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EVALUATION OF THE SUITABILITY OF SOME COWPEA GENOTYPE FOR MAIZE-COWPEA INTERCROP IN NORTHERN GHANA

BY

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DECLARATION

I hereby declare that this thesis is as a result of my research work and that no previous submission for the award of a degree in this university or elsewhere has been made. The work done by others, which served as a source of information has been duly acknowledged by reference to the authors in question.

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I hereby declare that the preparation and presentation of the thesis was supervised in accordance with the guidelines on supervision of thesis laid down by the University for Development Studies.

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ABSTRACT

Council for Scientific and Industrial Research – Savanna Agricultural Research Institute (CSIR-SARI) in collaboration with University of California, Riverside are phenotyping 300 Recombinant Inbred Lines (RILs) of Multi–parent Advanced Generation Inter-Cross (MAGIC) cowpea population from eight elite cowpea cultivars in Northern Ghana. Among the traits being targeted in the phenotyping is extra early duration cowpea genotypes in Sudan Savanna agro ecological zone of Ghana. This study evaluated some selected early and extra early cowpea genotypes from the MAGIC population in intercrop with maize to identify genotype(s) that can maintain agronomic performance and grain. The experimental design used was split plot with three replications. The cropping patterns (row, strip and sole cropping) were assigned to the main plot. Ten cowpea genotypes (MAGIC 008, MAGIC 043, MAGIC 048, MAGIC 055, MAGIC 076, MAGIC 118, MAGIC 154, MAGIC 176, CB27, and SARC 1-57-2) were assigned to sub-plots. Data were collected on plant height, days to 50 % flowering, number of pod per plant, seed per pod, biomass weight, grain yield and 100 seed weight. The results showed that number of seed per pod and maturity was not affected by genotype and intercrop pattern interaction; however, it influenced grain yield, pod per plant, height, 50% flowering and 100 seed weight of cowpea. MAGIC genotypes, M008, M048, M055, M154, recorded higher grain yield under strip intercropping and sole cropping. SARC1-57-2 also recorded the highest grain yield under row intercropping. M048, M055, M076 M176 and SARI collection SARC1-57-2 were the top five genotypes in fodder production. Intercropping advantage compared to sole cropping was assessed and land equivalent ration (LER) > 1 was observed for all the genotypes with MAGIC 048 recording the highest LER of 1.824 at strip intercrop. MAGIC

048 and MAIGIC 055 in strip intercrop is therefore recommended to farmers since it gave the highest LER and Benefit cost ratio in the intercrop.

DEDICATION

I dedicate this work to my father Mr. Amadu Adam for his prayers and financial support throughout my course of study.

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Blessed be the name of the lord for his immense guidance and protection throughout my course of study. My sincere thanks go to Dr. Raphael Adu-Gyamfi for his constructive suggestions and directions which have greatly contributed to the success of this work. I am also grateful to Dr. Francis Kusi of the Savanna Agricultural Research Institute (SARI) of the Council for Scientific and Industrial Research (CSIR), Manga-Station, for his immense intellectual contribution and funding of this work.

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CHAPTER ONE:

1.0 INTRODUCTION

1.1 Background of the study

Intercropping maize with cowpea is a common practice among farmers in Northern Ghana. This exercise serves as a guard against total crop failure and ensuring food security. Moreover, harvesting of the cowpea before the maize is due for harvesting serves as a bridge to the "hunger gap" experienced by farmers as they await the harvesting of their cereals. Despite these benefits from cowpea-maize intercrop systems, farmers still suffer from the "hunger gap". This is due to the fact that they intercrop maize with late maturing, indeterminate and photoperiod sensitive cowpea varieties which are harvested after the maize is matured. An example is Kusaal Benga which is mostly cultivated in the Sudan Savanna zone of Ghana. However, the improved early maturing and determinate cowpea varieties available to the farmers which can be harvested between 55 and 60 days after planting are also not suitable for intercropping. This deprives the farmer's opportunity to utilize the space under the maize canopy to plant cowpea varieties that can be harvested early in the season to bridge the "hanger gap" during the growing season. Additionally, the spreading nature of the cowpea varieties used for the intercrop interferes with some agronomic practices of the farmers such as reshaping of ridges and weeding. It is therefore important to evaluate early and extra early cowpea varieties with the potential to bridge the hunger gap and not interfere with cultural practices needed to ensure healthy plant growth. In this regard Council for Scientific and Industrial Research – Savanna Agricultural Research Institute (CSIR-SARI) in collaboration with University of California, Riverside are phenotyping 300 Recombinant Inbred Lines (RILs) of Multi–parent Advanced

Generation Inter-Cross (MAGIC) cowpea population from eight elite cowpea cultivars in Northern Ghana. Among the traits being targeted in the phenotyping is extra early duration cowpea genotypes in Sudan Savanna zone of Ghana. The current study therefore evaluated the selected early and extra early cowpea genotypes from the MAGIC population in maize/ cowpea intercrop to identify genotype(s) that can maintain agronomic performance and grain yield.

1.2 Problem statement

Farmers in Northern Ghana do not have suitable extra early cowpea varieties to intercrop their maize, this makes them suffer from hunger during the period between planting and harvesting of their cereal crops.

1.3 Justification

The MAGIC population offer the opportunity for selection of high yielding early and extra-early genotypes for intercropping.

1.4 Objectives

General objective

The general objective of this study was to identify extra early maturing cowpea line(s) among the MAGIC cowpea population for intercropping with maize in Sudan Savanna zone of Ghana.

The Specific objectives were to:

a) To determine the growth and yield of component crops in maize cowpea intercrop

b) To identify cowpea genotypes with high and stable agronomic performance in cowpea- maize intercrop

c) To assess the economics of cowpea- maize intercrop using early and extra-early maturing genotypes of cowpea.

CHAPTER TWO:

2.0. LITERATURE REVIEW

2.1 Cowpea (*Vigna unguiculata* (L.)

2.1.1 Morphology of cowpea

Based on the investigation conducted by Padulosi and Ng (1997) and supported by Baudouin and Merechal (1985); and Padulosi (1987) about the range of variation and number of varieties found in wild cowpeas as well as their primitive characteristics, such as hairiness, small size of pods and seeds, pod shattering with pronounced exine on the surface of the pollen, out-breeding and bearded stigma. Variability in morphology of different cowpea accession is very high. There are three types according to their uses: for grain, forage or dual purpose. *Vigna unguiculata* is a herbaceous trailing, prostrate, climbing, bushy, or sub erect annual plant, growing 15-80 cm high. The lateral leaflet is opposite and asymmetrical, while the central leaflet is symmetrical and ovate. The inflorescences are racemose or intermediate at the distal ends of 5-60 cm long peduncles. The flowers are borne in alternate pairs, with usually only two flowers per inflorescence. These are conspicuous, self-pollinating, borne on short pedicels and the corollas may be white, cream, pink, pale, blue, yellow or purple. Flowers open in the early day and close at approximately midday. After blooding (opening once) they wilt and collapse. Growth pattern is either determinate or usually indeterminate under favourable conditions. Fruit are pods that vary in size, shape, colour and texture. They may be erect, crescent-shaped or coiled. They are usually slightly yellow when ripe, but may also be brown or purple in colour. Seeds are relatively large (0.2-1.2 cm long) and weigh 5-30 g/100 seeds. They are variable in size and shape: kidney, ovoid, crowder, globose and rhomboid (IBPGR, 1983). The testa may be smooth or wrinkled, white, green, buff, red, brown, black, speckled, blotched, eyed (hilum white surrounded by a dark ring) or mottled in colour. Seed shape is correlated with that of the pod. Pod length ranges from 8-22 cm with 10-20 seeds per pod. Depending on the variety of cowpea, the canopy heights can be 2-3 feet. The nodules of the roots are smooth and spherical, about 5mm in diameter, numerous on the main taproot and its branches but sparse on the smaller roots (Chaturvedi *et al*., 2011). Cowpea leaves are alternate and trifoliate with its first pair of leaves being simple and opposite. There is considerable variation in size (6-16 x 4-11 cm) with a linear, ovate shape and are usually dark green. The leaf petiole is 5-25 cm long. Striate, smooth or slightly hairy and sometimes tinged with purple are features attributed to cowpea stems. The flowers of cowpea are eye-catching, self-pollinating, borne on short pedicels and the corollas may be white, dirty yellow, pink, pale blue or purple in color (Fox and Young, 1982). Cultivated cowpea seeds types' weight between 80 mg and 320 mg and in shape range from round to kidney-shaped. The texture of cowpea seed coat varies (such as smooth, rough or wrinkled). Seed colour also varies (white, buff, green, cream, red, brown, black) Germination is epigeal, very quick and very high in cowpea seeds (Timko and Singh, 2008).

2.1.2 Geographic distribution of cowpea

Cultivated cowpeas are grown as warm-season-adapted annuals in tropical and subtropical zones (as defined by Hall (2001) in all countries in sub-Saharan Africa and in Asia, South America, Central America, the Caribbean, the United States and around the Mediterranean Sea. In subtropical zones temperatures are only suitable for cowpea in the summer, whereas temperatures are suitable year-round in tropical zones. The vast majority of the world's cowpea production (over 95%) takes place in sub-Saharan Africa, with about 12.5 million hectares under cultivation worldwide in 2014 (Singh *et al.*, 2002; FAOSTAT, 2014) Asia is the second largest producing region, representing less than 3% of the global production in average over the 1993-2014 period), most of it being cropped in Myanmar (FAOSTAT, 2014). In Africa, cowpea can be cultivated up to 1 800 m altitude but is mainly grown in the lowlands. The centre of maximum diversity of cultivated cowpeas and land races is found in West Africa in a region comprising the Sudan savannah zone of Nigeria (at 4 million ha, Nigeria has the largest area of cowpea cultivation according to FAOSTAT), central Burkina Faso, Ghana, Togo, northern Benin and the north-western part of Cameroon (Padulosi and Ng, 1997). Substantial cowpea cultivation also occurs in the semi-arid Sahelian zone, which is a transition zone between the Sahara Desert in the north and the Sudan savannah zone in the south. The Sahel encompasses northern and central Senegal and southern Mauritania in the west to central Sudan in the east, passing through central Mali, northern Burkina Faso, southern Niger (at 5 million ha, Niger has the largest area of cowpea cultivation) and central Chad. Significant cowpea production also occurs in the northern Guinea savannah zone and the forest and southern Guinea savannah zones of West Africa, the United Republic of Tanzania and Uganda, and some cowpeas are cultivated in central, southern and north-eastern Africa. In Asia, cowpea (“asparagus bean”) ranks as one of the top ten fresh vegetables. It is cultivated across a broad geographic range, except for some permanently cold regions. According to the FAO statistics, Myanmar is the main cowpea producer in Asia (FAOSTAT, 2014). China, India, Japan, Korea and Thailand are among the major asparagus bean-producing countries. The estimated annual cultivation area in Asia in total is 1 million ha, China alone making up roughly one-fifth of the world’s fresh pods production with over 1.5 million tonnes (equivalent to an additional 0.2 MMT of dry matter). Compared with the African cowpea, “asparagus bean” is more adapted to cool climates and is less tolerant to very high temperatures.

2.1.3 Cowpea production systems

Traditionally in West and Central Africa, and Asia, cowpeas are grown on small farms often intercropped with cereals by the small scale farmers. Most cowpea grown in the African region is intercropped with sorghum (Sorghum bicolor) or pearl millet (Pennisetum glaucum), and sometimes with other crops such as maize (Zea mays), cassava (Manihot esculenta) or cotton (Gossypium spp.) (Blade et al., 1996). The crop is typically planted at wide spacing (1 m) irregularly through young stands of the component cereal or other crop. Because the cowpea is planted after cereal crop establishment, at low density and without inputs, dry grain cowpea yields in the range of 300 kg/ha only are typically achieved in such systems. Fertilizers and pesticides are generally not used, because they are too expensive or not available for the small farmers. In Western Africa; Ghana, Mali, Niger and Nigeria both fodder and grain type varieties are grown sometimes as a pure crop and its commercial production is mostly done in these states. The cultivation of cowpea is mechanized in developed countries (Fery, 1985; Ajeigbe et al., 2010). In Senegal, most of the cowpea production is sole-cropped (Thiaw, Hall and Parker, 1993) in part due to the light sandy soils and availability of horse-drawn peanut seed drill which can easily be modified to plant cowpea in rows, making possible animal-draft cultivation to control weeds. In the last decade, an increasing portion of the cowpea crop in other parts of Africa has been planted in pure stand, at relatively higher density, using improved varieties and with agricultural inputs, especially insecticides, resulting in average yields of between 1-2 tonnes/ha. Strong demand for cowpea-based foods in urban areas and good prices are driving this transition to more intensified production practices. In Asia and Brazil, both sole-cropping and intercropping are practiced (Pandey and Ngarm, 1985; Watt, Kueneman and de Araújo, 1985), while in the United Statesgenerally only sole-crops are grown. In Brazil and India, some intercropping of cowpea is still practiced, but the majority of the crop is produced under sole-cropping with inputs. Cowpea production in the United States is entirely mechanised with machinery and agronomic practices adapted from other crops such as common beans or soybeans. Large growers in Brazil have adopted similar modern farming practices to produce high yields (Freire Filho et al., 2011).

2.1.3.1 Cowpea production in Ghana

Cowpea is an important component of sustainable cropping system in Ghana. It is cultivated for the leaves, green pods, grain and haulm for livestock feed. Cowpea provides 11 important sources of vegetable protein and minerals for over 70% of Ghana population and it is the second most important grain legume. It is currently a food security crop (MOFA, 2010). Thus, rotating or intercropping cowpea with crops such as maize, sorghum, millet and cassava contribute to the improve soil fertility. Sources of cowpea seeds for planting include market/traders, stored seed from own farm and from other farmers who preserve seeds for sale (ash is used to preserve seeds) (MOFA, 2005).

2.1.4 Effect of cowpea on cereal production

Cowpea when intercrop with cereals plays an important role in nutrient improvement, which is often practiced in sub-sahara Africa, Cultivated cowpeas have symbiotic relations with rhizobia and mycorrhizae that enhance the flow of reduced nitrogen and phosphate into the cropping system. These nutrients frequently limit the productivity of cereals in sub-Saharan Africa, and associated legumes can bring a beneficial effect. Certain cowpea genotypes can cause suicidal germination of the seeds of the weed parasite *Striga hermonthica*, which is a major pest of pearl millet, sorghum and maize that has been difficult to solve by other means (Singh and Matsui, 2002). Some cowpea genotypes can reduce the reproduction of certain plant parasitic nematodes (including *Scutellonema cavenssi*) that can damage pearl millet, sorghum and peanut (Germani, Baujard and Luc, 1984; Hall *et al.,* 2001). Consequently, cowpea can enhance the edaphic conditions and thus the productivity of the cereals and other crops that are grown in rotation or as intercrops with it. An increase in the area of cowpea cultivation over present levels in sub-Saharan Africa would not only benefit cereal productivity but also livestock production, whole farming systems and human nutrition and welfare.

2.1.5 Economic importance of cowpea

Cowpea is a multipurpose crop grown for both its grains and fodder making (FAOSTAT, 2008). The versatile nature of cowpea is such that it serves as food for the people, feed for their livestock and its nitrogen fixing ability improves the soil. Cowpea has a key contribution to ensuring food security, in a sustainable environment while generating income for millions of small scale cowpea farmers in Africa (Singh *et al.,* 2003). In the Saharan and sub - Saharan Africa where cowpea is produced, the grains serves as a rich source of protein in the diet and feed (Singh *et al.,* 2003) with about 24 % crude protein, 53% carbohydrate and 2 % fat (FAOSTAT, 2008), A meal containing one part of cowpea and three parts of cereal is near complete. In such a diet, cowpea plays the role of a protein source that is often economical than protein from animal source (Hall, 2012). In some parts of Africa especially Senegal, the intake of fresh ‘Southern pea’, prepared from cooking cowpea grains of green pods, has now become a common practice. Fresh ‘southern peas’ have become common in Senegal because of the introduction of extra early cowpea varieties that mature and are harvested, making the accessibility during the “hunger period” just before the harvest of cereals. About 30% of Senegal’s cowpea grains in the early 2000s were consumed as fresh ‘southern peas’ (Hall, 2012). Fresh cowpea leaves are consumed in sauces (Hall, 2012) in East Africa. It is a rich source of vitamins, minerals, carotenoids and phenolic compounds. These are important bio-active elements in foods that prevent occurrence of diseases like atherosclerosis and cancer (Hall, 2012).

Hay is prepared from the plants’ remains after harvesting the pods. Livestock farmers normally save this hay and feed it to their animals during the long dry season. The hay is also used to fatten animals for festivals and to upsurge their market value. In Niger cowpea hay fetches about half the price of the cowpea grain (Hall, 2012). Comparatively, cowpea is more productive on soils with little fertility and under low rainfall (Abayomi *et al.,* 2008) than most tropical cereals. Cowpea is used in rotation and inter-crop with cereals in most cropping systems in Africa. It does not only fix atmospheric nitrogen and augment the soil but also suppresses some populations of nematodes and *Striga hermontica* which causes considerable yield loss to most cereals (Hall, 2012). The very early maturity characteristics of some cowpea varieties provide the first harvest earlier than most other crops during production period. This is an important component in hunger fighting strategy, especially in the Sub-Saharan Africa where the peasant farmers can experience food shortage a few months before the maturity of the new crop. Its drought tolerance, relatively early maturity and nitrogen fixation characteristics fit very well to the tropical soils where moisture and low soil fertility is the major limiting factor in crop production (Hall, 2004; Hall *et al.,* 2002). This crop is grown worldwide with an estimated cultivation area of about 12.5 million hectares annually and an annual worldwide production of over 3 million metric tons (Li *et al.*, 2001). About 70% of the cowpea production occurs in marginal areas of West Central, East and Southern Africa.

