EVALUATION OF THREE FORAGE LEGUMES AND INTERCROPPING PATTERN FOR IMPROVED PRODUCTIVITY OF MAIZE (*Zea mays* L.)

BY

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DECLARATION

I, Albert Mbuyoti Mate, here by declare that all the work presented in this dissertation is my own and has never been submitted for a degree at this or any other university.

Signature. ______Mbuyoti______

Date. ______18/10/98______

APPROVAL

This dissertation **Mr. Albert Mbuyoti Mate** is approved as fulfilling the requirements for the award of the degree of Master of Science in Agronomy by the University of Zambia.

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ABSTRACT

The objective of the study was to determine a maize/ forage legume combination and an approppriate row arrangement that would result in high maize grain and total stover/legume straw yield, enhanced crude protein content of the maize stover/ legume straw and increased crude protein content of the maize grain and stover. This would form a basis for the good quality feed for cattle during the dry season. The treatments consisted of the maize(variety MM 603) intercropped with the three legume species, namely cowpea (*Vigna unguiculata* (L) Walp), siratro (*Macropitilium atropurpureum*) and archer (*Macrotyloma axillare*) in either 1:1 or 2:1 row arrangement. A randomised complete block design was used with four replications. Data was collected on the following parameters: maize plant height, legume spread, maize grain and stover yield and crude protein content, legume straw yield and crude protein content as well as the legume straw and maize stover non-detergent fibre content. Analysis of variance (ANOVA), separation of means and correlation analysis were carried out on the field and laboratory data collected. The maize/forage legume combinations and their row arrangements did not increase the maize grain yield and the crude protein content of the maize grain and stover. However, the addition of the forage legume straw to the maize stover enhanced the crude protein content of the dry matter yield by about 3-4 times i.e. 3.3 to 4.6 % in the maize stover and 13.8 to 16.4 % in the forage legume straw. The plant height of the sole maize (2) of 1.48m was significantly taller and had a higher crude protein content of 11.15 % in the maize grain than the sole maize (1) and the intercrops. Cowpea exhibited the highest plant spread of 1.88m which positively correlated (r = 0.84)** with straw yield but was the least in crude protein content of the straw (13.4 %). Cowpea was able to grow and complete its life cycle being an annual crop compared to archer and siratro which are perennials and hence were still growing at the time of harvesting the maize crop. The results demonstrates that maize can be intercropped with the three forage legumes in either 1:1 or 2:1 row arrangement and result in improved quality and quantity of the total dry matter which can be fed to livestock. However, the maize crop could not directly benefit from nitrogen from the three forage legumes. There is therefore, need for further research to look at nitrogen transfer to companion maize over several growing seasons with emphasis also on factors that affect nodulation and capacity of companion forage legumes to fix and transfer nitrogen. The effect on digestibility should also be investigated.

DEDICATION

To my wife Helen and children; Mate and Nakena for their love and patience while away on study leave.

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CHAPTER ONE

INTRODUCTION

The introduction of forage legumes in cereal - based cropping systems is a promising strategy for increasing crop and livestock productivity in sub-Saharan Africa (Gryseels and Anderson, 1983; Tothill, 1986). This is because forage legumes enhance soil fertility, sustain soil productivity assist in combating soil erosion thus leading to improved yeilds and sustainable food production. The nutritive value of the harvested products is also improved, resulting in increased livestock productivity (Mohamed - Saleem 1985; le Hoverow, 1989; Izaurralde et al.,1990; Garba and Renard, 1991).

Whitney and Green (1969) observed that the association of legumes with grass species tends to increase total dry matter yield per hectare. These authors further reported that association of *Digitaria decumbens,* a grass species with *Desmodium canum* and *Desmodium intortum* (legumes) resulted in increases in total dry matter and crude protein yields. In beef cattle, daily live weight gains of up to 0.8 kg have been obtained from feeding diets comprising 50 % maize stover (O'Donavan and Gebrewolde, 1983, as cited by Kaonga, 1996). Despite the high weight gains, it is the often too low crude protein levels that limits cattle production from the maize stover. At harvest, the crude protein level of maize stover can be as low as 1 % (Ishuguri, 1983; Rusell, 1986, as cited by Kaonga, 1996). Therefore, the adoption of forage crops by farmers will depend on the demonstration of their productivity and subsequent positive impact on cereal and livestock production. However, the beneficial effects of legumes vary according to crop species, management and environmental factors (Waghmare and Singh, 1984; Nnadi and Haque, 1988; Varvel and Peterson, 1990). Since forage legumes do not contribute directly to food security, farmers are reluctant to devote land and other resources solely to forage production.

Sources of available feeds for livestock in the Western Province of Zambia are mainly natural pastures and crop residues. The current availability of these feeds cannot adequately sustain cattle requirements throughout the year,the most critical period being the dry season from May to November when both the quality and quantity of the grass is poor and low, respectively.

In Kaoma District of Western Province, in particular, the productivity of oxen is one of the major constraints in the agricultural system. In view of poor grazing and browsing opportunities, body condition of oxen declines towards the end of the rainy season. Thus, during the critical period of the ploughing season (at the onset of the rains) the draught animals are not in the best condition to perform the job. Hence, in order to keep the draught oxen and other classes of livestock in reasonable body condition, a strategy to provide extra food during the dry season should be sought. The use of forage legumes in the maize-based cropping system offers a possibility to increase and improve the quality of the harvested stover. A study on selecting companion forage legumes and an intercropping pattern with a view to improving maize productivity is necessary. Such a study would provide data on the productivity of maize/legume combinations and subsequent impact on maize grain yield necessary for adoption by farmers. Specifically, the objective of this study was to determine a maize-forage legume combination and row arrangement that would result in high maize grain yield, enhanced crude protein content of dry matter, high stover and legume yield and increased crude protein content of the maize grain.

CHAPTER TWO

LITERATURE REVIEW

2.1. APPROACHES IN INTERCROPPING RESEARCH

2.1.1 Replacement series

In this system of intercropping, some specific population of a component crop is replaced by the same proportion of another component as in a 1:1 arrangement, where 50% of the population of a component crop is replaced (Natarajan and Willey, 1980a; Willey, 1979). This adjustment can be attained through different configurations of stand establishment like paired-row planting or skip-row planting (Wahua et al., 1981). This approach is chosen in a situation where there is no land pressure but growing of crops in pure stands is constrained by labour shortage but farmers want to grow two or more crops on the same piece of land. It is a common practice where farmers want to diversify crop production but face labour shortage (ARPT, 1993). In this approach, Wahua et. al. (1981) reported that the yield of a legume intercropped with a cereal can be maximized through the provision of enough space for penetration of light and reduction in plant density of the cereal that offers more competition for the available nutrients.

2.1.2 Additive series

In this approach, the emphasis is on having the full population of the main crop, in addition to accommodating some population of the other crop, i.e, 100 : 50 or 100 : 100. Enyi (1975) reported that this approach is common where there is pressure of land but still farmers want to maintain the density of the main crop which usually is the cereal. It is possible to prepare the land at the same time for the two crops, and the other crop can be planted during the weeding of the crop planted earlier. Agboola and Fayemi (1972) indicated that on a soil with low fertility this approach can result in lower yield of both crops as there will be very high competition for the less nutrients. In this approach, density of plants per unit area is very high and therefore the maximisation of yield particularly of the legume would depend on the configuration followed to avoid the shading of the crop and interplant competition that always favours cereals because of their high growth rates, height and vigorous root system (Mead and Willey, 1980). On the other hand, Eaglesham et al. (1981b) reported that the cereal can benefit from the nitrogen fixed by the companion legumes more readily because of the proximity of the plants to each other.

2.2 INDICES OF EVALUATING PRODUCTIVITY AND EFFICIENCY OF I NTERCROPPED COMPONENT CROPS

Different indices have been suggested for evaluating productivity and efficiency per unit area of land in a cereal-legume intercrop system (Willey, 1979). These include comparison of absolute yields, protein yields, caloric equivalent and economic returns from intercrops and sole crops. Land Equivalent Ratio (LER) and Crop Performance Ratio (CPR) are two examples of yeild based indices.

2.2.1 Land Equivalent Ratio (LER)

LER is defined as the total land area required under sole cropping to give the yield obtained in the intercropping mixture. It is expressed as:

$$LER = (Yij/Yii) + Yji/Yjj)$$

Where Y is the yield per unit area, Yii and Yjj are sole crop yields of the component crops i and j and Yij and Yji are intercrop yields (Mead and Willey, 1980). The partial LER values, Li and Lj represent the ratios of the yield of the crops i and j as intercrops relative to sole crops. Thus;

$$Li = (Yij/Yii) \text{ and } Lj = (Yji/Yjj)$$

LER is the sum of the two partial Land Equivalent Ratios so that $LER = L_i + L_j$.
When LER = 1, there is no advantage to intercropping in comparison with sole cropping. When LER>1, a large area of land is needed to produce the same yield of sole crop of each component than with an intercropping mixture and when LER < 1, it means that the same yield in the intercropping mixture can be attained when the two crops are grown as sole crops using less land.

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 cultivars performance, relative time of sowing and crop combinations in an intercrop system in a locality or as an index of productivity across geographical locations to compare a variety of intercrop systems (Chetly and Reddy, 1984) as reported by Ofori and Stern (1987a).

The LER is the most frequently used index to determine the effectiveness of intercropping relative to growing crops separately (Willey, 1979). Generally, the value of LER is determined by several factors including density and competitiveness of the component crops in the mixture, crop morphology and duration and management that affect individual crop species (Enyi, 1975; Natarajan and Willey, 1980a; Fawusi and Agboola, 1980). The values of LER follow the density of the legume component rather than that of the cereal (Ofori and Stern, 1987a).
Willey and Osiru (1972) proposed the concept of Land Equivalent Ratio (LER) as an index of combined yield for evaluating the effectiveness of all forms of intercropping.

