EVALUATION OF YIELD AND PROTEIN CONTENT OF TWO COWPEA CULTIVARS GROWN UNDER DIFFERENT MANAGEMENT PRACTICES

by

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DECLARATION

I declare that the ______________________________ (mini-dissertation /dissertation/thesis) hereby submitted to the University of Limpopo, for the degree of _____________________(degree & filed of research) has not previously been submitted by me for a degree at this or any other university; that it is my work in design and in execution, and that all material contained herein has been duly acknowledged.

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ABSTRACT

Field experiments were conducted at the University of Limpopo experimental farm, Syferkuil during 2005/06 and 2006/07 production seasons. This was initiated to examine the effect of leaf removal on cowpea biomass, protein content and grain yield under sole and binary cultures. Treatments consisted of cowpea varieties (Pan 311 and Red caloona), cropping systems (sole and intercropping) and cowpea-leaf pruning regimes (pruning and un-pruned). Sweet corn was planted, as a component crop in the intercropped plots while sole sweet corn plot was included as a treatment. All treatment combinations were laid out as Randomize complete block design (RCBD) with four replicates. Supplementary irrigation was carried out during the plant growth period. Fully expanded leaves were harvested once on all cowpea plants in the two middle rows from designated plots at seven weeks after planting for each year. Growth and yield data were collected from component crops during the course of the trial while the protein content of harvested leaves and immature pods as well as the different cowpea plant parts at harvest were determined. Results of the study revealed that leaves of cowpea variety, Pan 311 harvested prior to the reproductive stage had significantly higher protein content than those of Red caloona. Protein content of immature Pan 311 pods had higher (18.8 to 25.1%) than Red caloona (17.9 to 20.7%) during both planting seasons. The percent protein content of cowpea stem obtained at harvest for Pan 311 varied between 9.3 and 9.4%, and between 9.9 and 12.3% for Red caloona during both planting seasons. Grain yield obtained for Pan 311 and Red caloona were 1703.7 kg ha^{-1} and 1479.8 kg ha^{-1}, respectively during 2005/06 and 1290.7 kg ha^{-1} and 511.7 kg ha^{-1} respectively during 2006/07 planting seasons. Sweet corn intercropped with Red caloona during both planting seasons had higher average grain yield than when intercropped with Pan 311. Although intercropping decreased the partial land equivalent ratio (LER) value of individual component crops, the combined LER values of between 1.1 and 2.3 under intercrop for the different treatment combinations implies that the practice is advantageous. The results of post harvest soil analyses revealed that topsoil has the pH value of 7.11-7.29 indicating neutral soil while subsoil pH value of 6.27-6.91 indicated slightly acidic to neutral soil during both planting seasons. Based on the findings of this study, cowpea variety Pan 311 can be recommended as a better vegetable crop than Red caloona since it has higher leaf and immature pod protein content. It also had higher grain yield than Red caloona when intercropped with sweet corn. Sweet corn had high grain yield when intercropped with Red caloona than when intercropped with Pan 311.

Keywords: Cropping systems, protein content, grain yields, leaf pruning and cowpea.

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CHAPTER 1

INTRODUCTION

Cowpea (*Vigna unguiculata*) is an important grain and fodder legume crop generally grown in many parts of tropical Africa. It is an important nutritious food crop that provides protein, vitamins and minerals, thus making it an extremely valuable crop particularly where many resource-poor people cannot afford protein-rich foods such as meat and fish. Cowpea grows in low fertility soils, where it responds well to phosphorus and potash following fertilizer application (Barrett *et al*., 1997). It is able to cover the soil surface through its production of dense green canopy and thus protect the soil against adverse weather conditions such as excessive sunshine, high rain drop impact leading to splash, soil wash and erosion; and hence conserve soil moisture (Barrett *et al*., 1997). The improved erect largely determinate and short-duration varieties of cowpea have high yield potential in the tropics (Barrett *et al*., 1997).

Cowpea is widely grown under sole and/or intercropping systems. Intercropping is the growing of two or more species simultaneously in the same field during a growing season (Pinheiro and Filho, 2004). Crop production under intercrop is reported to be better than mono-crop because of the yield advantage, protection against risks of drought and pests, even out of the distribution of labor requirements, and the provision of a more balanced human diet (Pinheiro and Filho, 2004). However, this cropping practice has received limited attention from the South Africa agricultural research community (Pinheiro and Filho, 2004).

Crops differ in the way they use environmental resources particularly when grown in mixtures. Mpangane *et al*., (2004) reported that intercropping maize with cowpea is a common practice in smallholder farming systems. Maize usually performs better when intercropped with cowpea variety, Pan 311 than with other varieties due to its small structure and early maturity, which offer low competition to the maize (Mpangane *et al*., 2004). However, 53% grain yield reduction of Pan 311 when intercropped was attributed to increased competitiveness of the associated maize crop as indicated by its superior yield performance (Mpangane *et al*., 2004). Cowpea variety, Pan 311 can be generally incorporated into maize-based cropping systems without depressing the yields of maize (Mpangane *et al*., 2004). In contrast, smallholder farmers produce sweet corn either as fresh or processed product. Sweet corn is highly nutritious, containing moderate level of protein, vitamin A and potassium (Dickerson, 1996).

Introduction of leguminous crop species into cropping systems had been recognized as an important approach to soil fertility improvement (Mpangane *et al*., 2004). The component crops complement each other when grown together, making better use of resources than in mono-crop (Mpangane *et al*., 2004). When the environment of one species is modified in a positive way by a second species such that the first is facilitated by the second, the facilitative production principle will come into play (Pinheiro and Filho, 2004). Competition for resources may however develop due to varying time of planting, root growth patterns and different resource demand (Pinheiro and Filho, 2004). Thus, intercropping maize and cowpea can be an advantageous practice due to better utilization of environmental resources, particularly at low level of inputs and technology (Aggarwal and Sidhu, 1988). Consequently, the success of intercropping vis-à-vis sole cropping will depend on how existing agronomic practices can be manipulated to improve the land use efficiency of various intercrop systems (Ofori and Stern, 1986).

Cowpea is used at all stages of its growth as a vegetable crop. The tender green leaves constitute an important food source often prepared as potherb, like spinach. The immature snapped pods are used in the same way as snap beans, often mixed with other foods. Green cowpea seeds are boiled as a fresh vegetable or may be canned or frozen. Dry matured seeds are also suitable for boiling and canning. Barret *et al*., (1997) reported that some varieties are suitable for harvesting as leaves, young pods and mature seeds, each over a long period for human consumption as well as for feeding livestock. If seeds are desired, leaf harvesting should cease before the pods begin to expand (Barret *et al*., 1997). In bean and cowpea, removing too many young leaves at once will impair seed yield, while removing the oldest leaves has increased it (Barret *et al*., 1997).

However, information on the nutritional advantage of cowpea leaf removal under dryland conditions and cropping systems that include binary culture are scanty but crucial to achieving household food security, particularly in the dry Limpopo province where rainfall is quite limiting. Thus, the goal of this study is to provide empirical data on appropriate production practice that will guarantee increased availability of cowpea grains and its important plant parts for human consumption. The specific objectives of the study include the following:

i. To assess the effects of intercropping of early and late maturing cowpea varieties with sweet corn on performance of component crops.

ii. To determine the impact of cowpea leaf removal on biomass yield; protein content and grain yield under sole and binary cultures.

iii. To assess the effects of cowpea grown under sole and binary cultures on soil nitrogen.

CHAPTER 2

LITERATURE REVIEW

2.1: Cowpea production and performance under different cropping systems.

Henriet *et al*., (1997) reported that the overall productivity of cowpea under traditional intercropping is very low, due to shading and severe competition for nutrients. Efforts should be made to develop alternative systems, which will minimize shading and maximize gains from limited application of fertilizers and agrochemicals. It was also noted that, among several systems evaluated, a strip cropping system involving two rows of densely planted cereal, four rows of densely planted cowpea appeared to be significantly more productive, particularly when limited amounts of fertilizer were applied to the cereal and one or two sprays were given to cowpea (Henriet *et al*., 1997).

Performance of the improved cowpea variety was superior to the local cowpea in sole crop as well as in intercrop system (Henriet *et al*., 1997). Ehler (1994) reported that under traditional intercropping, farmers normally plant millet first at the onset of rain, and about three weeks later, they plant cowpea as an intercrop. This causes shading of cowpea by the fast growing millet. Cowpea is an integral component of the traditional cropping systems due to its beneficial effect on sustainability and as a source of nutritious food and fodder (Ehler, 1994).

2.1.1: Cowpea N, P & K fertilizer requirements and performance under different cropping systems.

The success of crop production on many agricultural lands is largely dependent on availability of essential plant nutrients particularly nitrogen (N), phosphorus (P) and potassium (K). Ofori and Stern (1986) reported that although intercropping usually includes the integration of a legume; the application of N might confer some benefits to the system since the cereal component depends on it for maximum yield. Alsup and Kahn (2002) also reported that legumes also utilize both N and P, but tend to take up P at relatively high rates thereby depleting soil P.

Adetiloye *et al*., (1984) reported that increased level of nitrogen fertilizer application in a corn-cowpea intercrop did not only decreased corn-lodging percentage but also increased the height at which corn stems lodged. The three main causes of stalk lodging are late season severe weather, European corn borer and stalk rot disease complex. It was also reported that lodged sweet corn plants increased combine operator fatigue during harvest. Often in field situation, wind lodging results in different degrees of plant leaning (Hoffmann *et al*., 2000). It was further stated that when some of the plants are standing or lodged to a lesser degree than other plants, the leaf canopy is rougher and light can penetrate to lower levels in the canopy. Weak stalks that are leaning because of wind lodging may break over sooner, which will also add to the pre-harvest loss. Plant lodging is affected by the interaction of insecticide and planting date and the interaction of variety and planting date in most studies (Hoffmann *et al*., 2000).

Murray and Swensen (1985) reported that intercropping had been successfully used to improve yield and efficiency of land use for several warm season food annuals. Reduction of cowpea grain yields in a corn-cowpea intercrop was attributed to competition for nutrients, including nitrogen, since competition for nitrogen is apparent from the nitrogen uptake patterns of those crops at the peak of flowering (Murray and

Swensen, 1985). Ofori and Stern (1986) recorded between 40 and 60% seed yield reduction of cowpea under intercropping.

The yield reduction was attributed to the direct effect of shading by the associated corn, which limits the degree of light interception and consequently reduced dry matter production in cowpea. This implied that there was a lesser degree of competition between cowpea intercropped with short corn compared with taller corn. Although the tall corn plants in a cowpea intercrop produced a significantly greater kernels size, it gave much lower yields through production of fewer kernels compared to the short corn plants.

