treatments.

Aboud (1987) reported that in Potato\ broad bean system, intercropping gave higher potato yield than potato monocropping. Roy *et al* (1990) stated that intercropping of roselle with groundnut and cowpea remained commercially viable, though roselle yield was generally reduced, but it was compensated for by the high yield of the intercrop.

For legumes, Agboola (1971) suggested that the yield of legume is usually depressed than that of the non legume. However Paudel (1995) found that intercropping did not influence yield and yield components of pigeonpea, sole pigeonpea gave significantly higher yield than pigeonpea intercropped with rice, maize and peanut.

For cowpea it was shown that intercropping cowpea with cereal in alternate rows is more productive (IITA 1997). However, no difference existed in yield/ plant between the intercrop and the same monocrop, which indicates that intercropping had no beneficial effect on the individual legume plants and only contributed to the yield reduction per hectare in the legume component. (Keswani *et al* 1982). The pod yields of groundnut were reduced significantly by intercropping (Rao and Mittra 1990).

3.Chemical composition:

3.1 Protein content.

Ibrahim *et al* (1971) found that Sudanese roselle contain 7.1-9.5 %protein. And Duke (1984) reported 1.9 % protein, 84.5% water, 0.14% ascorbic acid in roselle calyx. Hago and Osman (1999) found that application of nitrogen significantly increased calyx protein content.

3.2 Anthocynin content.

Yamamota and Oshima (1932) detected red anthocyanin monoxide in roselle and they gave it the name hibiscine. Eltinay and Ismail (1985) worked on local roselle varieties and found 1.4-% anthocynin, whereas, Hassan (1988) found that Rahad and Gezira type of roselle contained 2.6% and 0.66% anthocynin, respectively.

Salo *et al* (1991) reported 1.1 % anthocynin content among improved varieties compared to 0.30% for the commercial types.

Alshoosh (1997) worked on the same cultivars as this study (CVI) under Shambat conditions and found 1.20 % anthocynin. Hago and Osman (1999) found that application of nitrogen significantly increased anthocynin content.

Harborne (1973) stated that the anthocynin content is more affected by metals. Segal and Negutz (1969) mentioned that the stability of anthocynin was greatly affected by temperature.

3.3 Organic acids.

Oxalic, citric, malic and lactic acids were reported to be present in dry calyx of roselle (Pritzker *et al*1937). Alshoosh (1997) reported 14.66% citric acid and 0.61% oxalic acid. Hago and Osman (1999) found that application of nitrogen significantly decreased oxalic acid content.

2.4.3 Land equivalent ratio. (LER):

Willey (1979) defined LER as the relative land area under sole crop that is required to produce the yield achieved in intercropping. LER is the single most useful index of yield advantage since it can provide a standardized estimate of the total biological efficiency of the intercroping system (Russel *et al* 1989). On the other hand Babatunde (2000) defined it as the land area that would be required for sole crops to produce the yield achieved in intercropping combination.

To calculate LER, the intercrop yields are divided by the pure stand yields for each component crop in the intercrop. Then, these two figures are added together. When a LER measures 1.0 it means that there is more advantage of intercropping in utilizing resources than sole cropping.

CHAPTER THREE
MATERIALS AND METHODS

3.1 Experimental.

A field experiment was conducted for one season (2003/2004) in the Experimental Field of the Faculty of Agriculture, University of Khartoum at Shambat (Latitude 15º 40´ N, Longitude 32º 32´ E, and Altitude 380m above sea level). The soil at the site is heavy (64% clay) and alkaline with pH of 8.05.

The objectives were to study the response of roselle (*Hibiscus sabdariffa L.)* to intercropping with two legumes Pigeonpea (*Cajanus cajan L.Mill spp)* and Cowpea (*Vigna unguiculata l. Walp*) under irrigation. Seeds of roselle cultivar CV1 were obtained from the Department of Agronomy, Faculty of Agriculture, University of Khartoum, whereas seeds of pigeonpea (CV-Tieba) and cowpea (CV-Einalgazal) were obtained from Elobied Agriculture Research Station.

The treatments were sole roselle (R), sole pigeonpea (P), sole cowpea (C) and three planting patterns of roselle intercropped with each of the two legumes: alternate holes, the same holes and alternate rows designated as (RP1, RC1), (RP2, RC2) and (RP3, RC3) for pigeonpea and cowpea intercrops respectively.

The experiment was laid out in a Randomized complete block design (RCBD) with four replications. The experimental unit was a plot 4x5 m^2 in area, consisting of 4 ridges at 70cm spacing each in length.

The crops were sown on the 9th of July 2003 at the rate of 4 seeds per hole and spacing of 50cm between holes for all crops. Thinning to two plants per hole was carried out after the third irrigation. Population density of sole plants was 72 plants /plot, and 36 plants /plot for each intercrop component.

Urea (46%N) and triple super phosphate (48% P_2O_5 /ha) were applied on one side of the ridge at rate of 40 kg N/ha and 50kg P_2O_5/ha respectively. The crops were irrigated immediately after sowing, then subsequent irrigations were given every 7 days. Three manual weedings were done at appropriate stages during the growing season.

3.2 Parameters

3.2.1 Growth attributes:

Measurements of vegetative attributes for each crop were based on three random plants taken from the outer two ridges in each plot every two weeks starting one month after sowing until the flowering stage.

1. Plant height (cm).

Measured from the point immediately above the soil to the tip of the youngest leaf.

2. Number of leaves /plant.

Determined by counting all the leaves of the sampled plants and then obtaining the mean number of leaves per plant for each crop.

3. Number of branches /plant.

Was obtained by counting all branches of the plants in each sample and from that mean number of branches per plant for each crop was determined.

4. Fresh and dry weight of shoots.

Shoots and roots of the three plants were separated, then shoots were weighted fresh, left to air dry in the laboratory and weighed to determine shoot dry weight for each crop.

5. Fresh and dry weight of roots.

Roots separated from plants used in above-mentioned parameter were washed, dried of water and weighed fresh, then air-dried and weighed to determine root dry weight for each crop.

6. Nodule number/ plant.

Nodules were separated from roots of each sample, cleaned, then counted to determine the number of nodules per plant for each of the two leguminous crops.

3.2.2 Reproductive attributes:

3.2.2.1 Time to 50 % flowering.

Number of days from sowing until 50% of plants in each plot flowered was determined and then the time to 50%flowering was obtained for each crop.

3.2.2.2 Time of maturity.

Number of days from sowing till maturity was obtained for each crop**.**

3.2.3 Yield and yield components:

3.2.3.1 Rosalle

1. Number of calyces/plant.

Fruits of five random roselle plants were taken from the three central ridges of each plot (yield area) and counted to determine number of calyces per plant.

2. Calyx fresh and dry weight (g).

Calyces of the above mentioned plants were picked, weighed fresh and then left to air-dry and weighed to determine calyx dry weight / plant.

3. Calyx yield (kg/ha).

Calyces were picked from an area of 1.4m² in the three central ridges (yield area) in each plot at maturity, when capsules turned to yellowish colour and started to crack at the tips. The calyces were air dried and weighed to obtain dry calyx yield, then the dry calyx yield for each treatment was converted to final yield (kg/ha).

4. Hay yields.

Shoots of plants harvested for calyx yield were air dried, weighed and hay yield (kg/ha) was estimated.

3.2.4 Chemical analysis:

1. Protein Content.

Nitrogen content of calyces was determined by using micro-Kjeldahl Method (Appendix 5). A sample of 2.5g was taken from each treatment to estimate protein content.

2. Anthocyanin Content.

Anthocyanin content of roselle calyces was determined by using Extraction Method described by Allen and Quarmby (1989) using a sample of 2.5g from each treatment (Appendix 6).

3. Oxalate Content.

Oxalate content was determined by using Titration Method Against Alkali described by Peter *et al* (1976) using a sample of 2.5g from each treatment for this purpose. (Appendix 7).