2.2.2 Crop Performance Ratio (CPR)

Crop Performance Ratio is defined as the performance of one crop in relation to another crop in the same mixture (Azamm -Ali et al. ,1990). For each crop species of the intercrop, productivity can be expressed as a partial crop performance ratio (CPR). For a crop designated as "a", its CPR is given by:

Qia/Pia.Qsa where:

Qia= Productivity per unit area in the intercrop

Qsa=Productivity per unit area in the sole crop.

Pia=Proportion of the intercrop area sown with the species "a".

For an intercrop composed of two species, a and b, the total CPR is expressed as:

$$CPRab = (Qia + Qib)/(Pia.Qsa) + (Pib.Qsb)$$

A value of CPR greater than unit implies an intercrop advantage and a value less than unit an intercrop disadvantage(Azamm-Ali et al., 1990).

2.3. COMPANION CROPS IN AN INTERCROP

2.3.1 Siratro (*Macroptilium atropurpureum* cv siratro)

Siratro is unique among currently used sub-tropical pasture legumes in that it is the only one which has been bred rather than selected from a naturally occurring material. Siratro is adapted to a very wide range of soils, excluding poor sands and very heavy clays. It is probably the most versatile sub-tropical pasture legume in terms of soil requirements. It grows over a range of pH from 4.5 to 8.0 but it cannot tolerate waterlogging and frost. It requires at least 615 mm and preferably more than 850 mm of annual rainfall. It is extremely drought tolerant due to its deep rooting habit. In summer droughts, large leaves are shed and small leathery leaves produced until conditions are more favourable Davis and Hutton, (1970) as reported by Skerman (1977).

Rhizobium relationship

Siratro nodulates freely with native rhizobia but the seed could still be inoculated with the cowpea type inoculum at sowing. It fixes a good deal of nitrogen (about 100 to 175 kg/ha/year). Kretschmer (1966) as reported by Chileshe et al. (1993) found that introducing siratro at 1:1 in an intercrop raised the crude protein level of the pangola grass from 4.7 to 7.1% in Florida.

Dry matter yield

Roe and Jones (1966) as reported by Chileshe et al. (1993) obtained 3.4 t/ha siratro in a mixture with *Nandi setarria*, the mixture yielding 12.2 t/ha at Gympie, Queensland in 1962/63. van Rensburg (1967) obtained an average dry matter yield of 74.9 t/ha over a two year period in Zambia (1965-66). In some areas of Kaoma, Kulich (1976) reported a yield of between 2 and 3 t/ha DM over a series of trials. At the Golden Valley Research Trust the dry matter production of the perennial legumes increased with the years of establishment. Siratro was able to give 0.5 t/ha in the first year and 2.9 t/ha in the third year (Kaonga, 1996). However, in the first year in pure stand, it only produced 1.1 t/ha.

Chemical Composition

Milford (1967) as reported by Chileshe et al. (1993) analysed mature siratro at the seed shedding stage. He recorded figures of 35% dry matter, 16.8% crude protein, 33.4% crude fibre, 1.2% ether extract, 38.8% nitrogen free extract and 9.8% ash. Protein levels for siratro increase each year the plant grows. In their trials in Jamaica, Jennings and Logan (1987) reported that crude protein levels in siratro increased from 14.9% in the first year to 16.4% in the third year. Kaonga (1996) however, reported a decrease in protein levels i.e, 13.2 % CP in the first year and 11.7 % in the third year but this was due to the differences in the time of harvesting the straw.

2.3.2 Archer (*Macrotyloma axillare* cv Archer)

Macrotyloma axillare var. Archer is found naturally more or less throughout tropical Africa, occurring also in Arabia and Madagascar. It is indigenous and widespread in Zimbabwe, but this particular strain was collected from Kenya which is also the source of the strain that was sent to Australia. It grew well at a number of sites in northern New South Wales and Queensland and was released as a pasture cultivar in 1967. Archer is adapted to a wide variety of soil types provided they are well drained. It is adapted to cooler conditions than siratro. Archer is tolerant to fire and is drought resistant as it can grow in areas receiving as little as 700 mm rain annually. However, Kulich (1976) reported that archer planted in Kaoma, Western Province of Zambia did not perform well. However, trials that followed in the same area revealed that archer is one of the promising pasture legumes (Chileshe, 1992). During these trials, it was able to give a DM yields of about 1.5 t/ha.

Rhizobia relationship

Trials done in Zimbabwe indicated that archer does not need any inoculum during sowing. It has no specific rhizobium as it is able to nodulate under local conditions. This has been shown also in a series of trials conducted in Kaoma (Chileshe, 1992).

Dry matter yield

Archer was able to give 1.5 t/ha dry matter as a pure stand when planted early in the rainy season but the yield dropped to 0.5 t/ha when late planted in the trials done in Kaoma (Chileshe et al., 1993). Archer was able to give a dry matter yield of 0.3 t/ha in the first year, 1.7 and 3.5 t/ha in the second and third year, respectively (Kaonga, 1996).

Chemical composition

Kaonga (1996) found a crude protein content of 10.4 % in the first year, 9.7% and 12.8% in the second and third year, respectively. The crude protein content can, however, be altered by the drought and the fertility status of the soil. The Ca content in the first year was 1.1 % , and for the second and third year was 0.4 and 0.7%, respectively. Phosphorus was found to be 0.06, 0.15 and 0.14% for the first, second and third year, respectively.

2.3.3. Cowpea (*Vigna unguiculata* (L) Walp)

Among the grain legumes of sub-Saharan Africa, the importance of cowpea is second only to that of groundnut. In Africa, it is predominantly grown by smallholders, whereas in the USA it is grown on a commercial scale and under more intensive conditions. It exists in at least three forms, which are often described as separate species. There are many landraces, which may show high degrees of adaptation to the ecosystems in which they have evolved. The cowpea is a crop of the savannas and forms exist which are well adapted to poor soil fertility and low rainfall. However, not all varieties are equally drought or heat tolerant. Many are profoundly affected by night temperature differences which can alter their vegetative and reproductive development. Generally, temperatures in the range of 20-35^0 C are most suitable although high temperatures retard growth and flower and pod shedding occur above 35 ^{0} C. Cowpeas do not tolerate temperatures below 15^{0}C very well and temperatures of 5-10 ^{0} C can be injurious to young plants. Cowpea is very sensitive to frost.

Many varieties are drought resistant or evading. Short-duration, determinate varieties are adapted to cultivation during the short rain season and are little affected by drought after flowering. The water relations of cowpea have been described by Steel et al. (1985), mainly from West Africa.

Most cowpeas exhibit some photoperiodism and are short-day plants. However, sensitivity to day length varies a great deal . For practical purposes, the classification of Steel and Mehra (1980) is useful. They divide cowpea cultivars into three groups:

Type 1A: reproductively day-neutral, determinate genotypes with erect growth and few branches. Type 1A cowpeas are often favoured by plant breeders who see their determinate habit and their stability over diverse environments as desirable characteristics.

Type 1B: reproductively day-neutral, indeterminate genotypes. These continue to produce new vegetative growth while fruiting. Type 1B is typical of the many landraces in Africa. Its indeterminate habit lends stability within locations and is well suited to subsistence farming systems.

Type 11: reproductively photo-sensitive, indeterminate genotypes, typical of the landraces of the West African savannas. Type 11 has the same indeterminate character but photoperiodism controls flowering so that fruit maturation tends to occur under sufficiently dry conditions. This type is frequently intercropped with sorghum, the two crops having co-evolved so that they flower more or less simultaneously. Thus the cowpea can mature its fruits as the sorghum leaf area declines, reducing shading and competition. These cowpeas are highly dependent on assimilates produced after flowering, whereas the cereal relies heavily on the reserves built up beforehand.

The question of determinate versus indeterminate habit is an important one in semi-arid agriculture. Fast-maturing, determinate varieties are suited to certain well defined situations, for instance where the rainy season is short (2-2.5 months) but reliable, or where cowpea is planted late in the rainy season and must mature on rapidly declining soil moisture. In addition, the determinate habit gives less insurance against pest attack during the reproductive phase.

Provided drought begins after first flowering , it does not affect the determinate varieties (Rachie and Roberts, 1974), presumably because most of the assimilates used for fruit development are produced before flowering. In indeterminate varieties by contrast, it seems that a significant amount comes from photosynthesis at or after flowering.

Utilization and nutrition

Cowpea is a typical pulse in its nutritive value and is considered to be tasty. It contains only relatively small amounts of anti-nutritional and toxic factors, but its digestibility is improved by cooking. The traditional method of cooking cowpea resembles that of the other pulses. In Zimbabwe, for example, the whole seeds may be boiled in salted water (often mixed with whole maize) or roasted and winnowed to remove the seed coats then coarsely ground and boiled in salty water. Mature leaves are boiled then sun-dried for storage until needed, while young shoots and leaves are used as a spinach-like vegetable (Johnson, 1970). Fresh mature but not dry seeds and young pods are also frequently cooked. These methods are traditional throughout East and Southern Africa. In West Africa, the ground flour is made into savoury, spiced cakes which are then deep fried or boiled.

The stover is commonly grazed after harvest by livestock and in more intensive farming systems, cowpea may be grown for hay or as a green manure or a cover crop for erosion control. The livestock make a better use of the high-protein foliage or stover when grazing the residues of mixed cowpea-cereal crops than when grazing a sole crop residue.

Rhizobia Relationship

At the Internatonal Institute of Tropical Agriculture (IITA), cowpea VITA 3, an indeterminate variety from Kenya, fixed 124 kg N/ha, almost three times the nitrogen fixed by TVu 4552, a determinate variety from Nigeria. Eaglesham et al. (1982b) concluded that late-maturing cowpea cultivars increase the available soil N after seeds are harvested and plant residues returned to the soil and that early maturing varieties, because of their smaller potential for nitrogen fixation were not likely to contribute N. When he assessed N contribution of the cowpeas in a poor soil (0.073% N) at IITA, Eaglesham (1982) found a positive balance of 2-52 kg N/ha when a starter dose of ammonium sulphate (25 kg N/ha) was applied to late and medium-maturing cowpeas. With N fertilizer (100 kg/ha), nodule numbers, weights and activities were reduced, and amount of nitrogen fixed was 50% less. Under these conditions, cowpeas removed up to 34 kg N/ha from the soil and fertilizer -N pool (Eaglesham, 1982).