According to Ofori and Stern (1986), intercropping corn with cowpea significantly reduced total nitrogen concentration of cowpea at 54 days after sowing by about 30 kg ha^{-1} compared to sole cowpea. It was further stated that though N fertilizer application and intercropping did not affect nitrogen contents of straw and seeds, the intercropped cowpea had significantly reduced kernel number.

2.1.2: Leaf harvesting from cowpea plants.

In Africa, removing all young leaves of cowpea cultivars from the apex down to the fourth fully expanded leaf reduced seed yield but raised the combined dry weight of seeds and leaves by 18% on the average (Barrett *et al.*, 1997). A study by Karikari and Molatakgosi (1999) revealed that cowpea is not only grown for grain but also for leaves and used as vegetables. This study revealed that harvesting of up to 50% of leaves increased grain yield while harvesting up to 75% leaves resulted in decreased cowpea grain.

It was revealed that harvesting by completely removing the whole plant parts above the second node, rather than harvesting at the tips decreased leaf yield. Bubenheim *et al.*, (1990) reported that removal of young expanding leaves during vegetative phase just prior to flowering and periodic partial defoliation stimulates leaf production. Twice as much cumulative leaf dry weight was produced in the vegetative/seed-harvest strategy than by plants in the traditional seed-harvest strategy (Bubenheim *et al.*, 1990). Other studies also reported that, the suppression of biomass accumulation and diversion to the vegetative portion of the plant resulting from vegetative/ seed harvest is unaffected by harvest strategy.

Seed yield, seed number and pod number per plant in other studies were severely suppressed as a result of partial defoliation. While the reduction in source leaves limited reproductive sink size (seed number per plant), individual seed size is always not affected (Bubenheim *et al.*, 1990). After flowering, leaves lose desired texture and palatability. Most of the farmers harvest leaves for consumption. It was reported that, farmers believed that leaf picking also increased yield and reduces pest infestation.

According to farmers, foliage beetles and pod borers are attracted to dense leaf canopies, and reducing the leaf canopy through leaf picking, expose pests to sunlight and improved the performance of pesticide application (Isubikalu *et al.*, 1999). Most farmers wait for 3-5 days to pick leaves, following pesticide application. Although farmers preferred picking leaves before spraying, some women growers indicated that they pick leaves immediately after spraying, because of hunger and poverty (Isubikalu *et al.*, 1999).

2.1.3: Harvesting of cowpea grains in a corn-cowpea intercropping system.

Alghali (1991) and Rubatzky and Yamaguchi (1999) reported that flowers of cowpea start to appear as early as four to six weeks after seedling emergence; with edible pods formed about two weeks after anthesis. Alghali (1991) also noted that days to physiological maturity of cowpea pods differ across cowpea cultivars and cropping systems. Thus, according to Rubatzky and Yamaguchi (1999), harvesting of cowpea grain most often begins about 70 days after planting and may continue for 25 to 30 days.

According to Kadam and Salunkhe (1998), the time of harvesting of cowpea grains is determined largely by the appearance of the pods (which should be well filled with tender young peas) and change in color from dark to light green. Cowpea harvest should be made when the peas are still in prime condition, but without sacrificing the yield. Delayed cowpea grain harvesting results in a steady decrease in the proportion of small peas thereby leading to an increased crop grain yield (Kadam and Salunkhe, 1998).

Ofori and Stern (1986) had earlier reported that though intercropping did not influence the number of cowpea seeds per pod and individual seed weight, the harvest index was nonetheless, increased markedly indicating that cowpea was more efficient in the utilization of available photosyntate for seed formation in an intercropping system. However, Alghali (1991) noted that the number of pods per plant differs significantly among cropping systems at different locations with sole cowpea producing the highest number of pods.

Henriet *et al*., (1997) reported that productivity of different cropping systems was tested in other studies involving improved cowpea varieties in sole crop and intercrop systems using one row of millet, one row of cowpea with a minimum basal application of 15 kg N, 15 kg P_2O_5 and 15 kg K_2O, top dressing of the cereals only at the rate of 30 kg/N/ha.

In other studies, the result of cropping system trial have shown that the sole crop is most profitable and the strip cropping involving two cereal, four rows cowpea is the best in terms of economic productivity (Henriet *et al*., 1997). Egli and Bruening (2005) reported that continuous shade affect the length of the pod-production period. The length of the flowering period is also tolerant of treatments that influence photosynthesis or individual plant productivity. The primary cause of reduced pod load under moderate shade stress seems to be the production of fewer small pods with little change in the length of the pod-production period or pod abortion (Egli and Bruening, 2005). The fact that cowpea plants are smaller coming out of the shade, probably with less leaf area and fewer nodes also could limit pod production and survival. Shade due to intercropping may reduce flower per cowpea plant or per node or could stimulate flower and small pod abortion, which can make a significant contribution to total abortion (Egli and Bruening, 2005).

2.1.4: Nutritional and chemical composition of cowpea leaves and grains

According to Bubenheim *et al*., (1990), cowpea leaf contains carbohydrate which increased with leaf age and greatest in the seed; with the protein content in older leaves similar to that of seeds. It was reported that the protein content of young leaves is usually greater than that of older leaves while the fat content is greater in leaf tissue than in seed and is not affected by leaf age. The study also revealed high inorganic mineral content for cowpea foliage, which is greater than that for seed regardless of leaf age; with both leaves and seeds providing low fat and high protein food choice for both human and animal.

Coulibaly *et al*., (2002) observed that the protein in cowpea seeds is rich in amino acids, lysine and tryptophan but deficient in methionine and cystine. It was noted that the 20-23% protein content in cowpea makes it suitable as poor mans meat while the high vitamins and minerals content of young leaves, pods and grains fuelled cowpea usage for human consumption and animal feeds. Barrett *et al*., (1997) reported crude protein as well as digestible crude protein contents of cowpea leaves of between 13.0 and 12.8% percent and 7.9 and 8.7%, respectively. It was also reported 24 % crude protein, 53% carbohydrate and 2% fat contents in cowpea seeds (Barrett *et al*., 1997).

Similarly, Aveling and Adandoron (2000) reported a chemical composition of 4.7 % protein in cowpea leaves and seed composition of 22 to 24 % protein. Nakasathien *et al*., (2000) reported that increased nitrogen concentration in seeds of cowpea is primarily the result of protein accumulation rather than soluble N accumulation. Developing seeds of normal cowpea variety has intrinsic biochemical capacity to synthesize high protein concentration when adequate substrate is available (Nakasathien *et al*., 2000).

Since leaves contribute most of the nitrogenous substrates to developing seed, the increase in total amino acid concentration in leaves may contribute to increase in seed protein concentration (Nakasathien *et al*., 2000). According to Muhammad *et al*., (2006), cowpea sown alone produce more crude protein. Early flowering cowpea varieties are better suited for the production of green pods during the period of food shortages (Muhammad *et al.*, 2006). Cisse *et al.*, (1995) reported that all the cowpea needs for nitrogen could be met by nitrogen fixation, but this process become effective about three weeks after planting. Thus, Cisse *et al.*, (2006) recommended that fertilizer should be applied just before sowing and should be incorporated to a depth of at least 10 cm by harrowing.

2.1.5: Effect of intercropping on cowpea insect pests and diseases control.

Numerous benefits were reported to be associated with the practice of intercropping. Results of research conducted by Pitan and Odebiyi (2001) indicated that damage by cowpea aphids could sometimes be reduced through the use of intercropping with other crops such as corn and sorghum. It was reported that the introduction of cowpea into corn for the control of pod sucking bugs in cowpea could be an important strategy in integrated pest management for cowpea pest control (Pitan and Odebiyi, 2001).

It was also noted that the level of bug infestation on cowpea in a corn/cowpea intercrop is always reduced while cowpea grain yield is increased; with the highest yield obtained when the corn plants provided adequate cover for the cowpea plants. It was further reported that cowpea flowers and pods are hidden under the canopy of corn and thus mask the odor from cowpea flowers thereby disrupt insects' visual search for a preferred host. It was concluded that the prospect of utilizing corn-cowpea mixture for the control of cowpea bugs requires careful management through manipulation of time of intercropping. Nonetheless, cowpea stands intercropped with corn are sometimes exposed either because of immature or dying of corn stands, which could not provide cover.

Nick and Bradley (1994) reported that a cover crop takes up soil nitrogen that might otherwise be lost by leaching or denitrification if the field were left fallow, and this reduces potential nitrate pollution and conserve the N in organic form, which become available to subsequent crops when the cover crops are incorporated in to the soil. Intercrop can also provide these benefits and if the intercrop is an economic crop, it can be harvested as well. For example, corn yield and N uptake in a humid tropical region increases by 15-20 percent due to intercropping with soybean or cowpea, a yield comparable to that from addition of fertilizer N (Nick and Bradley, 1994).

2.2: Botany of Sweet corn and its production requirements.

Peet (2001) reported that sweet corn (*Zea mays*) is a monocot in the grass family, gramineae. Modern sweet corn cultivars arose in the Latin century when a single gene mutated in field corn. Plant descended from this mutant had kernel with sugary rather than starchy endosperm and a creamy texture. Corn is wind pollinated and must be planted in blocks. To avoid cross-pollination, different kernel types must be planted at least 14 days apart (Peet, 2001). Wiseman and Isenhour (1994) reported that variety selection is an important consideration in sweet corn production and includes factors such as sweetness, days to maturity, seed color, size, yield potential and tolerance to pests.

Modern sweet corn varieties are classified as normal sugary, sugary enhanced and shrunken also called super sweet. These differ in flavor and tenderness and in the rate at which starches are converted to sugar. Cross-pollination of sweet corn with other kind of corn or some other sweet corn genotypes can result in starchy-taste (Wiseman and Isenhour, 1994). Generally, minimal isolation distance of 76.2 meters between those varieties or types is recommended, 213.4 meters, however, is preferred for more complete isolation (Wiseman and Isenhour, 1994). Where irrigation is not an option and weed management is good, plants might be seeded further apart to reduce inter plant competition (Enrique and Raulston, 1995).

According to Hallauer (2002), sweet corn is consumed fresh and as processed vegetable. Among canned vegetables in USA, sweet corn ranks second behind tomatoes in per capita consumption of canned products. Sweet corn ranks sixth among fresh vegetable for per capita consumption. Interest in sweet corn as a fresh vegetable is increasing in many other parts of the world (Hallauer, 2002). It is a fairly heavy feeder hence; proper soil fertility is critical for high yield and good growth. Once stunted by lack of nutrients, sweet corn may never fully recover (Grubinger and Minoti, 1990). Bravo *et al*., (1995) reported that sweet corn does best with a pH of 6.0 to 6.5 and needs moderate to high level of phosphorus (P) and potassium (K).