Nigeria is the largest producer and consumer of cowpea at estimated annual yields of 2 million metric tons (Singh *et al.*, 2002; Timko *et al.*, 2008). In Tanzania, cowpea is regarded as a ‘women’s crop, because, contrary to other crops, the production process to marketing is often handled by women. Thus, it is among the crops that are generating income to female farmers and traders. Cowpea is among the dominating grains legumes traded almost in all local markets especially in the central, southern and western part of Tanzania. Significant amount of cowpea is also produced in Peru, northern Brazil, parts of India and the southeastern and southwestern regions of North America. The United States are estimated to produce about 80,000 metric tonnes (Fery, 2002).

2.1.6 Importance of extra-early maturing cowpea varieties

Singh et al. (2007) and Dugje et al. (2009) classified cowpea varieties that mature in less than 60 DAP as extra- early, 61-75 DAP as early and more than 80 DAP as late. Farmers’ preference for extra-early and early maturing cowpea cultivars in Sub-Saharan Africa is similar to other regions in the world and has been well documented (Singh et al., 2007).

In efforts to cope with rainfall risk in Sub-Saharan Africa, many small-scale farmers purposefully pursue multiple planting dates over extended periods of time in order to avoid total crop failure (Rorhrbach, 1998). Pswarayi and Vivek (2007) reported that, farmers grow early maturing crop varieties because such varieties provide an early harvest to bridge the hunger period before harvest of a full season crop. In Savanna regions of Sub-Saharan Africa, farmers adopt extra-early maturing varieties because they provide food security during the period of food scarcity in August/September; the emphasis is on earliness of crop maturity rather than on yield (Alpha et al., 2006). Extra-early maturing varieties are ideal for offseason plantings in drying riverbeds; they are also suitable for intercropping as they provide less competition for growth resources than the late maturing varieties (CIMMYT, 2000; FAOSTAT, 2013).

Singh et al. (1997) noted that extra-early varieties have opened the possibility of successful sole cropping in areas with short rainy season, double/triple cropping in areas with relatively longer rainfall, and relay cropping after millet, sorghum or maize as well as intercropping with cereals and root and tubers.

2.1.7 Nutritional value of cowpea

The protein found in cowpea is, similar as the one from other legumes, rich in the essential amino acids lysine and tryptophan (Timko and Singh, 2008). However, the protein nutritive value of these legumes is lower than that of animal proteins because they are deficient of sulfur amino acids and contain a non-nutritional factor (phytates and polyphenols), enzymes inhibitors (against trypsin, chymotrypsin and R-amylase) and hemagglutinins (Jackson, 2009). Minerals and vitamins are the other nutritional important constituents of the cowpea seeds. It has been reported that folic acid, a vitamin B necessary during pregnancy to prevent birth defect in the brain and spine content is found in higher quantity in cowpea compared to other plants (Hall *et al.*, 2003; Timko and Singh 2008). Total seed protein content in seed ranges from 23% - 32% of the seed weight (Nielsen *et al.*, 1993). The total crude protein in foliage ranges from 14-21% and in crop residues, it is 6-8%. This crop has no toxicity effect to ruminants, however for the monogastrics, trypsin inhibitors and some tannin need to be considered. Diet containing 20-25% untreated grain pose no problem, further more heat treatment reduces trypsin inhibitors (Cook *et al.,* 2005). The presence the high protein content in all cowpea parts consumable by human and animal (leaves, stems, pods and seeds), is the key factor in alleviating the malnutrition among women and children and improvement of healthy status of the livestock in resource limited households where regular access to animal protein is limited due to low economic status.

2.1.8 Constraints in cowpea production

Cowpea has a potential yield of about 3000 kg ha^{-1} however, cowpea is cultivated under the traditional system, considering the large yield differences (25 to 300 kg/ha) is produced from farmer's field in Savannah of sub Saharan Africa and (1500 to 2500 kg/ ha) in experimental stations (Ajeigbe *et al.,* 2010). It is also the second most essential leguminous crop in northern Ghana after groundnut and serve as an economical source of protein and income but yields are low, averaging 0.8MT/ha on farmers' fields (CSIR-SARI, Annual Report 2011). Cowpea is a hardy crop compared to other crops that will be unproductive when exposed to unfavourable conditions; nevertheless, production is still constrained by several biotic stress such as insect pests, disease infestations, root parasitic weeds, nematodes and abiotic stress which includes drought, low soil fertility, high salinity and post – harvest losses (CSIR-SARI, Annual Report 2011). Cowpea is susceptible to a wide array of bacteria, viral and fungal diseases and numerous insect pests (Singh, 2005). Aphids, thrips, maruca pod borer, a complex of pod sucking bugs and the storage weevil *Callosobruchus maculatus* are major insect's pest of cowpea. Other important constraints of cowpea in some areas are nematodes and parasitic weeds such as *Striga gesnerioides* and *Alectra vogelii* are a major limitation to the production of cowpea in Africa (Timko *et al*., 2007b). Both abiotic and biotic stresses can result in a significant yield reduction in cowpea. Despite cowpea being more drought tolerant than many other crops, still moisture availability is the major constraints to growth and development, especially during germination and flower setting. Erratic rainfall affects adversely both plant population and flowering ability, resulting into tremendous reduction of grain yield and total biomass in general (Timko and Singh, 2008).

Under these conditions, early maturing varieties could be the coping strategy. Insect pests, a wide range of bacterial diseases, fungal and viral diseases are further causative factor for yields losses experienced by cowpea growers. Under proper insect pest management the yields are as high as 2.0 t/ha compared to the low average yields (1.0 t/ha) normally experienced in subsistence farming in West and East Africa (Quin 1997; Timko and Singh, 2008).

The major constraints to cowpea production in Ghana are insect pests, diseases, drought and low soil fertility (ICRISAT, 2013). Kan‟ankuk‟a (1999) also identified absence of right strains of rhizobia in the soil as one of the constraints to cowpea production. Lack of inputs such as fertilizer, insecticides and improved seeds, poor cultural practices and lack of appropriate machinery for expanding planted area are other constraints experienced. Most cowpea crops are rain fed and although it is drought tolerant, cowpea farmers in the dry areas of sub-Saharan Africa obtain low yields, estimated at about 350 kg per hectare. The major insect pests in East Africa are aphids [*Aphis craccivora* Koch (Homoptera:Aphididae)], thrips (*Megalothrips sjostedti*), cowpea weevil [*Collosobruchus* *maculatus* Fabricius (Coleoptera: Bruchidae)] and a multiple of sucking bugs and leaf eating beetles.

In Tanzania, aphids are the major causing factor for significant yield losses. Early infestation, especially during seedling stage, often results in total crop failure. Also due to thrips infestation, a tremendous yield loss have been reported in Tanzania, Ghana, Cameroon and Nigeria (Ezueh 1981; Price *et al.*, 1983; Ta'Ama 1983). Omo-Ikerodah *et al.* (2009) stated that yield loss due to thrips infestation ranged between 20 to 80%. Under severe infestation, a 100% yield loss has been observed. The parasitic weed (striga) also poses a major threat to cowpea production in Africa. Two striga species and its distribution in Africa have been reported. *Striga gesneriodes* is mostly found in Sudan and West Africa, while *Alectra vogelii* is found in Guinea, Sudan, West and Central Africa and part of Eastern and Southern Africa (Timko and Singh, 2008).

2.1.9 Biological nitrogen fixation in legumes

Through the process called biological nitrogen fixation (BNF), which takes place in the atmosphere and released through decomposition of organic mineral is converted to ammonia. This process is done by means of rhizobial fixation in legumes by free-living diazotrophs. Ammonia is further converted by reduction and oxidation to the forms NH^{4+-} N and NO_3^{-} $^{-}$N respectively, which are available to plants (Zahran, 1999). The plant furnishes the necessary energy that enables the bacteria to fix gaseous N_2 from the atmosphere and pass it on to the plant for use in producing protein. During nodulation, host plants excrete flavonoids and bacteria Nod-protein recognize proper flavonoids, and initiate synthesis of Nod factor by a series of nod genes products (Date and Halliday, 1987). Nod factor, in return initiate early processes of nodulation. The first nodules form within one week after seedling emergence and become visible as they increase in size. After ten to fourteen days, the nodule bacteria are able to provide most of the plant's nitrogen requirements. The nodules allow fixation of atmospheric nitrogen but are energetically expensive to develop and maintain (Shantharam and Mattoo, 1997). Hence the host suppresses the growth of most potential root nodules soon after the initial bacterial invasion of root hairs (Spaink, 1995). It also further regulates nodule number in response to environmental factors such as the presence of nitrate or other sources of fixed nitrogen in the soil (Vandyk, 2003). The nodules which are red or pink in colour are effective while the nodules white in colour are ineffective, or have not yet developed to a stage at which they can fix nitrogen. The partnership is termed symbiotic nitrogen fixation (Adjei-Nsiah *et al.*, 2008). Biological Nitrogen Fixation **(**BNF) by legumes is a key process in External Input Agriculture (LEIA) technologies as it potentially results in a net addition of N to the system. However, the quantity of nitrogen fixed by legumes is difficult to quantify and varies according to the species involved and the location (Webster and Wilson, 1998). The average global use of N- fertilizer has increased from 8 to 17 kg N/ha for agricultural purpose since 1973 to 1988 (FAO, 1990) and this significant increase has occurred in both developing and developed countries (Peoples *et al.*, 1995).

The requirement for fertilizer N are predicted to increase in future, however, with current technologies for fertilizer application both economic and ecological cost of fertilizer usage will eventually become prohibitive. The importance of biological nitrogen fixation as a primary source of nitrogen for agriculture has diminished in recent decades as the amount of N fertilizer increased for the production of food and cash crops (FAO, 1990). In recent years, the international emphasis on environmentally sustainable development focuses on the use of renewable resources, which include attention on the potential role of biological nitrogen fixation for supplying nitrogen for agriculture (Zahran, 1999). Excess nitrogen delays maturity, promotes lush vegetative growth, reduce seeds yield and may suppress nitrogen fixation. Cowpeas perform well under low N condition due to a high capacity of N fixation. A starter N rate of about 12.25 kg/ha is sometimes required for early cowpea plant development on low N soils (Davis *et al*., 1991). Even though cowpea has the ability to fix atmospheric nitrogen, it requires a starter dose of nitrogen for early growth and establishment. Higher level of nitrogen tended to reduce the pod yield in their study. The authors highlighted that the reduction in yield at higher dose of nitrogen might be due to the excessive vegetative growth at the expense of pod production (Geetha and Varughese, 2001). Abayomi *et al*. (2008) reported that a parameter such as number of branches per plant, pod weight, plant height, number of pods per plant and shelling percentage were significantly improved by the application of nitrogen fertilizer and hence significant increase in grain yield. It was concluded that the application of inorganic fertilizer to cowpea is beneficial, although in a small quantity of 30 kg N ha^{-1}. Otieno *et al*. (2007) reported that when sufficient levels of nitrogen are present in the soil, nodulation is inhibited. Nitrogen fertilizer application significantly reduced the number of nodules and nodule dry weight per plant in most species during long rains. The addition of 20 kg N ha-1 as ammonium nitrate depressed nodulation and nitrogen fixation. Nitrogen is known to impact negatively on nodulation but phosphorus has been reported to improve nodulation. Rhizobia inoculation increased number of nodules and nodule dry weight per plant for most species but the increase in the nodulation was neither translated to dry matter accumulation in the shoot and root nor to the yield and yield components (Otieno *et al*., 2007). Dadson and Acquaah (1984) reported that in N deficient soils, smaller starter doses of applied N may stimulate nodule formation and enhance the grain yield of legumes. The low soil N status of the soils is expected to encourage a positive response to Rhizobium inoculation particularly in the presence of applied phosphorus. Nodulation of faba bean was markedly restrained by N fertilization at the later growth stage of faba bean but facilitated remarkably by inoculation, and the facilitation of intercropping on nodulation was erratic (Omar and Abd-Alla, 1994). Sangakkara and Marambe (1989) reported that inoculation increased nodulation of bush beans and to a lesser extent of mungbean. This effect was more evident with time. Nodulation was reduced in the presence of nitrogen fertilizer, and the effect was more pronounced in the extensively nodulating species, mungbean. Nitrogen and nodulation increased yield of both species. The study indicated the inability of bush beans to meet all nitrogen requirements by nodulation and nitrogen fixation alone. This suggests the need for some fertilizer nitrogen for tropical legumes, in addition to inoculation, to obtain yields (Sangakkara and Marambe, 1989). Otieno *et al*. (2007) reported that when sufficient levels of nitrogen are present in the soil, nodulation is inhibited. Nitrogen fertilizer application significantly reduced the number of nodules and nodule dry weight per plant in most species during long rains.

They further indicated that, the addition of 20 kg N ha^{-1} as ammonium nitrate depressed nodulation and nitrogen fixation in soybean. Nitrogen is known to impact negatively on nodulation but phosphorus has been reported to improve nodulation. Rhizobia inoculation increased number of nodules and nodule dry weight per plant for most species but the increase in the nodulation was neither translated to dry matter accumulation in the shoot and root nor to the yield and yield components (Otieno *et al*., 2007). Davis *et al*. (1991)

reported that cowpea, like all legumes forms a symbiotic relationship with a specific soil bacterium (Rhizobium spp). Rhizobium makes atmospheric nitrogen available to the plant by a process called nitrogen fixation. Excess nitrogen promotes lush vegetative growth, delays maturity, reduce seeds yield and may suppress nitrogen fixation. Cowpeas perform well under low N condition due to a high capacity of N fixation. A starter N rate of around 12.25 kg ha^{-1} is sometimes required for early cowpea plant development on low N soils (Davis *et al*., 1991).

Geetha and Varughese (2001) also reported that even though cowpea has the ability to fix atmospheric nitrogen, it requires a starter dose of nitrogen for early growth and establishment. Higher level of nitrogen tended to reduce the pod yield in their study. The authors highlighted that the reduction in yield at higher dose of nitrogen might be due to the excessive vegetative growth at the expense of pod production (Geetha and Varughese, 2001). Abayomi *et al*. (2008) reported that a parameter such as plant height; number of branches per plant, number of pods per plant, pod weight and shelling percentage were significantly improved by the application of nitrogen fertilizer and hence significant increase in grain yield. It was concluded that the application of inorganic fertilizer to cowpea is beneficial, although in a small quantity of 30 kg N ha^{-1}.

2.2.0 Maize (*Zea mays*)

2.2.1 Morphology of maize

Maize or corn (*Zea mays*) is a plant belonging to the family of grasses (*Poaceae*). It is a typical tropical plant with a tall, leafy structure having a fibrous root system, supporting a single culm with as many as 30 leaves. It is susceptible to invasion by weeds (Paliwal, 2000). The leaf axils in the upper part of the plant develop more prominently one or two lateral branches (Paliwal, 2000). These are terminated by a female inflorescence, a silk which develops into an ear well covered by the husk leaves which served as the storage part of the plant. In addition, the plant is terminated by a male inflorescence, the tassel with prominent central spike and many lateral branches with male flowers, all of which produce abundant pollen grains (Paliwal, 2000). Maize plant is an annual grass monocot which forms a seasonal adventitious root system bearing a single erect stem made up of nodes and internodes. However, some cultivars may develop elongated lateral branches or tillers that save as feeder to the root system. Maize height varies with varieties and its height ranges from about 0.5 to 5meters standing at flowering, but normally average height is 2.4m (Mejia, 2003). Maize plant produces one to four ears. Maize plant has distichous leaves which are produced in alternate position forming ranks of single leaves (Mejia, 2003). Each leaf consists of a sheath surrounding the stalk and an expanded blade connected to the sheath by the blade joint or collar. The leaves are held at right angles by the leaf blades and to the sun by stiff mid-ribs. Mejia (2003) reported that the outer surface of the leaf blade has little hairy structures for trapping solar energy and the internal surface is shiny and hairless with has a number of stomata for gaseous exchange and is hairiness and shiny. The male inflorescence which is the tassel forms at the top of the stem and is arranged in a loose panicle. The flowers are organised into paired spikelet into each spikelet there are two functional florets and each one has three anthers which contains pollen. Each male tassel may produce around 25 000 000 pollen grains this means that there are available for each kernel to be fertilized an average of 25 000 pollen grains on an average of 1 000 kernels per ear (Mejia, 2003).