In the tropics, where cowpea is predominantly intercropped with cereals, positive interactions between the crops have been documented (Eaglesham et al.1977; Remison, 1978). In soils low in N, cowpea roots may excrete N for the benefit of the companion crop. Cowpea litter, soluble leaf N and N from decaying nodules could also account for the N transferred to the cereal.

Grain yield

When grown by subsistence farmers in the low tropics of West Africa, cowpeas yield about 88 kg/ha (Slade, 1977). However, they are usually intercropped with cereals and are grown at populations of 1000 plants /ha or less without fertilizer or protection from insects and diseases. In a cowpea trial conducted at Nangweshi Farmers Training Centre in the Western Province of Zambia, the genotype IT 82E-16, an early maturing semi-erect variety produced the best grain yield of 634 kg/ha but genotype IT 84D-368 an erect variety, produced only 600 kg/ha (ARPT, 1991). When grown as a monocrop with good management, cowpea crop can produce yields ranging from about 1000 to 4000 kg/ha. The largest yields have been achieved by crops grown under controlled conditions or environments. In several instances, local unimproved cultivars achieved yields as high as for improved cultivars.

Dry matter yield

Genotypes IT 82E-16 and IT 82E-32 both strap leaf and semi-erect varieties produced the highest straw yield of 1200 and 1033 kg/ha, respectively. Correlation between the growth habit (legume spread) and straw yield was significant (ARPT, 1991; 1993). Bhagavandoss et. al. (1992) found that cowpea contributed 21.9 - 50.6 % to the mixed crop dry matter yield. They also found that the contribution of cowpea to the total biomass was higher in 1:1 than in 2:1 row arrangement.

2.3.4 Maize (*Zea mays L*)

Maize is known only as a cultivated species (*Zea mays*), the wild ancestor and closest relative being teosinte (*Zea mexicana (Schrad.) Kuntze)* (Galinat, 1977). Maize and all major cereal crops are members of the grass family, *Gramineae*. Today, nearly 40 % of the total world production of maize is produced in the United States, where the average yield is 7.5 ton/ha. Africa produces about 6 % of the total world production, most of which is for human consumption (Jennifer, 1991). The maize crop has its natural habitat in the tropics but its wide range of adaptability has made its cultivation possible in cool temperate areas (Wilsie, 1962). It is however, not ideally suited to semi- arid conditions. Dryland maize production in East Africa has benefitted from the development of early maturing drought avoiding genotypes (Njoroge, 1982).

The range of temperature during the maize growing season extends from 10 °C to 45 °C. The crop requires warmth throughout its active life and sensitive to frost at all stages of development.

Maize is more sensitive than sorghum to mild water stress partly because the leaves are not strongly cutinized. With only mild to moderate moisture stress, the stomata close and leaves roll upon themselves. This in-rolling is due to the collapse of the billiform cells which lie along the midribs of the laminae (Wadren, 1983). Maize is however, an efficient crop so far as the use of water is concerned. It produces about one kilogram of dry matter for about 370-400 kg of water used, provided that the water requirement of the crop is met at all stages of the crop growth. The moisture needs of the maize crop vary with the stage of crop growth (Moolani and Behl, 1968).

Maize will grow over a relatively wide range of soils as compared to other crops. It is considered a relatively tolerant crop to toxic concentrations of alminium and manganese

(Kamprath and Foy, 1971). While many factors are involved, field studies with liming acid soils indicate that maximum maize yield usually occurs at pH 6.0 and above (Hussan et al. 1970)

Growth and Development of the maize plant

Planting to Emergence

Temperature, water, nutrients and physical conditions in the surface soil are of utmost importance during this period (Shaw and Thom, 1951a). When maize seed is planted, the radicle elongates and emerges within two to three days. A little later, the plumule and the seminal roots begin to grow. The first internode elongates until it is about 3 cm from the soil surface and the lengthening of the coleoptile brings the top of the plant above the ground. Depth of planting influences the time from planting to emergence.

Emergence to Tasseling

During this period, the photosynthetic factory of the plant is established and begins operating at full capacity. As dry matter and nutrients accumulation becomes rapid, demands for water and nutrients become large and deficiency of any nutrient will limit plant growth and the potential final yield. Since the growing point is below the soil surface for the first two to three weeks of this period, damage such as from frost or hail to the above ground plant parts may have only a small insignificant effect on the final yield. The rate of leaf development is usually two leaves per week but growth in height and dry matter accumulation is rather slow in the first four weeks of growth (Aldrich and Leng (1965). Cultural practices before and during this period which reduce or eliminate competition from weeds, improve soil temperature and water conditions which are of prime importance. Any stress during this period may reduce the size of the photosynthetic factory, subsequently the number of potential kernels initiated in the ear.

Tasseling to Silking

Soon after tassel initiation, a period of rapid elongation starts and the plants accumulate dry matter and plant nutrients very rapidly, placing heavy demands on the root system to supply water and nutrients. Ear development begins within a week of tassel initiation. The number of rows that would develop on the ear is reduced if nitrogen becomes limiting at this stage of growth. The potential number of ovules on the ear is also determined by six weeks after emergence. Pollen shedding takes place five to six weeks after tassel initiation. The leaves and the tassels are then fully developed and internode elongation ceases. Any stress such as inadequate water, fertility or light may delay silking for two or more weeks and may reduce seed set because of inadequate viable pollen at the time of silking.

Silking to Physiological Maturity

After pollination and ovule fertilization, the silks turn brown and within the next two weeks the kernels grow very rapidly. Dry matter accumulation in the plant is entirely in the kernel at this time. Nutrients are translocated from other plant parts to the grains. Dry matter accumulation ceases about 50 to 60 days after silking. Unfavorable enviromental or nutritional conditions will result in unfilled kernels and chaffy ears. Water stress, however, will not cause severe reduction in yield as it will during the tasseling to silking stage because pollination and the number of grains would have taken place and determined, respectively. When the kernels are mature, a black layer will develop in the placental region and cuts off movement of assimilates into the developing floret (Daynard and Duncan, 1969). At this stage, kernel will have 30 % or more water. The stage when the kernels reach full dry weight is called physiological maturity.

Dry matter accumulation in maize

The rate of growth is very slow for a period of about five weeks from planting and by the end of this time only 15 % of the total dry matter has been accumulated. Later, the growth rate is almost linear until the grain is in the dough stage. At silking stage, dry matter is about 40 % of the final dry weight (Jennifer, 1991). Later increases in dry matter are mainly in form of cobs, husks and grains. Nutrients move rapidly from leaves, stalks and other parts of the plant to the developing ear although uptake of nitrogen and phosphorus continues until near maturity (Marschner, 1986).

Importance of Management in the growth of maize

Timeliness in planting

Steward (1980) suggested that the potential yield of maize could be increased by delayed planting if the rainy season is short due to the great level of radiation encountered. However, reduced radiation is probably a major factor cotributing to lower yields if maize is planted late where the rainy season is long. Maize, a short day or day neutral crop, is usually sown when rains are fully established (Kumar et al., 1987).

Nutrition of the maize plant

The need for adequate and balanced nutrition of maize has become obvious after the introduction of high yielding hybrids and composites. A maize crop producing 5 to 6 ton/ha of grain will remove about 100-150 kg N, 40-60 kg P_2O_5 and 100-150 kg K_2O per hectare (Prasad and Turhede, 1971).

Nitrogen requirement of maize

A maize crop in a hactare will accumulate at least 200 kg of nitrogen in the grain and stover (Arnon, 1975; Prasad and Turkhede, 1971). Only the most fertile soils will supply this much nitrogen unless maize follows a legume in the cropping system or the nitrogen has been applied as manure or N-fertilizer. The degree of N deficiency is reflected in the condition and colour of the maize plants (Marschner, 1986). With adequate nitrogen, maize plant leaves are dark green. Early season N deficiency results in spindy, stunted growth with light yellowish green colour. Later deficiency results in yellowing especially along the leaf midribs producing a characteristic Y-shaped pattern, followed by browning and death of the leaf tissue. Marschner (1986) reported that since nitrogen is translocated from older to new tissues, the older, lower leaves show these deficiency symptoms first. The loss of functional leaf tissue restricts photosynthesis which results into barren ears or ear tips and/or smaller kernels, resulting in lower yields.

Cropping patterns in maize growing

Maize can be grown as a sole crop or intercropped with other crops such as pumpkin, cucumber, cowpea, millet or sorghum (ARPT, 1993). The reasons for growing maize with other crops vary from food security to improving fertility of the soil. Chileshe et al. (1993) reported that in a maize/siratro intercrop planted at the same time, maize grain yield was 8.6 ton/ha but in the maize -archer intercrop also planted at the same time the yield was 10 ton/ha. This suggests that, the performance of the maize in an intercrop is influenced by the type of legume species.

2.4. SOME AGRONOMIC FACTORS INFLUENCING PRODUCTIVITY AND EFFICIENCY OF AN INTERCROPPING SYSTEMS

The productive efficiency of cereal-legume intercrop systems are affected by the various agronomic variables that affect crop yield. The influence of variables such as competition relationship between component crops, component crop density, plant spacing and arrangement and the effect of applied nitrogen is considered.

2.4.1 Competitive relationship between component crops

In plant populations, competition is defined as the situation in which each of two or more plants growing together in the same area seek the same growth factor which is below their combined demands (Clements et al., 1929; Donald, 1963) as reported by Ofori and Stern, (1987a).