4. Citric Acid Content.

Citric acid content was estimated by using Titration Method described by Ruck (1963). A sample of 2.5g from each treatment was used for this purpose (Appendix 8).

3.2.3.2 Legumes.

1. Number of pods/plant.

At maturity, pods from five random pigeonpea and cowpea plants, from the middle of the three central ridges in each plot were picked, then their pods were dried and counted to determine mean number of pods per plant.

2. Number of seeds /pod.

Five pods were taken randomly from the above-mentioned plants, and then their seeds were counted to determine number of seeds per pod.

3. 100-Seed weight (g).

A sample of 100-seed was taken randomly from each of the above-mentioned plants, then weighed to determine mean 100-seed weight for each treatment.

4. Seed weight/plant (g).

Seeds of the above five plants were weighed to determine weight of seeds per plant.

5. Seed yield (kg/ha).

Pods of plants in an area of 1.4m^2 from the three central ridges (yield area), in each plot were picked, sun dried, threshed, weighed and adjusted to yield in kg/ha.

3.3 Data Analysis.

All data collected were statistically analyzed using Randomized Complete Block Design RCBD, and treatment means were compared by using the Duncan's Multiple Range Test (DMRT) described by Gomez and Gomez (1984).

CHAPTER FOUR
RESULTS

4.1 Growth Parameters

4.1.1 Roselle.

4.1.1.1 Plant height.

There was no significant difference in plant height between all treatments, but intercropping tended to reduce roselle plant height. Sole plants recorded the greatest plant height at all stages (Table 1). There was also variation in response between intercropping treatments. With pigeonpea intercropping in general the greatest plant height was given by alternate holes (RP1) treatment and the lowest was given by the same hole (RP2) treatment. However at the 11^{th} week, alternate rows (RP3) with pigeonpea produced the tallest plants. The same trend was also shown by cowpea intercropping (Table 1).

4.1.1.2 Number of leaves/ Plant.

Intercropping significantly reduced leaf number of roselle plants. At the 5^{th} week all intercropping treatments caused a significant reduction in leaf number, the greatest reduction produced by the same hole (RC2) treatment (Table 2). At the 7^{th} week, only cowpea intercropping caused significant reduction in leaf number, the greatest reduction produced by the same hole (RC2) treatment. Pigeonpea intercropping caused consistent but insignificant reduction. At the 9^{th} week, all intercropping treatments reduced leaf number, but the reduction was significant when roselle was sown in alternate holes (RP1) and in the same hole (RP2) with pigeonpea (Table 2). At 11^{th}

Table (1): Effect of intercropping on plant height of roselle.

Parameters	Plant height			
Treatments	5th week	7th week	9th week	11th week
R	9.59 a	16.17 a	19.50 a	36.75 a
RP1	9.46 a	15.37 a	18.62 a	33.87 a
RP2	9.07 a	15.05 a	18.37 a	33.25 a
RP3	9.17 a	15.25 a	18.62 a	34.37 a
RC1	8.50 a	14.75 a	18.37 a	34.62 a
RC2	8.00 a	14.62 a	17.87 a	34.37 a
RC3	8.28 a	14.62 a	18.12 a	35.12 a
SE±	0.51 ns	0.71 ns	0.69 ns	1.17 ns
CV%	11.62	9.39	7.48	24.48

Means followed by the same letter are not significantly different at (0.05) levels of probability according to DMRT.

Table (2): Effect of intercropping on number of leaves of roselle.

Parameters	Number of leaves/plant			
Treatments	5th week	7th week	9th week	11th week
R	16.75 a	29.75 a	43.17 a	75.25 a
RP1	10.75 bc	29.50 a	37.87 b	61.50 a
RP2	10.43 bcd	26.62 ab	37.50 b	59.50 a
RP3	11.62 b	23.25 abc	39.25 ab	54.00 a
RC1	9.70 cd	19.25 bc	41.87 ab	68.25 a
RC2	9.30 c	16.42 c	42.62 ab	66.00 a
RC3	10.27 bcd	20.12 bc	40.18 ab	68.87 a
SE±	0.13 **	1.88 **	1.67 *	4.61 ns
CV%	5.58	16.00	8.28	14.23

Means followed by the same letter(s) are not significantly different at (0.05) levels of probability according to DMRT.

week all intercropping treatments produced consistent but non-significant reduction in leaf number, and the greatest reduction was obtained with the same hole and alternate rows (RP2, RP3) treatments.

4.1.1.3 Number of Branches /Plant.

Intercropping significantly reduced number of branches /plant, with significant differences observed between treatments at all stages (Table3). Sole plant treatments produced more branches than intercropped treatments, whereas at the same hole treatments (RP2, RC2) within each system gave lowest values at all stages. Alternate rows treatments (RP3, RC3) within each system gave more branches than all other intercropping treatments, with significant differences some times (Table3).

Moreover plants intercropped with pigeonpea tended to have more branches than those intercropped with cowpea until the 7th week stage, there after, no difference occurred in this parameter.

4.1.1.4 Shoot fresh weight/plant (g).

There was a significant reduction in shoot fresh weight of roselle plants in response to intercropping at all stages, except in 9th- week, which showed a consistent but non-significant reduction, and the greatest reduction was produced by the same hole with cowpea (RC2) treatment (Table.4). Monocropped roselle treatments recorded higher shoot fresh weight than all other treatments. Generally cowpea tended to have greater effect than pigeonpea combinations (Table 4).

4.1.1.5 Shoot dry weight (g).

Generally, intercropping reduced shoot dry weight at all stages, but the reduction was significant at the 7th and 9th week only (Table 4). Monocropped roselle plants gave greater shoot dry weight than intercropped plants (Table 4).

Table 3:Effect of intercropping on number of branches / plant of roselle.

Parameters	Number of branches/ plant			
Treatments	5th week	7th week	9th week	11th week
R	9.25 a	12.62 a	13.75 a	13.50 a
RP1	8.25 ab	10.50 b	11.87 c	12.25 c
RP2	7.62 b	10.37 bc	11.25 c	11.75 c
RP3	9.18 a	11.87 a	12.62 b	13.13 ab
RC1	6.00 cd	9.06 cd	12.62 b	12.25 c
RC2	5.13 d	8.75 d	11.37 c	11.87 c
RC3	6.50 c	9.62 bcd	13.00 b	12.87 b
SE±	0.25 **	0.30 **	0.20 **	0.19 **
CV%	6.74	5.91	3.27	3.09

Means followed by the same letter(s) are not significantly different at (0.05) levels of probability according to DMRT.

Table 4: Effect of intercropping on Shoot fresh and Shoot dry weight of roselle (g).

Parameters	Shoot fresh weight				Shoot dry weight			
Treatments	5th wk	7th wk	9th wk	11th wk	5th wk	7th wk	9th wk	11th wk
R	3.65 a	10.12a	26.10a	38.87a	0.67 a	2.08 a	5.58 a	9.37a
RP1	2.95 ab	8.20 b	24.17a	37.37ab	0.65 a	1.34 b	3.69 b	8.37a
RP2	2.95 ac	7.80 b	23.80a	35.35b	0.55 a	1.53ab	2.64 c	7.55a
RP3	3.52 a	7.80 b	23.80a	36.13ab	0.59 a	1.37 b	3.22bc	8.36a
RC1	2.02 cd	8.62 ab	24.37a	35.00b	0.59 a	2.03 a	2.85 c	8.62a
RC2	1.73 d	7.50 b	24.62a	34.80b	0.34 a	1.47a	2.71c	7.80a
RC3	2.16 bcd	8.70ab	24.55a	35.00b	0.57 a	1.73ab	2.71c	8.52a
SE±	0.19 **	0.53*	0.68 ns	0.87*	0.06ns	0.14**	0.15**	0.47ns
C.V	14.98	12.85	5.59	4.87	25.12	17.63	10.43	11.41

Means followed by the same letter are not significantly different at (0.05) level of probability according to DMRT.

4.1.1.6 Root fresh weight (g).

Intercropping caused a consistent reduction in root fresh weight of roselle, the reduction being significant, except at the 7th week (Table 5).