According to Burril *et al*., (1987), sweet corn does have some specific environmental and cultural needs that must be met for the plant to produce high marketable yield. It is described as a warm season crop that requires high temperatures for optimum germination and rapid growth, with soil temperature requirements of between 70 and 80°F for best germination (Burril *et al*., 1987). Sweet corn does not tolerate cold weather and frost, both of which will injure sweet corn at any stage of growth (Burril *et al*., 1987). Nitrogen deficiency is fairly common in sweet corn producing areas, particularly in flooded, dry and sandy soil (Grubinger and Minoti, 1990). Nitrogen deficiency in young plants causes the whole plant to be pale with spindly stalks and yellow leaf tips while in older plants, nitrogen stress is often expressed by shriveling of tip kernel (Grubinger and Minoti, 1990).

2.2.1: Sweet corn production under different cropping systems

Grubinger and Minoti (1990) reported that sweet corn should be planted in blocks of at least four rows for good pollination to occur while prevention of pollination problem could be achieved through separation from other types of corn by at least 366 meters. It was also advised that different types or cultivars of sweet corn should be planted at least one month apart, or cultivars with different maturity dates should be planted. Dickerson (1996) reported that planting depth of sweet corn varies for the soil and type of sweet corn.

Super sweet types should be planted half as deep for each soil type (Dickerson, 1996). It was also reported that more seed might be needed for early varieties planted closer together. Plant spacing within the row will vary depending on row width. Plant spacing on rows of 91.44 cm to 96.52 cm apart may range as follows: early, 20.32 cm - 25.4 cm; mid to late 22.86 cm - 30.48 cm. In-row spacing between plants may increase if rows are narrower or decrease with wider rows.

Some varieties may respond to wider spacing by producing more tillers or suckers (Dickerson, 1996). Kwabiah (2004) reported that planting of the kernel/seed must be 1.27 cm deep in cool, moist soil and 2.54 cm deep in warm, dry soil. If sweet corn is crossed with field corn or popcorn, it will not develop high sugar content and will be starchy.

Cross-pollination between yellow and white sweet corn varieties affects only the appearance of the white corn, not the eating quality (Kwabiah, 2004).

2.2.2: Fertilizer, Moisture (Irrigation) requirements and harvesting of sweet corn.

Gardner *et al*., (2000) reported that the fertilizer application of sweet corn should ensure adequate level of all nutrients. Optimum fertilization is essential for top quality and yield. Where the plant population exceeds 20000 plants per hectare, fertilizer rates should be increased by 10 percent for each additional 5000 plants per hectare. Irrigation when corn is 30 to 45 cm high will ensure most efficient utilization of banded fertilizer (Gardner *et al*., 2000). It was also reported that sweet corn requires a good supply of available N. An optimum response to N fertilization depends on adequate irrigation. If the band application of N exceeds 65 kg ha^{-1}, there will be danger of seedling injury from the concentration of salt.

Phosphorus is essential for vigorous early growth of seedlings. All of the P should be banded 5.08 cm to the side and 5.08 cm below the seed at planting (Gardner *et al*., 2000). Grubinger and Minoti (1990) reported that nitrogen (N) is especially important in sweet corn production, not only on plant growth, but also for the production of amino acids that influence flavor and nutrition. It was also indicated that supplemental side-dress N fertilizers used in organic vegetable production include plant and animal by-products like blood meal, fish meal and soybean meal as well as pelletized compost products.

While corn is relatively drought tolerant, yields are increased by irrigation, especially when applied during silking and ear filling (Grubinger and Minoti, 1990). Griffin *et al*.,

(2000) reported that side dress nitrogen (N) application on sweet corn can improve the effectiveness of fertilizer N by lowering losses that might occur from pre-plant applied N through leaching or denitrification. It was mentioned that corn uses very little N during the first four weeks after planting. This means that side dress N applied four to six weeks after planting is available to meet the high crop demand for N during this period and avoid any losses that might have occurred during the first four weeks of the growing season (Griffin *et al*., 2000).

Stoyanova (2005) investigated the effect of variable fertilizer N rates (120, 160 and 200 kg N/ha) on sweet corn and reported that though nitrogen application did not actually affect plant growth rate, strong changes were observed according to the stages of plant development. The researcher also reported increased plant height at tillering and tasseling and changed growth rate from 0.04 to 1.28 cm for sweet corn following fertilizer application. The study recorded better rate of growth for plants fertilized at 160 and 200 kg N/ ha than those fertilized at 120 kg N/ ha; with highest grain yield obtained at 160 kg N/ ha rate of application.

On the other hand, water availability is recognized as critical to the success of any crop production. Coleman (1995) noted that after tassels are produced, sweet corn requires high amount of water each week. When the sweet corn plant experiences water deficit during its active physiological stage, it reduces growth and yield by reducing both the size (leaf area index, LAI) and activity of the crop canopy (Stone *et al*., 2001). Hence, Stone *et al*., (2001) reported that the aim of irrigated crop management is to optimize yield while minimizing the incidence of damaging deficits. Maximum leaf area in sweet corn is reduced by the effect of water deficit on rate of leaf expansion, in spite of the effects of deficit on duration of leaf expansion (Stone *et al*., 2001). The relative response of sweet corn to water shortage in most sweet corn canopy affects the development variable, which decreased with plant age (Stone *et al*., 2001). This was because when plants and their organs are small, minor changes in absolute values naturally have a large effect on relative response than when plants or organs are large. Early water deficit tended to affect the canopy by reducing the rate of leaf expansion, and therefore maximum individual leaf area and maximum leaf area index, whereas late deficit mainly increases leaf senescence (Stone *et al*., 2001).

Coleman (1995) reported that each sweet-corn plant will produce at least one large ear that could be harvested at prime maturity, when the silks are dry and brown and the ear has enlarged to the point that the husks are tight. Vigneault *et al*., (2007) reported that sweet corn matures approximately three to four weeks after silking, and it can be determined when it should be ready from the date of 50% silking. It was also indicated that as sweet corn matures, the silks dry off and turn brown and at this stage the kernels and the tip of the cob will be approximately 75% full. Another way of testing is to squeeze the kernel at the base of the cob and the milky fluid will shoot out or sometimes the embryo will pop out if the cob is mature (Vigneault *et al*., 2007). This stage is usually 17 to 20 days after silking under warm day and night conditions, or 22 to 24 days after silking during cool weather conditions (Coleman, 1995). Matured sweet corn cob is removed (harvested) from the plant by simultaneously snapping and twisting from the stalk (Coleman, 1995).

2.2.3: *Tasseling and kernel production in sweet corn as affected by fertilizer application and different cropping systems.*

Bruns and Abbas (2005) reported that tasseling indicates the last vegetative stage of growth. Tasseling starts just prior to silking and the number of days between tasseling and silking will vary with hybrid and environmental conditions. It was reported that complete leaf removal by hail at this stage of tasseling would result in complete loss of grain yield because the tassels and all leaves are exposed. Nitrogen is taken-up continuously by the corn plants through its seedling stage to maturity. The rate of N uptake after silking is slower than just before tasseling (Bruns and Abbas, 2005). It was also hinted that tasseling in corn is hastened by N fertilization.

Increasing plant density from 25000 to 75000 plants per hectare increases plant height, dry matter production and delays tasseling but reduces ear diameter, kernel depth, grains and number of ears per plant. In other studies, no yield increase has been found from nitrogen applied after the silk and tassel period. Only grain N content is increased with N applied after tassel emergence (Bruns and Abbas, 2005). Cirilo and Andrade (1996) reported that grain yield in sweet corn is mostly dependent on variations in the number of kernels harvested. However, growth conditions during grain filling could also affect grain yield by affecting dry matter allocation to kernels.

It was also reported that increase in temperature during grain filling increases the metabolic rate and sink strength of corn kernels, and the rate of grain filling. Delayed sowing in a temperate climate causes slower rate of grain filling, shortens the duration of grain filling and decreases the final weight of kernel. Late-sown corn appears to be limited by the source of assimilates, which restricts the final kernel size and triggers premature physiological maturity (Cirilo and Andrade, 1996). Carcova *et al*., (2000) reported that corn kernel set could be significantly improved through synchronous pollination, both between ears at low plant population and within ears at high plant population. It was reported that by delaying fertilization of early silking ovaries later developing flowers are able to achieve their potential for kernel set (Carcova *et al*., 2000).

2.2.4: Pollination and silk formation in sweet corn

Uribelarrea *et al*., (2002) reported that increased plant density promotes a large reduction in total pollen production per tassel, which was compensated for by the number of tassels per square meter. Plant density effects on the other hand affect tassel growth at early stages, with the reduction in pollen production per plant. Selection for reduced tassel size should not be accompanied by a reduction in the duration of pollen shedding per plant to avoid the risk of lack of pollen for late appearing silks from the late-silking plants of the population. Uribelarrea *et al*., (2002) reported that the negative effect could be expected if selection is based on reduced tassel branch number.

Pollen shed starts on the main branch of the tassels and continues downward to the bottom most lateral branch. It was estimated that increased plant density promotes a reduction in the duration of the pollen-shedding period of an individual tassel (Uribelarrea *et al*., 2002). Tassels can affect grain yield by reducing light interception into the canopy as well as by utilizing carbohydrate resources. Mickelson *et al*., (2002) reported that de-tasseled plants yielded 19 % more than plants with intact tassels or plants that had tassels cut off and re-attached. Since plants with intact tassels and those with re-attached dead tassels both exhibited same yield reduction, some studies showed that shading is the predominant effect of the tassels on maize yield. A viable tassel is required for adequate pollination both in the production of hybrid seed as well as in grain production fields. From the standpoint of light interception, a smaller tassel is best (Mickelson *et al*., 2002). Tassel size may be particularly important in stress environments where pollen shed is often reduced.

Under severe stress condition, the majority of pollen may be shed before the silks first appear, causing barrenness and poor grain filling (Mickelson *et al*., 2002). In cereal crops, final kernel weight depends on the relationship between kernel sink capacity and the availability of assimilates to fill the sink. Kernel sink capacity is highly dependent on growth conditions during the early stages of grain filling. During the stage of active biomass accumulation, known as the effective grain-filling period, kernel weight responds positively to the assimilate availability per kernel, but this response holds up to a threshold beyond which no increase is observed in kernel biomass (Borras *et al*., 2002).

Carcova and Otegui (2001) reported that under stress conditions, ear barrenness, incomplete ear pollination because of lack of pollen, and kernel abortion are the most important source of reduction in yield of sweet corn. The time gap between male (anthesis) and female (silking) flowering usually lengthens when plants are exposed to stress before anthesis, since silking is delayed more than the start of pollen shedding. Kernel abortion can be partially overcome by increasing assimilate supply of plants under stress conditions. Corn kernel set can be improved significantly through synchronous pollination, both between ears at low plant population and within the apical ears at high standard densities (Carcova *et al*., 2001).