Willey (1979) pointed out that the efficiency of production in cereal-legume intercrop systems could be improved by minimizing interspecific competition between the component crops for the growth-limiting factors. Growing component crops with contrasting maturities so that they complement rather than compete for the same resources at the same time is one way of achieving this. Where the rainy season is long enough, e.g.150-200 days , cereal-cowpea relay-cropping can be practised. Cowpea in these systems is planted towards the end of the crop season so that pods mature during dry, sunny weather. A local cowpea variety produced almost nothing when intercropped and planted at the same time with maize in Kaoma District of the Western Province of Zambia because it was an early maturing variety and therefore matured under humid conditions . However, in a study done by Mariga (1990) planting cowpea at the same time as maize did not reduce maize yields but achieved higher cowpea yields than planting the crop at the time of top dressing maize. An improved cowpea variety, IT 82E-32 also gave better yields than the local both in pure and mixed stands when planted at the same time with maize (ARPT, 1993). Maize grain yield was not affected in the intercrop for both the improved and the local cowpea varieties when compared with the sole maize crop. However, Nadar (1984b) reported that well ,fertilized trials at Kitumani, Kenya revealed substantial varietal differences in the way that the cowpea component affected the maize component of the intercrop. The land equivalent ratio for maize was only 0.54 when the maize was grown with the local cowpea variety, compared with 0.91 when intercropped with an improved variety, Machakos 68, due to the local type climbing on the maize plants.

The results of intercropping maize with pasture legumes from an experiment done at Golden Valley Research Trust from 1994 to 1996 growing seasons showed that legumes did not cause any significant loss in maize grain but there was a significant increase in the dry matter in the intercrops over the sole maize crop (Kaonga, 1996).

In contrast, lesser advantages have been reported in crop combinations in which interspecific competition is evident due to similar or almost overlapping growth durations. No yield advantages were found in maize-cowpea (Haizel, 1974) and sorghum-cowpea intercrop systems in which components were of similar growth duration (Andrews, 1972; Rees, 1986) as reported by Ofori and Stern (1987a). Competition between component crops for growth limiting factors is regulated by basic morpho-physiological differences and agronomic factors such as the proportion of crops in the mixture, fertilizer applications and relative time of sowing (Trenbath, 1976). Where component crops are arranged in defined rows, the degree of competition is determined by the relative growth rates, growth durations and proximity of roots of the different crops. The cereal component with relatively higher growth rate, height advantage and a more extensive rooting system is favoured in the competition with the associated legume. The cereal is described as a dominant component and the legume as the dominated component (Huxley and Maingu, 1978) as reported by Ofori and Stern (1987a). In considering the relative yields of cereals and legumes in intercropping systems, a survey of 40 published papers as reported by Ofori and Stern, (1978a) shows that the yield of the legume component declined on average by about 52% of the sole crop yield, whereas the cereal yield was reduced by only 11%. Thus, the general observation is that yields of legumes components are significantly depressed by cereal components in intercropping.

2.4.2 Component crop density

The overall mixture densities and the relative proportions of component crops are important in determining yields and production efficiency of a cereal-legume intercrop system (Willey and Osiru, 1972; Lakhani, 1976). When the components are present in approximately equal numbers, productivity and efficiency appear to be determined by the more aggressive crop, usually the cereal (Willey and Osiru, 1972; Lakhani, 1976). In a study of maize intercropped with cowpea at densities ranging between 10,000 and 40,000 plants/ha for either crop and planted in the same hill, maize was more competitive than cowpea. The response of intercropped maize to increasing component density was similar to that of sole maize. At the *lowest mixture density, the intercrop maize yield was 15% less than that of sole maize and* increased to 8% less than sole maize at 40,000 plants/ha. Pod yield of intercrop cowpea with lowest density of maize was reduced by 41% of the sole cowpea at optimum density. At the highest overall density, intercrop cowpea showed a reduction of 66%. When sole yields of maize and cowpea in the optimum density treatment were used to standardize mixture yields, LER values rose with the increasing mixture density. From the lowest to the highest density, the LER values were 0.91, 1.14, 1.20 and 1.36, respectively. The growth and yield of the legume component is reduced markedly when intercropped with high densities of the cereal component.

Under moisture limitation, Shumba et al., (1990) found that the yield of the companion cowpea improved generally with a decrease in plant population of the cowpea which suggested that the detrimental effect of drought in intercropping can be minimised by using less than the generally recommended populations. Similar results were reported by (Willey and Osiru, 1972; Nadar, 1980; Lightfoot and Taylor, 1978) , as cited by Shumba et al., (1990). The results also showed that intercropping may not have any special advantage over sole cropping in moisture limiting situations. In a normal year such as 1989/90, however, maize yields were very high but cowpea performed poorly, probably because of excessive vegetative growth and shading in intercropping (Shumba et al. 1990). The sensitivity of low canopy legumes, such as cowpea to the shade of maize in intercropping was noted by Nadar (1980) as reported by Shumba et al.(1990).

Using replacement series designs in a maize-cowpea intercrop system, some researchers showed that level of maize population generally imposed a limit on the yield of the intercrop cowpea, and that there was no effect of increasing cowpea density. Even though the cereal contributes a greater proportion of the mixture yield, the magnitude of intercropping advantage and efficiency seems to be determined by the legume component (Ofori and Stern, 1987a;1987b). Therefore, it seems that the density of the cereal component determines the level of combined mixture yield but that the production efficiency of cereal- legume intercropping system measured in terms of LER, follows the trends of the legume component.

2.4.3 Plant arrangement and spacing:

Row arrangements, in contrast to arrangement of component crop within the rows, improve the amount of light transmitted to the lower legume canopy. Such arrangements enhance legume yields and efficiency in the cereal-legume intercrop system (Monta and De, 1980). However, Agboola and Fayemi (1972) did not observe any difference whether maize and cowpea were planted in the same or alternate rows. The use of double rather than single alternate row arrangements of component crops improves the yield and light penetration to the canopy of the legume component.

Widening inter-row spacing of the cereal component to accommodate more rows of the legume component improves legume yield and efficiency of the intercrop system. From several studies, it would appear that the yield of cereal component is usually less affected by component densities and manipulation of spacing between component crops. Intercrop legume yield usually is reduced significantly, however, this is influenced by proximity to the cereal component. The detrimental effect of shading on cowpea in association with cereals was demonstrated by Wahua et al., (1981). They showed that the more light transmitted to cowpea, the greater was it's growth and yield.

2.4.5.0 Effect of Nutrient use in Intercropping

2.4.5.1.Advantage of Nitrogen Nutrients

Legumes do not compete for nitrogen with component crops but rather provide some nitrogen benefit to a non-legume, growing in association or a residual benefit to a subsequent crop (CIAT, 1974; Wien and Nangju, 1976) as reported by Ofori and Stern, (1987a) and Eaglesham et. al., (1982b). (Searle et. al. (1987) and Chan (1971) as reported by Ofori and Stern (1987a) observed that legume grown in shade could exude a considerable amount of fixed nitrogen.

2.4.5.2. Nitrogen transfer

Evidence in the literature suggests that nitrogen fixed by the intercrop legume may be available to the associated cereal in the current growing season (Agboola and Fayemi, 1972; Remison, 1978; Eaglesham et. al. 1981) or as a residual nitrogen for the benefit of a succeeding cereal crop (Singh and Peterson, 1990). Both forms of nitrogen transfer are considered to be important and could improve the nitrogen economy of various legume- based intercropping systems. This led to the suggestion that both current and residual nitrogen benefits should be evaluated in intercrop systems in which legumes are a component
(Willey, 1979). The degree to which nitrogen from the intercrop legume may benefit a cereal crop depends on the quantity and concentration of the legume nitrogen, and microbial degradation (mineralization) of the legume residues (Hanzell and Vallis, 1977; Herridge, 1982).

The nitrogen in the legume may be tied up in the soil organic pool and may not be readily available to the cereal crop.

In a green house experiment, Agboola and Fayemi (1972) observed that early maturing legumes could possibly improve yields and N nutrition of associated maize in the current season. Although cowpea fixed 450 kg/ha of nitrogen in 98 days, the nitrogen fixed did not influence the yield of associated maize. Eaglesham et. al.(1981) presented evidence from the field about the transfer of nitrogen from legume to an intercrop cereal, using the N^{15} - labelled fertilizer method. It was evident that at the low nitrogen rates, i.e. N_0 and N_{25}, nitrogen concentrations (percentages) of the intercrop maize were higher in the presence of cowpea than in the sole maize. The transfer of N was confirmed by the significant dilution of N^{15} in the intercrop maize compared to sole maize at N_{25}. This was because fixed nitrogen would have an enrichment close to natural abundance and its transfer would result in the dilution of N^{15} enrichment in the intercrop maize derived from the fertilizer. Using replacement series designs, some researchers have reported substantial transfer of nitrogen from the legume to the associated cereal in maize-cowpea intercrop systems in both green house and field studies. However, they did not provide N^{15} data to demonstrate transfer of legume nitrogen that would have obviously resulted in higher enrichment of the intercrop cereal compared to sole crop.

In contrast, the transfer of nitrogen from cowpea to the associated maize was not evident from either the field or the green house pot studies by Ofori and Stern (1987b) because similar ^{15}N enrichments were obtained in the sole maize and intercropped maize. They concluded that cowpea intercropped with maize was competing for applied nitrogen and that the nitrogen fixed by the cowpea ended up in the seed and was harvested from the system. In a maize and cowpea combination planted without nitrogen fertilizer, Remison (1978) attributed a 72% increase in intercrop maize grain yield over that of sole maize to the transfer of nitrogen from cowpea to the associated maize. Unfortunately, no crop nitrogen analysis data were provided to justify the conclusion of current nitrogen transfer claimed by the author. In a tillage and nitrogen levels trial that were done in Mangango, Western Province of Zambia by Kulich (1976) in the 1972/73 season, there was a strong linear yield response to increasing nitrogen with complete tillage.