Monocropped plants produced greater root fresh weight than intercropped combination, except at the last stage where alternate rows treatments (RP3, RC3) recorded the greatest values (Table 5).

4.1.1.7 Root dry weight/ plant (g).

Root dry weight showed the same trend as root fresh weight. There was significant reduction in root dry weight with intercropping, except at the 5th week. (Table 5). Monocropped roselle plants produced higher root dry weight than intercropped plants, except in the last stage (11th week) when RC1and RC3 treatments recorded higher values than the control. (Table 5).

4.1.2 Legume Crops:

4.1.2.1 Plant height.

Intercropping consistently reduced plant height of pigeonpea, but the effect was not significant. (Table 6). Sole crops had greater plant height followed by alternate rows treatment (RP3), whereas the same hole treatment (RP2) recorded the lowest value. (Table 6).

On the other hand intercropping cowpea with roselle caused significant reduction in plant height of cowpea with RC1 and RC2 treatments at the 5th week and RC2 at the 7th week (Table 6).

4.1.2.2 Number of leaves/ plant.

Intercropping caused consistent reduction in number of leaves of the leguminous crops. Intercropped pigeonpea plants showed no significant difference in number of leaves at the 5^{th} and 9^{th} week, but significant

Table 5: Effect of intercropping on root fresh and root dry weight of roselle (g).

	Root fresh weight				Root dry weigh			
Treats	5th wk	7th wk	9th wk	11th wk	5th wk	7th wk	9th wk	11th wk
R	0.87 a	1.61 a	2.77 a	4.17 bcd	0.36 a	0.43 a	1.74 a	2.61 abc
RP1	0.62 bc	1.31 a	2.75 a	3.90 d	0.32 a	0.20 b	1.63 a	2.35 d
RP2	0.58 c	1.06 a	2.37 b	4.63 abc	0.21 a	0.22 b	1.43 b	2.38 d
RP3	0.55 c	1.06 a	2.68 a	4.68 b	0.15 a	0.22 b	1.45 b	2.57 bc
RC1	0.68 bc	1.13 a	2.50 ab	4.10 bcd	0.18 a	0.21 b	1.38 b	2.68 ab
RC2	0.78 ab	1.31 a	2.56 ab	3.95 cd	0.13 a	0.26 b	1.40 b	2.48 cd

RC3	0.67 bc	1.50 a	2.69 a	4.96 a	0.34 a	0.25 b	1.44 b	2.74 a
SE±	0.04 **	0.43 ns	0.06**	0.21*	64.41 ns	29.13**	5.25**	2.97**
CV	14.08	67.76	5.02	9.93	0.07	0.03	0.03	0.03

Means followed by the same letter(s) are not significantly different at (0.05) levels of probability according to DMRT.

Table 6: Effect of intercropping on plant height of legume crops (cm).

Pigeonpea					Cowpea		
Treats	5th week	7th week	9th week	11th week	Treats	5th week	7th week
P	27.60 a	34.97 a	63.75 a	96.60 a	C	16.99 a	56.37 a
RP1	23.80 a	33.07 a	61.90 a	90.75 a	RC1	12.87 b	49.62 a
RP2	23.20 a	32.52 a	61.00 a	89.37 a	RC2	13.35 b	42.25 b
RP3	24.29 a	33.80 a	62.92 a	93.25 a	RC3	16.50 a	47.75ab
SE±	1.27 ns	0.15ns	1.46ns	1.67ns	SE±	0.44**	2.66 *
CV	10.34	0.94	4.69	3.61	CV	5.95	10.8

Means followed by the same letter(s) are not significantly different at (0.05) levels of probability according to DMRT.

Table 7: Effect of intercropping on Number of Leaves / plant of Legume crops.

Pigeonpea					Cowpea		
Treatments	5th week	7th week	9th week	11th week	Treatments	5th week	7th week
P	9.32 a	24.20 a	70.36 a	173.13 a	C	12.87 a	33.75 a
RP1	8.90 a	20.92 b	67.13 a	160.30 bc	RC1	11.52 b	30.95 b
RP2	8.77 a	20.62 b	64.87 a	150.12 c	RC2	11.33 b	31.00 b
RP3	8.97 a	22.13 ab	68.50 a	167.75 a	RC3	12.42 ab	32.45 b
SE±	0.42 ns	0.69 *	2.49 ns	1.24 **	SE±	0.24 **	0.50 *
CV	9.54	6.31	7.36	1.52	CV	4.01	3.16

Means followed by the same letter(s) are not significantly different at (0.05) levels of probability according to DMRT.

decrease in 7th and 11th week (Table 7). Sole pigeonpea plants had significantly higher number of leaves followed by alternate rows (RP3) treatment, whereas the same hole treatment (RP2) recorded the lowest leaf number (Table 7).

Intercropped cowpea plants showed significant reduction in number of leaves/plant at 5th and 7th week (Table 7). Monocropped cowpea plants had the highest number of leaves followed by alternate rows (RC3) treatment (Table 7).

4.1.2.3 Number of branches / plant.

Roselle/pigeonpea intercropping caused a consistent decrease in number of branches / plant, the reduction being significant at all stages, except at 7th week (Table 8). Sole pigeonpea plants had significantly higher number of branches followed by alternate rows (RP3) treatment, whereas the same hole (RP2) treatment recorded the lowest number of branches (Table 8).

Roselle/cowpea intercropping also caused consistent decrease in number of branches/plant, which reached significant level at the 7th week with alternate holes (RC1) treatment (Table 8).

4.1.2.4 Shoot Fresh weight (g).

This parameter showed consistent and sometimes significant response to intercropping. Intercropped pigeonpea showed significant reduction in shoot fresh weight at 7th and 11th week only. (Table 9). At 7th week, all intercropping treatments caused significant reduction in shoot fresh weight of pigeonpea whereas at 11th week, only the same hole (RP2) treatment did so. Sole pigeonpea treatments showed greater shoot fresh weight followed by alternate rows (RP3) treatment, whereas the same hole treatment (RP2) recorded the lowest value, except at 9th week (Table 9).

Table 8: Effect of intercropping of number of branches per plant of legume crops.

pigeonpea					Cowpea		
Treatments	5th wk	7th wk	9th wk	11th wk	Treatments	5th wk	7th wk
P	5.62 a	9.12 a	10.68 a	11.25 a	C	3.18 a	4.62 a
RP1	4.37 ab	8.00 a	9.31 bc	10.32 bc	RC1	2.75 a	3.37 b
RP2	3.80 b	7.87 a	8.75 c	9.82 c	RC2	3.00 a	4.43 a
RP3	5.12 ab	8.75 a	9.50 b	10.47 b	RC3	3.15 a	4.50 a
SE±	0.29**	0.35ns	0.13**	0.14**	SE±	0.28 ns	0.25*
CV	12.5	8.35	2.8	2.63	CV	18.9	11.8

Means followed by the same letter(s) are not significantly different at (0.05) levels of probability according to DMRT.

Table 9: Effect of intercropping on Shoot fresh weights of legume crops.

Pigeonpea					Cowpea		
Treatments	5th week	7th week	9th week	11th week	Treatments	5th week	7th week

P	2.19 a	7.75 a	24.87 a	168.25 a	C	35.75 a	81.50 a
Rp1	2.10 a	6.45 c	20.50 a	164.50 a	RC1	28.25 c	65.50 c
Rp2	1.69 a	6.30 c	20.62 a	153.92 b	RC2	25.65 d	66.80 c
RP3	2.28 a	7.07 b	24.25 a	165.25 a	RC3	31.12 b	72.70 b
SE±	0.21 ns	0.10 **	2.68 ns	1.22 **	SE±	0.51 **	0.63 **
CV%	20.8	2.94	23.83	1.50	CV%	3.40	1.77

Means followed by the same letter(s) are not significantly different at (0.05) levels of probability according to DMRT.