2.2.5: Pests of sweet corn

Ngollo *et al*., (2000) reported that early planting of sweet corn has fewer problems with corn earworm and fall armyworms. Sweet corn should be rotated with other crops each year to prevent insect and disease problems. It was also reported that choosing varieties resistant to these and other diseases is the most effective control strategy. In other studies, the diversification of sweet corn with a strip of soybean/cowpea significantly reduces corn earworm damage. Pest management benefits can also be realized from intercropping due to increased diversity (Ngollo *et al*., 2000).

2.3: Comparison of productivity of intercrop and Sole crop using Land equivalent ratio.

According to Benites *et al*., (1993), comparison between intercrop and sole crop can be made via land equivalent ratio. Land equivalent ratio (LER) is defined as the summation of relative yield of sole crop over intercrop components (Benites *et al*., 1993). The partial land equivalent ratio for cowpea decreased in a corn-cowpea intercrop while that of corn increased with an increase in soil nitrogen level (Benites *et al*., 1993). Land equivalent ratio is based on land alone and can also be used to measure the impact of pests and diseases on intercrops (Benites *et al*., 1993). Where intercropping legumes with corn leads to heavier pests and diseases attack on the legume components and reduced yield, land equivalent ratio is likely to be lowered towards unity (Benites *et al*., 1993). Hence from the equation:

LER= (cowpea intercrop yield/cowpea sole yield) + (corn intercrop yield/corn sole crop yield).

When LER$\leq$1, intercropping is disadvantageous while LER $\geq$ 1, implies intercropping is advantageous (Benites *et al*., 1993). Other ways by which comparison between intercrop and sole crop could be made include relative crowding coefficients. Cowpea changes from a dominated species at lower nitrogen level to a dominated species at higher nitrogen (Aggarwal and Sidhu, 1988). Cowpea is more competitive than corn only when grown under nitrogen and irrigation constraints (Aggarwal and Sidhu, 1988).

CHAPTER 3

MATERIALS AND METHODS

3.1: Description of experimental sites and details of its cropping history.

This study was conducted at University of Limpopo experimental farm, Syferkuil (23° 85′S and 29° 67′E, Altitude 1250 m) during 2005/06 and 2006/07 planting seasons. The soil at Syferkuil is a sandy loam, 77-81% sand in the 0-60 cm depth and soil depth varies from 90 to 120 cm (Mpangane *et al*., 2004). Syferkuil has relatively higher soil fertility due to its long history of fertilization (Mpangane *et al*., 2004). The area usually receives a mean annual rainfall of 500 mm, with mean daily temperature range of 12˚C to 35˚C during planting season (Mpangane *et al*., 2004). Rainfall and temperature data obtained for the site during the period of experimentation are as contained in Table 1.

3.2: Land preparation and pre-planting soil sampling.

Seedbed preparation involved disc ploughing and harrowing. Representative soil sample was collected from the experimental plot at 0-15 cm and 15-30 cm following land preparation but prior to seed sowing during each planting season. The soil samples were collected from three random samples at the depth of 0-15 cm and 15-30 cm during 2005/06 before and after planting. Three random soil samples were also collected before planting at the depth of 0-15 and 15-30 cm during 2006/07 planting season and from each plot after harvest. The soil samples after harvest of 2006/07 planting season were collected at the depth of 0-15 and 15-30 cm in each plot.

Table 1: Mean rainfall and temperature values at Syferkuil during 2005/06 and 2006/07 planting seasons.

		Temperature °C	
Month/year	Rainfall (mm)	Minimum	Maximum
October 2005	51	16.5	28.8
November 2005	63	17.5	27.5
December 2005	33	17.5	30.5
January 2006	26	18	29.5
February 2006	23	17.5	26.8
October 2006	55	17.5	29
November 2006	61	17	26
December 2006	45	19.5	30
January 2007	28	19	30.2

Source: University of Limpopo experimental station records.

All samples were air-dried, sieved (2mm) and nutrient determinations carried out using standard laboratory procedures. Nutrients analyzed included total N, available P, exchangeable K and pH using standard laboratory procedures (Page *et al*., 1982). Total N was determined according to the Kjeldahl digestion procedure and available P by using Bray 1 procedure described by Bray and Kurtz (1945). Exchangeable K was extracted using neutral normal ammonium acetate solution and K concentration in solution read on an atomic absorption spectrophotometer (AAS) while pH determination in KCl was done using a glass electrode pH meter. Total mineral N determination carried out on pre-planting and post-harvest soil sampling during 2006/07 planting season was obtained through the sum of NH_4-N + NO_3-N, which were individually determined following 1M KCl extraction.

3.3: Planting of the trial and sources of planting materials.

The field experiment was conducted during the period of October to January 2005/06 and repeated during 2006/07 planting season (on a different experimental plot). During each planting season, sweet corn was planted with the two-cowpea cultivars (Pan 311 and Red Caloona). Red Caloona seeds were ordered from outside the country while Pan 311 and sweet corn hybrid seed (MMZ 9903) were bought from Mayford seed-company at Tzaneen. The two cultivars of cowpea were the determinate cowpea type.

3.4: Details of the trial, experimental design and field layout

The trial involved the evaluation of the performance of two cowpea varieties (Pan 311 and Red Caloona) under two different cropping systems (sole & binary cropping) and pruning regimes. Two pruning regimes (pruned & un-pruned) were used for the study;

with the pruning restricted only to cowpea leaves. Thus, the trial was a 2^3 factorial experiment fitted into random complete block design (RCBD) with four replicates. These gave eight (8) treatment combinations with a sole sweet corn treatment added to obtain the ninth (9) treatment. Treatments were randomized and each laid out on 3.6 m x 3.6 m (12.96 m^2) plot size. Each sole cowpea and sweet corn plots had five planted rows, while each intercropped plots had five and four rows of sweet corn and cowpea, respectively.

Cowpea seeds were sown at an intra-row spacing of 19 cm and 37 cm, respectively under sole and intercropped plots, whilst intra-row spacing of 37 cm and 74 cm were used for sweet corn on sole and the intercropped plots, respectively. Inter-row spacing of 90 cm was used for both crops in sole cropping. Seed sowing for both sweet corn and cowpea was manually done using hand. The different plant spacing as indicated gave an approximate value of 60 000 and 30 000 plants ha^{-1} for sole and intercropped sweet corn, respectively. Population of 58480 plants ha^{-1} on sole plots and 30864 plants ha^{-1} on intercropped plots was obtained for both cowpea cultivars. The total area of land used for the experiment was 20.4 m x 40.4 m; with a total of 36 plots. Inter-row intercropping was done during both planting seasons.

3.5: Fertilization and other cultural practices

Management practices carried out during the 2-year field experiment included thinning, fertilization and weed control. Thinning of both cowpea and sweet corn was carried out three weeks after seed emergence. Weeding was done two weeks after crops emergence, with a total of three weeding frequencies at early growth stage, vegetative stage and towards crop maturity during both planting seasons to prevent weed interference and crop-weed competition for nutrients. Super-phosphate and potassium chloride were separately weighed at the rate of 50 kg ha^{-1} and 40 kg ha^{-1} respectively, mixed and broadcasted on each fertilizer applied plots before planting. Malathion 50 EC was used to control aphids infestation on cowpea crops.

3.6: Trial monitoring and Data collection

3.6.1: Cowpea growth and yield data collected.

3.6.1.1: Cowpea flowering

Days to 50% and 100% flowering were taken and recorded during 2005/06 planting season while only days to 100% flowering was recorded during 2006/07 planting season.

3.6.1.2: Cowpea plant population, biomass and grain yield at harvest

Cowpea plant population for 2005/06 planting season was recorded at harvest from the entire area in each plot, and from 4 m^2 harvest area within each plot during 2006/07 planting season. Fully expanded leaves were harvested once on all cowpea plants in the two middle rows from designated plots at seven weeks after planting for each year. Three fully developed immature pods were harvested from each cowpea plant of one middle row in each plot, during vegetative stage. Leaves and stems together constituted the biomass production (yield) harvested during 2005/06 and 2006/07 planting seasons. Dried pods of cowpea were harvested, counted and recorded per plot, and thereafter shelled and weighed for grain yield determination.

3.6.2: Sweet corn growth and yield data collected.

The sweet corn plant height was recorded at monthly intervals for the two planting seasons. Days to 50% and 100% tasseling were recorded during 2005/06 while only days to 100% tasseling was recorded during 2006/07 planting season. Yield data were taken at harvest from within 3.24 m^2 sampling area per plot during 2005/06 planting season but from 4 m^2 sampling area during 2006/07 planting season. Such yield data taken and recorded included number of cobs per plant, grain yields, and number of plants per plot.

3.6.3: Chemical analysis of cowpea harvests.

Fully expanded leaves of cowpea during the vegetative stage were harvested during 2005/06 and 2006/07 planting season and oven dried at 65°C. Similarly at maturity, stems and seeds of cowpea were harvested and grain yields determined for both years. Sub-samples were taken, oven-dried at 65°C and percent N content determined. The percent protein content of the different plant parts (i.e. leaves, stalk & seeds) were estimated using the relationship:

Crude protein % = N % x 6.25 (Ezeagu *et al*., 2002).

3.7: Data analysis

All data generated were subjected to analysis of variance (ANOVA) using the Stat-graphics plus version 5.0. Treatments were tested at 5% level of significance and all probability less than 0.05 are significant ($P \leq 0.05$). The difference between treatments means separated using Duncan Multiple Range test (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

4.1: Effects of cropping systems and leaf removal on growth, leaf protein contents and yields of cowpea.

4.1.1: Phenological and growth parameters.

The summary of selected phenological and growth data obtained during the 2-year planting seasons is as shown in Table 2. Cropping system (C) and cowpea variety (V) as well as C x V interaction had significant effect ($P < 0.05$) on days to 50 % flowering during 2005/06 planting season. The mean number of days to 50 % flowering in Pan 311 was approximately 63 days and 73 days for Red caloona. Mean number of days to 50 % flowering under intercrop for both two cowpea varieties, was approximately 67 days but 69 days under sole cropping. The mean number of days to 100 % flowering was significantly affected ($P < 0.05$) by cowpea variety during both planting seasons.

During 2005/06, the mean number of days to 100% flowering in Pan 311 was approximately 84 days and 94 days for Red caloona. However during 2006/07, Pan 311 attained 100 % flowering in approximately 73 days and 77 days for Red caloona. During 2005/06, cropping system (C) x pruning (P) interaction exerted significant effect ($P < 0.05$) on days to 100 % flowering. During 2006/07, a significant V x C x P interaction effects ($P < 0.05$) on days to 100 % flowering was obtained.