However, there was a negative correlation between siratro yield and nitrogen fertilizer application.

Prins, (1975) was concerned with the establishment of pasture legumes under maize or the sowing of maize into an established legume crop. He showed that siratro did not grow vigorously in the first year and therefore, there was no danger that it would smother the maize. He also showed that maize benefitted from the nitrogen released by the legumes and after harvest, the stover plus legume gave better grazing than stover alone. However, these benefits were obtained in more than one year of trials.

2.5.0. Potential of crop residues in ruminant nutrition

Data on chemical composition of straws and stovers revealed their nutritional compositions (Chimwano, 1978) and suggestions on their potential integration into ruminant nutrition during the hot and dry season has been stressed (Aregheore, 1993). Their potential as a source of feed to meet the nutritional requirements of the Zambian ruminant population would depend, among others, on the treatment and supplementary methods that would improve the availability of the nutrients. Generally, most of the cereal crop residues are deficient in protein, minerals and vitamins and in some cases low in energy (Aregheore, 1994).

2.5.1 Maize stover as a crop residue in ruminant feed

The actual quantification of crop residues generated annually in Zambia has not been carried out although chemical compositions (Aregheore,1993) and nutritional evaluations (Tembo, 1991) of some locally available crop residues show that they are economically viable source of feeds. However, they have not been fully and effectively integrated as feed for ruminants due to the unavailability of production data, knowledge of processing and level of incorporation in rations. Where they are available, they are haphazardly used, left to rot after harvest and processing of crops or grazed in situ (Aregheore, 1994).

Maize is the most widely grown crop in Western Province. Kaoma alone accounts for 50% of the provincial production. In this district, about 130,008 ton of stover is produced per year (van der Hoek, 1995). Usually this stover is grazed in the field with a small proportion harvested by some farmers for use in the critical feed shortage in the dry season. The proportion of this stover that can be used or consumed as animal feed is about 30%. This constitutes 85% dry matter but with only 1.9% digestible crude protein (ARPT, 1993).

However, according to Walton (1983), ruminant animals require 8-10 % crude protein for maintenance and up to 15 % in the case of high producing dairy cattle. Therefore, forage legumes can give a useful contribution to the ration of the livestock when combined with maize stover. The quality of these forage legumes is high with approximately 60% TDN and 15% digestible crude protein and legumes, like archer and siratro can remain green up to the onset of the rainy season (Chileshe et al., 1993).

CHAPTER THREE

MATERIALS AND METHOD

3.1 Study site

The field trial was conducted during the 1995/96 cropping season at Longe sub- Research Station in Kaoma District of the Western Province of Zambia. The site is situated 45 km east of Kaoma boma and is in agro-ecological zone two which normally receives between 800 and 1000 mm rainfall per annum. The texture of the soil is sandy loam. The field used has been fallow for one year prior to this experiment after being cropped with maize.

3.2 Experimental Design and Layout

The Randomized Complete Block Design with two factors was used. It was laid in 4 blocks separated by 1 m path with the whole experimental area measuring 29 m in width and 40 m in length. Each block had 8 plots measuring 5 m x 5 m in area with an effective harvested area of 10 m^2. The following treatments were assigned at random to each block and were replicated 4 times.

3.3 Treatments

There were 8 treatments consisting of:

- Maize x siratro in 1:1 row arrangement
- Maize x siratro in 2:1 row arrangement
- Maize x archer in 1:1 row arrangement
- Maize x archer in 2:1 row arrangement
- Maize x cowpea in 1:1 row arrangement
- Maize x cowpea in 2:1 row arrangement
- Sole maize 1 and 2

Sole maize 1 received the top dressing fertilizer (60kg urea/ha) as in intercrops

Sole maize 2 received the normal top dressing fertiliser (200kg urea/ha)

3.4 Land preparation and Planting

The land was ploughed just before the onset of the rains using oxen- drawn plough. Planting of the maize and the legumes was done on the same day on 28 December, 1995. The maize and legumes were planted in alternating rows. The 1:1 and 2:1 row arrangements were followed in which there was one row of maize to one row of the legume and two rows of maize to one row of the legume, respectively. This maize variety (MM 603) is the most frequently planted seed in Kaoma. The maize seeds were planted at the normal spacing of 90 cm between rows and 25 cm between plants within the row with one seed per station.

The legumes species were *Vigna unguiculata, Microtyroma axillare* and *Micropitilium atropurpureum* which performed well in pure stands in the same area based on results of previous studies. These were planted using the same spacing as that for the maize with one seed per station for cowpea as the seed is easy to select due to the large size, but 3-4 seeds per station for siratro and archer which were later thinned after germination and emergence.

3.5 Emergence

The emergence of maize was more than 75%, but among the legumes, cowpea had the best emergence followed by archer and then siratro. The emergence of archer and siratro were less than 75% and this was due to the fact that the seeds were washed away by a heavy down pour of rain that fell immediately after planting. However, gapping was done two weeks after planting and this led to improved emergence of archer and siratro. Due to good germination after gapping, thinning was carried out on 24th february 1996 to leave 1-2 legume plants per station.

3.6 Management Practices

3.6.1 Fertilizer application

All the treatments were given the recommended fertilizer rate of compound D. The rate that was applied was 400kg/ha. The basal dressing was applied at the three leaf stage because it is believed by small scale farmers in the area that fertilizer should only be applied to plants that have emerged and hence no basal dressing was applied at planting time.

The top dressing fertilizer in form of urea was applied 6 weeks after emergence at rate of 200kg/ha for the sole maize (2) treatment. For the maize/legume combinations and the other sole maize (1), 30% of the recommended rate was applied, corresponding to 60kg urea per hectare so that they difference was going to be provided by the companion legumes in the intercrops.

3.6.2 Weeding

Weeds were removed by hand hoeing on 7 February 1996 and only a sigle weeding was done throughout the growing period of the crops. All the plots were cleared of the weeds on the same day. Weeds are normally not a problem in Kaoma District and due to this, most farmers only carry out single weeding throughout the growing season.

3.6.3 Pests and diseases

There was no disease noticed to have infected the crops. The only problem experienced was with beetles (*Monolepta gossypiperda*) that are known to attack legumes but were controlled with the spraying of thiodan at a rate 1kg a.i/ha using a CP15 knapsack sprayer and was done two times. The first spraying was when the legumes were starting to spread and the second one just before flowering of the cowpeas.

3.7 Data collection and analysis

The maize plant height was measured using a 30 cm ruler and cariburated tape every two weeks and at the same time the legume spread was also taken in order to assess the growth of the plants.

The maize grains were harvested from randomly selected plants and only middle rows (an area of approximately $10m^2$) were harvested in each of the plots and these were weighed to determine the weight per plot. The grains were then analyzed for crude protein.

After the harvest of the maize grains, the maize stover and the legume biomass were cut and dried to constant weight at temperatures between 65 to 70 ^{0}c and again weighed to determine the weight of the maize stover and legume dry matter per treatment then expressed on a per hectare basis.

The maize stover, legume straw and the maize grains were milled to pass through a 2 mm sieve. The milled maize grains, stover and legume straw were analyzed for crude protein according to standard procedures. The total N was analyzed by micro-kjeldahl digestion followed by distillation and titration (AOAC, 1980). The maize stover and the legume straw were then analyzed for crude fibre through the neutral detergent fibre (NDF) procedures of Goering and Van Soest (1970).

3.8 Statistical analysis

The Mstat package was utilized to analyze the field and the laboratory data that were collected. Analysis of Variance(ANOVA), separation of means and correlation were carried out as described by Little and Hills (1980) and Montgomery (1991). The means were separated using Duncan's Multiple Range Test (DMRT).

CHAPTER FOUR

RESULTS

4.1 General

The soil was fairly fertile with an optimum pH in water of 5.56 and in calcium chloride of 4.53 before planting. The soil chemical fertility was optimum for both maize and the legumes in exchangeable bases except for calcium and magnesium as indicated by the soil analysis results in Appendix 9.

The results of the trial are presented in Tables 1 to 5 and Figures 1 and 2. The detailed ANOVA tables are presented in the Appendices 3 to 8.

4.2 Maize plant growth (plant height)

The sole maize (2) that had received the normal N fertilizer application was significantly taller than the rest except for the maize x archer intercrop in the 1:1 row arrangement. The results in Figure 1 show that the mean plant height was highest in the sole maize (2) which was 1.48 m and was lowest in the other sole maize and maize x cowpea in the 2:1 row arrangement. The correlation between the maize plant height and the maize stover yield was low and insignificant (r= 0.28).