2.2.2 Growth stages of maize

Maize like any other plant has what is referred to as growth stages during which the physiological, anatomical and morphological processes are noted. Maize has eleven growth stages and of the eleven, germination and emergence are stage zero while stages 6 to 10 occur after silking. In terms of crop management the stages are narrowed down to six incorporating, dry-down and grain harvesting (Colless, 1992). Notwithstanding, the vegetative growth stages are described by Paliwal (2001f) as Germination and emergence. The stages are as follows: Stage 1: approximately from zero to fourteen days after sowing depending on factors such as soil temperature and moisture, sowing depth and surface hardness. During this stage the radical emerges and one to two days after that the plumule breaks the seed coat. The plant develops seminal roots, a temporary root system until about the three leaf stage of the seedling. Six to ten days after planting the coleoptiles emerges from the soil, splitting the tip to allow the growth of the first foliage leaves and the shoot meristem remains below the soil surface. Stage 2: Early vegetative phase, about fourteen to forty two days after planting and this is marked by secondary or adventitious roots development from the first node below the soil surface. This develops into a thick, permanent fibrous root system reaching down to 1-2cm where some adventitious roots may also emerge from the above ground. The number of leaves that will develop on the plant, up to about 30, is determined (Irish and Jegla, 1997). The tassel begins to differentiate when about 5 leaves have emerged. The shoot meristem and the tassel primordium emerge above the soil surface by the six leaf stage and when eight leaves have fully emerged, the shoot meristem will be about 15cm above the soil. The lower leaves may start to senesce by the end of the stage. Stage 3: Late vegetative, about 42 to 60 days after sowing. This is the stage of rapid growth development, linear dry matter accumulation of both roots and leaves. During this stage there is a basic repeating unit structure comprising leaf blade, leaf sheath, node and internodes that make up the entire vegetative shoot. Internodes elongation produces a new leaf every 3-4 days. Eventually, the elongation of the lower internodes contributes to the formation of a stalk like structure that rises up through the leaf sheaths. By the end of stage 3, the 16th leaf will have reached full size, although it will not have fully emerged and the ears within the husks will be a few centimeters long. The first 5-6 lower leaves may senesce and cease to be functional.

The brace roots usually emerge from the lower, above ground nodes. The extent of brace root production is cultivar dependent as well as influenced by the planting and nutrition. Also, there is a correlation between the final number of leaves produced on a plant and the time between sowing and silking. The length of vegetative development is linked to the thermal interval between the appearances of successive leaf tips and differs according to the temperature found in latitudinal zones, being higher in tropical than temperate areas (Tojo Soler *et al.*, 2007). The first reproductive stage is the anthesis or male flowering stage when pollen shed begins while the last reproductive stage is referred to as physiological maturity which is identified by a black layer visible at the base of the grain.

2.2.3 Growth of maize in association with other crops

Maize has been recognized as a common component in most intercropping system. It seems to lead as the cereal constituent of intercrop and is regularly combined with dissimilar legumes (Maluleke et al., 2005). Maize yield is generally higher in high solar intensities, lower night temperatures and lower incidence of pest and diseases (Adesoji et al., 2013). Hongchun et al. (2013) reported that intercropping with maize did not disturb fresh weight of peanut associated with monocropping. Generally, several reports revealed that on the maize/groundnut combination is that g/nut yield is readily depressed by competition from Maize (Thayamini & Brintha, 2010). Conversely, ICRISAT reported a poor maize growth in Maize/Groundnut intercrop that was without N-fertilizer application, and there was no visual evidence of growth being any better if the groundnuts intercrop were present. However, where nitrogen was applied to the maize, the growth was suppressed (Thayamini & Brintha, 2010), and the residual benefits rapidly diminished (Rao & Willey, 1980). Bhagad et al. (2006) further emphasized that the yield Mechanisms of maize like length of cob and regular weight of cob were meaningfully higher once groundnut + sweet corn were intercropped in 3:1 ratio and provided with 125% RDF. Also Koli (1975) reported a little productivity of maize-groundnut mixture which he say was possibly due to relatively high maize population such that the nearness of maize to groundnut did not make for considerable spatial complementary among the two crops. Fresh weight of peanut associated with monocropping.

2.2.4 Importance of maize

Maize (*Zea mays*) is the most important cereal crop grown in Ghana and it is also the most widely consumed staple food in Ghana with increasing production since 1965 (FAO, 2008). It is the staple cereal for about 99% of Zimbabwe inhabitants. Farnham *et al.* (2003) indicated that maize comes first in production for both smallholder and large scale commercial producers, and also covers the largest area among all crops grown in Zimbabwe. Maize according to Farnham *et al.* (2003) is one of the crop species which is highly productive with the average yield of more than 4t/ha. Maize has more uses than any other cereal, as human food, as food grain, as fodder crop and for many industrial purposes because of its broad global distribution, prices reasonably low compared to other cereals, grain type are various and its wide range of biological and industrial properties (Downswell *et al.,* 1996). Isaac (2011) indicated that maize is very important as human food, constitutes about 70.4% carbohydrate and is used in different ways as a staple food. Maize can directly consume as food at various developmental stages from baby corn to mature grain. Fresh maize can be consumed boiled or roasted. Also crushed or pounded maize grain can prepare various foods. In the USA maize has various uses as human food, it is processed to number different consumable items like corn flakes, maize flours, and breakfast cereals are partially derived from maize (Downswell *et al.,* 1996).

Farnham *et al.* (2003) observed that in the tropics about 40% of the maize produced is for animal feeding and in developed countries more than 60% of maize harvested is used as livestock feeds. The relatively low price of maize compared to other cereals and its availability have contributed to its wide use in livestock feeds. Maize compared to other grains used in livestock feeds gives highest conversion ratio to milk, meat and eggs (Isaac, 2011). Also, maize is low in fibre contents and high in starch thus becoming an excellent energy source for livestock production. Maize is also used as fodder for livestock at different growth stages mainly from the early reproductive stage onwards and maize is a high energy forage crop (Isaac, 2011). Dried stalks and leaves of maize can be used as animal fodder which is called stover after harvesting of the grain.

Maize demands in industry is exponentially rising with industrial developments, it is becoming a vital industrial raw material for production of starch, gluten, oil, flour, alcohol and for further processing to produce a wider range of products and by-products (Makinde and Bello, 2009). White (1994) indicated that maize is the main starch source worldwide and is used as food ingredient, either in its natural form or when modified chemically. In industry maize is also an important raw material for production of ethanol and fuel. In brewing and fermentation based industries, manufacture of adhesives and pharmaceutical industries maize plays an important role as a raw material.

2.3.0 Intercropping as a practice

Intercropping is a type of mixed cropping and defined as the agricultural practice of cultivating two or more crops in the same space at the same time. Intercropping can be subdivided into four different categories. Grossman and Quarles (1993) divided intercropping into four basic spatial arrangements, which seem most practical:

i. Row intercropping: planting of two or more crops simultaneously with both crops planted in distinctive rows.

ii. Strip intercropping: planting of two or more crops together in strips wide enough to permit separate crop production practices using machines, but close enough for the crops to interact.

iii. Mixed intercropping: planting of two or more crops together without any distinct row arrangement.

iv. Relay intercropping: planting of a second crop into an already standing crop at a time when the standing crop is at its reproductive stage or has completed its development, but before harvesting. The primary objective of all farmers is to sustain production at reasonable levels and at low risks in order to sustain their needs (Beets, 1990).

Most of farmer's needs have increased due to the increased population and subsequent reduction in arable land per unit capita. Therefore, the important approach to increase agricultural production is to improve yield of individual crops per unit area at disposal. Farmers with limited resources have limited capacity to tolerate production failure and, therefore, are compelled to practice intercropping where a legume is combined with a cereal as a nutritious food and fodder source (Henriet *et al.*, 1997). Resource poor farmers mostly practice intercropping because of limited land but also for the beneficial interaction regarding chemical application. Sole crops require more chemicals to control insect pests and diseases and these chemicals (pesticides, herbicides and insecticides) may not be available even if financial resources are available (Singh and Adjeigbe, 2002).

2.3.1 Suitable crops in intercropping

Selection of the right crop combination is more important in intercropping systems due to the reason that competition of plant could be minimized not only by spatial arrangement, but also by combining those crops which have best able to exploit soil nutrients. Intercropping of cereals and legumes would be valuable because the component crops can utilize different sources of Nitrogen (N) (Chu *et al.*, 2004). The cereal may be more competitive than the legume for soil mineral N, but the legume can fix N symbiotically if effective strains of *Rhizobium* are present in the soil. However, some combinations have negative effects on the yield of the components under intercropping system. For example, Mucuna *(Mucuna utilis)* when intercropped with maize was found lowering down the maize yields, while cowpeas *(Vigna sinensis) and* greengram *(Phaseolus aureus)* had much less effect on maize and where themselves tolerant to maize shade Maize- bean intercrop is predominant in eastern Africa, and whilst in southern Africa maize is intercropped with cowpeas, groundnuts and bamabara nuts (Chu *et al.*, 2004).

2.3.2 Plant density in intercropping system

There is a correlation between population density of cereals and the yield of the various legume components in intercropping, when the population density of cereal increases there is growth and yield reduction in legumes, For instance, Ofori and Stern (1987b), reported that increasing maize density from 18000 to 55000 plants/ha reduced leaf area index by 24% and seed yield by 70% in the component bean. The plant involved will determine the total population required to obtain a yield advantage in intercropping. The total density can also be determined depending on the environmental resources and growth habits of the species. When there was severe drought, intercropping beans with maize resulted in greater stability of production, since any loss of plant density of one crop tended to be compensated by the other crop which is a major factor influencing the decision to intercrop When the component crop densities are approximately equal, productivity and efficiency of intercropping appears to be determined by the aggressively dominant crop. An experiment on the effect of plant densities of sorghum, spatial arrangement of component crops and fertilizer on growth and yield components of sorghum and bean (Phaseolus vulgaris) also showed significant differences on pod setting, pod retention, pod length, number of branches and nodulation of intercropped bean (Kassu, 1993). The results of field experiments conducted in Nigeria involving varying densities of sorghum and maize intercropped with soybean indicated that yields of component crops in the intercrop varied significantly with the components population density (Pal *et al.*, 1993). Most annual crops respond to population changes and this offers choice of planting density that result in better yields. Choice of plant population is vital so as to have less competition on component crops whilst maintaining a high proportion of the potential yield (Isaac, 2011). The required plant population of a particular crop in a mixture is governed by the crop species associated and temporal differences between two crops.

2.3.3 Crop geometry in intercrop

Crop geometry is the pattern of distribution of plants over the ground or the shape of the area available to the individual plant (Isaac, 2011). The arrangement and density of crops have to be manipulated to enhance complementarities and to minimize competition between component crops. Different arrangements of component crops in time and space are practiced in intercropping to reduce competition. Some farmers plant crops in strips intercrop to reduce difficulties in crop management like weeding, fertilizer application and also reducing shading effect.

2.3.4 Time of planting in intercrop

Time of planting of component crops is an important factor if advantage of intercropping is to be realized. Isaac (2011) reported that crops may be grown at the same time to serve as a guard against drought in areas prone to erratic rainfall and reduce competition between component crops. Singh *et al,* (2002) noted that planting may be done at interval to increase temporal differences which result in higher yield advantages. Date of planting depends upon several factors as soil moisture, time, and weather, labour constraints faced by farmer, variety and crop production system (Isaac 2011). Most studies have shown that the effect of competitions between crops is greatly reduced when their maximum demands on the environment occur at different times. Date of planting has a major effect on the yields of maize and cowpea (Sesay, 2000). Date of planting can change over time, due to changes in climate (Kucharik, 2006). The relationships between climate and planting date for maize can be useful for estimating planting dates in regions (Sacks *et al*., 2010). It was further reported that climate alone cannot fully explain farmer's choices about when to plant their crops. Planting date depends on the weather variability at the location and varies among years and locations (Saseendran *et al*., 2005). It was further reported that studies for determining planting date recommendations for a locality should be based on field experiments that have been done periodically with limited multiyear and multi-location replications (Saseendran *et al*., 2005). Fabunmi *et al*. (2012) study showed that cowpea height and canopy was significantly affected by planting date at two and five weeks after planting. Plant height of succeeding maize responded significantly to date of planting of preceding cowpea green manure at eight weeks after planting. Time of introducing cowpea into maize significantly affected the growth of cowpea (Adipala *et al*., 2002). The reduction in the growth of cowpea was due to increased shading from the maize plants especially when cowpea was introduced at the fourth week.

A study by Amujoyegbe and Elemo (2013) showed that the time of introducing cowpea in intercropping system had significant effect on canopy height of crops across seasons and locations. High cowpea canopy formation is attained when cowpea is planted together with maize. A study by Aziz *et al*. (2007) showed that late planting of maize reduced vegetative growth because of less photosynthetic activity at later stages of plant growth. Late planting of maize terminated vegetative growth and resulted in shorter plant with fewer and smaller leaves. Ofori and Stern, (1987) stated that yield decreased sharply as planting date was delayed in maize, while yields of cowpea were higher with a later planting date. Amjadian *et al*. (2013) indicated that planting date affected maize yield qualities such as grain weight, number of kernels number of rows and grain performance. The delay in planting time decrease number of grains per maize plant, number of rows and seed performance. Myaka (1995) reported that yield of cowpea was not significantly different when sown with maize or two weeks after maize, while yield was 67% lower when sown four weeks compared with two weeks after maize. According to Mariga (1990) cowpea sowing date did not affect grain yield of the maize intercrop and the best intercropping treatment was simultaneous sowing.

2.3.5 Maturity of component crops

The peak periods of growth should not coincide when two or more crops are grown together. Crops which mature at different times should be intercropped. Crops of different maturity periods should therefore be chosen so that early maturing crop completes its life cycle before the major growth period of the crop commences (Seran and Brintha, 2010). The component crops peak growth periods should not coincide to reduce competition on the resources. By this time there is high demand of nutrients to crops so these periods should differ to reduce competition on nutrients. Complementarity in an intercrop can occur when the growth patterns of the component crops differ in time or when they make use of resource in space. Isaac (2011) observed that nutrient competition in intercropping can be minimized by selecting the species with varying rooting patterns, different nutrient requirement and different time of high demand for nutrient and plant spacing.

2.3.6 Intercropping and nitrogen fixation

The overall benefit of growing two crops in a mixture is the net benefit in which the increase in growth of one crop exceeds a small competitive reduction in the growth of the other (Willey, 1979) and this is often seen where a slow growing legume is intercropped with a tall cereal. Competition for soil N between the cereal and legume components of the intercrop often results in the legume deriving a greater proportion of its N from N_2 – fixation, as demonstrated with pigeon pea/cereal intercrops (Tobita *et al*., 1994; Sakala *et al*., 2001).

For grain legume to play important role in soil fertility maintenance it must leave behind more nitrogen from N2- fixation than the amount of soil nitrogen that is removed by the crop. The amount of nitrogen added to the cropping system is very variable for all of legume species. The largest net benefits tend to found with groundnut and cowpea as some varieties of these crops have small nitrogen harvest index (Bell *et al*., 1994). A study in northern Nigeria indicated that maize grain yield was found to be greater following a groundnut than after cowpea, cotton or sorghum. The yield increase was related to an increased availability of mineral nitrogen in the soil after groundnut. The fact that no such beneficial effect was found after growth of cowpea in the same experiment indicates that residual effects do not always occur. Groundnut and cowpea were found to have roughly equal residual effects on the growth of a subsequent maize crop in northern Ghana, equivalent to the addition to 60 kg fertilizer nitrogen. This was despite the fact that 68 kg N ha^{-1} was left behind in above ground residues after groundnut and 150 kg Nha-1after cowpea (Dakora *et al*., 1987). Over 12 years, yields of sorghum were consistently higher following a sorghum/pigeon pea intercrop than after an oil crop safflower (*Carthamnus tinctorius*), and the soil nitrogen content had increased significantly where pigeon pea had been grown (Rego and Rao, 2000). Yield of maize grown after soybean on an Alfisol were increased to 4 tone ha-1, compared with only 1.8 tone in continuous maize cropping where all the legumes stover had been removed (Kasasa *et al*.,1999). There is little evidence for direct transfer of significant amount of nitrogen between roots of legumes and cereals in mixtures, and this conclusion is supported by measuring natural N abundance in intercrops of pigeon pea and sorghum (Tobita *et al*., 1994). Although pigeon pea loses large amount of nitrogen in leaves that fall during crop growth, the leaves cause an initial immobilization of soil nitrogen when they decompose and so little of the nitrogen is available for use by the intercropped cereal (Sakala *et al*., 2000). Although intercrops can produce greater yields, they generally do so by extracting more nutrients from the soil than sole crops (Mason *et al*., 1986) and may cause more rapid decline in soil fertility. Similarly, intercrops use more water for growth. When rainfall was adequate a cowpea /maize intercrop gave superior crop yields, but competition for moisture in a drought year caused drastic reduction in yields of intercropped maize (Shumba *et al*., 1990).

2.3.7 Assessment of intercropping systems

2.3.7.1 Land equivalent ratio (LER)

Hardter *et al*. (2008) reported that maize yields of the intercropping systems, especially of maize cowpea mixed cropping, were significantly lower than in sole cropping. They further indicated that, by reducing the seeding rates of each crop; the crops have a chance to yield well within the mixture. It is suggested that the most important practical situation is where intercropping is called on to produce higher total crop yields than where each crop component is grown separately. It was concluded that LER (Land equivalent ratio) is probably the most useful term at present available for assessing the advantage of intercropping.