Since number of days to 100% flowering in both planting seasons ranged from 73 to 84 days in Pan 311 and 77 to 94 days in Red caloona, the results agreed with similar findings reported by Mpangane *et al*, (2004) who reported that the early maturing cowpea lines flowered 10 days earlier than the late maturing ones. There was no significant difference in the number of days to flowering in relation to pruning treatments.

Table 2: Effect of cropping system, variety and pruning on flowering and growth of cowpea.

Treatments	2005/06			2006/07	
	Days to 50% flowering	Days to 100% flowering	No. leaves plant^{-1} at 100% pod formation	Days to 100% flowering	No. leaves plant^{-1} at 100% pod formation
Cropping (C)					
Intercrop	67	89	23.3	75	41.7
Sole	69	89	22.6	75	44.6
SE	0.4	0.6	1.7	0.4	4.5
CV%	0.7	0.7	7.6	0.5	10.5
(Prob.)	0.004	ns	ns	ns	ns
Variety (V)					
Pan 311	63	84	21.9	73	35.9
Red caloona	73	94	24.1	77	50.4
SE	0.4	0.6	1.7	0.4	4.5
CV%	0.7	0.7	7.6	0.5	10.5
(Prob.)	0.000	0.000	ns	0.000	0.03
Pruning (P)					
Pruned	68	89	22.3	75	40.4
Un-pruned	67	90	23.6	75	45.9
SE	0.4	0.6	1.7	0.4	4.5
CV %	0.7	0.7	7.6	0.5	10.5
(Prob.)	ns	ns	ns	ns	ns

ns implies not significant. SE implies standard error while CV implies coefficient of variation.

The mean number of leaves per plant at 100% pod formation for the two-cowpea varieties differed significantly ($P < 0.05$) during 2006/07 planting season. Red caloona had significantly higher average number of leaves than Pan 311. During both planting seasons, the un-pruned cowpea had higher average number of leaves per plant than the pruned cowpea. Though neither cropping systems nor pruning regimes had significant effect on the mean number of leaves per plant for both cowpea varieties, a significant C x P interaction as well as V x C x P interaction on number of leaves per plant were obtained during 2006/07 planting season. The higher number of leaves per plant in Red caloona may be attributed to its higher nutrients absorbing capacity due to its root system as compared to Pan 311. This agrees with previous findings by Mpangane *et al*., (2004) who reported that, the longer-season cowpea cultivars have higher fresh and dry matter at the mid- vegetative growth stage.

4.1.2: Biomass production at harvest.

The fresh and dried biomass of the two-cowpea varieties for 2-year cropping seasons is as shown in Table 3. During 2005/06 planting season, mean fresh and dried biomass production obtained at harvest were not significantly affected by either cowpea varieties, cropping systems or cowpea leaf pruning regimes. Nevertheless, Red caloona had higher fresh and dried biomass of 808 and 179.8 kg ha^{-1} respectively than Pan 311. Similarly, fresh and dried biomass of 837 and 195.7 kg ha^{-1}, respectively were higher under sole cropping.

During 2006/07 planting season, none of cropping system, cowpea variety or cowpea pruning regimes (P) treatments had significant effect on fresh leaf biomass. However, fresh leaf biomass was higher under sole cropping than under the intercrop. Similarly, fresh leaf biomass was higher with Red caloona than Pan 311. Dried leaf biomass was significantly ($P < 0.05$) affected by cropping system with higher biomass obtained under sole cropping than intercropped plots. Red caloona had higher dried leaf biomass of 430.4 kg ha^{-1} than Pan 311. Un-pruned cowpea plots also had higher dried leaf biomass of 417 kg ha^{-1} than the pruned cowpea plots.

Cowpea fresh stem biomass was significantly ($P \leq 0.05$) affected by cropping system and cowpea variety during 2006/07 planting season. Sole cropping had significantly higher fresh biomass of 4874.8 kg ha^{-1} than intercrop. Fresh stem biomass was significantly higher in Red caloona had (5217.3 kg ha^{-1}) than Pan 311 (3266.1 kg ha^{-1}). Dried stem biomass was significantly ($P \leq 0.05$) affected by cropping system and cowpea variety during 2006/07 planting season, with dried stem biomass of 1515.6 kg ha^{-1} under sole crop being higher than under intercrop.

This may be attributed to higher rainfall during planting and growing season of crops, which was higher during 2006/07 planting season as compared to 2005/06 planting season. The maximum temperature for 2006/07 were lower as compared to 2005/06, and this caused crops to accumulate more moisture than in warmer period of 2005/06 (University of Limpopo experimental station records). Dried stem biomass of 1535.9 kg ha^{-1} for Red caloona is significantly higher than for Pan 311. The higher biomass of Red caloona may be attributed to its large canopy (higher prolificacy) and higher absorption of nutrients by its root system compared to Pan 311 (Bubenheim *et al.*, 1990). This agrees with previous findings by Mpangane *et al*., (2004) who reported that, the longer-season cowpea cultivars have higher fresh and dry matter at the mid- vegetative growth stage.

These biomass results agreed with similar findings reported by Henriet *et al*., (1997) on the low productivity of cowpea under traditional intercropping due to shading and severe competition for nutrients.

Table 3: Effect of cropping system, variety and pruning on biomass of cowpea.

Treatments	2005/06		2006/07			
	Fresh biomass (kg ha^{-1})	Dried biomass (kg ha^{-1})	Fresh leaf biomass (kg ha^{-1})	Dried leaf biomass (kg ha^{-1})	Fresh stem biomass (kg ha^{-1})	Dried stem biomass (kg ha^{-1})
Cropping (C)						
Intercrop	606.6	132.5	1329.1	315	3608.6	1058.1
Sole	837	195.7	1786.3	511.3	4874.8	1515.6
SE	134	26	164	34	311	116
CV%	18.6	15.9	10.6	8.2	7.3	9.0
(Prob.)	ns	ns	ns	0.000	0.009	0.01
Variety (V)						
Pan 311	634.8	148.4	1402.9	395.9	3266.1	1037.8
Red caloona	808.8	179.8	1712.5	430.4	5217.3	1535.9
SE	134	26	164	34	311	116
CV%	18.6	15.9	10.6	8.2	7.3	9.0
(Prob.)	ns	ns	ns	ns	0.000	0.006
Pruning (P)						
Pruned	632.6	149.6	1624.9	409.3	4187	1288.3
Un-pruned	811	178.7	1490.5	417	4296.4	1285.4
SE	134	26	164	34	311	116
CV%	18.6	15.9	10.6	8.2	7.3	9.0
(Prob.)	ns	ns	ns	ns	ns	ns

ns implies not significant. SE implies standard error while CV implies coefficient of variation.

4.1.3: Grain yields and yield components obtained at harvest.

4.1.3.1: Plant population at harvest and number of pod per plant.

Plant population and mean number of pods per plant for the two-cowpea varieties obtained during the two-year planting seasons are summarized in Table 4. During 2005/06 planting season, the differences in cowpea plant population at harvest in relation to cropping system (C) was significant ($P \leq 0.05$). Cowpea population of 22762 plant ha^{-1} under sole crop was significantly higher than 15722 plant ha^{-1} under intercrop. Though neither cowpea variety nor cowpea-leaf pruning regimes had significant effect on plant population, Pan 311 had higher population of 19820.6 plant ha^{-1} than Red caloona. This may be attributed to plant morphology of Pan 311, which was less dense and compared to bushy/more branches plant morphology of Red caloona. During 2006/07 planting season, neither cropping system nor cowpea variety exerted significant effects on the mean plant population at harvest. Pan 311 had significantly higher plant population of 37031.3 plant ha^{-1} than Red caloona. During both planting seasons, the variation in terms of pruning regimes and plant population at harvest was inconsistence.

Cowpea variety (V) differ significantly ($P \leq 0.05$) in terms of number of pods per plant at harvest during 2005/06 planting season, with higher number of pods per plant observed in Red caloona compared to Pan 311. Though neither cropping systems nor pruning regimes had significant effect on number of pods per plant during 2005/06 planting season, sole cropping had higher pods per plant than intercrop. Similarly, un-pruned cowpea plants had higher number of pods per plant than pruned cowpea plants. During 2006/07 planting season, both cropping system and cowpea variety had significant effect ($P \leq 0.05$) on number of pods per plant at harvest, with higher number of pods per plant obtained under sole cowpea plots than intercrop plots.

Red caloona had significantly higher number of pods per plant of 44.9 than Pan 311. The number of pods per plant was not significantly affected by cowpea-leaf pruning regime during 2006/07 planting season. During 2006/07 planting season, significant V x C interaction ($P \leq 0.05$) was obtained in terms of number of pods per plant at harvest. Similarly, V x P x C interaction was significant ($P < 0.05$) in terms of number of pods per plant at harvest. Red caloona in both planting seasons produced higher number of pods and this might be related to its larger canopy compared to Pan 311 (Bubenheim *et al.*, 1990). Sole cowpea plots during both planting seasons produced higher number of pods per plant at harvest. This agrees with previous findings by Alghali (1991), who reported significantly higher number of pods with sole cowpea than among intercropped cowpea at different locations.

4.1.3.2: Cowpea grain yield

Cowpea grain yield obtained during the two-year planting seasons is also shown in Table 4. During 2005/06 planting season, none of cropping system, cowpea variety and cowpea-leaf pruning regimes treatments had significant effect on cowpea grain yield. Nonetheless, grain yield obtained under sole cropping was (1917 kg ha^{-1}) than that of intercrop. While Pan 311 had higher grain yield of 1704 kg ha^{-1} than Red caloona. During 2006/07 planting season, cropping system and cowpea variety had significant effect ($P \leq 0.05$) on cowpea grain yield. Grain yield of 1068 kg ha^{-1} under sole crop was significantly higher than (735 kg ha^{-1}) under intercrop. Pan 311 grain yield of 1291 kg ha^{-1} was significantly higher than (512 kg ha^{-1}) for Red caloona. During 2006/07 planting season, the differences observed in grain yield in relation to V x P as well as C x P interactions was significant ($P \leq 0.05$). In terms of pruning treatments in both planting seasons, no particular trend was observed in relation to grain yield.

The higher grain yield under sole cropping agreed with similar findings reported by Alghali (1991), who attributed this to higher number of pods under sole cowpea plots. Pan 311 in both planting seasons produced higher grain yield than Red Caloona and may be attributed to better pods filling (Kadam and Salunkhe, 1998). The reduction in cowpea grain yield under intercrop obtained this study agreed with previous study by Murray and Swensen (1985) who attributed the reduction to competition for nutrients including nitrogen and possibly shading effects.

Table 4: Effect of cropping system, variety and pruning on plant population, number of pods per plant and grain yield of cowpea.