4.3 Companion legume growth (plant spread)

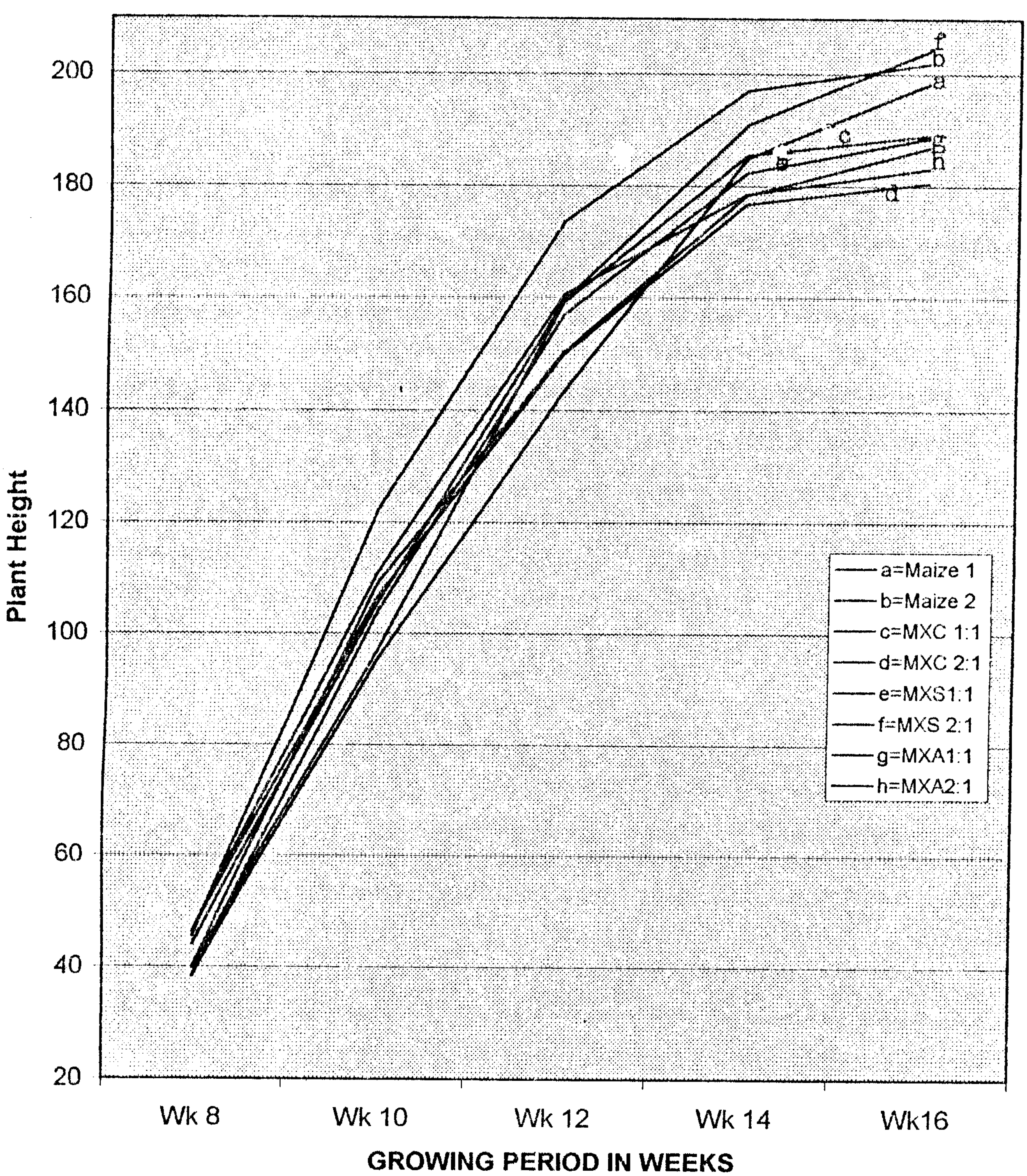
Among the companion legumes, cowpea had the largest spread compared to archer and siratro as shown in Figure 2. The mean plant spread for cowpeas was 1.88 m as compared to 0.76 and 0.68 m for archer and siratro, respectively. The two row arrangements did not statistically show any difference in terms of plant spread for archer and siratro. On the other hand, cowpeas showed a significant difference in plant spread between the 1:1 and the 2:1 row arrangement with the 2:1 arrangement showing more increase in plant spread from the start.

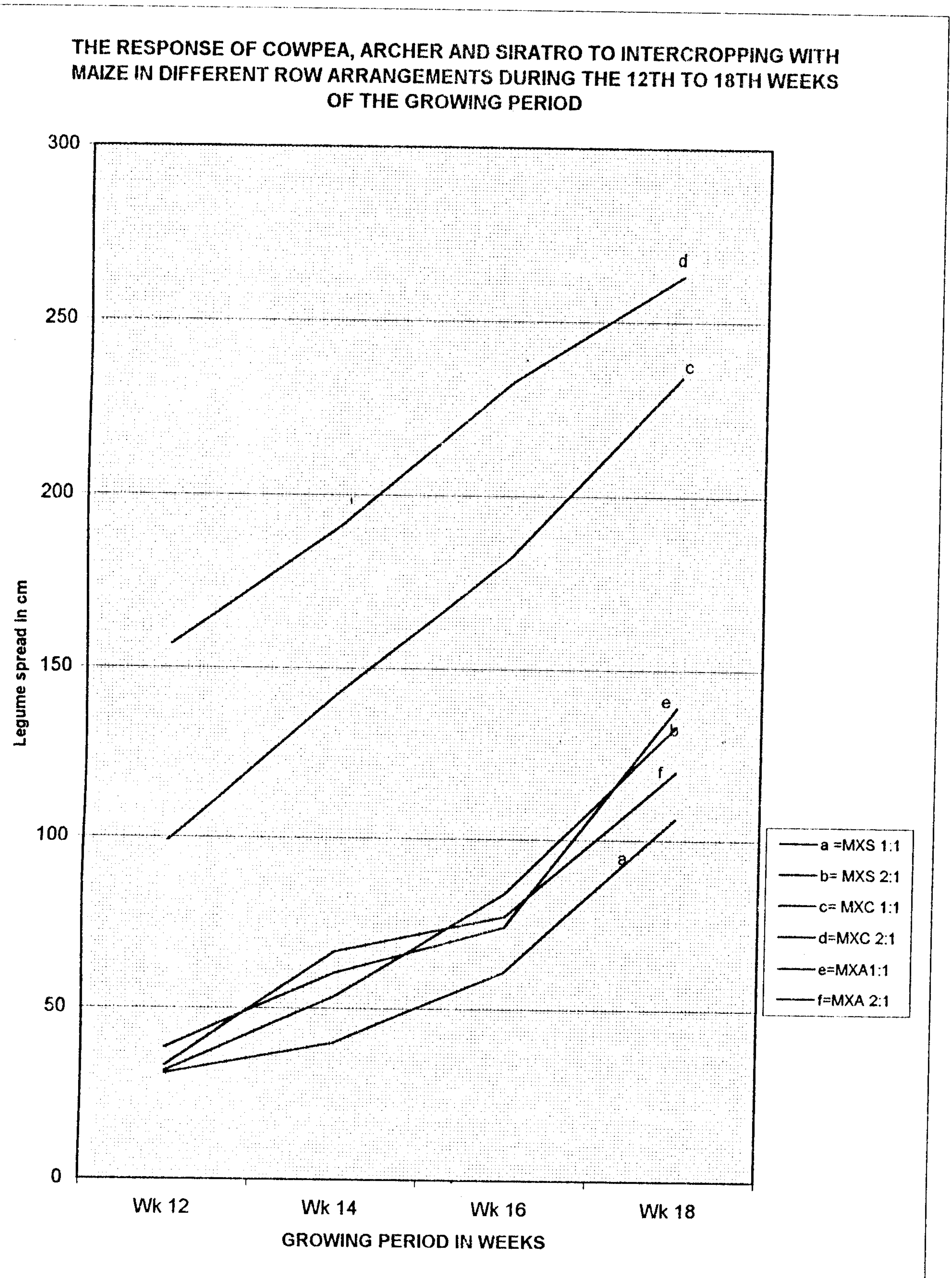
Table 1: Effect of intercropping and row arrangement on the Maize grains yield and grain crude protein content.

Cropping pattern	Row arrangement	Grain yield(ton/ha)	Crude protein (%)
Sole maize:			
Maize (1)	-	2.42 ab[1]	10.02 b[1]
Maize (2)	-	2.48 ab	11.15 a
Intercrops:			
Maize x cowpea	1:1	2.30 ab	9.73 b
Maize x siratro	1:1	3.02 a	10.05 b
Maize x archer	1:1	1.94 ab	10.60 ab
Maize x cowpea	2:1	1.66 b	10.25 ab
Maize x siratro	2:1	2.04 ab	9.60 b
Maize x archer	2:1	1.78 b	10.35 ab
LSD		0.99	0.96
CV		30.57%	6.40%
$P \leq 0.05$		*	*

[1]Means in the same column followed by the same letter are not significantly different from each other according to Duncan's Multiple Range Test.

EFFECTS OF INTERCROPPING AND ROW ARRANGEMENT ON GROWTH AND DEVELOPMENT OF MAIZE




THE RESPONSE OF COWPEA, ARCHER AND SIRATRO TO INTERCROPPING WITH MAIZE IN DIFFERENT ROW ARRANGEMENTS DURING THE 12TH TO 18TH WEEKS OF THE GROWING PERIOD
300
250
200
150
100
50
0
Legume spread in cm
d
c
e
b
f
a
a =MXS 1:1
b= MXS 2:1
c= MXC 1:1
d=MXC 2:1
e=MXA1:1
f=MXA 2:1
Wk 12
Wk 14
Wk 16
Wk 18
GROWING PERIOD IN WEEKS

4.4 Maize Grain Yield

Maize x siratro in 1:1 row arrangement gave the highest maize grain yield which was significantly higher than the maize x cowpea in 2:1 and maize x archer in 2:1 row arrangement ($P \leq 0.05$)(Table 1). The highest yield was 3.02 ton/ha and the lowest grain yield was obtained in the maize x cowpea in 2:1 row arrangement which was 1.66 ton/ha. The sole maize grain yields were not significantly different from those of the intercrops.

4.5 Maize Grain Crude Protein Content

The crude protein content of the sole maize that had received the normal N fertilizer rate was significantly higher from the sole maize that received N fertilizer as in the intercrops (Table 1). Crude protein content was also significantly lower in the maize x cowpea in 1:1, maize x siratro in 1:1 and maize x siratro in 2:1 row arrangement than sole maize (2). Therefore, the highest crude protein content was obtained in the sole maize (2) which was 11.15% and the lowest was obtained in the maize x siratro in 2:1 row arrangement which was 9.60%.

4.6 Maize stover yield

Maize stover yield for both the sole maize and the intercrops were not significantly different (Table 2). Maximum stover yield was obtained in the maize x archer in the 1:1 row arrangement which was 1.36 t/ha while the minimum was obtained in the maize x cowpea in the 2:1 row arrangement which was 0.71 t/ha.