When LER $\leq$ 1, intercropping is disadvantageous while LER $\geq$ 1 implies intercropping is advantageous (Benites *et al*., 1993). Better use of growth resource as a result of the complementary effect between component crops is considered to be a major source of yield advantage from intercropping (Willey, 2006). Zuo and Zhang (2009) reported that monocropping has maintained crop productivity through heavy chemical inputs including the application of fertilizers and pesticides. Monocropping has therefore resulted in substantial eutrophication, environmental pollution, a food security crisis and economic burdens on the farmer.

2.3.7.2 Income equivalent ratio

IER is similar in concept to LER, except that yield is measured in terms of net income, rather than plant product productivity (Bhatt et al., 2010). Because income is a function of both yield and crop price, even if the agronomic response is consistent, IER for intercrops may vary in different years as crop prices fluctuate. LER (or IER) can be determined for systems involving more than two crops by summing the intercrop to sole crop yield (or net income) ratios of each crop included in the intercropping system (Yayeh, 2015).

2.3.7.3 Intercropping and yield of component crops

Newman *et al*. (1997) reported that intercropping with maize in sub-arid regions is a way to grow a staple crop while obtaining several benefits from the additional crop. Intercropped maize may produce LER of 0.58 the yield of monocropped maize and intercropped beans may produce 0.67 LER the yield of monocropped beans. They further indicated that, when nitrogen fertilizer is not applied; intercropped legume will fix most of their nitrogen from the atmosphere and not compete with maize for nitrogen resources. High densities of maize maximized maize yield and calorie production, but high densities of beans maximize financial return (Ullah *et al*., 2007).

Chabi-Olaye *et al*. (2005) reported that maize monocrops had more stems tunnelled and more cob damage than intercropped maize. Each percentage increase in stem tunnelling under monocrop lowered maize grain yield by 1.10 and 1.84 g per plant. Maize yield losses due to stem borer were 1.8-3.0 times higher in monocrops than in intercrops. Khandaker (1994) reported that intercropping of maize and cowpeas is beneficial on nitrogen poor soil. The author reported that, maize yields were significantly not affected by intercropping with cowpea in that study. It was reported that, cowpeas planted three weeks after maize had significantly reduced yields during previous studies and therefore it was recommended to plant cowpeas with maize simultaneously (Khandaker, 1994).

2.3.9 Effects of fertilizer application in intercropping system

In cereals-legumes intercropping, the legume component is capable of fixing atmospheric nitrogen under favorable conditions and this is thought to reduce competition for nitrogen (Trenbath, 1976; Sakala *et al*., 2000). In the absence of an effective nitrogen fixing system, both the cereal and legume components compete for available soil nitrogen (Ofori and Stern, 1987a). In a maize cowpea intercropping system, Wahua (1983) found that at 105 kg N/ha, component crops exerted competition for nitrogen just before flowering. The competition for nitrogen was severe for cowpea at 40 days after planting and for maize 10 days later. In the same study it was indicated that nitrogen uptake of intercropped maize was reduced by 19% compared to sole maize. Pal and Shehu (2001) reported that the contribution of legumes to the total N uptake of maize in a mixture ranged between 25 to 28 in soybean, 24 to 29 in lablab, 20 to 22 in green gram, 18 to 19 in black gram, 1 to 5 in cowpea and 1 to 5 kg N/ha in groundnut, respectively. Senaratne *et al*. (1995) also reported that when cowpea, mung bean and groundnut were intercropped with maize, the proportion of N uptake by maize in the associated legume varied from 7-11% for mung bean, 11-20% for cowpea and 12-26% for groundnut which was about 19 to 22, 29 to 45 and 33 to 60 mg N/maize plant, respectively. The high N2 – fixation potential of groundnut and its relatively low harvest index for nitrogen apparently contributed to greater beneficial effect on nitrogen uptake of associated crops. Odoemana (1997) has found that Yam *(Dioscorea rotundata*) maintained higher value of protein as an intercrop with melon than sole cropping. Similarly, Bulson *et al*. (1996) reported that in a wheat/faba bean intercropping the nitrogen content of the wheat grain and whole plant biomass increased with the increase in faba bean density, thus resulting in a significant increase in grain protein. The addition of nitrogen to legume based intercrops generally favors growth of the non-legume at the expense of the legume. With minimal nitrogen, growth of the legume is less restricted than that of the non- legume (Cenpukdee and Fukai, 1991). Additional nitrogen directly antagonizes rhizobium N_2- fixation in the legume, it enhances lateral and vertical growth of the non-legume component. (Cenpukdee and Fukai, 1991). Greater competitiveness, however, does not necessary result in greater yields, especially in crops or varieties for which the harvest index is very sensitive to high nitrogen (Cenpukdee and Fukai, 1991). However, increased shading over the legume, with increase in competitiveness effected by nitrogen fertilizer application to the non-legume, does reduce the contribution of nitrogen fixation by the legume crop thereby reducing yield compared to mixtures without nitrogen fertilizer. Where the legume is responsive to added nitrogen and has the opportunity to shade the non-legume crop, yields of the non-legume may effectively decline at higher nitrogen application rates (Olasantan, 1991: Sakala *et al*., 2001). Nitrogen fixation in intercrop is influence by many factors such as soil moisture availability, plant population, and canopy structure of component species, and differential temporal demands for nitrogen by component crops. Consistent effects of nitrogen fertilization on the relative competitive abilities of maize and soybean across sites have been attributed to difference in soil moisture and nitrogen availability. The combination of high population density of maize and high fertilization caused shading and yield depression of cowpea when intercropped with maize (Chang and Shibles, 1985b). Data from Ofori and Stern (1987) suggest that intercropping efficiency is greater under low than high fertility.

2.4.0 Advantages and disadvantages of intercropping

Many researches have been done on intercropping systems and have proved its importance compared to the monoculture system. The principal reasons for farmers to intercrop are flexibility, profit maximization, risk minimization against crop failure, soil conservation and maintenance, weed control, balanced nutrition and effective utilization of resources (Shetty *et al*., 1995: Jarenyama *et al.,* 2000; Dhima *et al.,* 2007; Ofosu-Anim and Limbani, 2007; Muoneke *et al.,* 2007; Agegnehu *et al.,* 2006; Carrubba *et al.,* 2008; Launay *et al.,* 2009; Mucheru- Muna *et al.,* 2010). Viljoen and Allemann (1996) stated that some of the intercropping advantages over the sole cropping include: higher yields, probably due to more efficient use of environmental resources, greater yield stability, less intra-specific competition, better weed control, provision of insurance against total crop failure, improved quality by variety, also maize as a sole crop requires a larger area to produce the same yield as maize in an intercropping system. The legumes used in intercropping help farmers to fight soil erosion and the declining levels of soil organic matter and available N (Scott *et al*., 1987). Despite all these importance of intercropping it has got its draw backs, The major disadvantage is that intercropping is not well adapted to very dry, poorly drained and heavy clay soils and also implies difficulty in harvesting, using machinery (Prochaska, 2001) and Allelopathy, Recent yield declines in cropping systems has been attributed to allelopathic effects (El-Khawas and Shehata, 2005). There is difficulty in using machines to do operations such as weeding, sowing, fertilizer application and harvesting, these are made for uniform fields, therefore, intercropping on large scale using machinery is generally believed to be impossible although there are intercropping examples using modern machines that exists (Ghaffarzadeh, 1999 and Baumann, 2001). Cereal and legume intercropping performance requires critical investigation to know the cause of the inconsistency in areas where farmers are to benefit from intercropping in that specific locality (Mpangane *et al*., 2004). Intercropping maize with cowpea has been reported to increase light interception in the intercrops, reduce water evaporation, and improve conservation of the soil moisture compared with maize grown alone (Ghanbari *et al.*, 2010).

Improved resource use gives in most cases a significant yield advantage, increases the uptake of other nutrients such as N, P, K, and micronutrients, and provides better rooting ability and better cover-up ground as well as higher water use efficiency. Pandey *et al.* (1999) research on maize intercrop results showed that intercropping systems reduced the values of grain yield of maize than sole cropping of maize, but significant reduction in grain yield was recorded only with sesame, turmeric, and forage intercropping systems. However, all intercropping systems resulted into significantly higher productivity. Pathak and Singh (2006) also observed that the grain yield of maize was not significantly influenced by the different intercropping treatments at Pantnagar. Several researches have shown that intercrops are most productive when component crops differ greatly in growth duration (Fukai and Trenbath, 1993). For example, when a long-duration pigeon pea cultivar was grown in mixture with three cereal crops of different growth durations, i.e. setaria, pearl millet, and sorghum, the Land Equivalent Ratio was highest with the quick-maturing setaria and lowest with the slow-maturing sorghum. The efficiency of intercropping for using the environmental resources compared with monocropping is calculated using Land Equivalent Ratio. When the Land Equivalent Ratio is greater than one the intercropping favours the growth and yield of the species, whereas when the Land Equivalent Ratio is lower than one the intercropping negatively affects the growth and yield of the plants grown in mixtures (Willey, 1979: Willey, 2006).

2.4.1 Water use efficiency (WUE)

One of the most important factors determining productivity in legume/cereal cropping systems is the availability of water. Intercropping systems can allow for spatial and temporal increase in nutrients uptake (Flores-sanchez *et al.*, 2013). Cereals and legumes use water equally and competition for water may not be important in determining intercrop efficiency, except under unfavourable conditions, Water use by intercrops has mostly been studied in terms of water use efficiency (WUE) (Ofori and Stern, 1987). An intercrop of two crop species such as legumes and cereals may use water more efficiently than a monoculture of either species through exploring a larger total soil volume for water, especially if the component crops have different rooting patterns (Willey, 2006). Hulugalle and Lal (1986) reported that WUE in a maize/cowpea intercrop was higher than in the sole crops when soil water was not limiting. However, under water limiting conditions, WUE in the intercrop compared to sole maize can be higher resulting in retarded growth and reduced yield.

2.4.2 Nutrient use efficiency (NUE)

Intercropping maize with cowpea has been reported to increase light interception in the intercrops, reduce water evaporation, and improve conservation of the soil moisture compared with maize grown alone (Ghanbari *et al.*, 2010). It is unclear, however, if better nutrient uptake is the cause or the effect of higher yield potential (Willey, 1979). There is enhancement in the Fe nutrition of peanut intercropped with maize and it is mainly caused by rhizosphere collaboration between peanut and maize (Zuo *et al.*, 2009). Improved resource use gives in most cases a significant yield advantage, increases the uptake of other nutrients such as N, P, K, and micronutrients, and provides better rooting ability and better cover-up ground as well as higher water use efficiency.The inconsistency of cereal and legume intercropping performance requires critical investigation in areas where farmers are to benefit from intercropping in that specific locality (Mpangane *et al*., 2004). Recent efforts to improve soil fertility have been through the introduction of legumes as an intercrop and in rotation to minimize external inputs.

2.4.3 Insurance against crop failure

Another reason why farmers practice intercropping is its stability, intercropping is more stable than monocropping (Jarenyama *et al.*, 2000). When there is an extreme weather condition such as frost, drought, flood, intercropping provides high insurance against crop failure and provides greater financial stability for farmers, making the system particularly suitable for labor-intensive small farms. Thus, if a single crop may often fail because of adverse conditions such as frost, drought, flood, or even pest attack, farmers reduce their risk for total crop failure by growing more than one crop in their small farm (Clawson, 1985). Intercropping is also important that even if one crop from the mixture fails a farmer can harvest from the other crop. Intercropping has been found to increase crop yield and improve yield stability in environments where water stress are more common.

2.4 4. Conservation of soil

Intercropping systems control soil erosion by preventing rain drops from hitting the bare soil where they tend to seal surface pores, prevent water from entering the soil and increase surface runoff (Seran and Brintha, 2010). Kariaga (2004) mention that in maize + cowpea intercropping system, cowpea act as best cover crop and reduced soil erosion. Deep roots penetrate more breaking up hardpans into the soil and utilize moisture and nutrients from deeper down in the soil. Shallow roots bind the soil particle at the surface and thereby help to reduce erosion. Shallow roots help to aerate the soil which increase water holding. Reduced runoff and soil loss were observed in intercrops of legumes with cassava (El-Swaify *et al.*, 1988: Seran and Brintha, 2010).

2.4.5 Weed suppression

Intercropping helps in controlling weeds. Evidence of better weed control is pronounced where intercropping results in a more competitive effect against weeds either in time or space than what is done by mono-cropping (Seran and Brintha, 2010). The nature and level of crop weed competition varies considerably between mono and intercrop combinations. The crop species, population density, crop distribution, duration, growth rhythm of the component crop, the moisture and fertility status of the soil and tillage influence weed flora in cropping systems (Seran and Brintha, 2010). Crop weed competition is determined by growth habits of crop in the intercrop. Beets (1990), observed that increased leaf canopy cover in the intercrop system provide a shading effect which helps to reduce weed populations once crops have established fully. Mixed cropping reduces effect of weed incidences in cropping system (Zuofa *et al.*, 1992). Makindea *et al.* (2009) found that leafy greens when intercropped with maize lead to weeds control in the tropics and also result in increased productivity. Interception or solar radiation in intercrops is increased and accounts for maximising productivity of intercrop system and their greater competence to suppress weed competition than what mono-crops of either the component crops done (Mashingaidze *et al.*, 2000, Akobundu, 1993). Crop mixtures changes both quality and quantity of light and thus reducing the photosynthetic capacity of weeds. Shading results in a reduced incident light which lowers weeds photosynthetic capacity, also reduce the activity of ribulose-biphosphate carboxylase and chlorophyll content of weeds thereby limiting growth of weeds (Madumbu and Karavina, 2012).

Maize-pumpkin and maize-bean intercropping reduces weed biomass by 50-66% when established at a density of 12300 plants/ha for pumpkins and 222 000 plants/ha for beans (Mashingaidze, 2004). Sole maize crops were weeded twice or thrice to achieve the same weed biomass as intercrops weeded once showing that intercropping could reduce the weeding requirements of maize. The results of some studies have shown that in intercropping compared to mono-cropping result in more effectively use of resources and thereby reducing the amount of available resources channelled towards weeds for them to grow (Yadollahi *et al.*, 2014). Ghanbari *et al.* (2006) observed that in intercropping of maize and squash, weed control was more effective than in maize mono-crop. Weed suppression by crop interference has been referred to as one determinant of yield advantage of intercrop, being a possible alternative to reduce the dependence on use of herbicides in weed management (Agegnehu *et al.*, 2006, Banik *et al.*, 2006). Recent studies have addressed intercropping as an option for Integrated Weed Management (IWM), mainly in those farming systems which have low external inputs. Henrik *et al.* (2003) reported that weed density and biomass is noticeably reduced compared to sole cropping.

2.4.6 Improvement of soil fertility

Fixing of atmospheric nitrogen by legumes enrich soil by converting it from an inorganic form to forms that are available for plants to use. Biological nitrogen fixation of atmospheric nitrogen can replace nitrogen fertilization entirely or partly. Biological nitrogen fixation is the major source of nitrogen in legume-cereal mixed cropping systems when nitrogen fertilizer is finite (Fujita, *et al.,* 1992). Moreover, because inorganic fertilizers harm the environmental such as nitrate pollution, intercropping with legumes are regarded as a sustainable and alternative way of introducing nitrogen into lower input agro ecosystems (Fustec *et al.,* 2010). Furthermore, roots of the legume component can decompose and release nitrogen into the soil where it made available to subsequent crops (Lunnan, 1989). Intercropping corn with legumes was far more effective than corn sole to produce higher roughage for silage with better quality and dry matter yield (Geren *et al.,* 2008). Also, intercropping common bean with corn in 2 row-replacements improved protein content of forage and silage yield compared with monocropping (Lithourgidis *et al.,* 2007). The ash content of maize, dry matter yield, forage and crude protein increased yield by intercropping with legumes compared with maize sole cropping (Javanmard *et al.,* 2009). Furthermore, intercropping legumes with maize significantly reduced acid detergent fiber and neutral detergent fiber content, increasing digestibility of the forage. It is evident from the above that intercrops of maize with legumes can substantially increase forage quantity and quality and decrease the requirements for protein supplements compared with maize sole crops (Javanmard *et al.,* 2009). Maize and cowpea intercrops gave higher total forage dry matter digestibility than maize or cowpea sole crops and led to increased forage quality (crude protein and dry matter digestibility concentration) than maize monoculture and higher water-soluble carbohydrate concentrations than sole cowpea (Dahmardeh *et al.*, 2009).