Treatments	2005/06			2006/07		
	Plant population at harvest (ha^{-1})	No. Pods $plant^{-1}$ at harvest	Cowpea grain yield (kg ha^{-1})	Plant population at harvest (ha^{-1})	No. Pods $plant^{-1}$ at harvest	Cowpea grain yield (kg ha^{-1})
Cropping (C)						
Intercrop	15721.5	38.9	1266.1	29062.5	31.1	734.5
Sole	22762.3	45.6	1917.4	36718.8	39.6	1067.9
SE	1515	4	239	2439	1.3	37
CV%	7.9	10.1	15	7.4	3.6	4.1
(Prob.)	0.004	ns	ns	0.04	0.000	0.000
Variety (V)						
Pan 311	19820.6	33.6	1703.7	37031.3	25.7	1290.7
Red caloona	18663.2	51.0	1479.8	28750	44.9	511.7
SE	1515	4	239	2439	1.3	37
CV%	7.9	10.1	15	7.4	3.6	4.1
(Prob.)	ns	0.009	ns	0.03	0.000	0.000
Pruning (P)						
Pruned	18663.2	36.4	1581.5	34218.8	34.4	926.2
Un-pruned	19820.6	48.1	1602	31562.5	36.2	876.2
SE	1515	4	239	2439	1.3	37
CV%	7.9	10.1	15	7.4	3.6	4.1
(Prob.)	ns	ns	ns	ns	ns	ns

ns implies not significant. SE implies standard error while CV implies coefficient of variation.

4.1.4: Protein content of different plant parts prior to maturity.

4.1.4.1: Protein content of cowpea leaves harvested prior to flowering.

The protein content of cowpea leaves harvested prior to crop flowering (reproductive stage) during the two-year planting seasons is as shown in Table 5. During 2005/06 planting season, the differences in the leaf protein contents was not significant in terms of cropping system and cowpea variety. Although, cowpea leaves from sole crop plots had higher protein content of 25.47 and 29.64 % respectively during 2005/6 and 2006/7 planting seasons than intercrop. This is similar to findings by Muhammad *et al*., (2006) who reported that cowpea sown alone produce more crude protein than when intercropped. Furthermore, in both growing seasons, Pan 311 had higher leaf protein content than Red caloona. During 2006/07 planting season, significantly higher leaf protein contents ($P < 0.05$) was observed in Pan 311 (30.68 %) compared to Red caloona (28.08 %). This may be attributed by higher accumulation of nitrogen from soil by short season cowpea variety, Pan 311.

Table 5: Effect of cropping system and variety on percent leaf protein of cowpea.

Treatments	2005/06	2006/07
	Leaf protein	Leaf protein
Cropping (C)		
Intercrop	24.66	29.12
Sole	25.47	29.64
SE	1.2	0.5
CV%	4.9	1.7
(Prob.)	ns	ns
Variety (V)		
Pan 311	25.98	30.68
Red caloona	24.14	28.08
SE	1.2	0.5
CV%	4.9	1.7
(Prob.)	ns	0.01

ns implies not significant. SE implies standard error while CV implies coefficient of variation.

4.1.4.2: Protein content of immature pods and other cowpea plant parts at harvest.

The protein content of immature pods and other plant parts obtained during the two-year planting seasons is as shown in Table 6. During 2005/06 planting season, none of cropping system, cowpea variety and cowpea-leaf pruning regimes had significant influence on percent protein content of immature pods. However, immature pods from Pan 311 cowpea variety had higher protein content of 18.8 % than Red caloona. Similarly, immature pods from un-pruned cowpea plants had higher protein content of 18.7 % than those from pruned plants.

During 2006/07 planting season, the percent protein content of immature pods for the two cowpea varieties differed significantly ($P \leq 0.05$) with protein content of immature pods from Pan 311 (25.1 %) being significantly higher than Red caloona (20.7 %). Protein content of immature cowpea pods from plots under sole crop (23.1 %) was higher (though not significant) than from under intercrop. Immature pods from un-pruned cowpea-leaf plots similarly had higher percent protein content of 23.4% than pruned cowpea-leaf plots. The lower percent protein content of immature cowpea pods from intercrop plots may be attributed to the fact that, cowpea sown alone always produce more crude protein than intercrop, because of low competition for resources in sole plots as compared to intercropped plots (Muhammad *et al*., 2006).

Table 6: Effect of cropping system, variety and pruning on percent protein content of cowpea plant parts harvested during vegetative stage and maturity.

Treatments	2005/06			2006/07			
	Immature pods	Stem	Seed	Immature pods	Leaf	Stem	Seed
Cropping (C)							
Intercrop	18.4	9.8	23.7	22.7	19.9	10.5	26.3
Sole	18.4	9.6	23.7	23.1	20.2	11.2	25.7
SE	0.5	0.5	0.2	0.4	0.5	0.4	0.4
CV%	2.7	5.1	0.9	1.6	2.3	4.0	1.6
(Prob.)	ns	ns	ns	ns	ns	ns	ns
Variety (V)							
Pan 311	18.8	9.4	23.8	25.1	18.6	9.3	24.7
Red caloona	17.9	9.9	23.5	20.7	21.4	12.3	27.2
SE	0.5	0.5	0.2	0.4	0.5	0.4	0.4
CV%	2.7	5.1	0.9	1.6	2.3	4.0	1.6
(Prob.)	ns	ns	ns	0.000	0.001	0.000	0.001
Pruning (P)							
Pruned	18.1	10.2	23.7	22.4	20.3	10.7	25.6
Un-pruned	18.7	9.2	23.7	23.4	19.8	10.9	26.4
SE	0.5	0.5	0.2	0.4	0.5	0.4	0.4
CV%	2.7	5.1	0.9	1.6	2.3	4.0	1.6
(Prob.)	ns	ns	ns	ns	ns	ns	ns

ns implies not significant. SE implies standard error while CV implies coefficient of variation.

During 2005/06 planting season, percent stem protein content was not significantly affected by cropping system, cowpea variety and cowpea-leaf pruning regimes treatments. Furthermore the effects of cropping system and cowpea-leaf pruning regime on stem protein during both planting seasons were inconsistence. Red caloona had higher stem protein content (9.9 %) than Pan 311 (9.4 %). However, during 2006/07 planting season, significantly ($P \leq 0.05$) higher stem protein content of 12.3 % was observed in Red caloona compared to 9.3 %. The higher stem protein content in Red caloona may be attributed to better ability to utilize fixed N in late maturing cowpea variety as reported by Cisse *et al*., (1995). The intercrop and sole cowpea had equal amount of seed protein. The pruned and un-pruned cowpea also had equal amount of seed protein.

During 2006/07 planting season, the seed protein contents of the two varieties differ significantly ($P \leq 0.05$). Higher seed protein of 27.2 % was observed in Red caloona compared to Pan 311. Seed protein content of cowpea grown under intercrop was higher than that under sole crop. Un-pruned cowpea-leaf plots also had higher seed protein of 26.4 % than pruned cowpea-leaf plots. The protein content of leaves harvested at crop maturity during 2006/07 planting season, was significantly ($P \leq 0.05$) affected by cowpea variety. Thus, Red caloona had significantly higher leaf protein of 21.4 % than Pan 311. The higher protein in matured leaves and seeds of Red caloona may similarly be attributed to its late maturing status and the possibility of better utilization of soil resources including fixed N (Cisse *et al*., 1995).

4.2: Sweet corn performance as influenced by different treatments.

4.2.1: Sweet corn phenology and growth data.

The number of days to 50 % and 100 % tasseling as well as measured plant height at 31 and 62 days after planting for sweet corn during the two planting seasons are as shown in Table 7. During 2005/06 planting season, the number on days to 50 % tasseling differ significantly ($P < 0.05$) based on cropping system. Sweet corn intercropped with Red caloona attained 50 % tasseling at 67 days as compared to 70 and 72 days, respectively for sweet corn intercropped with Pan 311 and sole sweet corn plots. Though the number of days to 50 % tasseling was not significantly affected by cowpea-leaf pruning regimes, sweet corn planted under intercrop with and without cowpea-leaf pruning attained 50 % tasseling at approximately 69 days. The number of days to 50 % tasseling was significantly affected ($P < 0.05$) by C x P interaction during 2005/06 planting season.

Neither cropping system (C) nor cowpea-leaf pruning regime (P) had significant effect on plant height after 31 and 62 DAP for both planting seasons. During 2005/06 planting season, sweet corn intercropped with Red caloona had taller plants (70.7 cm) than when intercropped with Pan 311. Sole planted sweet corn similarly had taller plants (70.1 cm) than sweet corn intercropped with Pan 311 while leaf-pruned cowpea plots gave taller sweet corn plants than un-pruned cowpea plots when intercropped. Sweet corn intercropped with Pan 311 and Red caloona had equal plant height of 119.1 cm after two months of sowing (i.e. 62 DAP). Sweet corn planted under sole crop had taller plants (121.9 cm) than when intercropped.

During 2006/07 planting season, sweet corn plants under Pan 311 and Red caloona intercrop had less plant height (92.9 and 92.2 cm, respectively) compared to sweet corn planted under sole at one month after planting (31 DAP). However, at two months after planting (62 DAP), sweet corn grown under Pan 311 intercrop had the shortest height of 97.1 cm compared to 100.6 cm and 105.2 cm under Red caloona intercrop and sole crop plots, respectively. Sweet corn plant height under leaf-pruned cowpea plots consistently had taller plant height of 97 and 103.3 cm, respectively at one month and two months, after planting than in un-pruned cowpea plots. The taller plants obtained in sole sweet corn plots may be attributed to less competition for nutrients. The results agreed with the similar findings reported by Murray and Swensen (1985), who noted that competition for nitrogen became apparent from the nitrogen uptake patterns of cowpea and sweet corn at the peak of flowering.

Table 7: Effect of cropping system and pruning on plant height and duration to tasseling of sweet corn.

Treatments	2005/06				2006/07		
	Days to 50% tasseling	Days to 100% tasseling	Plant height (cm) 31 DAP	Plant height (cm) 62 DAP	Days to 100% tasseling	Plant height (cm) 31 DAP	Plant height (cm) 62 DAP
Cropping (C)							
Sole corn	72.0	97.0	70.1	121.9	76.0	98.3	105.2
Pan + corn	70.0	94.0	57.0	119.1	75.0	92.9	97.1
RC + corn	67.0	95.0	70.7	119.1	75.0	92.2	100.6
SE	0.9	1.2	9.7	5.5	0.3	4.2	3.7
CV%	1.3	1.2	14.7	4.6	0.5	4.4	3.7
(Prob.)	0.007	ns	ns	ns	ns	ns	ns
Pruning (P)							
Pr + corn	69.0	95.0	59.0	119.6	75.0	91.5	98.0
UP + corn	69.0	95.0	74.3	119.7	75.0	97.0	103.3
SE	0.9	1.2	9.7	5.5	0.3	4.2	3.7
CV%	1.3	1.2	14.7	4.6	0.5	4.4	3.7
(Prob.)	ns	ns	ns	ns	ns	ns	ns

RC implies Red caloona, Pr implies pruned leaf- and UP implies Un-pruned leaf-plots.

ns implies not significant. SE implies standard error while CV implies coefficient of variation.