Intercropped cowpea plants showed significant reduction in shoot fresh weight at 5th and 7th week (Table 9). Sole plants had the greatest shoot fresh weight followed by alternate rows (RC3) treatments. (Table 9).

4.1.2.5 Shoot dry weight (g).

Legume shoots dry weight showed similar response to intercropping as shoot fresh weight. Intercropped pigeonpea plants showed consistent but non-significant reduction in shoot dry weight at the 5th and 9th week, but significant decrease in 7th and 11th week (Table 10). Sole pigeonpea plants recorded the greatest shoot dry weight followed by alternate rows (RP3) treatments, except in 7th week in which RP3 treatment recorded greatest value, whereas the same hole treatments produced lowest shoot dry weight at all stages (Table 10).

Intercroppeimg also significantly reduced shoot dry weight of cowpea. At the 5th week all intercropping treatments caused significant reduction shoot dry weight, whereas at the 7th week, only the same hole treatment had such effect (Table 10)

4.1.2.6 Root fresh weight (g).

Intercropping caused consistent and sometime significant reduction in root fresh weight of both legumes. (Table 11). Pigeonpea root fresh weight showed significant reduction in response to intercropping at all stages, except at the 5th week, which also showed marked, but non-significant reduction (Table 11). Monocropped pigeonpea had the greatest root fresh weight followed by alternate rows treatment (RP3). On the other hand at the same hole treatment (RP2) recorded the lowest root fresh weight (Table 11). Intercropped cowpea also showed consistent reduction in root fresh weight, the reduction being significant at the 7th week with alternate holes (RC1) and the same hole (RC2) treatment (Table 11).

Table 10: Effect of intercropping on shoot dry weight of legume crops.

Pigeonpea					Cowpea		
Treatments	5th week	7th week	9th week	11th week	Treatments	5th week	7th week
P	0.52 a	2.56 b	8.81 a	27.60 a	C	4.44 a	12.80 a
RP1	0.48 a	2.53 c	7.62 a	24.56 b	RC1	3.56bc	11.00ab
RP2	0.43 a	2.52 c	7.13 a	13.86 d	RC2	3.45 c	9.47 b
RP3	0.52 a	2.62 a	7.67 a	16.67 c	RC3	3.71 b	11.82ab
SE±	0.12ns	0.006**	0.63 ns	0.44**	SE±	0.04**	0.51*
CV%	15.34	0.52	16.33	4.19	CV%	2.27	9.17

Means followed by the same letter(s) are not significantly different at (0.05) levels of probability according to DMRT.

Table 11: Effect of intercropping on Root fresh weight of legumes.

Pigeonpea					Cowpea		
Treatments	5th week	7th week	9th week	11th week	Treatmens	5th week	7th week
P	0.90 a	1.70 a	5.00 a	14.95 a	C	1.86 a	3.41 a
RP1	0.24 a	1.55 ab	4.20 ab	13.36 b	RC1	1.76 a	2.96 b
RP2	0.15 a	1.36 b	3.56 b	12.83 b	RC2	1.75 a	2.68 b
RP3	0.30 a	1.67 a	4.72 a	14.21 ab	RC3	1.81 a	3.45 a
SE±	0.07ns	0.04**	0.18**	0.3**	SE±	0.23 ns	0.07**
CV%	65.71	5.24	8.29	4.38	CV%	26.44	5.30

Means followed by the same letter(s) are not significantly different at (0.05) levels of probability according to

DMRT.

4.1.2.7 Root dry weight (g).

Intercropping caused significant reduction in root dry weight of pigeonpea at all stages, except the 11th week (Table 12). At the 5th week, all intercropping treatments caused significant reduction in root dry weight of pigeonpea, whereas at the 7th and 9th weeks only the same hole (RP2) treatment did so. Sole pigeonpea plants gave the highest root dry weight followed by alternate rows (RP3) treatments. The lowest values were shown by the same hole (RP2) treatments.

Intercropped cowpea plants also showed significant reduction in root dry weight at the 5th and 7th weeks, with alternate holes (RC1) and the same hole (RC2) treatments which recorded similar but significantly lower values than the others (Table 12)

4.1.2.8 Number of Nodules / Plant.

In both legumes, number of nodules showed non significant response to intercropping, although there was a general decrease with intercropping (Table 13). Sole legume plants had greater number of nodules followed by alternate rows (RP3, RC3) treatments, whereas the same hole (RP2, RC2) treatments produced the lowest number.

4.2 Reproductive Attributes:

4.2.1 Days to 50 % flowering.

All intercrops showed no significant differences in days to 50 % flowering (Table 14 and 15). However roselle intercropped with cowpea showed a delay in time to 50 % flowering in comparison to roselle intercropped with pigeonpea treatments (Table14). Moreover, intercropping also tended to delay 50% flowering of both legumes (Table

15).

4.2.1Days to maturity.

There was no significant effect of intercropping on days of maturity of all crops (Tables 14 and 15).

Table 12: Effect of intercropping on Root dry weight of legume crops (g).

Crops	Pigeon pea				Cowpea		
Treatments	5th week	7th week	9th week	11th week	Treatments	5th week	7th week
P	0.95 a	0.81 a	2.12 a	7.65 a	C	0.64 a	2.76 a
RP1	0.73 b	0.72 a	1.83 ab	4.97 a	RC1	0.34 b	1.82 b
RP2	0.54 c	0.61 b	1.54 b	4.57 a	RC2	0.31 b	1.69 b
RP3	0.74 b	0.75 a	1.88 ab	5.91 a	RC3	0.55 ab	2.76 a
SE±	0.003**	0.03*	0.07**	0.91ns	SE±	0.05**	0.05**

CV%	9.14	9.72	7.68	31.90	CV%	21.73	4.39

Means followed by the same letter(s) are not significantly different at (0.05) levels of probability according to the DMRT.

Table 13: Effect of intercropping in number of nodules / plants.

Treatments	Pigeonpea	Treatments	cowpea
P	7.50 a	C	10.00 a
RP1	6.25 a	RC1	8.75 a
RP2	4.50 a	RC2	5.75 a
RP3	7.75 a	RC3	8.25 a
SE±	0.93 ns	SE±	1.47 ns
CV%	28.74	CV%	35.99

Means followed by the same letter (s) are not significantly different at (0.05) level of probability according to DMRT.

Table 14: Effect of intercropping on days to 50% flowering and days to maturity of roselle.

Treatments	Days to 50% flowering	Days to maturity
R	110.25 a	149.00 a
RP1	110.00 a	149.75 a
RP2	108.50 a	149.75 a
RP3	109.00 a	149.75 a
RC1	112.00 a	148.50 a
RC2	113.50 a	148.50 a
RC3	112.00 a	148.25
SE±	1.28 ns	0.44 ns
CV	2.32	0.60

Means followed by the same letter are not significantly different at (0.05) level of probability according to DMRT.

Table 15: Effect of intercropping on days to 50 % flowering and days to maturity of legumes.

Treatments	Days to 50% flowering	Days to maturity	Treaments	Days to 50%flowering	Days to maturity
p	113.5 a	169.50 a	C	51.75 a	60.00 a
RP1	120.50 a	170.50 a	RC1	51.50 a	60.00 a
RP2	127.25 a	169.50 a	RC2	53.00 a	60.75 a
RP3	118.25 a	169.25 a	RC3	52.00 a	60.25 a
SE±	2.82 ns	0.37 ns	SE±	0.77 ns	0.35 ns
CV%	4.82	0.44	CV%	2.96	1.17

Means followed by the same letter(s) are not significantly different at (0.05) level of probability according to DMRT.

4.3. Yield and Yield Components:

Generally roselle / legume intercropping had significant effect on all yield parameters. Intercropping tended to have a negative effect on all yield components of roselle, particularly when the companion legume was pigeonpea (Table 16).

4.3.1 Roselle.

4.3.1.1 Calyx Number/ Plant.

Intercropping roselle with pigeonpea significantly reduced calyx number/plant, the greatest reduction produced by the same hole (RP2) treatments and the least by alternate holes (RP1).