4.7 Maize stover crude protein

Maize stover crude protein contents in the sole maize and the intercrops were also not significantly different from each other (Table 2). The maximum crude protein content was obtained in the maize x archer 1:1 which was 4.63% and the minimum stover crude protein was obtained in the maize x cowpea in 2:1 arrangement, which was 3.30%.

Table 2: Effect of intercropping and row arrangement on maize stover yield and stover crude protein.

Cropping pattern	Row Arrangement	Maize stover yield(ton/ha)	Maize stover crude protein (%)
Sole maize:			
Maize (1)	-	1.20 a[1]	3.80 a[1]
Maize (2)	-	1.06 a	3.35 a
M x C	1:1	1.21 a	3.95 a
M x S	1:1	1.00 a	3.80 a
M x A	1:1	1.36 a	4.63 a
M x C	2:1	0.71 a	3.30 a
M x S	2:1	1.06 a	3.50 a
M x A	2:1	0.99 a	4.40 a
LSD		0.64	1.50
CV		40.54%	26.58%
P≤ 0.05		n.s	n.s

[1]Means in the same column followed by the same letter are not significantly different from each other according to Dunca's Multiple Range Test.

4.8 Maize stover crude fibre

Maize stover crude fibre contents in the sole maize and the intercrops were not statistically different from each other (Table 4). The maximum maize stover fibre content was recorded in the maize x cowpea intercrop in 1:1 which was 79.05 % and the minimum was obtained in the maize x archer in the 2:1 arrangement, which was 74.95 % .

4.9. Companion Legume Straw Yield

Cowpea straw yield was significantly higher than both archer and siratro straw yield. Archer and siratro straw yield did not differ from each other. The cowpea straw yield also showed a significant difference based on the 1:1 and 2:1 row arrangement that was a reflection of the advantage displayed during the growth in terms of plant spread (see Table 3). The correlation between the legume spread and legume straw yield was highly significant ($r = 0.80$).

4.10. Companion legume crude protein content

The crude protein content of siratro straw as indicated in Table 3 was significantly higher than that of cowpea ($P \leq 0.05$). Siratro had a crude protein content of 16.40 % compared to 13.88 % for cowpea (see Table 3). The crude protein content of archer was not statistically different from that of siratro and cowpea. The row arrangement did not seem to have affected the crude protein content in all the legumes.

4.11. Legume Non Detergent Fibre Content

All the three legumes did not statistically differ from each ($P \leq 0.05$) in their non detergent fibre content (see Table 4) except archer and siratro in 2:1 and 1:1 row arrangement, respectively.

Table 3: Effect of intercropping and row arrangement on the companion legume straw yield and crude protein content

Cropping Pattern	Row Arrangement	Legume straw yield (ton/ha)	Legume crude protein (%)
Archer		0.08 b[1]	15.08 ab
Siratro		0.10 b	16.40 a
Cowpea		0.39 a	13.88 b
Row arrangement			
M x A	1:1	0.07 c	15.33 c
M x A	1:1	0.09 c	14.83 c
M x S	1:1	0.14 c	15.40 c
M x S	2:1	0.07 c	17.40 c
M x C	2:1	0.47 a	13.55 c
M x C	2:2	0.30 b	14.20 c
LSD		0.13	
CV		46.10	13.20
$P \leq 0.05$		n.s	n.s

[1] Means in the same column followed by the same letter are not significantly different from each other according to Duncan's Multiple Range Test.

TABLE 4:Non Detergent fibre content of maize stover and legume straw

Treatment	Row arrangement	Maize stover NDF	Legume straw NDF
Maize (a)		75.85 a[1]	-
Maize (b)		76.63 a	-
M x C	1:1	79.05 a	41.98 c
M x S	1:1	76.73 a	48.60 a
M x A	1:1	77.33 a	38.33 c
M x C	2:1	75.98 a	43.00 bc
M x S	2:1	76.15 a	40.92 c
M x A	2:1	74.95 a	47.35 ab
CV		5.47 %	11.66 %
$P \leq 0.05$		n.s	*

[1] Means in the same column followed by the same letter are not significantly different from each other according to Duncan's Multiple Range Test

Table 5: Combined maize stover and legume straw yield:

Cropping pattern	Row Arrangement	Maize stover and legume straw yield
Maize (1)		3000 ab[1]
Maize (2)		2650 b
Maize x Cowpea	1:1	4200 a
Maize x Siratro	1:1	2850 ab
Maize x Archer	1:1	3600 ab
Maize x Cowpea	2:1	2850 ab
Maize x Siratro	2:1	2900 ab
Maize x Archer	2:1	2700 ab
LSD	1553.66	
CV	34.81 %	
P ≤ 0.05		

[1] Means in the same column followed by the same letter are not significantly different from each other according to Duncan 's Multiple Range Test.

The combined maize stover and legume straw yield showed significant differences. The maize stover x cowpea straw combination in 1:1 row arrangement was the highest followed by maize stover x archer in 1:1. The minimum yield of stover was obtained in the sole maize (2) that received the normal N fertilizer rate as Table 5 indicates.

CHAPTER FIVE

DISCUSSION

5.1 Maize plant height and legume spread response

5.1.1 Maize plant height response

The sole maize (2) that had the normal nitrogen fertilizer rate had significantly taller plants compared to the rest of the treatments, except for the maize x archer intercrop in the 1:1 row arrangement. This is an indication that the sole maize (2) had sufficient nitrogen for this positive response in vegetative growth compared to the other sole maize (1) and the intercrops. However, the pattern of growth from the 8^{th} week to the 16^{th} week showed more or less a similar trend with only differences in increase in plant height as shown by Figure 1.

The response observed in the maize x archer intercrop in 1:1 row arrangement could be explained based on competitive nature of the maize plants. According to Trenbath (1976) when the component crops are arranged in defined rows, the degree of competition is determined by the relative higher growth rates, growth durations and proximity of the roots of the different crops. In this study, maize with relatively higher growth rate, height advantage and a more intensive rooting system was favoured by the competition. Maize is termed a dominant component crop and archer and other legumes as dominated crops as reported by Ofori and Stern (1987a).

5.1.2. Legume spread response:

Among the legumes, cowpea had significantly wider plants (plant spread) as Figure 2 shows. Siratro exhibited the least plant spread which probably accounted for the least competition it offered to the companion maize. The subsequent poor performance of siratro could be due to the poor emergence it showed at first planting.

Cowpea grew vigorously and, being an annual plant, was also able to flower and produce seeds. Cowpea used the nitrogen to form protein in the seeds. The source was the applied nitrogen or the nitrogen it fixed. Consequently, this was not likely to have been transferred to the companion maize. Its competition with the maize for nitrogen was reflected in the maize grain yield, stover yield and stover crude protein. The other legumes are perennials which were still growing at the time of harvesting the maize crop.

These legumes had not flowered and thus produced no seed at the time of harvesting maize. Their capacity to fix nitrogen was not pronounced in this first year and thus, it was not possible for maize to have benefitted from them in terms of nitrogen transfer. However, the positive correlation (r=0.84) between the legume spread and straw yield shows that the more the legume spreads the more would be the straw yield. This relationship was obtained in the cowpea trials that were conducted at Nangweshi Farmers Training Centre (FTC) by ARPT (1991) in the Western Province of Zambia.

5.2 Maize grain yield of the sole maize and intercrops

The results showed that the sole maize and the intercropped maize grain yield were not significantly affected. The mean separation conducted revealed that maize x siratro in 1:1 maize grain yield was significantly higher than the maize x cowpea in 2:1 and maize x archer in 2:1. It is likely that maize x siratro in 1:1 was high in maize grain yield because there was no interspecific competition between the maize and siratro. The other reason could be that siratro plots could have gained from the nutrients lost from other neighbouring plots through run off.

Siratro, being too young at the time, could not exert competition for growing factors including nitrogen. Thus, most of the available nitrogen was used by the maize. In this study, the interspecific competition between maize and siratro was minimized due to their contrasting maturity periods. In support of this, Willey (1979) pointed out that the efficiency of production in cereal-legume intercrop could be improved by growing of crops with contrasting maturities. In addition, Prins (1975) showed that siratro did not grow vigorously in the first year and did not affect the companion maize. Similar results were also obtained in the pasture legumes intercropping experiment that was conducted at Golden Valley Research Trust for three seasons (Kaonga, 1996).

On the other hand, the maize grain yield was low in the maize x cowpea in 2:1 because of the interspecific competition between the cowpea and maize as well as intraspecific competition among the maize plants. The cowpea competed for available nitrogen with the maize. The available nitrogen was not enough to satisfy both crop requirements. Cowpea was able to grow vigorously probably because of more light that was penetrating the lower canopy. A similar response was observed by Wahua et al. (1981) who studied the detrimental effect of shading on cowpea in association with a cereal. This led to cowpea competing well with maize as was shown in Figures 1 and 2 in which cowpea was growing vigorously while the companion maize growth declined.

There was no evidence that maize benefitted from any nitrogen fixed by the legume. In fact, what was evident was that the legume i.e, cowpea competed for the nitrogen with the maize as evidenced by low crude protein in the stover and low stover yield. These results were also obtained by Ofori and Stern, (1987b) who concluded that cowpea intercropped with maize was competing for applied nitrogen and that the nitrogen fixed by the cowpea ended up in the cowpea seed and was harvested from the system. In contrast, Agboola and Fayemi (1972) observed that early maturing legumes could possibly improve yields and nitrogen nutrition of the associated maize in the current season. Eaglesham et al.(1982b) concluded that late maturing cowpea cultivars increase the available soil nitrogen after the seeds are harvested and plant residues returned to the soil.

The degree to which nitrogen from the intercrop legume may benefit a cereal crop depends on the quantity and concentration of the legume nitrogen and microbial degradation of the legume residue as was observed by Hanzell and Vallis (1977) and Herridge (1982).