2.4.7 Pests and diseases in intercropping

There are many pest and disease outbreak when crops are grown in monoculture, which might reduce when grown in intercrop. Maize is susceptible to many insects such as beetles, weevils, bollworms, chilo borers and stalk borers and the ones that suck plant sap such as leafhoppers and maize aphids (Drinwater *et al*., 2002). Stalk and leaf streak, dwarf mosaic and streak diseases and cob, tassel smut and root knot are common infectious diseases that affect maize (Flett *et al*., 1996). On the other hand Cowpea is normally affected by insects such as aphids, foliage beetles, thrips and legume pod borers (Adipala *et al*., 1999). Diseases such as rusts, viral diseases (e.g. athracnose) and scab blight being an important disease in cowpea (Edema, 1995). Pests find it very difficult to find their hosts because of visual disturbance for their search pattern and tend to stay for shorter times because of disruptive effect of landing on non-host plants resulting in slow survival. Intercropping cereal with cultivars resistant to airborne diseases has also been used to control rapidly evolving specialized fungal diseases such as rusts and mildews. Maize leafhopper (*Dalbus maindis*) was significantly reduced from different maize cultivars under intercropping (Power, 1990). The same results occurred with fungal spores on leaves, root parasitic nematodes (eelworms) intercepted by roots of hosts and non-hosts (Trudgill, 1991). Yield in bean was found to be declined by intercropping as well as aphid attack (Ogenga-Latigo *et al*., 1992a). The variability of yield improvement and insect pest control in intercropping systems relative to sole cropping have been inconsistent over component species, habits, varieties, row arrangement, moisture, soil fertility and density (Ayisi and Mposi, 2001). Ogenga-Latigo *et al*., (1992a, b) stated that higher plant densities were also reported to reduce aphid infestation under intercropping and there was a possibility that low viral disease(s) under these conditions were due to unfavorable microclimate for the aphids in intercrops).

2.4.8 Allelopathic effects

Allelopathy is defined as the direct or indirect release of chemical substances into the environment by one plant to harmfully affect another. Allelopathy can also be defined as the beneficial or harmful effect that is caused by one plant on other thus releasing chemicals from plant parts by leaching, root exudates, volatilisation, residue decomposition and other processes in both natural and agricultural systems (Ferguson and Rathinasabapathi, 2003). Allelopathy can affect many parts of the plant ecology such as plant occurrence, growth, and plant succession, the structure of the plant communities, dominance, diversity and productivity. The magnitude of the effect of allelopathy depends on the extent of any other stresses, such as environmental conditions or biological factors (insect or disease pressure) that occur during the growing season. Allelopathy also plays an important role in suppressing the growth of weed species (Reigosa *et al*., 2000). According to Creamer and Bennet, (1997) Cover crops when planted with cereals can take an advantage of allelopathic potential where they suppress the weed growth. The suppression of weeds through allelopathy has been shown to be species sensitive; therefore, a broader spectrum of weed control may be possible by growing a mixture of different crop species, each contributing allelopathic activity towards specific weed species. Commonly known effects of allelopathy include reduction in seed germination and seedling growth and there is no common mode of action or physiological target site for all allelochemicals (Ferguson and Rathinasabathi, 2003). However, there are some known sites of action for some allelochemicals including cell division, pollen germination, mutant uptake, photosynthesis, and specific enzyme functions. Allelopathic inhibition is complex and can involve the interaction of different classes of chemicals like phenolic compounds, flavinoids, terponoids, alkaloids, carbohydrates, and amino acids with mixtures of different compounds sometimes having a greater allelopathic effect than individual compounds alone. Most of the chemicals are found to be inhibitory and are caused by phytotoxic substances that are actively released from the living plants into the environment through root exudation, leaching, volatilization, and passive liberation through decomposition of plant residues. These phytotoxic substances, termed allelochemicals, are usually considered to be secondary metabolites and do not appear to play a role in primary metabolism essential for plant survival. Putman (1988) identified a number of classes of allelochemicals causing inhibition of germination and growth. Factors such as physiological and environmental stress, pests and diseases, solar radiation, herbicides, and less than optimal nutrients, moisture, and temperature levels can also affect allelopathic weed suppression.

Different plant parts can also have allelopathic activity that varies over a growing season and include flowers, leaves, leaf litter and leaf mulch, stems, bark, root, soil and soil leachates and their derived compounds. Allelochemicals can also persist in the soil, affecting both neighbouring plants as well as those planted in succession (Ferguson and Rathinasabathi, 2003). These allelopathy associated problems have been observed both in monocultures and multiple cropping systems. Continuous monoculture causes the accumulation of phytotoxins and harmful microbes in the soil that give rise to phytotoxicity and reduced soil fertility. A number of weed species possesses allelopathic properties, which have growth inhibiting effects on crops.

2.5.0 Economic benefits of cereal-legume intercropping systems

Segun-Olasanmi and Bamire, (2010) mentioned that maize-cowpea intercropping was found to be profitable than their sole crops. Intercropping system gave higher cash return to smallholder farmers than growing as the monocrops (Seran and Brintha, 2010). Gross economic returns were increased in maize-soybean intercropping system (Gunasena *et al.*, 1978). On the other hand, using monetary advantage index (MAI), Osman *et al.* (2010) reported that intercropping 1 row of millet and with 2 rows of cowpea gave significantly higher economic return than mixture with one row of each of the crops. Using the same MAI, losses are compensated and the income for smallholder farmers are increased due to uneven condition. Oseni (2010) found that intercropping with 1 row of cowpea and 2 rows of sorghum gave higher economic benefits compared to the other planting arrangements and sole cropping. These results suggest that intercropping could improve the system's productivity, Osman *et al.* 2010 and could enhance total productivity of the system with low input investment by changing planting configuration and density (Banik *et al.*, 2006). Ullah *et al.* (2007) found that soybean+maize in 90 cm spaced in a double row strips gave maximum maize grain equivalent yield and maximum land equivalent ratio. Dhima *et al.* (2007) found that bean+wheat (55:45) and bean+oat (65:35) as the most profitable intercropping system with higher intercropping advantages. Despite the benefits of cereal-legumes intercropping systems, there are some limitation that need to be solved so as to attain progress (Odendo *et al*., 2011; Bationo *et al.*, 2011; Mugendi *et al.*, 2011).

2.6.0 Productivity of intercropping system

2.6.1 Land equivalent ratio (LER)

Maize yields of the intercropping systems, especially of maize cowpea mixed cropping, were significantly lower than in sole cropping. By reducing the seeding rates of each crop; the crops have a chance to yield well within the mixture. It is suggested that the most important practical situation is where intercropping is expected to produce higher total crop yields than where each crop component is grown separately. LER (Land equivalent ratio) is probably the most useful term at present available for assessing the advantage of intercropping (Hardter *et al*., 2008).

LER is expressed in the following equation:

$$\text{LER}= \frac{cowpea\ intercrop\ yield}{cowpea\ sole\ yield} + \frac{maize\ intercrop\ yield}{maize\ sole\ yield} \text{------------} \textit{equation 1}$$

When LER ≤ 1, there is disadvantage in intercropping while LER ≥ 1 implies that there is advantage in intercropping over sole cropping (Benites *et al*., 1993: Willey, 2006). Better use of growth resource as a result of the complementary effect between component crops is considered to be a major source of yield advantage from intercropping (Willey, 2006). Monocropping has maintained crop productivity through heavy chemical inputs including the application of fertilizers and pesticides. Monocropping has therefore resulted in substantial eutrophication, environmental pollution, a food security crisis and economic burdens on the farmer (Zuo and Zhang, 2009).

2.6.2 Income equivalent ratio (IER)

Income equivalent ratio (IER) is similar in concept to LER, except that yield is measured in terms of net income, rather than plant product productivity (Bhatt *et al.*, 2010). Because income is a function of both yield and crop price, even if the agronomic response is consistent, IER for intercrops may vary in different years as crop prices fluctuate. LER (or IER) can be determined for systems involving more than two crops by summing the intercrop to sole crop yield (or net income) ratios of each crop included in the intercropping system (Yayeh, 2015). To calculate the IER market price or gross income (GI) obtained from intercropping a hectare of land were used. It is calculated by the formula developed by Ghaffarzadeh, (1997).

$$\text{LER}=\frac{GI\ per\ Ha\ of intercrop\ crop\ A}{GI\ per\ Ha\ of\ sole\ crop\ A}+\frac{GI\ per\ Ha\ of\ intercrop\ B}{GI\ per\ Ha\ of\ sole\ crop\ B}\text{-------------}\textit{equation 2}$$

2.6.3 Monetary advantage index (MAI)

Monetary advantage index suggests that the economic assessment should be in terms of the value of land saved; this could probably be most assessed on the basis of the rentable value of this land. It is also calculated to give some economic evaluation of intercropping as compared to sole cropping. The effective monetary advantage index (MAI) was calculated by the formula developed by Willey (1979).

MAI = value of combined intercropped yield x (LER -1)/LER-------------*Equation* 3

Effective monetary advantage index (EMAI) is calculated by multiplying the respective yields of the component crops by their lowest market prices during the experiment and divided by respective LER (Yayeh, 2015).

CHAPTER THREE:

3.0 MATERIALS AND METHODS

3.1 Experimental location and description of soil in the study areas

The experiment was conducted at the Manga Station of Council for Scientific and Industrial Research-Savannah Agricultural Research Institute (CSIR-SARI) in Upper East Region of Ghana. Manga is located within Latitude 11° 1’0’’ North and Longitude 0 ° 16’ 0’’ West with on elevation of 249 m above sea level (Asei, 2014), situated within the Sudan savannah ecological zone of Ghana. The Soil in the Upper East Region is underlain by granites interspersed with some pyroclastic rocks (Runge-Metzger, 1993). The soil type at the station is generally of Savannah ochrosol type. Features common to the soils at Manga include low fertility, low organic matter content, low pH and a moderately acidic, upper layer easily prone to erosion and quite permeable with moderately good water retention. The experiment was conducted from July 2018 to November, 2018.

3.2 Climatic condition during the experimental period

During the experimental period, minimum temperatures ranged from 20.9 °C to 23.2 °C, monthly rainfall distribution ranged between 0 mm to 277 mm and the total rainfall recorded was 788.6 mm, while relative humidity ranged between 28.5% and 99%.

Table 3.1: Mean monthly temperature (°C), rainfall (mm) and relative humidity (%) during the experiment

Month	Temperature (°C)		Rainfall	Relative humidity (%)	
	Minimum	Maximum	(mm)	Minimum	Maximum
July	23.2	-	243.1	68.75	99
August	23.3	-	207.5	72	98
September	23.1	-	277	73	98
October	23.3	-	61	62	95
November	20.9	-	0	28.5	68

Source: Ghana Meteorological Agency, Manga Station

3.3 Treatments and experimental design

There were three types of cropping patterns in this trial comprising of: Row intercropping, Strip intercropping and sole cropping. Ten cowpea lines from the MAGIC population were used (Table 3.2). The Ten cowpea lines were obtained from the Project leader of Feed the Future Innovation Laboratory for Climate Resilient Cowpea project at SARI and the maize variety used was Wang-Data which is well adopted in the Sudan Savanna Zone due to its earliness (90 days), drought and Striga tolerance. The experimental design used was split plot with three replications. The three cropping patterns were assigned to the main plots and the cowpea genotypes were assigned to the sub-plots measuring 4 m x 1.5 m (6m^2). In the row intercrop pattern, four rows of maize were planted at a spacing of 75 cm × 40 cm, then the cowpea was planted within the inner two rows of maize. Data were taken on the two inner rows where cowpea had complete shade from the maize.

In the strip intercrop pattern, two rows of maize and that of cowpea were planted in alternation such that there were two rows of sole cowpea followed by two rows of sole maize.

Table 3.2: Planting materials used

Cowpea genotypes and Maize variety	
MAGIC 008	MAGIC 118
MAGIC 043	MAGIC 154
MAGIC 048	MAGIC 176
MAGIC 055	CB27
MAGIC 076	SARC 1-57-2
Wang-data (maize)	

Table 3.3: Treatments used in the study

Row intercrop	Strip Intercrop	Sole cropping
MAGIC 008 + Maize	MAGIC 008 + Maize	Sole MAGIC 008
MAGIC 043+ Maize	MAGIC 043+ Maize	Sole MAGIC 043
MAGIC 048+ Maize	MAGIC 048+ Maize	Sole MAGIC 048
MAGIC 055+ Maize	MAGIC 055+ Maize	Sole MAGIC 055
MAGIC 076+ Maize	MAGIC 076+ Maize	Sole MAGIC 076
MAGIC 118+ Maize	MAGIC 118+ Maize	Sole MAGIC 118
MAGIC 154+ Maize	MAGIC 154+ Maize	Sole MAGIC 154
MAGIC 176+ Maize	MAGIC 176+ Maize	Sole MAGIC 176
CB27 + Maize	CB27+ Maize	Sole CB27
SARC 1-57-2 + Maize	SARC 1-57-2 + Maize	Sole SARC 1-57-2
		Sole WANG-DATA

3.4 Field preparation and planting of maize and cowpea

The experimental field was prepared by harrowing with tractor to a depth of 20 cm and later ridged with bullocks. Cowpea was planted ten days after the maize was planted since cowpea yields are higher with a later planting date (Ofori and Stern, 1987). Three maize seeds were sown at a depth of 5 cm at a spacing of 75 cm × 40 cm and thinned to two plants per hill at 2 weeks after planting. Three cowpea seeds were sown later at a depth of 5 cm at a spacing of 75 cm × 20 cm and thinned to two plants per hill at 2 weeks after planting.

3.5 Cultural practices carried out

Reshaping of ridges was done 27 days after planting the maize. Aphids and pod borer in cowpea were controlled by the use of lambda- cyhalothrine 15g/l + acetamipride 20g/l at the rate 1 L/ha. The field was sprayed three times to control insect pests. Weeding was carried out at 6 weeks after planting with hoe. Fertilizer was applied to the maize: Yara Actyva NPK fertilizer (20-10-10+ 3S) was applied nine days after planting at the rate of 125 kg/ha by side placement. Sulphate of Ammonia at the rate of 125 kg/ha was also applied to the maize 5 weeks after planting by side placement.

3.6 Soil sampling and chemical analysis

Five core soil samples were taken from the field before land preparation at a depth of 0-20. A composite sample was taken after bulking the core samples. The composite sample was air dried. Sample was sent to the soil laboratory in Nyankpala for analysis. Laboratory Physico-Chemical analyses were conducted on the soil samples collected from the experimental site.

3.6.1 Pre-treatment of soil for physico-chemical analysis

The soil samples were air-dried by placing in a shallow tray in well-ventilated area. Clay clods were broken and soil lumps crushed such that the gravel, roots and organic residues become separated. The crushed soil samples were sieved through a 2 mm sieve to a very fine soil samples.

3.6.2 Analysis of soil physico-chemical parameters

The soil physico-chemical properties that are considered in this research include; the pH and the particle size distribution, content, the level of nitrogen and organic Carbon content available phosphorus as well as available potassium and cation exchange capacity.

3.6.2.1 Determination of soil pH

Ten (10) g air- dried soil sample was weighed into a 100 ml beaker. 25 ml distilled water was added and the suspension stirred vigorously for 20 minutes. The suspension was allowed to stand for about 30 minute for the suspended clay to settle out from the suspension. The pH meter was calibrated with pH buffer 7 and 4. The electrode of the pH meter was inserted into the partly settled suspension. The pH value was then read and recorded.