On the other hand cowpea intercropping markedly, but insignificantly increased calyx number in roselle with alternate holes (RC1) and significantly with alternate rows (RC3) treatments (Table16), whereas the same hole treatments (RC2) significantly reduced calyx number.

4.3.1.2 Calyx Fresh weight /plant (g).

Intercropping roselle with pigeonpea caused significant and substantial reduction in calyx fresh weight, which amounted to 37.2 %, 37.60 % and 40 % for RP3, RP1 and RP2 respectively. Roselle intercropped with pigeonpea had much lower calyx fresh weight/ plant than roselle intercropped with cowpea (Table 16).

Cowpea combinations however affected calyx fresh weight significantly only with the same hole treatments (RC2) and the reduction was 4.14 % (Table 16).

4.3.1.3 Calyx dry weight / plant (g).

Calyx dry weight exhibited the same trend as calyx fresh weight, but the reduction (41.4%) in this parameter was significant at the same hole treatment with pigeonpea (RP2) only (Table 16).

Table 16: Effect of intercropping on yields and yield components of roselle.

Treatments	Calyx number/ plant	Calyx fresh weight (g)/plant	Calyx dry weight (g)/plant	Final dry yield in (kg/ha)	Hay yield (kg/ha)
R	49.61 bc	242.42 a	29.27 ab	585.5ab	402.75 a
RP1	46.85 cd	151.24 c	22.75 bc	455.0bc	90.75 c
RP2	37.77 e	145.31 c	17.15 c	343.00c	96.75 c
RP3	41.75 de	152.35 c	25.82 b	516.50b	130.50 bc
RC1	54.85 ab	247.38 a	29.15 ab	583.0ab	265.00 b
RC2	41.75 de	232.37 b	25.82 b	516.50b	193.75 b
RC3	56.62 a	248.90 a	34.85 a	697.00a	364.75 a
SE±	1.43 **	1.96 **	1.80 **	36.18**	16.22 **
CV%	40.9	1.93	13.70	13.70	14.70

Means followed by the same letter(s) are not significantly different at (0.05) level of probability according to DMRT.

The effect of intercropping roselle with cowpea on calyx dry weight was inconsistent and insignificant, showing an increase with alternate rows (RC3) and a decrease with the same hole treatment (RC2) and no change with alternate holes (RC1) treatment (Table 16). Roselle intercropped with pigeonpea produced lower calyx dry yield / plant than when intercropped with cowpea.

4.3.1.4 Final Calyx yield (kg / ha):

Pigeonpea intercropping consistently reduced final calyx yield, the reduction being significant at the same hole treatment (RP2) (41.42%). (Table.16). Again the effect of cowpea on calyx yield was significant and inconsistent, showing an increase at alternate rows (RC3=19.04%) a decrease at the same hole (RC2=11.78%) and no change at alternate holes (RC1) treatment (Table 16).

4.3.1.5 Hay yield /Kg /ha.

Roselle/pigeonpea intercropping caused a substantial and significant reduction in hay yield of roselle. The greatest reduction was caused by alternate holes (RPI) and the same hole (RP2) treatments which amounted to 77.47 %and 75. 98% respectively (Table 16).

Cowpea intercropping also reduced hay yield of roselle, but the reduction was significant at alternate holes (RC1) and the same hole (RC2) treatments only which amounted to 34.20% and 51.89% respectively (Table 16). Roselle intercropped with cowpea produced greater hay yield than when intercropped with pigeonpea.

4.3.2 Legume crops.

4.3.2.1 Number of pods/plant.

Intercropping caused a consistent but insignificant reduction in pod number of pigeonpea, the greatest reduction caused by the same hole (RP2) treatment (Table 17). Sole pigeonpea gave the highest number of pods than intercropped treatments. Cowpea intercropped with roselle produced consistently lower number of pods/plant, the reduction being significant with alternate holes (RC1) and the same hole (RC2) treatments. (Table 17).

4.3.2.2 Number of seeds / pod and 100 seed weight (g).

There was no significant effect of intercropping on number of seeds / pod and 100 seed weight of both legume crops. (Table 17).

4.3.2.3 Yield / plant (g).

There was no significant effect of intercropping on yield / plant of both leguminous crops (Table 17). However, intercropping tended to increase pigeonpea yield and reduce cowpea yield / plant.

4.3.2.4 Final seed yield kg / ha.

Intercropping caused consistent but insignificant reduction in yield of both leguminous crops. The greatest reduction of yield was observed with the same hole (RP2, RC2) treatments which amounted to 24.10% and 18.93% respectively. Whereas alternate rows (RP3, RC3) showed the least response to intercropping (Table 17).

4.3.2.5 Hay yields kg/ ha.

Intercropping reduced hay yield of both leguminous crops significantly. For pigeonpea, the reduction was significant with the same hole treatment (RP2=29.95%) only, whereas for cowpea a significant reduction in hay yield occurred with alternate holes (RC1=25.9%) and the same hole (RC2=43.18%) treatments (Table 17).

Table 17: Effect of intercropping on yields and yield components of legume crops.

Treatments	Pods/ plant	Seeds/ pod	100 seed wt (g)	Yield/ plant(g)	Yield kg / ha	Hay yield kg / ha
Pigeonpea						
P	544.05 a	3.22 a	8.77 a	88.90 a	2278.00 a	2337.50 a

RP1	503.22 a	3.30 a	8.87 a	112.80 a	2060.00 a	1937.50 ab
RP2	465.97 a	3.25 a	8.62 a	94.25 a	1729.00 a	1637.50 b
RP3	525.45 a	3.10 a	8.70 a	105.62 a	2202.00 a	2225.00 a
SE±	73.86 ns	0.16 ns	0.25 ns	15.14 ns	237.57 ns	155.24*
CV%	28.90	9.79	5.76	30.16	22.90	15.26
Cowpea						
C	15.00 a	9.25 a	15.50 a	32.03 a	640.60 a	376.25 a
RC1	11.01 bc	9.00 a	15.75 a	26.06 a	521.30 a	278.75 b
RC2	10.88 c	8.75 a	15.50 a	25.99 a	519.30 a	213.75 b
RC3	13.09 ab	9.00 a	15.50 a	31.69 a	633.50 a	298.75 ab
SE±	0.44 **	0.33ns	0.39 ns	1.83 ns	36.89 ns	17.87 **
CV%	0.25	7.40	5.03	12.69	12.74	12.25

Means followed by the same letter(s) are not significantly different at (0.05) level of probability according to DMRT.

4.4 Chemical Composition.

4.4.1 Roselle.

4.4.1.1 Protein Content:

Intercropping had significant effect on calyx protein content. Pigeonpea intercropping significantly increased calyx protein content, the greatest increase observed with alternate rows (RP3) treatment (Table 18). On the other hand, cowpea intercropping significantly reduced calyx protein content the greatest reduction recorded by the same hole (RC2) treatment. (Table 18).

4.4.1.2 Anthocynin Content.

Intercropping resulted in consistent but non-significant increase in anthocynin content. (Table 18), with RP3 and RC2 treatments recording the highest values of anthocynin content.

4.4.1.3 Oxalic acid Content.

Intercropping with each of the two legumes caused consistent increase in oxalic acid content of roselle calyces. The increase was significant with RC2, RC1 and RP1treatment in that order (Table 18).

4.4.1.4 Citric acid Content.

Generally there was no significant effect of intercropping on calyx citric acid content. Intercropping with pigeonpea caused a slight increase of citric acid with RP2 and RP3 treatments. On the other han, cowpea intercropping caused a slight increase in citric acid content with RC2 and a slight decrease with RC1 and RC3 treatments (Table 18).

Table 18: Effect of intercropping on chemical composition of calyces.