4.2.2: Sweet corn grain yields and yield components at harvest.

All measured yields and yield component data for sweet corn obtained at harvest during 2005/06 and 2006/07 planting seasons are presented in Tables 8. Neither cropping system (C) nor cowpea-leaf pruning regime (P) had significant effect on plant population during both planting seasons. During 2005/06 planting season, plant population was higher in sole planted and Pan 311 intercropped plots than in Red caloona intercropped plots. However during 2006/07 planting season, Pan 311 intercropped plots had higher plant population of 28750 plant ha^{-1} than Red caloona intercropped plots. The higher plant population of sweet corn under Pan 311 intercrop may be attributed to better seed emergence.

Similarly, neither cropping system nor cowpea pruning regime had significant effect on sweet corn stover yield in both planting seasons. During 2005/06 planting season, stover yields under Red caloona intercrop was higher (994 kg ha^{-1}) than in Pan 311 intercropped plots. Sole planted plots also had higher stover yield (1129 kg ha^{-1}) than intercropped plots. Sweet corn, which was intercropped with pruned–leaf cowpea plots had higher stover yield (1061 kg ha^{-1}) than the un-pruned plots. Lower stover yield production of sweet corn under Pan 311 intercrop may be attributed to higher competition for nutrients between Pan 311 and sweet corn. During 2006/07 planting season, sweet corn under Red caloona intercropped plots also had higher stover yield of 1231 kg ha^{-1} than under Pan 311 intercrop. Sole planted sweet corn had less stover yield than intercropped sweet corn while stover yields of sweet corn was higher in cowpea-leaf pruned plots than in un-pruned plots.

The effect of cropping systems and cowpea-leaf pruning regimes on the number of cobs produced per hectare was inconsistent over the two-year planting seasons. The higher rate of cobs produced during 2006/07 than 2005/06 planting seasons, may be attributed to higher frequency of irrigation and possibly better growth conditions. Neither cropping system nor cowpea-leaf pruning regime had significant effect on sweet corn grain yield during both planting seasons. During 2005/06 planting season, sweet corn intercropped with Red caloona gave higher grain yield of 770 kg ha^{-1} than Pan 311 intercropped plots. Sweet corn planted sole had less grain yield of 577 kg ha^{-1} than sweet corn intercropped with cowpea. Similarly during 2006/07 planting season, sweet corn under Red caloona intercrop also had higher grain yield of 944 kg ha^{-1} than under Pan 311 intercrop while sole sweet corn plots had higher grain yield of 1115 kg ha^{-1} than intercropped plots. Pruning of cowpea leaves had an inconsistent effect on sweet corn grain yield during both planting seasons. However, higher grain yield of sweet corn intercropped with Red caloona may be attributed to nitrogen utilization amongst two different crops in the plot. Griffin *et al.*, (2000) reported that sweet corn uses very little N during the first four weeks after planting. This implies that when sweet corn was intercropped with early maturing cowpea cultivar (e.g. Pan 311), N was utilized more by Pan 311 and lead to lower grain yield of sweet corn, compared to when intercropped with late maturing cowpea (e.g. Red caloona).

Table 8: Effect of cropping system and pruning on sweet corn yields (kg ha^{-1}) and yields component data obtained at harvest during 2005/06 and 2006/07 planting seasons.

Treatments	2005/06				2006/07			
	Plant population ha^{-1}	Stover yield	No of cobs ha^{-1}	Grain yield	Plant population ha^{-1}	Stover yield	No of cobs ha^{-1}	Grain yield
Cropping (C)								
Sole corn	18326	1129	16782	577	25625	1012	36875	1115
Pan + corn	18326	975	18229	693	28750	1208	30625	811
RC + corn	15721	994	15336	770	27813	1231	37500	944
SE	3147	242	2561	104	3015	160	3731	139
CV%	18	24	15	15	11	14	11	15
(Prob.)	ns	ns	ns	ns	ns	ns	ns	ns
Pruning (P)								
Pr + corn	18615	1061	19290	802	25313	1229	32188	863
UP + corn	16397	982	15111	633	29375	1144	36250	963
SE	3147	242	2561	104	3015	160	3731	139
CV%	18	24	15	15	11	14	11	15
(Prob.)	ns	ns	ns	ns	ns	ns	ns	ns

RC implies Red caloona, Pr implies pruned leaf and UP implies Un-pruned leaf-plots. ns implies not significant. SE implies standard error while CV implies coefficient of variation.

4.3: Land equivalent ratio

The calculated values of Land equivalent ratio (LER) for individual crop as well as the total LER values under the different cowpea varieties and cowpea-leaf pruning regimes are as contained in Table 9. Partial LER values for sweet corn during 2005/06 planting season were higher than those of 2006/07 planting season. The results revealed that pruning of leaves of both cowpea varieties when intercropped with sweet corn resulted in decreased partial LER values of component crops as well as the total LER values. However, an exception was observed with the partial LER of Red Caloona that was increased during 2005/06 planting season. Sweet corn's LER calculated values ranged between 0.8 and 1.6 during 2005/06 and between 0.6 and 1.0 during 2006/07 planting seasons.

The calculated LER value for sweet corn during 2005/06 planting season, when intercropped with Pan 311 was 0.8 and 1.6 for un-pruned- and pruned-leaf plots, respectively. This implies that intercropping of sweet corn with Pan 311 leaves un-pruned was disadvantageous to sweet corn. However, LER values for both pruned and un-pruned Pan 311 during 2006/07 were less than 1.0. On the other hand, intercropping sweet corn with Red Caloona (pruned and un-pruned leaf), respectively gave LER values of 1.2 and 1.5 during 2005/06 as well as 0.7 and 1.0 during 2006/07 season. The first year results showed that intercropping sweet corn and Red Caloona was advantageous with and without leaf pruning. Nonetheless, the second year data showed that pruning of Red Caloona decreased the LER value for sweet corn when intercropped.

Similarly, the calculated partial LER values for cowpea during 2005/06 planting season varied from 0.6 to 0.7 and from 0.5 to 1.6 during 2006/07 planting season. The results showed that intercropping sweet corn with either of the two-cowpea varieties was detrimental to cowpea in terms of grain yield production except Red Caloona that was advantaged only with the pruning of the leaves. However, total LER for each planting season ranged between 1.1 and 2.3; with values being generally higher during 2005/06 than 2006/07 planting season except for pruned Red Caloona. This indicated that intercropping was advantageous (higher productivity) for the two component crops grown together.

Table 9: Partial and total land equivalent ratio (LER) as affected by different treatment combination during 2005/06- and 2006/07-planting seasons.

Treatment combinations	2005/06			2006/07		
	LER for Sweet corn	LER for Cowpea	Total LER	LER for Sweet corn	LER for Cowpea	Total LER
Pruned leaf Pan 311 intercrop	1.6	0.7	2.3	0.8	0.7	1.5
Un-pruned leaf Pan 311 intercrop	0.8	0.6	1.4	0.6	0.5	1.1
Pruned leaf Red Caloona intercrop	1.2	0.6	1.8	0.7	1.6	2.3
Un-pruned leaf Red Caloona intercrop	1.5	0.7	2.2	1.0	0.5	1.5

4.4: Treatment effect on selected Soil chemical properties

4.4.1: Pre-planting and post planting soil analysis of 2005/06 and pre-planting soil analysis of 2006/07 planting season.

The results of selected chemical properties on pre- and post-planting soil samples are as shown in Tables 10 as well as 11 and 12, respectively. Analysis of pre- planting soil samples taken during 2005/06 planting season revealed pH (KCl) values of 6.89 in topsoil, indicating neutrality, while that of sub-soil sample gave value of 6.33 indicating slight acidity. Potassium levels of 115.3 and 193.7 mg/kg respectively at topsoil and subsoil before planting during 2005/06 planting season were above the critical level. Similarly, available P (Bray 1) value of 32 mg/kg for topsoil prior to 2005/06 planting was above critical level of 15-30 mg/kg for grain defined by FSSA (2003). The high content of soil P and K suggests a high fertilizer use from previous cropping.

Total nitrogen of both topsoil and subsoil analyzed before and after planting of 2005/06 was below the critical level of 0.15%, defined by Adeoye (1986) for basement, complex soils of South Western Nigeria suggesting the possibility of obtaining good response to N fertilizer application. However, post harvest soil analysis after 2005/06 planting season revealed increase in pH value by 0.22 and 0.58 units, respectively at top and subsoil, while total N decreased by 0.004% at the topsoil. Total N value at the subsoil increased by 0.009% after cropping.

Similarly, available P (Bray 1) value after 2005/06 planting decreased by 22.8% at the topsoil but increased by 38.2% at the subsoil. Exchangeable K values at both top and subsoil decreased after 2005/06 planting season. On the other hand, 2006/07 pre-planting soil analyses revealed top and subsoil pH values of 7.04 and 6.62, respectively. The topsoil pH value implies neutral soil while the subsoil value indicates slight acidity soil. The available P (Bray 1) values of 37.7 and 23 mg/kg, respectively for top and subsoil are above the critical values also indicating evidence of P (Bray 1) fertilizer use from previous cropping. Total N was below critical value in 2006/07 pre-planting soil analyses. Pre-planting top- and sub-soil samples revealed mineral N (NO_3-N + NH_4^- N) content of 10.48 and 13.46 mg/kg, respectively for 2006/07 indicating adequacy level according to Fox and Valenzuela (1989).

Table 10: Results of analysis of selected chemical properties of soil samples collected before planting and after harvest during 2005/06 and 2006/07 planting seasons.

Chemical properties	2005/06				2006/07	
	Before planting		After harvest		Before planting	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
pH (KCl)	6.89	6.33	7.11	6.91	7.04	6.62
Total N%	0.08	0.061	0.076	0.069	0.028	0.030
Mineral N (mg/kg)	nd	nd	nd	nd	10.48	13.66
Bray 1-P (mg/kg)	32	13	24.7	18.1	33.7	23
Exch. K (mg/kg)	193.7	115.3	130	104	216.7	160

nd implies not determined.

4.4.2: Post harvest soil analysis of 2006/07 planting season.