3.6.2.2 Determination of soil particle size distribution

Bouyoucos Hydrometer method as modified by Day (1965) was used for this analysis. 51.0 g air – dried soil sample was weighed into a one – litre screw lid shaking bottle. 100 ml distilled water was added and the mixture swirled thoroughly to wet the soil .20 ml of 30 % H_2O_2 was added in order to destroy the soil organic matter and hence frees the individual classes of soil. 50 ml of 5 % sodium hexametaphosphate solution was added. This was followed by the addition of three drops of amyl alcohol and gently swirled to minimise foaming. The sample was shaken on a mechanical shaker for 2 hours and the content transferred into a 1000 ml sedimentation cylinder. Distilled water was added washings all soil particles to the sedimentation tube and was made up to the 1000 -ml mark with distilled water. First Hydrometer reading and the temperature were recorded after 40 seconds. The sample was allowed to rest undisturbed for ~~3~~ 2 hours. The second hydrometer and temperature readings were recorded again after this duration. The formula below was used to calculate the percent Sand, Silt and Clay and then the textural.

$$\% \text{ Sand} = 100 - [H1 + 0.2\,(T1 - 20) - 2] \times 2$$

$$\% \text{ Clay} = [H2 + 0.\,2\,(T2 - 20) - 2] \times 2$$

$$\% \text{ Silt} = 100 - (\% \text{ Sand} + \% \text{ clay})$$

Where

H1 = 1st Hydrometer reading at 40 seconds

T1 = 1st Temperature reading at 40 seconds

H2 = 2nd Hydrometer reading at 3 hours

T2 = 2nd Temperature reading at 3 hours

– 2 = Salt correction to be added to hydrometer reading

0.2 (T – 20) = Temperature correction to be added to hydrometer reading

3.6.2.3 Determination of phosphorous

-The available phosphorus was determined by Bray 1 method according to the procedure adopted by Bray and Kurtz, 1945. 5.0g of the soil sample was weighted into a 50 ml shaking bottle and 35 ml of Bray1 P extracting solution added. The content was shaken on a mechanical shaker for 10 minute. It was then filtered into a 100 ml conical flask using whatman no 42 filter paper. 5 ml of the filtrate was pipette into a 25 ml volumetric flask and 1.0 ml of molybdate reagent added after which 1.0 ml of the dilute reducing agent added to develop a blue colour solution. The content was top up with distilled water to the 25 ml mark. This was swirled for the content to mix well and solution allowed to stand for 15 minutes for colour to develop. The absorbance was then measured at 600 nm wavelength on a spectrophotometer. The level of phosphorus was therefore calculated by the formula below

$$\text{Available phosphorus (mg/kg)} = \frac{c \times 7}{ADW}$$

Where c = phosphorus concentration from a chart

ADW = Air dry soil sample weight (g)

7 = dilution factor

3.6.2.4 Organic carbon determination

The method employed for this analysis was based on the procedure used by Walkley and Black (1934). Under this method, 2.0 g of soil sample was weighted out into a 500 ml Erlenmeyer flask. Exactly 10 ml of 1.0 N Potassium dichromate solution was added, followed by 20 ml of concentrated H_2SO_4. The mixture was swirled such that the solution was in contact with all the particles of the soil. The flask and content were allowed to cool on an asbestos sheet for 30 minutes. 200 ml of distilled water and 10 ml of orthorphosphoric acid were added. This followed by the addition of 2.0 ml (of 10 ml) of diphenylamine indicator. This was titrated with 10 N ferrous sulphate solution until the colour changes to blue and then to a green end – point. The titre value was recorded and corrected for the blank solution (> 10.5)

Calculation

% organic C in soil = (m. e. $K_2Cr_2O_7$– m. e. FeSO4) x 0. 003 x f x 100 wt. of soil

Where

m. e. = milli equivalent = Normality of solution x ml of soln. used

0.003 = m. e. wt. of C

f = correction factor = 1. 33

3.6.2.5 Nitrogen analysis

The Kjeldahl method was used for the analysis. The method was partitioned into three main steps. It begins with digestion of the sample in concentrated sulphuric acid. The solution resulted from the digestion is distilled and the distillate titrated against an acid. In the case of this analysis, 10 g of air dried soil sample was weighted into a 500ml long – necked kjeldahl flask. 10 ml distilled water was added and the content allowed to stand for 10 minutes to moisten. One spatula full of kjeldahl catalyst was then added. This was followed by the addition of 30 ml concentrated H_2SO_4. It was allowed to digest until clear and colourless solution obtained. The flask was allowed to cool. The solution obtained was decanted into a 100 ml volumetric flask and make up to the mark with distilled water.10ml of the solution was pipette and transferred into the kjeldahl distillation apparatus.20ml of 40% NaOH was added and the distillate collected over 10ml of 4% Boric acid and three (3) drops of mixed indicator in a 500 ml conical flask for 4 minutes. The distillate was titrated with 0.1 N HCl till a blue colour changes to grey and then suddenly flashed to pink at the end point. A blank determination was included in the titration. The percentage nitrogen in the soil sample was calculated from the relation

$$\% \text{ Nitrogen} = \frac{14 \times (A - B) \times N}{1000 ms(g)} \times 100$$

Where

A = volume of standard HCl used in the sample titration

B = volume of standard HCl used in the blank titration

N = Normality of standard HCl

ms = weight of soil sample(g)

3.6.2.6 Analysis of potassium in the soil sample

The potassium content was determined using ammonium acetate method as prescribed by (Toth and Prince, 1949). Under this, 10 g of 2 mm sieved air dried soil sample was weighed into a 50ml centrifuge tube. 50ml of 1.0N NH4OAc was added and content shake in a mechanical shaker at 200rpm for 5 minutes. The suspension was filtered through Whatman No.2 filter paper and the filtrate collected into a beaker. The amount of the potassium was then determined by flame photometer at after calibration with standards. From the calibration curve prepared from potassium standard, the content of the potassium was determined.

3.7 Data collection

Five plants on each plot were randomly selected for data recording. The following data were collected during the experiment:

3.7.1 Cowpea data

The number of days to first flowering and 50% flowering:

Days to first flowering and 50% flowering for each plot were determined by recording from the date of sowing to the day when first flower was seen per plot and when 50% of the plants flowered.

Height of plant from ground level:

Plant height was measured from the ground level to the tip of the apical meristem during flowering. Plant height was measured using a meter rule.

Chlorophyll content:

For five selected plants chlorophyll content for each plant were recorded with SPAD meter as the chlorophyll content per plant for each treatment.

Biomass per plot:

Biomass weight was determined after harvesting by cutting the plants above the soil surface, then plants were dried and weighed to determine dry biomass yield per plot.

Pods per plant

For five selected plants number of pods for each plant were counted and recorded as the number of pods per plant for each treatment.

Seeds per pod

Five pods were randomly taken from each treatment and the seeds in each pod were counted and recorded as number of seeds per pod

Seed weight per plot (kg)

All the crop from a plant were harvested and seeds from each plot were weighed to determine weight of seed for each treatment.

100 seed weight (g)

A sample of 100 cowpea seeds were randomly selected from each plot, weighed to determine 100 seed weight for each treatment.

3.7.2 Maize data

Plant height

Plant height was measured from the base of the selected plants at soil level to the crest of the uppermost leaf at harvest when they have attained full height. Plant height was measured using a meter rule.

Number of plants harvested

The total number of plants from each treatment was counted at harvest.

Number of plants harvested

The total number of plants from each treatment was counted at harvest

Number of cob per plot

The number of maize cob harvested for each treatment per plot was counted and recorded.

Cob weight per plot

All the crop from a plant were harvested and cobs from each plot were weighed to determine weight of cobs for each treatment

Seed weight per plot

All the crop from a plant were harvested and seeds from each plot were weighed to determine weight of seed for each treatment

3.7.3 Economic indices

3.8.3.1 Land Equivalent Ratio (LER)

The ratio of land required by pure (sole) crop to produce the same yield as that of intercrop (Mead and willey, 1980) Land equivalent ratio was determined according to the following formula:

$$\text{LER} = \frac{yc\ in\ mixed\ stand}{yc\ in\ pure\ stand} + \frac{ym\ in\ mixed\ stand}{ym\ in\ pure\ stand} \text{------------------}\textit{equation 4}$$

Where:

LER = Land equivalent ratio

YC = Yield of cowpea crop

YM = Yield of maize crop

3.7.3.2 Estimated parameters for land equivalent ratio

Land equivalent ratio was calculated for the following genotype under row and strip intercrop, MAGIC008, MAGIC043, MAGIC048, MAGIC055, MAGIC075, MAGIC118, MAGIC154, MAGIC176, CB 27 and SARC 1-57-2.

The yields of individual maize in intercrop were compared with the yield of equivalent maize in monoculture. All obtained yields of cowpea in intercrops were also compared with the yield of cowpea in monoculture. Calculating of LER index was based on yield data of maize and cowpea genotypes in intercrop and sole cropping. All values of LER which were more than one indicate advantage or productivity of intercrops over sole cropping. When LER is lower than one the intercropping negatively affects the growth and yield of the crops grown in mixtures.

3.7.3.3 Net monetary returns and profitability

In other to determine the actual amount of income a farmer may receive from any given pattern, net monetary returns was calculated as :

$$NMR = Gross\ Monitoring\ Returns - Total\ Production\ Cost \_\_\_\_\_\_\_\_\_\_ Equation\ 5$$

Considering the cost of major activity on the farm such as land preparation, planting, fertilizer management, weed control and harvesting (Kermah et al., 2017). The Total Production Cost was obtained by totaling the cost of this activities as at the time of farming. Treatments were subjected to the same cost of management. Labour cost for each activity was based on the amount paid to a person to perform by-day in Manga and multiplied by the total man-days required to complete the activity. Grain prices were also obtained from local market surveys at harvest time when most farmers sell their produce.

3.7.3.4 Benefit cost ratio

In other to determine the cost effectiveness of each of the pattern of intercropping, cost benefit ratio was calculated using the formula by (Mondal *et al.*, 2012)

$$BCR = \frac{Gross\ Monetary\ Returns}{Total\ Cost\ of\ Production} \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Equation\ 6$$

3.7.3.5 Monetary advantage index (MAI)

Monitory advantage index (MAI) was calculated by multiplying the respective yields of the component crops by their lowest market prices during the experiment and divided by respective LER (Yayeh, 2015). It was calculated using the formula below:

MAI = value of combined intercropped yield x (LER -1)/LER-------------*Equation* 7

3.8 Statistical analysis

Data was subjected to ANOVA using GenStat software 12th edition statistical package. Mean separation was carried out using Least Significant Difference (LSD) test at 5% probability.

CHAPTER FOUR:

4.0 RESULTS

4.1 Soil analysis report

The soil at the experimental site had a soil pH of 5.6, organic carbon of 0.51%, nitrogen content of 0.03 %, phosphorus content of 1.44 mg/kg, potassium content of 24.00 mg/kg, calcium content of 0.90 cmol/k and magnesium content of 0.74 cmol/kg. These was about 13 times as much sand as clay and had a sandy loam texture.

Table 4.1 : Soil physical and chemical properties

				NH4Ac Extractable Cations			Soil Physical Properties			
pH (1:2.5 H20)	% O.C	% N	P(mg/kg)	K(mg/kg)	Ca2+ cmol/kg	Mg2+ cmol/kg	% Sand	% Clay	% Silt	Texture
5.6	0.5	0.03	1.4	24.0	0.9	0.7	83.9	6.4	9.7	Loamy Sand

4.2 Growth and yield of cowpea under intercropping with maize

4.2.1 Days to 50% flowering

Cowpea genotype, cropping pattern and their interactions had significant effects on the days to 50% flowering of cowpea plants (Table 4.2). Flowering date ranged from 36 – 46 days after planting. The earliest to attain 50% flowering was MAGIC 154 under sole cropping which was about 8 % and 6 % decrease in days to flowering under row and strip cropping respectively. (Table 4.3). On the average it took 38 days after planting for all the genotypes under sole cropping to attain 50% flowering which was about 5 percent decrease in flowering date than that of row intercrop. Days taken by sole cropping to flower was however not significantly different from the 39 days that all genotypes under the strip intercrop took to attain 50% flowering after planting. Flowering was late on the average for the genotypes under the row intercrop. For the flowering of the genotypes across the intercrop patterns, CB 27 attained 50% flowering first in about 37 days after planting which was significantly earlier than MAGIC 076 which was the latest and took about 6 extra days to flower. The genotype x intercrop interaction effect was clearly observed in the flowering of MAGIC 008, MAGIC 048, MAGIC 076 and MAGIC 176 which showed significantly different days to attain 50% flowering within the genotypes. The flowering of genotypes CB27, MAGIC 043 and SARC 1-57-2 were not influenced by the intercrop effect (Table 4.3).

Table 4.2 : F-statistics of the sources of variation for grain yield and yield components of cowpea

Effect	50% flowering	Height	Seed per pod	Pod per plant	100 seed weight	Maturity	Grain yield	Biomass yield
Genotype (G)	<.001	<.001	<.001	<.001	<.001	0.023	<.001	<.001
Cropping pattern (C)	0.032	<.001	0.004	<.001	0.001	0.684	<.001	<.001
G x C	<.001	<.001	0.206	<.001	<.001	0.072	<.001	<.001

Table 4.3: Interaction effect of genotypes and cropping pattern on flowering of cowpea.

Genotype	Days to 50% flowering			
	Row (a)	Strip (a)	Sole	Genotype mean
CB27	38 (3)	37 (0)	37	**37**
MAGIC 008	42 (10.5)	39 (2.6)	38	40
MAGIC 043	38 (2.7)	38 (2.7)	37	37
MAGIC 048	41 (10.8)	38 (2.7)	37	39
MAGIC 055	39 (5.4)	40 (8.1)	37	38
MAGIC 076	43 (-6.5)	39 (-15.2)	46	**43**
MAGIC 118	41 (7.9)	39 (2.6)	38	39
MAGIC 154	**39 (8.3)**	**38 (5.6)**	36	38
MAGIC 176	42 (13.5)	40 (8.1)	37	40
SARC 1-57-2	38 (2.7)	39 (5.4)	37	38
Mean of pattern	40 (**5.3**)	39 (2.6)	38	

LSD (0.05) Intercrop= 1, Genotype=2, interaction=3, CV = 4%

G, Genotype; I, Intercrop pattern; LSD, Least Significant Difference; CV, Coefficient of Variation

a (% increase in flowering date relative to sole cropping)

4.2.2 Height (cm)

Genotype, cropping pattern and their interactions, all significantly (P=0.001) had effect on cowpea plant height at 5 WAP. Plant height increased between 34% and 432% under intercropping compared to sole cropping. Among all the cropping patterns, SARC 1-57-2 under row intercrop recorded the highest plant height which was about 432% increase in height relative to SARC 1-57-2 under sole cropping (Table 4.4). MAGIC 076 under the sole cropping recorded the shortest plants. It was generally observed that averaging the heights across genotypes, plants tend to be taller in the maize-cowpea intercrops than under the sole cropping with row intercropping recording higher height which was about 154 % increment relative to sole. Strip intercropping also had about 85% increase in height relative to sole cropping. Although the plant heights of CB27 and MAGIC 043 at strip were higher than their counterparts in the row intercrop, the differences in these heights were not statistically significant. Although MAGIC 008 produced the shortest plants when averaged across intercrop patterns, it was not significantly different from MAGIC 043, MAGIC 048, MAGIC 076 and MAGIC 154 (Table 4.4).

Table 4.4: Interaction effect of genotypes and cropping pattern on plant height of cowpea

	Plant height (cm)			
Genotype	Row (a)	Strip (a)	Sole	Genotype Mean
CB27	48.9 (111.7)	51.3 (122.1)	23.1	41.1
MAGIC 008	41.0 (87.2)	39.1 (78.5)	21.9	34.0
MAGIC 043	39.5 (63.9)	50.1 (107.9)	24.1	37.9
MAGIC 048	48.0 (108.7)	36.5 (58.7)	23.0	35.8
MAGIC 055	55.3 (119.4)	42.6 (69.1)	25.2	41.1
MAGIC 076	55.1 (155.1)	31.5 (45.8)	21.6	36.1
MAGIC 118	77.9 (224.6)	53.1 (121.3)	24.0	51.7
MAGIC 154	44.5 (73.2)	34.5 (34.2)	25.7	34.9
MAFIC 176	54.6 (128.5)	45.8 (91.6)	23.9	41.4
SARC 1-57-2	**141.9(431.5)**	56.5 (111.6)	26.7	75.0
Pattern Mean	60.7 (154.0)	44.1 (84.5)	23.9	
LSD (0.05) Intercrop= 5.971, Genotype= 6.417, interaction= 11.394, CV =15.8%				

G, Genotype; I, Intercrop pattern; LSD, Least Significant Difference; CV, Coefficient of Variation a (% increase in plant height relative to sole cropping)

4.2.3 Chlorophyll content

The genotype, cropping patterns and their interactions (P=<.001) had significant effect on the chlorophyll content of cowpea. Averaged across cropping patterns, SARC 1-57-2 had higher SPAD reading than all the genotypes while CB 27 produced the least chlorophyll content among all the genotypes. Among the M series three genotypes, M008, M154 and M 176 recorded high chlorophyll content. Chlorophyll contents were also higher in sole cropping pattern relative to the row and strip pattern with reduction of 40.1 % and 12.5 % respectively when averaged across genotypes (Table 4.5).

Table 4.5: Interaction effect of genotypes and cropping pattern on SPAD reading (chlorophyll content) of cowpea.

Genotype	Cropping pattern			
	Row (a)	Strip (a)	Sole	Genotype Mean
CB27	43.1	48.6	52.7	**48.1**
M008	60.0	65.5	67.0	64.2
M043	42.2	33.6	52.7	42.8
M048	44.8	56.8	63.0	54.9
M055	53.4	60.9	65.7	60.0
M076	48.8	51.8	55.7	52.1
M118	36.4	48.1	63.0	49.1
M154	53.2	67.7	80.3	67.1
M176	41.5	70.7	78.0	63.4
SARC 1-57-2	50.3	86.4	86.0	**74.2**
Pattern Mean	47.4 (40.1)	59.0 (12.5)	66.4	

LSD (0.05) Intercrop= 7.5, Genotype=6.7, interaction=12.3, CV = 12.3%

G, Genotype; I, Intercrop pattern; LSD, Least Significant Difference; CV, Coefficient of Variation

a (% decrease in chlorophyll content relative to sole cropping)

4.2.4 Maturity of cowpea

Maturity under the different cropping patterns were not significantly different (p=0.684) for cowpea. The genotypes took between 58 and 59 days to mature.

4.2.5 Number of pods per plant

There were significant genotype and cropping pattern interactions effect (P=0.001) on the number of pods per plant of cowpea. Generally, significantly higher numbers of pods per plant were produced under the strip intercrop than the other cropping patterns when averaged across genotypes (Table 4.6). With the exception of SARC 1-57-2 and MAGIC 076, all the genotypes produced their highest number of pods under strip intercrop. Similar to the trend of the grain yield, SARC 1-57-2 produced its highest number of pods under the row intercrop which significantly decreased moving to the strip then the sole. On the other hand, MAGIC 076, produced its highest number of pods under sole cropping but was not significantly higher than the pods under the strip intercrop. The number of pods per plant produced by MAGIC 076 under the row intercrop was significantly lower than what it produced under the sole cropping and strip intercropping. The results also showed that the genotypes generally produced significantly fewer pods under the row intercrop, thus the least number of pods per plant recorded under the row intercrop when averaged across the genotypes. Although the number of pods produced per plant significantly differed for a genotype grown under different maize-cowpea intercrop patterns. The number of pods per plant produced by MAGIC 118 did not significantly differ across the different cropping patterns (Table 4.6).