Treatments	Protein %	Anthocynin %	Oxalic acid %	Citric acid %
R	9.19 d	0.33 a	0.46 c	0.026 a
RP1	10.76 b	0.37 a	0.52 ab	0.026 a
RP2	10.48 c	0.39 a	0.50 abc	0.033 a
RP3	11.32 a	0.44 a	0.48 bc	0.033 a
RC1	7.87 f	0.39 a	0.53 ab	0.023 a
RC2	7.21 g	0.41 a	0.55 a	0.032 a

RC3	8.34 e	0.39 a	0.45 c	0.020 a
SE	0.044 **	0.024 ns	0.016 *	0.0079 ns
CV%	0.81	10.68	5.69	49.22

Means followed by the same letter (s) are not significantly different at (0.05) level of probability according to DMRT.

4.4.2 Legumes.

4.4.2.1 Protein Content.

There was significant increase in pigeonpea protein content with intercropping, at RP1 and RP2 treatments, but no change with RP3 treatment caused a slight reduction. (Table 19). On the other hand intercropping resulted in consistent but non-significant increase in seed protein content of cowpea seeds. (Table 19).

4.5. Land equivalent ratio.

All intercropping systems had LER values of more than one (Table 20). LER ranged between 1.33 -1.99 for the different treatments. Roselle/cowpea intercropping gave the highest LER values of 1.99 and 1.86 for RC3and RC2 treatments respectively. For pigeonpea intercropping the highest value of LER was 1.84 with alternate rows (RP3) treatment, and the lowest values was 1.33 with the same hole (RP2) treatment.

Table 19: Effect of intercropping on seed protein content of legumes.

Treatments	Pigeonpea	Cowpea	
P	19.70 b	C	9.72 a
RP1	20.89 a	RC1	9.87 a
RP2	20.92 a	RC2	10.64 a

RP3	19.69 b	RC3	10.47 a
SE ±	0.057 **	SE ±	0.38 ns
CV %	0.48	CV%	6.52

Means followed by the same letter (s) are not significantly different at (0.05) level of probability according to DMRT.

Table 20: Land equivalent ratios (LER) and Relative yield (RY) of intercropping roselle with legumes.

Parameters	RY	RY	LER
Treatments	Roselle	Legumes	Total
RP1	0.77	0.90	1.67
RP2	0.58	0.75	1.33
RP3	0.88	0.96	1.84
RC1	0.99	0.81	1.80
RC2	0.88	0.98	1.86
RC3	1.19	0.80	1.99

CHAPTER FIVE

DISCUSSION

5.1 Roselle.

5.1.1 Vegetative Growth:

Intercropping roselle with legumes resulted in non-significant decrease in plant height of roselle plants, but the combination of roselle /pigeonpea treatments resulted in greater plant height than the combinations with cowpea. This is probably due to slow growth of pigeonpea in the early stages, and thus less competition effect on roselle as compared to cowpea intercropping (Paudel 1995). This finding is in conformity with that of Umrani *et al*. (1987) who found that intercropping had no effect on plant height when sunflower was intercropped with pigeonpea. Roselle/ cowpea intercropping resulted in lowest vegetative growth in general during early stages of growth, possibly due to faster growth of cowpea and the greater competition with roselle seedlings. Baker (1979) reported that the reduction of plant height due to delayed sowing in cotton/ cereal mixture was associated with shorter internodes, which did not occur in sole cotton until the last sowing and with the competition from cereals which caused stunting.

Intercropping roselle with legumes resulted in consistent and some times significant reduction in number of leaves/ plant. This agrees with Roy *et al.* (1990) who observed a significant reduction in the number of leaves when roselle was intercropped with pulses and oil seed crops.

Intercropping resulted in decrease in number of branches and shoot and root dry weight of roselle plants, shoot fresh and shoot dry weight of roselle plants showed significant reduction and this may be related to competition for space and/ or nutrients. Kayhan *et al.* (1999) found that soybean shoots at high population developed in a plane perpendicular to the rows, and he found that soybean plants are sparsely branched at high densities.

Intercropping significantly reduced root fresh and root dry weights of roselle. Again this could be attributed to the competition between roselle roots and roots of the companion crops. This finding is in conformity with Skerman *et al.* (1988) who found that in cassava / legumes intercropping, competition for nutrients between component species in intercropping systems often occurs, since the depletion zones around roots for these resources would occur rapidly.

Wilson and Orville (1937) provided evidence, which suggested that the non-legumes in a mixture would benefit, because of excretion of nitrogen by the legumes.

5.1.2 Reproductive attributes and Yield:

Intercropping roselle with legumes did not affect days to 50 % flowering and days to maturity. This suggests that these traits are genetically controlled in the tested crops and are not affected by environmental factors.

Intercropping roselle with cowpea resulted in increase in number of calyx per plant which may be attributed to increase in number of branches due to addition or transfer of nitrogen from legumes. Mishara and Pandy (1987) reported that nitrogen resulted in significant increase in fruit number in okra.

Intercropping tended to decrease fresh and dry calyx yield per plant, especially in case of roselle/ pigeonpea combination. The decrease in final calyx yield by intercropping may be due to possible competition between the crops in the mixture for nutrients rather than nitrogen. This competition would be aggravated by enhanced vegetative growth resulting from increased nitrogen supply and consequently this will increase demand and competition for other nutrients. Sermsri and Murata (1987) reported that intercropping reduced roselle yields by 4-18% and groundnut yields by 67-85%, and that the groundnut: roselle yield ratio was affected by row spacing and nitrogen supply.

Roy *et al* (1990) found that the yield of roselle as a sole crop was greatest when planted in uniform rows 30 cm apart, probably because this pattern resulted in the least inter-row competition, and he stated that intercropping of roselle with groundnut and cowpea remained commercially viable, though roselle yield was generally reduced. Abu El Ala (1999) found that sole sunflower treatments outyielded the other two intercropping treatments because plant population was greater in the control. Increase in the dry matter of sunflower intercropped with guar might be favored by increased interception of radiation and the relatively stronger competitiveness of sunflower to the guar (Azam Ali 1990). Aboud (1987) recorded that intercropping gave higher potato yield than the control in potato /broad bean intercropping systems.

5.1.3 Chemical Composition:

Intercropping resulted in an increase in protein content of roselle calyces and this agreed with Keswani *et al.* (1982), who found that in maize/ soybean system, although intercropping tended to depress the protein content in some cases, the crude protein of combined treatments was significantly higher than that of the monocropped system. Anthocynin and organic acid contents of roselle also tended to be increased by intercropping.

5.2 Legumes.

All intercropping systems showed a reduction in most of the vegetative growth attributes of pigeonpea combinations. This agreed with Nadar (1978) who found that maize inhibited vegetative growth of pigeonpeas in comparison with monocroped pigeonpeas. However this inhibition was not reflected in reduction of yield, and that the intercrop yield was equal to that of monocrop yield. Reddy (1980) found that the seed yield of pigeonpea intercropped with *Vina radiata* was similar to that of pure stand. Paudel (1995) reported that sole pigeonpea gave higher yield than that intercropped with rice, maize and peanut, and he attributed this to higher number of plants per unit area. Keswani (1982) reported that when the intercropped bean population was equal to that of the monocropped, the yield reduction was mainly due to a decrease in the number of pods/ plant.

Cowpea intercropping also resulted in significant reduction of growth components, this may be due to the shading effect in the case of cowpea or the competition for nutrients. It also caused non-significant reduction in most of yield components that may be due to reduction in the number of pods/ plant. This is in conformity with Nadar (1978) who reported that maize/ cowpea intercropping resulted in reduction of cowpea yield, whereas Rao *et al* (1979) reported that growing cowpea under bananas did not affect seed yield of cowpea significantly. From these results, it is apparent that the degree of competition between intercropping components depends on crops used in the system, the adverse effect is directly related to population pressure. In roselle/ legumes intercropping Babatunde (2000) found that yield of roselle was minimally reduced by the legumes, but the yields of legumes were greatly reduced by roselle.