Cropping system, cowpea variety and cowpea-leaf pruning regime had no significant effect on top- and sub-soil pH during 2006/07 planting season, Table 11 and 12. Soil samples from intercropped and sole plots had pH value of 7.20 and 7.16, respectively indicating neutral soil (Fox and Valenzuela, 1989). Soil samples from sole sweet corn plots had pH value of 7.29 while samples from Pan 311 and Red caloona plots both had pH value of 7.16, indicating neutral soil. Furthermore, soil samples taken from cowpea plots with and without leaf pruning had pH value range from 7.13 to 7.22 also indicating neutral soil. However, subsoil pH values of between 6.36 and 6.39 under sole and intercropped plots as well pH value of 6.53 from as sole sweet corn plots indicate slightly acidic soil condition. Soil samples under Pan 311 and Red caloona had pH value of 6.36 and 6.53, respectively indicating slightly acidic soil. Subsoil samples from un-pruned and pruned cowpea leaf plots had pH values of between 6.27 and 6.46, also indicating slightly acidic soil.

Cropping system, cowpea variety and cowpea pruning regime had no significant effect on total N % of both topsoil and subsoil. In case of topsoil, the total N % of sole and intercropped plots soil samples was between 0.025 and 0.027 %. Soil samples from sole sweet corn, Pan 311 and Red caloona plots had total N % of between 0.025 and 0.028%. Topsoil samples from un-pruned and pruned leaf cowpea plots had total N % of between 0.026.and 0.027 %. These values fall below the critical value of 0.15 % (Adeoye, 1986). In the case of subsoil, total N % values under the different treatment combinations ranged between 0.021 to 0.023 %, which were also below the critical value. The reduction in percent soil total N content may be attributed to high utilization of nitrogen by crops from the soil.

During 2006/07 planting season, Bray 1-P values of between 39.0 and 41.68 mg/kg were obtained at the topsoil, Table 11. Topsoil samples from sweet corn, Pan 311 and Red caloona plots had Bray 1-P values ranging from 38 mg/kg to 46.11 mg/kg. Topsoil samples from un-pruned and pruned leaf cowpea plots had Bray 1-P values of between 39.86 and 40.99 mg/kg. All measured Bray 1-P values at the topsoil were above the critical value reported by FSSA, (2003). Subsoil Bray 1-P values under sole and intercropped plots varied between 11.36 and 13.86 mg/kg while values under sole sweet corn, Pan 311 and Red caloona plots ranged from 11.72 to 13.20 mg/kg, Table 12. The pruned and un-pruned leaf cowpea plots had subsoil Bray 1-P value range of between 11.37 and 13.67 mg/kg. These subsoil Bray 1-P values fall within the optimal level of 8-15 mg/kg reported by FSSA (2003).

Exchangeable K content at the topsoil during 2006/07 planting season was significantly affected ($P < 0.05$) by cropping system. Topsoil samples from intercrop had significantly higher exchangeable K of 139.17 mg/kg than from sole cropping, Table 11. Exchangeable K content ranged from 119.27 to 139.17 mg/kg in the topsoil but ranged from 61.53 to 67.50 mg/kg at the subsoil. These imply that both topsoil and subsoil had exchangeable K values above the critical value of greater than 40 mg/kg defined by Fox and Valenzuela (1989).

Mineral N content from topsoil, in sole and intercropped plots varied between 11.68 and 12.41 mg/kg, Table 11, indicating optimal level (Fox and Valenzuela, 1989). Topsoil samples from Pan 311 plots had mineral N content of 10.88 mg/kg, also indicating optimal level while similar samples from sweet corn and Red caloona plots as well as pruned and un-pruned cowpea-leaf plots were all above the critical level. However, subsoil mineral N content from sole and intercropped plots ranged between 7.04 and 7.31, indicating low level (i.e. below critical level). Sweet corn had subsoil mineral N of 8.06, which was at optimal level while samples from Pan 311 and Red caloona were below the critical value. Similarly, results of analysis of subsoil samples obtained from pruned and un-pruned cowpea plots gave values that were below the critical level reported by Fox and Valenzuela (1989).

Table 11: Effect of cropping system, variety and pruning on soil chemical properties of topsoil (0-15cm) samples collected after harvest during 2006/07 planting season.

Treatment	pH (KCl)	Total N%	Bray 1-P (mg/kg)	Exch. K (mg/kg)	Mineral N (mg/kg)
Cropping (C)					
Sole	7.16	0.025	41.68	119.27	11.68
Intercropping	7.20	0.027	39.0	139.17	12.41
SE	2.0	0.028	5.0	5.8	1.1
CV%	1.1	3.8	8.8	4.5	8.9
(Prob.)	ns	ns	ns	0.009	ns
Variety (V)					
Sweet corn	7.29	0.025	46.11	136	12.98
Pan 311	7.16	0.025	41.57	123.58	10.88
Red caloona	7.16	0.028	38	130.67	12.89
SE	2.0	0.028	5.0	5.8	1.1
CV%	1.1	3.8	8.8	4.5	8.9
(Prob.)	ns	ns	ns	ns	ns
Pruning (P)					
Un-pruned	7.22	0.026	40.99	129.33	12.28
Pruned	7.13	0.027	39.86	126.58	11.66
SE	2.0	0.028	5.0	5.8	1.1
CV%	1.1	3.8	8.8	4.5	8.9
(Prob.)	ns	ns	ns	ns	ns

ns implies not significant.

SE implies standard error while CV implies coefficient of variation.

Table 12: Effect of cropping system, variety and pruning on soil chemical properties of subsoil (15-30cm) samples collected after harvest during 2006/07 planting season.

Treatment	pH (KCl)	Total N%	Bray 1-P (mg/kg)	Exch. K (mg/kg)	Mineral N (mg/kg)
Cropping (C)					
Sole	6.36	0.023	11.36	61.53	7.31
Intercropping	6.39	0.021	13.68	67.50	7.04
SE	1.5	0.003	1.3	6	0.7
CV%	1.2	13.6	10.3	9	9.8
(Prob.)	ns	ns	ns	ns	ns
Variety (V)					
Sweet corn	6.53	0.021	13.20	63.33	8.06
Pan 311	6.36	0.022	11.72	64.25	6.56
Red caloona	6.35	0.023	12.86	64.33	7.61
SE	1.5	0.003	1.3	6	0.7
CV%	1.2	13.6	10.3	9	9.8
(Prob.)	ns	ns	ns	ns	ns
Pruning (P)					
Un-pruned	6.46	0.022	11.37	65.33	7.49
Pruned	6.27	0.022	13.67	62.75	6.82
SE	1.5	0.003	1.3	6	0.7
CV%	1.2	13.6	10.3	9	9.8
(Prob.)	ns	ns	ns	ns	ns

ns implies not significant. SE implies standard error while CV implies coefficient of variation.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Large proportion of poor-rural Africans feed on cowpea, which is a cheap source of plant protein. The traditional use of cowpea not only involves the consumption of dried harvested grains but also includes the harvesting of its young fresh leaves as well as immature pods for consumption as vegetables. The nutritional values of this important plant part, particularly the protein content, vary greatly depending on the variety. Hence, the yield potentials and protein content of two cowpea varieties (Pan 311 and Red caloona) were assessed under two cropping systems (sole and intercrop) and two cowpea-leaf pruning regimes (pruned and un-pruned) over two years production seasons. Results of the study revealed that the percent protein content of harvested Pan 311 leaves during the vegetative growth stage was higher than that of Red caloona.

Cowpea leaves obtained under sole crop had more protein content than those obtained under intercrop during the vegetative stage. Immature pods of cowpea Pan 311 variety similarly gave higher percent protein content than of Red caloona variety while protein content of immature pods from un-pruned leaf cowpea plots was higher than those from pruned leaf plots during both planting seasons. However, the protein content of Pan 311 leaves variety obtained at grain harvest was lower than that obtained during the vegetative stage. On the other hand, the stem protein content of Red caloona obtained at grain harvest was higher than that of Pan 311. The number of leaves produced per plant was higher in Red caloona than in Pan 311 cowpea variety. Similarly, the number of leaves per plant for Pan 311 cowpea variety was higher in sole cropped than intercropped plots as well as un-pruned than pruned leaf cowpea plots. Pan 311 cowpea variety flowered much earlier than Red caloona but the date of flowering was not significantly affected by cropping systems or cowpea pruning regimes. The number of pods produced per plant in Red caloona at harvest was higher than of Pan 311 with or without leaf pruning, but decreased by intercropping. Red caloona had higher percent seed protein content than Pan 311 seeds. Percent protein content of cowpea seeds obtained from intercropped and un-pruned cowpea leaf plots was higher than those from sole planted cowpea and leaf-pruned plots. Nevertheless, grain yields obtained at harvest during both production seasons was higher with Pan 311 cowpea variety than Red caloona. Intercropping decreased the grain yields obtained during both production seasons. The implication from all these is that Pan 311 would be better suited for vegetable production in view of the high protein content of the different plant parts during the vegetative growth stage while Red caloona is better suited for grain production with obtained plant residues (including forage) at harvest possibly used as animal feeds.

Sweet corn on the other hand, recorded higher grain yields under Red caloona intercrop than with Pan 311 intercrop during both production seasons. However, sweet corn plant height measured at monthly intervals was higher under Red caloona intercrop than Pan 311 intercrop. The number of harvestable cobs obtained per hectare during both production seasons was not significantly affected by cropping system. The results of this study revealed that intercropping practice was advantageous as revealed by the combined LER values of between 1.3 and 2.3 for the different treatment combinations. The highest value of 2.3 was obtained when both cowpea varieties were intercropped with sweet corn with the cowpea leaves pruned during the vegetative growth stage. The results of post harvest soil analyses revealed that topsoil was acidic to neutral based on the pH value while subsoil was slightly acidic to neutral in both planting seasons. Topsoil and subsoil samples of 2005/06 had increased in the amount of total N values after harvest. The subsoil samples had decreased total N values after 2006/07 cropping. Topsoil samples from all plots had decreased exchangeable K value while subsoil had decreased exchangeable K value in both planting seasons when compared with soil samples analyzed before the planting of 2006/07 season. Bray 1-P values of subsoil samples decreased after 2006/07 cropping. During 2005/06 planting season, topsoil had decreased Bray 1-P values after harvest and subsoil had increased Bray 1-P values.

Further study is recommended on the effect of cropping system and continuous cowpea leaf harvesting/pruning on the protein content of cowpea leaves at vegetative stage, since majority of small-scale farmers prefer to plant corn and cowpea together. This study revealed that the sole cropping tend to have higher percentage of leaf protein at vegetative stage than intercropping. Since greater proportion of peasant farmers harvest cowpea leaves as vegetable, further studies that could lead to improvement in quantity of protein and nutrients content of cowpea leaves and immature pods is necessary.

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