Table 4.6: Interaction effect of genotypes and cropping pattern on number of pod of cowpea

Genotype	Pod number			
	Row	Strip	Sole	Genotype Mean
CB27	12	17	18	16
MAGIC 008	13	33	33	27
MAGIC 043	22	28	24	25
MAGIC 048	12	34	24	23
MAGIC 055	12	32	26	23
MAGIC 076	10	15	17	14
MAGIC 118	13	14	14	14
MAGIC 154	11	23	21	18
MAGIC 176	11	24	20	18
SARC 1-57-2	34	30	22	24
Pattern Mean	15	25	22	

LSD (0.05) Intercrop= 2, Genotype=2, interaction= 3 CV (%) = 10 %

G, Genotype; I, Intercrop pattern; LSD, Least Significant Difference; CV, Coefficient of Variation

4.2.6 Number of seeds per pod

Although no significant genotype x cropping pattern interactions effect (P=0.206) was observed for number of seeds per pod, there were significant differences for the genotype (P=0.001) and cropping pattern (P= 0.004). The results of the number of seeds per pod of the cowpea genotypes are presented in Table 4.7. The highest number of seeds per pod was recorded in MAGIC 154 which was significantly higher than that of MAGIC 008. The number of seeds per pod of M154 was however not significantly higher than MAGIC 048, MAGIC 055 and MAGIC 176. The results of the intercrop pattern main effect on the number of seeds per pod are presented in (Table 4.7). The highest number of seeds per pod was recorded under strip intercrop when averaged for all the genotypes. Generally, the number of seeds per pod decreased significantly from strip to sole to row intercrop.

Table 4.7: Effect of cowpea genotype and cropping pattern on number of seed per pod

Genotype	Seeds per pod
CB27	12
MAGIC 008	9
MAGIC 043	11
MAGIC 048	12
MAGIC 055	12
MAGIC 076	12
MAGIC 118	11
MAGIC 154	13
MAGIC 176	12
SARC 1-57-2	11
LSD (0.05)	1
CV (%)	2
Intercrop pattern	Seeds per pod
Row	10
Strip	12
Sole	12
LSD (0.05)	1
CV (%)	3

4.2.7 100 Seed weight (g)

Hundred seed weight, a measure of seed size was assessed for the study. Genotype, cropping pattern and their interactions significantly influenced100 seed weight of cowpea ($P<0.001$). In terms of the cropping patterns, the lowest 100 seed weight was recorded for the average of all the genotypes under row intercrop (Table 4.8). The 100 seed weight of the genotypes when averaged under the control (Sole cropping) was significantly higher than that of the strip and the row intercrop (Table4.8). Averaging across the cropping patterns, SARC 1-57-2 had the highest 100 seed weight while MAGIC 076 had the lowest 100 seed weight. CB 27 under the sole cropping had the highest 100 seed weight but was not significantly different from that of SARC 1-57-2. The lowest 100 seed weight recorded in the study was for MAGIC 076 under row intercrop (Table 4.8). With the exception of MAGIC 055 which had its highest 100 seed weight under strip intercrop, all the other genotypes had their highest 100 seed weight under the sole cropping.

Table 4.8: Interaction effect of genotypes and cropping pattern on 100 seed weight of cowpea.

Genotype	100 seed weight (g)			
	Row	Strip	Sole	Genotype Mean
CB27	14.60	14.07	19.00	15.89
MAGIC 008	11.33	11.50	12.73	11.86
MAGIC 043	11.63	13.40	15.17	13.40
MAGIC 048	11.53	12.07	12.63	12.08
MAGIC 055	14.17	14.77	13.33	14.09
MAGIC 076	10.80	11.70	11.23	11.24
MAGIC 118	12.20	11.43	13.33	12.32
MAGIC 154	11.63	11.90	12.33	11.96
MAGIC 176	11.93	12.07	13.37	12.46
SARC 1-57-2	15.97	18.00	18.27	16.86
Pattern Mean	12.58	13.28	14.14	13.33
LSD (0.05) Intercrop= 0.4146, Genotype= 0.8238, interaction= 1.3843, CV = 6.5%				

G, Genotype; I, Intercrop pattern; LSD, Least Significant Difference; CV, Coefficient of Variation

4.2.8 Cowpea grain yield (kg/ha)

The genotype, cropping patterns and their interactions (p=0.001) had significant effect on the grain yield of cowpea. Averaged across cropping patterns, MAGIC 055 had the highest grain yield which was about half a tonne more than MAGIC 118 which produced the least grain yield among all the genotypes. Percentage yields of intercropping relative to sole cropping ranged between 11.7 and 77.5. Averaged across genotypes, percentage yields for row and strip intercrop relative to sole were 18.2 and 54.9 respectively. The average yield of cowpea genotype at sole cropping was about twice the yield at strip intercrop and about six times at row intercrop. (Table 4.9).

Table 4.9: Interaction effect of genotypes and cropping pattern on grain yield (kg/ha) of cowpea.

	Intercrop pattern			
Genotype	Row (a)	Strip (a)	Sole	Genotype Mean
CB27	338.8 (20.7)	801.3 (48.9)	1638.2	926.1
M008	271.1 (13.4)	1022.8(50.7)	2015.7	1103.2
M043	353.1 (23.5)	874.5 (58.8)	1503.1	910.2
M048	293.4 (11.7)	1437.3(57.5)	2501.3	1410.7
M055	365.3 (14.0)	1426.7(54.7)	2610.1	1467.4
M076	267.7 (16.3)	786.1 (47.8)	1644.6	899.5
M118	308.4 (22.7)	675.2 (49.7)	1359.6	781.1
M154	262.4 (12.8)	1072.1(52.4)	2047.4	1127.3
M176	287.6 (18.8)	846.5 (55.4)	1528.7	887.6
SARC 1-57-2	564.2 (42.0)	1041.9(77.5)	1343.7	983.3
Pattern Mean	331.2 (18.2)	998.4 (54.9)	1819.2	

LSD (0.05) Genotype =20.56, Intercrop = 20.56, Interaction (G*I) = 74.27 CV (%) = 4.0%

G, Genotype; I, Intercrop pattern; LSD, Least Significant Difference; CV, Coefficient of Variation a (percentage yield relative to sole cropping)

4.2.9 Cowpea biomass (kg/ha)

The genotype, cropping patterns and their interactions (p=0.001) had significant effect on plant biomass of cowpea. Percentage biomass yield for intercropping relative to sole cropping ranged between 19.7 and 68.8. MAGIC 055 recorded the highest biomass yield when averaged across cropping pattern which was about twice the biomass yield for M118 which had the least. A trend was observed in all the genotypes where biomass yield reduced from sole cropping to strip intercrop and to row intercrop. (Table 13).

Table 4.10: Interaction effect of genotypes and cropping pattern on biomass of cowpea (kg/ha)

Genotype	Intercrop pattern			
	Row (a)	Strip (a)	Sole	Genotype Mean
CB27	1384 (30.1)	2425 (52.7)	4604	2804
M008	2055 (31.2)	3741 (56.8)	6585	4127
M043	1624 (30.8)	2697 (51.2)	5267	3198
M048	2204 (30.3)	3815 (52.5)	7263	4428
M055	2586 (33.1)	3941 (50.5)	7808	4778
M076	2395 (30.8)	3787 (48.7)	7771	4651
M118	1171 (29.6)	2183 (55.2)	3957	2437
M154	1481 (23.2)	3462 (54.3)	6372	3772
M176	1271 (19.7)	3845 (59.5)	6467	3861
SARC 1-57-2	2338 (42.6)	3774 (68.8)	5484	3866
Pattern Mean	1851 (30.1)	3367 (54.7)	6158	

LSD (0.05) Intercrop=96.9 , Genotype=103.5 , interaction=183.9 CV = 3.3%

G, Genotype; I, Intercrop pattern; LSD, Least Significant Difference; CV, Coefficient of Variation

a (percentage yield relative to sole cropping)

4.3 Growth and yield of maize intercropped with cowpea

4.3.1 Height of maize

Plant height of maize was not affected significantly by genotype, cropping patterns and their interactions (p=0.283). Though no significant difference was observed maize height in row intercrop were relatively taller than their respective height in strip and sole cropping (Table 4.11).Percentage increase in height in row intercrop ranged between 7.5 and 18.9 while there was increase and decrease in height at strip intercrop relative to its sole cropping.

Table 4.11: Effect of cropping pattern on plant height of maize

Genotype	Intercrop pattern	
	Row (a)	Strip (a)
CB27+maize	180.7(18.9)	164.7(2.9)
M008+maize	169.9(11.8)	157.0(-1.9)
M043+maize	177.5(16.8)	161.4(0.8)
M048+maize	179.7(18.2)	161.4(0.8)
M055+maize	178.7(17.6)	155.5(-2.9)
M076+maize	167.3(10.1)	162.9(1.7)
M118+maize	163.4(7.5)	159.7(-0.2)
M154+maize	169.2(11.3)	159.1(-0.6)
M176+maize	177.0(16.4)	158.9(-0.7)
SARC 1-57-2+maize	180.1(18.5)	161.7(1.0)
Sole maize	152.0	160.1
Mean	172.3	160.2

LSD (0.05) Intercrop=30.92 , Genotype=16.70 , interaction=27.86 CV =1 %

G, Genotype; I, Intercrop pattern; LSD, Least Significant Difference; CV, Coefficient of Variation, a (% increase in height relative to sole cropping)

4.3.2 Grain yield of maize

There were significant differences between grain yield of maize under the various cropping pattern (p=0.001). Maize at sole cropping recorded higher grain yield than in row and strip cropping pattern (Table 4.12). There were no significant differences between the yield obtained under the sole cropping and the row cropping pattern, the lowest yield was obtained under strip cropping pattern. Percentage yield of strip intercropping relative to sole cropping ranged between 46.5 and 50.0.

Table 4.12: Effect of cropping pattern on grain yield of maize

Genotype	Intercrop pattern	
	Row (a)	Strip (a)
CB27+maize	4378 (0.8)	2201 (49.1)
M008+maize	4537 (-2.8)	2152 (48.0)
M043=maize	4251 (3.6)	2144 (47.8)
M048+maize	4436 (-0.5)	2240 (50.0)
M055+maize	4556 (-3.3)	2236 (49.9)
M076+maize	4309 (2.3)	2083 (46.5)
M118+maize	4089 (7.3)	2172 (48.4)
M154+maize	4344 (1.5)	2207 (49.2)
M176+maize	4550 (-3.1)	2183 (48.7)
SARC 1-57-2+maize	4611 (-4.5)	2150 (47.9)
Sole maize	4412	4484
Mean	4407	2387
LSD (0.05) Intercrop= 183, Genotype=164 , interaction= 238 CV =1 %		

G, Genotype; I, Intercrop pattern; LSD, Least Significant Difference; CV, Coefficient of Variation, a (% yield of intercropping relative to sole cropping

4.4 Economic indices

4.4.1 Land equivalent ratio (LER)

The results of the land equivalent ratio LER of the various cowpea genotype intercrop with maize in row and strip intercrop pattern are presented in table 4.14. All the genotype had LER > 1. Among the genotypes, higher LER was recorded in M048. SARC 1-57-2 also performed well in LER under both intercropping patterns (Table 4.13). M118 and M043 that recorded the least LER posted 24 % yield advantage over the sole cropping. Among the intercropping treatments, higher LER value was recorded in strip than the row intercrop. Overall highest LER was measured in MAGIC 048 in strip intercrop with lowest at MAGIC 154 in row intercrop.

Table 4.13: Land equivalent ratio of cowpea genotypes intercropped with maize

	LER for grain yield	
Genotype	Row	Strip
CB27+maize	1.2	1.4
M008+maize	1.2	1.5
M043+maize	1.1	1.3
M048+maize	1.2	**1.8**
M055+maize	1.2	1.7
M076+maize	1.2	1.4
M118+maize	1.1	1.4
M154+maize	1.1	1.4
M176+maize	1.2	1.5
SARC 1-57-2+maize	1.4	1.5
Pattern Mean	1.2	1.5

4.4.2 Net monetary return (GH₵)

The results of the net monetary return in row, strip and sole copping is presented in table 4.14. The results showed that there was higher monetary return in producing cowpea. The highest monetary return was obtained from MAGIC 055 under sole cropping. In row intercrop, maize intercropped with Sarc1-57-2 had the highest net monetary return which is less than the monetary return gotten under strip intercrop and sole cropping. Higher monetary return were obtained under strip intercrop with MAGIC 048 and 055 recording the highest net monetary return. There was similar monetary return between MAGIC 048 and MAGIC 055 under strip intercrop and between CB27 and MAGIC 008 under row intercrop.

Table 4.14: Net monetary return (GH₵)

Genotype	Cropping pattern		
	Row intercrop	Strip intercrop	Sole cropping
CB27	3291.6	2769.7	3182.0
M008	3265.3	3397.8	4348.5
M043	3189.7	2930.3	2764.6
M048	3218.1	4779.8	5849.0
M055	3578.2	4742.4	6185.2
M076	2992.6	2587.0	3201.8
M118	2865.3	2346.7	2321.2
M154	3016.5	3613.3	4446.5
M176	3331.2	2888.6	2843.7
SARC 1-57-2	4256.0	3454.5	2272.0
Maize			3580.2
Pattern Mean	3300.42	3351.00	3741.45

4.4.3 Benefit cost ratio (BCR) of the cropping patterns of cowpea genotypes and maize

The results of the benefit cost ratio of cropping patterns is presented in table 4.15. The results showed that benefit cost ratio for row and strip cropping pattern were greater than one. The BCR of the row was lower than that of the strip and sole cropping. The strip intercrop was lower than that of the sole cropping. Three MAGIC genotypes did not break even under row intercropping (M076, M118 and M154). Under strip cropping pattern

M118 again did not break even (Table 15). All cowpea genotypes under sole cropping broke even and recorded profit with four MAGIC genotypes (M008, M048, M055, M154) performing like the maize.

Table 4.15: Benefit cost ratio

Genotype	Cropping pattern Row intercrop	Strip intercrop	Sole cropping
CB27	1.08	1.14	1.54
M008	1.07	1.38	2.07
M043	1.05	1.20	1.35
M048	1.06	1.91	2.71
M055	1.17	1.89	2.85
M076	0.99	1.07	1.55
M118	0.95	0.97	1.14
M154	0.99	1.47	2.11
M176	1.09	1.18	1.39
SARC 1-57-2	1.38	1.40	1.12
Maize			2.04
Pattern Mean	1.08	1.36	1.79

4.4.4 Monetary advantage index (MAI)

An indicator of the economic feasibility of intercropping systems was measured. MAI values were positive under all the intercropping pattern in the study. The highest MAI in row intercrop pattern was measured in maize intercropped with SARC1-57-2 and the lowest was measured in maize intercropped with MAGIC 154. In the strip intercrop, maize intercropped with MAGIC 048 had the highest MAI while maize intercropped with MAGIC 118 had the lowest MAI (Table 4.16).

Table 4.16: Monetary advantage index

Genotype	Cropping pattern	
	Row	Strip
CB27	532.5	791.3
M008	528.2	1159.4
M043	401.5	748.4
M048	509.3	2159.3
M055	664.4	1941.2
M076	390.3	711.0
M118	329.6	609.7
M154	276.7	1021.3
M176	594.0	906.0
SARC 1-57-2	1124.3	1118.8

CHAPTER FIVE:

5.0 DISCUSSION

5.1 Growth and yield of cowpea and maize in intercrop

5.1.1 50% flowering of cowpea

Flowering is an important physiological process in crop survival and assurance for its continuity. Time of flowering is particularly of great importance in annual crops, including cowpea, as it is a component of the adaptation of a variety to a particular agro-ecological zone and it also determines pod set, crop yield and maturity period (Ishiyaku et al., 2005). Timing of flowering determines when crops ripen for harvest (Ayo-Vaughan et al., 2011). According to Singh (1993) cowpea genotypes whose days to first flowering is greater than 45 are photoperiod sensitive (long or short day) while those that flower in less than 45 days are photoperiod-insensitive or day neutral. All the genotypes had their first 50% flowering in less than 45 day and may be classified as photoperiod-insensitive cowpea. Among the cropping pattern flowering did not differ but differed for cowpea genotype. CB27 attained the earliest 50% flowering with MAGIC 076 having the late days to 50% flowering. The variations observed among the genotypes in days to 50% flowering are due to difference in their genetic makeup. Cowpea genotypes have different genetic makeup and have different physiological responds to flowering. This corroborates Verma *et al.* (2009) report on Yield parameter responses in a spreading (cv.M-13) and semi-spreading (cv.Girnar-2) types of groundnut to six growth regulators that changes in growth patterns in some groundnut genotypes were attributed to differences in their genetic makeup. Though no significant difference was observed, averaged across genotype, the sole cropping plots generally recorded earliest 50% flowering and row intercrop had the late 50% flowering. Sisay (2004) results in sorghum-green gram intercrop showed that though the difference was not significant statistically, sole green gram took the least days (45 days after emergence) to flower, while its mean days to flowering in the intercropping was 51. In maize-soybean intercropping, Muoneke, Ogwuche and Kalu (2007) study in maize/soybean intercrop did not show any significant differences on 50% flowering in sole and intercropping but the differences were observed between the cultivars. Again, in agreement with Karikari *et al*. (1999) results on intercropping Bambara Groundnut on Pearl Millet, Sorghum and Maize, sole Bambara groundnut flowered in a significantly shorter period than that of the intercropped one.