5.3 Land equivalent ratio:

The highest productivity in terms of land equivalent ratio was obtained under intercropping of roselle with legumes especially alternate rows (RP3 and RC3) treatments. Intercropping roselle with cowpea indicated more efficient land use than intercropping roselle with pigeonpea. A similar result was found by Sermsri (1987) who observed that the combined yield of roselle intercropped with peanut increased with increasing row spacing. This agrees with Sobban, (1986) who found that highest productivity (LER) and highest grain yield was obtained under intercropping when roselle was grown in alternate rows with mungbean. Also Bezerra (1996) found that LER for yield was highest when single rows of cotton alternated with single rows of the other species.

The study showed that alternate rows arrangement between roselle and each of the two legumes proved to be more productive than other sowing patterns. This may be attributed to the more suitable spacing between crops and better crop architecture.

This possibly enabled the plants to maximize utilization of the available resources rather than compete with each other.

SUMMARY AND CONCLUSIONS

A field experiment was conducted for one season (2003/2004) in the Experimental Farm of the Faculty of Agriculture at Shambat to study the effect of intercropping of roselle with legume crops (pigeonpea and cowpea) on the growth and yield of each crop.

Three planting patterns (alternate holes, the same hole and alternate rows) with the control of each crop was laid out in Randomized Complete Block Design with four replications.

The study investigated:

The effect of intercropping on vegetative and reproductive growth and yield and chemical composition of roselle as well as the legume crops. The finding of this study can be summarized in the following:

Roselle crop.

1-Vegetative growth: intercropping significantly reduced numbers of leave, number of branches, shoots and roots fresh and dry weight.

2-Yield parameters: intercropping had significant effect on all yield parameters.

3-Chemical composition: oxalic acid and protein content of calyces were significantly affected by intercropping.

Legume crops.

4-Vegetative growth: intercropping significantly reduced numbers of leave, number of branches, sometimes shoots and roots fresh and dry weight of pigeonpea. Intercroppd cowpea showed significant reduced on plant height, numbers of leaves, number of branches, shoots and roots fresh and dry weight.

5-Intercropping significantly increased seed protein content of pigeonpea.

6-The study showed that alternative rows of roselle intercropped with legumes was the most effective treatment of the system.

7-Intercropping proved to be an efficient productive system with the (LER) of more than one.

8-Further studies are needed to fully evaluate the potential of intercropping, using different crops and different crop ratios with special emphasis on economic returns.

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Appendix 1: Mean squares from analysis of variance showed the effect of intercropping on growth, yield, yield components and chemical composition of *Hibiscus sabdariffa*.

Source of variation	DF	5th week	7th week	9th week	11th week	5th week	7th week	9th week	11th week	5th week branch	7th week	9th week	11th week
Treatments	6	1.49ns	1.21ns	1.06ns	4.89ns	25.63**	109.58**	26.69ns	196.50ns	10.18**	8.16**	3.28**	1.73**
Block	3	0.38ns	4.87ns	2.38ns	4.29ns	0.33ns	40.46ns	10.33ns	26.69ns	0.07ns	0.49ns	0.09ns	0.03ns
Error	18	1.06	2.02	1.92	5.56	0.39	14.22	11.16	85.03	0.25	0.38	0.16	0.15
SE±		0.51	0.71	0.69	1.17	0.32	1.88	1.67	4.61	0.25	0.30	0.20	0.19
CV		11.62	9.39	7.48	24.48	5.58	16.00	8.28	14.23	6.74	5.91	3.27	3.09

Ns, *, ** = Not significant, significant at 0.05 and at 0.01 level of probability, respectively.

Appendix 1: Cont.

Parameters		Shoot fresh weight (g)				Shoot dry weight			
Source	**DF**	5th week	7th week	9th week	11th week	5th week	7th week	9th week	11th week
Treats	6	2.22**	3.14*	2.45ns	9.33*	0.04ns	0.37**	0.076**	1.38ns
Blocks	3	0.02ns	0.37ns	0.07ns	1.45ns	0.018ns	0.038ns	0.19ns	1.09ns
Errors	18	0.15	1.16	1.87	3.08	0.019	0.085	0.10	0.91
SE		0.19	0.53	0.68	0.87	0.06	0.14	0.15	0.47
CV		14.98	12.85	5.59	4.87	25.12	17.63	10.43	11.41

Appendix 1: Cont.

Parameters	Root Fresh weight					Root dry weight			
Source	**DF**	5th week	7th week	9th week	11th week	5th week	7th week	9th week	11th week
Treats	6	0.051**	0.19ns	0.086**	0.686*	0.039ns	0.026 **	0.073 **	0.112 **
Blocks	3	0.005ns	0.049ns	0.002ns	0.378ns	0.00009ns	0.0005 ns	0.0066 ns	0.016 ns
Errors	18	0.009	0.75	0.017	0.186	0.023	0.0056	0.0062	0.0057
SE		0.04	0.43	0.06	0.21	64.41	29.13	5.25	2.97
CV		14.08	67.76	5.02	9.93	0.075	0.037	0.039	0.037

Appendix 1: Cont

Source of variation	DF	**Days to 50% flowering**	**Days to maturity**	Calyx number	Calyx fresh weight	Calyx dry weight	Calyx yield kg/ha	Hay yield kg/ha
Treat	6	13.08 ns	1.80 ns	187.63**	10044.95**	124.52**	49807.14**	64645.35 **
Block	3	3.08 ns	0.14 ns	0.27 ns	1.80ns	0.103 ns	41.66 ns	1493.75 ns
Error	18	6.64	0.81	8.14	15.46	13.096	5238.44	1051.97
SE		1.28	0.44	1.43	1.96	1.80	36.18	16.22
CV		2.32	0.60	40.9	1.93	13.70	13.70	14.70

Appendix 1: Cont

Source of variance	DF	Protein %	Anthocynin %	Oxalic acid %	Citric acid %
Treats	6	7.47 **	0.0016 ns	o.oo33 *	0.00010 ns
Blocks	2	0.005 ns	0.007 ns	o.oooo3 ns	0.00004 ns
Error	12	0.0058	0.0018	0.00081	0.00019
SE	-	0.044	0.024	0.016	0.0079
CV	-	0.81	10.68	5.69	49.22

Appendix 2: Mean squares from analysis of variance showed the effect of intercropping on growth, yield, yield components and chemical composition of pigeonpea.

Parameters		**Plant height**				**Numbers of leave**				**Numbers of branch**			
source	**DF**	**5th week**	**7th week**	**9th week**	**11th week**	**5th week**	**7th week**	**9th week**	**11th week**	**5th week**	**7th week**	**9th week**	**11th week**
Treats	**3**	**15.51 ns**	**4.48 ****	**5.74 ns**	**40.54 ns**	**0.22ns**	**10.53 ***	**20.09 ns**	**395.65****	**2.59 ****	**1.256 ns**	**2.65 ****	**1.39 ****
Blocks	**3**	**2.15 ns**	**0.24ns**	**3.42 ns**	**22.50 ns**	**2.66 ns**	**1.35 ns**	**9.94 ns**	**2.09 ns**	**0.189 ns**	**0.23 ns**	**0.05 ns**	**0.03 ns**
Errors	**9**	**6.53**	**0.10**	**8.58**	**11.20**	**0.73**	**1.92**	**24.87**	**6.19**	**0.35**	**0.49**	**0.075**	**0.076**
SE		**1.27**	**0.15**	**1.46**	**1.67**	**0.42**	**0.69**	**2.49**	**1.24**	**0.29**	**0.35**	**0.136**	**0.14**
CV		**10.34**	**0.94**	**4.69**	**3.61**	**9.54**	**6.31**	**7.36**	**1.52**	**12.5**	**8.35**	**2.8**	

Ns, *, ** = Not significant, significant at 0.05 and at 0.01 level of probability, respectively.

Appendix 2: Cont.