5.3 Maize grain crude protein

Sole maize that received the normal nitrogen fertilizer rate was significantly different from the sole maize that received the nitrogen rate as in the intercrops. However, it was not significantly different from maize x cowpea in 2:1 and maize x archer in 2:1 despite these two intercrops having given low grain yields. This indicates that the sole maize (2) had sufficient nitrogen that resulted in accumulation in the grains compared to the other sole maize. Despite the interspecific competition between the maize x cowpea and maize x archer in 2:1, the maize was able to compete well and accumulated high nitrogen in the grains. This agrees with Huxley and Maingu (1978) as reported by Ofori and Stern (1987a) that the cereal component with relatively higher growth rate, height advantage and more intensive rooting system is favoured in the competition with the associated legume.

5.4 Maize stover yield and crude protein content

Both the sole maize and the intercrops were not significantly different in terms of the maize stover and its crude protein content. This indicates that the maize plant draws its nutrients to satisfy the requirements for grain formation and filling. The stover will only have enough nutrients if the seed requirements have been satisfied. The maize stover yield was lowest again in the maize x cowpea in 2:1, indicating further the interspecific and intraspecific nature of competition for growth factors, among them nitrogen, between the component crops. The trend was similar in terms of crude protein of the stover which was lowest again in the maize x cowpea in 2:1, showing that the two crops were competing to satisfy the nitrogen requirement for the grains leaving the maize stover and legume straw respectively at a minimum protein (3.30 %and 13.8 %). Aregheore (1994) also showed that most cereal crop residues are deficient in protein, minerals and vitamins and in some cases low in energy. It was found that the proportion of the stover that can be used or consumed as animal feed is about 30% and this constitutes 85% dry matter but with only 1.9% digestible protein (van der Hoek, 1995).

5.5 Legume straw yield and crude protein

5.5.1. Legume straw yield

Cowpea performed differently from siratro and archer based on straw yield and crude protein (see Table 3). Cowpea, unlike the other two fodder legumes, is an annual crop that flowered and produced seeds in the same growing season. In contrast, the other two forage legumes are perennials which were still growing vigorously even at maturity of the companion maize (see Figure 1 and 2). They neither flowered nor produced seed during the same growing period of the maize. These factors seem to account for the differences obtained in straw yield and crude protein content and even the competitive characteristic of the cowpea with companion maize.

Cowpea gave the highest straw yield, (Table 3) as it was able to grow and complete its life cycle in the one season. The higher yield obtained in the 1:1 row arrangement compared to 2:1 seems to be due to the proportion of the area planted with cowpea. In addition, it could be due to the larger amount of light transmitted to the lower cowpea canopy as reported by Monta and De (1980) . Bhagavandoss et al. (1992) obtained similar results when cowpea was planted in 1:1 and 2:1 row arrangement.

For siratro however, trials done by Kulich (1976) over several seasons gave yields of between 2 and 3 t/ha dry matter of siratro as compared to the 0.1 t/ha (Table 3) obtained in this research. However, a similar dry matter yield was reported by Kaonga (1996) in the first year (0.5 t/ha) .

5.5.2. Legume straw crude protein

Cowpea straw crude protein was lower than the other two legumes because part of the nitrogen that was taken up by the plants was used to meet protein requirement for seed formation. On the other hand, siratro had the highest crude protein content in the straw as it was vigorously growing vegetatively at the time of maturity of maize and hence at the time of harvest. This vigorous growth at the time of maize maturity signifies the absence of interspecific competition with the maize.

Crude protein content of siratro obtained in this research of 16.4% (Table 3) agrees with that reported by Milford (1976) as cited by Chileshe et al. (1993) and Jennings and Logan (1987). However, Kaonga (1996) found a value of 13.3 % in the first year which went down to 11.7 % in the third year, seemingly supporting the fact that some of the nitrogen tends to accumulate in the seed as the legume flowers and produces seeds.

5.6. Maize stover and legume straw quantity and quality

Among the three legumes that were intercropped with maize, cowpea planted in 1:1 row arrangement with maize gave the highest combined maize stover/legume dry matter. The lowest dry matter quantity was obtained in the sole maize (2) (Table 5). Hence, the maize and legume combination gave a higher dry matter yield as compared to maize stover alone from the sole maize. Similar results were obtained by Kaonga (1996) when the legume components were added to the maize stover. In addition, the quality of maize stover could be improved greatly if fed together with the companion legume. The enhanced crude protein would be high if the maize stover is in combination with siratro regardless of the row arrangement used. The companion legumes are able to contribute 13.8 to 16.4 % crude protein which is about 3 to 4 times more than that of maize stover alone (3.3 to 4.6 %) as Table 2 shows.

These results stress the fact that even though the maize contributed a greater proportion to the mixture yield, the magnitude of intercropping advantage and efficiency seems to be determined by the component legume as was observed by Ofori and Stern (1987a; 1987b).

CONCLUSION

The maize/legume combinations and their row arrangement neither increased maize grain yield nor grain and stover crude protein content in this study. Nevertheless, the possibility of intercropping maize with the three forage legumes in the maize based cropping system has been demonstrated with the intercrops giving similar maize grain yield as the sole maize. Furthermore, the possibility of increasing the overall dry matter production through addition of the companion forage legume straw to maize stover as in the maize x cowpea combination in 1:1 row arrangement has been shown. In addition, the quality of the maize stover was enhanced in protein content as shown by the maize x siratro combination in both row arrangements.

Threfore, the direct improvement in the maize grain and stover crude protein levels in terms of nitrogen transfer to the maize from the companion forage legumes has not been demonstrated by this research and hence, need for further research looking at nitrogen transfer to the companion maize over several growing seasons. Emphasis should also be placed on factors that affect nodulation and capacity of companion legumes to fix and transfer nitrogen.

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Appendix 1: Maize plant height (cm) over the growing period

Treatment	WK 8	WK 10	WK 12	WK 14	WK 16
Maize (a)	38.60	95.25	143.10	184.90	198.28
Maize (b)	45.50	122.25	173.65	196.90	201.88
M x C 1:1	39.80	96.80	159.15	185.45	189.00
M x C 2:1	46.30	106.70	149.80	176.70	180.60
M x S 1:1	38.25	103.90	156.85	182.35	188.53
M x S 2:1	40.05	109.10	150.20	178.30	186.90
M x A 1:1	44.05	105.50	159.45	190.85	204.25
M x A 2;1	46.40	111.00	160.45	178.55	183.10

Appendix 2: Legume spread (cm.) over the growing period

Treatment	WK 12	WK 14	WK 16	WK 18
M x S 1:1	30.75	39.90	61.00	106.40
M x S 2:1	31.40	53.40	84.05	133.50
M x C 1:1	99.05	142.70	182.40	234.13
M x C 2:1	156.85	191.20	232.35	263.13
M x A 1:1	38.45	60.50	74.15	138.90
M x A 2:1	33.05	66.70	77.20	120.05

Appendix 3: ANOVA of maize grain yield for the sole maize and intercrops

S.V:	df	SS	MSS	F	Prob.
Blocks	3	8706.00	2902.00	2.55	P≤ 0.05
Sole/inter.	7	13702.00	1957.43	1.72	P≤0.05
Error	15	2362.00	1136.29		

Appendix 4: ANOVA of maize stover yeild of sole maize and intercrops

S.V:	df	SS	MSS	F	Prob.
Blocks	3	479.63	159.88	0.34	P≤ 0.05
Sole/inter.	7	2670.60	381.51	0.80	P≤ 0.05
Error	15	9960.47	474.31		

SV: = Source of variation

df = Degree of freedom

SS = Sum of Squares

MSS = Mean sums of squares

Sole/inter. = sole maize and intercrop treatments

Appendix 5: ANOVA of maize stover crude protein

S.V:	df	SS	MSS	F	Prob.
Blocks	3	16.22	5.41	5.19	P≤ 0.05
Sole/inter.	7	6.37	0.91	0.86	P≤ 0.05
Error	15	21.88	1.04		

Appendix 6: ANOVA of maize grains crude protein

S.V:	df	SS	MSS	F	Prob.
Blocks	3	3.34	1.11	2.61	P≤ 0.05
Sole/inter.	7	6.89	0.99	2.30	P≤ 0.05
Error	15	8.97	0.43		

Appendix 7: ANOVA of legume straw yeild

S.V:	df	SS	MSS	F	Prob.
Blocks	3	94.38	31.46		P≤ 0.05
Crops	2	1153.85	576.93	29.82	P≤ 0.05
RA	1	87.40	87.40	4.52	P≤ 0.05
C x RA	2	90.33	45.17	2.33	P≤ 0.05
Error	15	290.23	19.35		

Appendix 8: ANOVA of legume straw crude protein

S.V:	df	SS	MSS	F	Prob.
Blocks	3	10.93	3.64		P ≤ 0.05
Crops	2	25.52	12.76	3.20	P ≤ 0.05
RA	1	3.08	3.08	0.77	P ≤ 0.05
C x RA	2	6.26	3.13	0.79	P ≤ 0.05
Error	15	59.74	3.13		

RA = Row Arrangement

C x RA = Crop x row arrangement interaction

Appendix 9: Analysis of Variance for the maize stover and legume straw:

SV	df	SS	MSS	F	Probability
Blocks	3	1573750.00	524583.33	0.45	$P \leq 0.05$
Treatments	7	7988750.00	11411250.00	0.98	n.s
Error	21	24356250.00	1159821.43		

Appendix 10: Soil analysis results

	Before cropping:	After:
pH^{Water}	5.56	5.60
pH^{cacl2}	4.53	4.61
K me/100 g.	0.26	0.27
Ca me/100 g.	trace	0.04
Mg me/100 g.	trace	trace
N %	0.05	0.03
P mg/kg.	8.30	7.90
Cu mg/kg.	0.20	0.20
Fe mg/kg.	6.32	4.89
Mn mg/kg.	5.75	8.12
Zn mg/kg.	0.04	0.07