Parameters		Shoot fresh weight				Shoot dry weight				Root fresh weight				Root dry weight			
Source	DF	5th week	7th week	9th week	11th week	5th week	7th week	9th week	11th week	5th week	7th week	9th week	11th week	5th week	7th week	9th we	11th w
Treat	3	0.27ns	1.75 **	21.60ns	156.30**	0.007ns	0.0076**	2.035ns	167.72**	0.019ns	0.096**	1.58**	3.47**	0.11**	0.026*	0.22**	7.48n
Block	3	0.07 ns	0.123ns	12.93ns	1.05ns	0.0039 ns	0.0006ns	1.23 ns	1.90ns	0.057ns	0.007 ns	0.26 ns	0.56 ns	0.006 ns	0.0016ns	0.0007 ns	0.58n
Error	9	0.18	0.041	28.92	5.99	0.063	0.00018	1.62	0.79	0.021	0.0067	0.132	0.36	0.0045	0.0049	0.020	3.38
SE±		0.21	0.10	2.68	1.22	0.12	0.006	0.63	0.44	0.07	0.04	0.18	0.30	0.003	0.03	0.07	0.91
CV		20.8	2.94	23.83	1.50	15.34	0.52	16.33	4.19	65.71	5.24	8.29	4.38	9.14	9.72	7.68	31.9

Appendix 2: Cont.

souurce	DF	Days 50% flowering	Days of maturity	Pods /plant	Seeds / pod	100 /seed weight	Yield/plant (g)	Final yield (kg/ha)	Hay yield (kg/ha)
Treat	3	34.08 ns	1.166 ns	4509.05 ns	0.05 ns	0.046 ns	468.17 ns	256512.7ns	393489.58 *
Block	3	9.08 ns	0.166 ns	19218.5 ns	0.04 ns	0.197 ns	110.96 ns	16018.0 ns	1822.916 ns
Error	9	32.02	0.55	21826.79	0.10	0.254	917.038	225776.5	96406.25
SE±		2.82	0.37	73.86	0.16	0.25.	15.14	237.57	155.24
CV		4.28	0.44	28.90	9.79	5.76	30.16	22.90	15.26

Appendix 3: Mean squares from analysis of variance showed the effect of intercropping on growth, yield and yield components of Cowpea.

Parameters		Plant height		Leave numbers		Branch numbers		Shoot fresh weight		Shoot dry weight		Root fresh weight		Root dry weight	
Source	DF	5th week	7th week	5th week	7th week	5th week	7th week	5th week	7th week	5th week	7th week	5th week	7th week	5th week	7th week
Treat	3	17.87**	135.87**	2.14 **	7.14 *	0.16 ns	1.34 *	74.88 **	212.30 **	0.79 **	7.92 **	0.009 ns	0.64 **	0.10 **	1.366 **
Block	3	1.91 ns	72.33 ns	0.24 ns	0.12ns	0.13 ns	0.05 ns	0.50 ns	0.50 ns	0.002 ns	2.19 ns	0.53 ns	0.03 ns	0.00034 ns	0.0028ns
Error	9	0.79	28.48	0.23	1.03	0.32	0.25	1.05	1.60	0.007	1.068	0.224	0.027	0.01	0.0098
SE±		0.44	2.66	0.24	0.50	0.28	0.25	0.51	0.63	0.043	0.51	0.23	0.07	0.05	0.05
CV		5.95	10.8	4.01	3.16	18.9	11.8	3.40	1.77	2.27	9.17	26.44	5.30	21.73	4.39

NS, *, ** = Not significant, significant at 0.05 and at 0.01 level of probability, respectively.

Appendix 3: Cont.

Source	DF	Days to 50% flowering	Days of maturity	Number of pods /plant	Seeds /pod	100/seed weight	Yield /plant(g)	Final yield (kg/ha)	Hay yield (kg/ha)
Treat	3	1.73 ns	0.50 ns	15.24 **	0.166 ns	0.06 ns	45.66 ns	18139.68 ns	17922.9**
Block	3	0.063 ns	0.33 ns	0.146 ns	0.50 ns	0.06 ns	16.71 ns	6556.589 ns	1956.25 ns
Error	9	2.39	0.50	0.79	0.44	0.61	13.507	5445.407	1278.47
SE±		0.77	0.35	0.44	0.33	0.39	1.83	36.89	17.87
CV		2.96	1.17	0.25	7.40	5.03	12.69	12.74	12.25

Appendix 4: Mean squares from analysis of variance showed the effect of intercropping on chemical composition of legumes.

Source of variance	DF	Pigeonpea protein %	Cowpea protein %
Treat	3	3.46 **	0.61 ns
Block	2	0.0075 ns	0.22 ns
Error	6	0.01	0.44
SE±	-	0.057	0.38
CV	-	0.48	6.52

NS, *, ** = Not significant, significant at 0.05 and at 0.01 level of probability, respectively.

Appendix 5:Nitrogen Content

Micro- Kjeldahl Method

Reagents

1.Sulphuric-Salicylic acid

2.Sodium thiosulphate

3.Sulphate mixture (Potassium sulphate and ferrous)

4.Sodium hydroxide

5.Boric acid

6.Bromocresol +methyl red dissolved in 100 ml.

7.95% ethanol

Procedure

Transfer a weighed sample of dry material to an 800ml kjeldahl flask. Add 50ml of the sulphuric-salicylic acid mixture and swirl so as to bring the dry sample quickly into intimate contact with the reagent. Allow to stand overnight. Add 5 g of Sodium thiosulphate and heat the sulphate mixtur gently, and digest in kjeldahl apparatus at full heat. The digestion is continued for one hour after the solution has cleared.

When the digestion is complete, cool and add 300 ml of concentrated sodium hydroxide. Add a large piece of mossy zinc. Connect the distillation head, agitate and distil of 150 ml into 50 ml of 2% boric acid solution. Add 10 drops of the bromocresol green-methyl red indicator and titrate to the first faint pink point with standard sulphuric acid. Blanks should be run and the titration is carried to the same end point.

Calculation

$$\text{Nitrogen \%} = \frac{S\text{-}B \times N \times 14 \times 100}{100 \times \text{weight of plant sample}}$$

Where as:

S = ml H_2SO_4 equivalent to sample titration.

B = H_2SO_4 equivalent to the blank titration.

N = Normality of the acid.

Appendix 6: Anthocyanin Content

Extraction Method

Reagents

1. Folten-Denes regent
2. Sodium carbonate

Procedure

Put 0.1 g of a sample into 100ml conical flask. Add 50 ml of water, boil gently for 1 hour. Filter the solution and complete the filtrate to volume. Add 2.5ml folten-Denes regent then add 10 ml of Sodium carbonate using 50ml flask. Dilute the solution to volume and heat in water-bath at 25°C for 30 minutes.

Use calibration curve by standard at 760 nm. Deduce sample concentration from the standard curve.

$$\text{Anthocyanin \%} = \frac{\text{Con. (Mg) x Extract volume (ml)}}{\text{10x aliquot (ml) x sample wt (g)}}$$

Appendix 7: Oxalic Acid Content

Titration Method against Alkali

Reagents

1. Sodium hydroxide (2M)
2. Potassium manganate (0.2M)
3. Sulphuric acid

Procedure

Prepare a solution of oxalate by accurate weighing. Dissolve 0.5 g of a sample in hot water, add 5ml of 2M Sodium hydroxide until no more precipitation will be formed. Boil the solution to coagulate the precipitation and then filter. Cool the filtrate and dilute to mark with water.

Acidify an aliquot of oxalate solution with 10ml of 2M sulphuric acid and heat to 60°C, and then titrate with standard 0.2M Potassium mamganate.

Calculation:

$$\text{Oxalate \%} = \frac{\text{an aliquot x mol/1 of a sample}}{\text{titre x mol/1 of oxalate salt}}$$

Appendix 8: Citric acid content

Add 50ml of distilled water to 1g of dry calyx. Heat in water bath for 5 minutes under continues shaking. Filter the mixture through a fluted filter paper into 50ml volumetric flask. Cool to the room temperature. Complete the volume to 15ml using distilled water. Pipette 10ml of the test solution into a tube and titrates with 0.1 N sodium hydroxide to pH 8.1.

Citric acid % =

$$\frac{1/10 \times \text{equivalent wt} \times \text{normality of NaoH} \times \text{titrate}}{\text{Weight of sample}}$$