5.1.2 Height of cowpea

The arrangement of the cropping pattern ensured that shading of the cowpea in the row cropping pattern was higher than that of strip and strip also experienced shading more than the sole cropping. Plant height of cowpea increased steadily from sole cropping plot to strip intercrop and to row intercrop. Crops respond to shading by growing taller in order to intercept light. Plant growing in low light condition responds to light stress by devoting more of their available carbon to shoot growth resulting partly in taller stems in search of more light (Adelusi and Aileme, 2006). Growing higher to intercept light explains the difference observed among the cropping patterns. Plant height of SARC1-57-2 was tallest in row intercrop and helped it to compete for light with the maize plant than their respective height in sole cropping and strip intercrop, this had effect on the number of pod produced in row intercrop and eventually leading to the highest yield in row intercrop. The differences in height of cowpea in the various intercrop patterns could be attributed to shading effect. In row intercrop there was a complete shade over cowpea making them to grow taller in search for sunlight. SARC1 57-2 recorded tallest height in row intercrop. It was able to climb the maize plant in search for light. This agrees with Ibrahim *et al*. (1993) report on Pioneer Sorghum/Lablab purpureus intercrop that plant height and other growth parameter such as number of internodes were higher significantly in lablab-Sorghum intercropping than in sole cropping due to shading effect. Similarly, Abate and Alemayehu (2018) also reported that the intercropped field pea was greater than that of sole for height due to less moisture stress and shading effect. Moreover, Mustapha *et al.* (2016) results in maize- groundnut intercrop showed that, the groundnut intercropped plants produced higher heights than the sole groundnut and this might be due to competition for sunlight between the maize and groundnut. Ibrahim (1994) also observed that sorghum – cowpea mixtures showed higher plant height than pure sorghum due to competition which include light.

5.1.3 Height of maize

Height of maize was not affected by intercrop pattern and its interaction with cowpea genotype. This may be because intercropping maize and cowpea has no effect on ability of maize to trap light. The maize is the taller component in the intercrop and had advantage to access light in intercrop. This corroborate findings of Sisay (2004) on Sorghum/Green gram intercropping that plant height of sorghum at harvest was not affected by intercropping because sorghum was the tallest component. Also in maize - haricot bean intercrop Amare (1992) reported that intercropping had no effect on plant height of maize. Similarly, Wanki and Fuwusi (1982) reported that maize height was not affected due to intercropping with cowpea. In addition, Karikari et al. (1999) showed that there was no difference in plant height of cereals between bambara groundnut-maize intercrop, Bambara groundnut-sorghum intercrop and their respective sole cropping because they had equal access to light. Mohammed et al. (2008) also reported that sorghum plant height was not affected significantly by cowpea genotype because they are taller component in intercrop.

5.1.4 Cowpea chlorophyll content

Chlorophyll is an important pigment involved in absorbing, transmitting and converting solar energy into electrochemical energy (Liu *et al.,* 2014). Availability of solar radiation has an effect on chlorophyll content of plant. Some research results showed that at a shade level of more than 50%, there is a drastic reduction in production. It was observed that there were significant differences in the chlorophyll content among the genotypes. Generally, chlorophyll content increased from row cropping pattern to strip cropping pattern and to sole cropping which shows that there is a direct link between available light and chlorophyll content of cowpea. Genotypes under sole cropping had higher chlorophyll content than their respective genotypes in strip and sole cropping. This could be caused by shading effect. In row cropping pattern higher degree of shading over cowpea was observed while in strip intercrop there was partial shading over the cowpea emanating from maize planted 75 cm from the cowpea which give them reduced sunlight. Similar finding was made by Li *et al*. (2014a, b) on the Effect of shading on photosynthetic and chlorophyll fluorescence characteristics of soybean and Effects of mutual shading on the regulation of photosynthesis in field-grown sorghum that soybean chlorophyll contents are significantly affected by changes in light availability and decrease with the reduction in light.

5.1.5 Number of pod per plant of cowpea

Pods per plant is one of the determinant factor of yield in cowpea. It was observed that there were differences in number of pods per plant among the genotypes. The differences could be caused by genotypes being made up of different genetic constitution which affected their growth and performances at the fields. Similar finding was made by Chemeda (1997) on haricot bean/maize intercrop who found that different genotypes of haricot bean differed significantly with regard to number of pods per plant. Also number of pod was higher at strip intercrop and lowest at row intercrop and it may be attributed to shading. Shading effect from maize might have caused lesser pod per plant in row intercrop since genotypes under row intercrop were under complete shade with the exception of Sarc1-57-2 which was able to climb the maize plant to intercept sunlight hence its ability to produce more pod than the other genotypes that did not grow taller under row intercrop. Ndakidemi and Dakora (2007) study on maize cowpea showed a reduction in cowpea number of pods per plant under intercropping compared to sole cropping due to competition for resources which include light. In a system where cowpea was intercropped with maize, shading had significant effects on cowpea yield and yield components because it was the shorter variety, and could not compete effectively for resources (Eskandari, 2012).

5.1.6 Number of seed per pod

Number of seeds per pod is one of the major determinant factors of yield in cowpea (Malik et al., 1983). Though no significant difference was observed in genotype x intercrop pattern interaction, significant difference was seen in the genotypes. This observation could attributed to the growth habits and also the genetic makeup of the genotypes which gave some superiority over others in terms of seeds per pod. The results is in conformity with the report made by Bouquet (1998) on Yield and Risk Utilizing Short-Season Soybean Production in the Mid- Southern United States of America, that, genotype selection is one of most important factors to increase pod yield in soybean. Ahmad and Mohammed (2004) also reported that there is an inherent varietal difference in seed number per pod in pigeon pea. In the intercrop pattern there was significant difference in seed per pod, row intercrop recorded relatively lower number of seeds per pod than the respective counterpart in strip and sole cropping which may be due to high level of competition in row intercrop. This is in conformity with Abate and Alemayehu (2018) on maize/fenugreek intercrop that the sole fenugreek produced higher number of seeds per pod compared to the intercropped fenugreek due to competition effect.

5.1.7 100 seed weight of cowpea

The measure of seed size, 100 seed weight is also one of the determinant factor of yield in cowpea, the study showed that highest 100 seed weight was produced by a collection from SARI, and CB27. The top genotypes from the MAGIC collections were MAGIC 055 and 043. The genotype with the least 100 weight was MAGIC 076. Differences in 100 seed weight recorded in SARC1-57-2 and MAGIC 076 reflected in their respective grain yields, lower yield was recorded for MAGIC 076 while SARC1-57-2 had higher yield. This could be attributed to their genetic makeup and corroborates Wuni *et al* (2006) who reported that genetic constitution of some soybeans gives them a slight edge over others and this resulted in the differential seed weight recorded by genotypes. The differences in 100 seed weight could be attributed to genetic differences and the environment created by the cropping pattern. In the intercrop pattern, 100 seed weight were significantly higher in the sole cropping plot than in the intercrop and even within the intercrop the row intercrop where cowpea competed with maize and light interception was reduced by maize recorded the least 100 seed weight. This may be due to decrease assimilates moving into seeds in intercrop caused by competition for light and nutrients. Similarly, Davis and Garcia (1987) and Maurice *et al.* (2010) reported that there is decrease in hundred seed weight of legume in legume-maize intercrop as compared to that of sole cropping perhaps due to competition exerted by maize plants.

5.1.8 Grain yield of maize

The results of the grain yield indicate that the yield of maize under strip intercrop is about half of the yield of maize under row and sole cropping. This could be attributed to the reduced population density in maize under strip intercrop. At strip intercrop cowpea occupy half of the land and the maize also occupy half of the land but at row and sole cropping pattern the population density of maize is the same. There was no significant difference between the yield of maize under sole and row intercrop. However, it was observed that maize yield in sole was higher than maize yield in intercrop and this conform Mustapha et al. (2016) report on maize groundnut intercrop that sole maize gave the highest grain yield than maize in intercrop. Similarly, Tamado and Eshetu (2000) report on Sorghum, Maize and Common Bean also showed that sorghum grain yield in mono cropping was higher than that of the intercropping.

5.2 Genotypes with high and stable yields in sole and intercropped systems

The common maize-cowpea intercrop practiced among farmer in northern regions of Ghana is the row intercrop. Integrated approach to select suitable genotype for maize-cowpea intercrop for farmers was investigated. The results in this investigation shows that grain yields of cowpea in maize-cowpea intercrop varied in the different intercrop pattern.

The results showed that all the genotypes had their highest yield in sole cropping pattern. Comparing row and strip cropping patterns, it was observed that yield of SARC1-57-2 was higher in row intercrop than in strip intercrop while the remaining genotypes had their highest yields in strip intercrop. These variations may be attributed to SARC 1-57-2 erected nature and being able to climb the maize plant to access sunlight in the row intercrop. The rest of the genotypes were not able to climb the maize plant to trap enough sunlight for photosynthesis leading to lower number of pod production in row intercrop. As has previously been reported by Isenmilla *et al.* (1981) on maize cowpea intercrop, different cultivars respond differently to intercropping conditions. Averagely higher yield was obtained in sole cropping and strip intercropping with relatively lower yields recorded in row cropping pattern and this could be attributed to more sunlight, less competition for nutrients leading to greater number of seed per pod and increase in pod production. This corroborates with earlier findings by Eskandari, (2012) on Intercropping of maize (Zea mays L.) with cowpea (Vigna sinensis) and mung bean (Vigna radiate). He reported that in a system where cowpea was intercropped with maize, shading had significant effects on cowpea gain yield and yield components because of cowpea's short nature, and its inability to compete effectively for resources. Similar findings was reported by Egli (1988) and Alhaji (2008) who showed that at low planting densities, where there was no interplant competition, yield was more higher than in high plant density.

5.3 Economic of intercropping early maturing cowpea with maize

At the end of production farmers may like to know whether they made profit or loss, economic indices helps farmers to know the expected output in practicing the various cropping systems. Land Equivalent Ratio (LER) shows whether intercropping is advantageous than monocropping. All values of LER which are more than one indicate advantage or productivity of intercrops over sole cropping. Whereas when the LER is lower than one, the intercropping negatively affected the growth and yield of the crops grown in mixtures. It was observed that the LER values were greater than one in all intercropping with different intercrop pattern, which indicated a yield advantage of intercropping over monocropping of maize. Eighty two percent yield advantage of M048 was achieved under strip intercropping system and the genotype average of 51 % yield advantage over sole cropping was a little above SARC 1-57-2 which gave yield advantage of 41 %. The least LER in this study giving a yield advantage of 24 % demonstrates the importance of intercropping. Higher LER in intercropping than monocropping has been reported in corn-legume by (Dhima *et al*., 2007), in Maize-cowpea intercropping (Dahmardeh *et al*., 2010). Addo-Quaye *et al*. (2011) reported that in corn-soybean intercrop LER was greater than 1. Similarly, Eskandari, (2012) submitted that in corn mungbean the intercrop showed higher LER than in monocropping.

Benefit-cost ratio, an indicator of relative performance of a treatment was measured. A treatment is said to be economically viable when the benefit cost ratio (BCR) is greater than 1 (Aziz *et al*., 2012). Data from this study show that most genotype under row and strip intercrop pattern gave benefit-cost ratios greater than 1. Three MAGIC genotypes did not break even under row intercropping (M076, M118 and M154) and one (M118) under strip intercrop. This means that intercropping cowpea with maize yielded significant return on investment in most of the genotypes. Some cowpea genotypes (M008, M048, M055, M154) and the maize under sole cropping gave BCR that was above 2. These same genotypes were the top five in grain yield under sole cropping. Under the intercropping, the strip gave better BCR than row and M048, M155 and SARC1-57-2 were the top three genotypes. These three were among the top five in grain yield. When farmers want to maintain the row intercropping then SARC1-57-2 and M055 which broke even with 38 % and 17 % profit and were among the top five in grain yield could be recommended to them.

The results also show that MAI values were positive under all the intercropping pattern in the study. SARC1-57-2 had the highest MAI in row intercrop and MAGIC 048 also had the highest in strip intercrop. The higher MAI values for these genotype indicate that they had the highest economic advantage and implies that there was better utilization of resources between maize-cowpea intercropping. This results is in consistent with Mahapatra, (2011) in his study of grass legume intercrop. Similarly, Ghosh, (2004) found positive MAI in groundnut-cereal intercrop.

CHAPTER SIX:

6.0. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Significant differences in plant height and grain yield was observed among the genotypes of cowpea. SARC1-57-2 was superior to the other genotypes in terms of shade tolerance and also recorded the tallest height. For selection of genotypes based on fodder production under intercropping system four MAGIC genotypes, M048, M055, M076 M176 and SARI collection SARC1-57-2 were the top five genotypes. The same genotypes also topped in fodder production under sole cropping except SARC1-57-2 which was replaced by M008. In terms of grain yield under intercropping system SARC1-57-2 was found to have performed well under row intercropping and among the MAGIC genotypes M055 was the best. In the Strip intercropping system four MAGIC genotypes M008, M048, M055, M154 together with SARC1-57-2 were top in grain yield. The same magic genotypes had high and stable yield in sole and intercropped systems. M076 or CB27 could be considered among the top grain yielders under sole cropping.

Competition index in the form of Land Equivalent Ratio (LER) showed that the genotypes were good for intercropping and the economic index like benefit cost ratio proved that intercropping was profitable though less than sole cropping. Based on BCR four MAGIC genotypes, M008, M048, M055, M154 and M176 were top genotypes under sole cropping. When it comes to intercropping SARC1-57-2 was excellent under row intercropping. Four genotypes under sole cropping M008, M048, M055, and M154 together with SARI's SARC1-57-2 could be considered as profitable when strip intercropping is considered. Intercropping did not have effect on maize grain yield.

6.2 Recommendations

From the discussion and conclusions made it is recommended that MAGIC genotypes M008, M048, M055and M154 together with SARI's collection SARC1-57-2 should be considered for selection when grain yield of cowpea is the objective for selection. When fodder is important consideration MAGIC genotypes M048, M055, M076 M176 and SARI's collection SARC1-57-2 are recommended. For both fodder and grain yield, M048, M055 and SARC1-57-2 are recommended. SARC1-57-2 was able to tolerate shade under row intercrop and is recommended for row intercropping.

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APPENDICES

Appendix 1: Days to 50% flowering of cowpea

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	0.689	0.344	0.09	
BLOCK.INTERCROP stratum					
INTERCROP	2	73.156	36.578	9.23	0.032
Residual	4	15.844	3.961	1.57	
BLOCK.INTERCROP.ENTRY stratum					
ENTRY	9	213.956	23.773	9.43	<.001
INTERCROP.ENTRY	18	135.511	7.528	2.99	<.001
Residual	54	136.133	2.521		
Total	89	575.289			

Appendix 2: Plant height of cowpea

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	46.33	23.17	0.33	
BLOCK.INTERCROP stratum					
INTERCROP	2	20329.76	10164.88	146.53	<.001
Residual	4	277.48	69.37	1.51	
BLOCK.INTERCROP.ENTRY stratum					
ENTRY	9	12431.64	1381.29	29.97	<.001
INTERCROP.ENTRY	18	14780.87	821.16	17.82	<.001
Residual	54	2489.02	46.09		
Total	89	50355.11			

Appendix 3: Pod per plant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	3.692	1.846	0.18	
BLOCK.INTERCROP stratum					
INTERCROP	2	3611.887	1805.944	176.67	<.001
Residual	4	40.889	10.222	3.74	
BLOCK.INTERCROP.ENTRY stratum					
ENTRY	9	1781.092	197.899	72.33	<.001
INTERCROP.ENTRY	18	932.066	51.781	18.93	<.001
Residual	54	147.743	2.736		
Total	89	6517.371			

Appendix 4: Number of seed per pod

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	4.304	2.152	1.63	
BLOCK.INTERCROP stratum					
INTERCROP	2	80.414	40.207	30.48	0.004
Residual	4	5.277	1.319	0.94	
BLOCK.INTERCROP.ENTRY stratum					
ENTRY	9	104.181	11.576	8.24	<.001
INTERCROP.ENTRY	18	33.682	1.871	1.33	0.206
Residual	54	75.872	1.405		
Total	89	303.730			

Appendix 5: 100 seed weight of cowpea

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	2.8202	1.4101	3.85	
BLOCK.INTERCROP stratum					
INTERCROP	2	40.3176	20.1588	55.06	0.001
Residual	4	1.4644	0.3661	0.51	
BLOCK.INTERCROP.ENTRY stratum					
ENTRY	9	280.6712	31.1857	43.51	<.001
INTERCROP.ENTRY	18	51.1958	2.8442	3.97	<.001
Residual	54	38.7020	0.7167		
Total	89	415.1712			

Appendix 6: Days to maturity of cowpea

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	11.667	5.833	1.00	
BLOCK.INTERCROP stratum					
INTERCROP	2	4.867	2.433	0.42	0.684
Residual	4	23.267	5.817	1.03	
BLOCK.INTERCROP.ENTRY stratum					
ENTRY	9	121.511	13.501	2.40	0.023
INTERCROP.ENTRY	18	170.689	9.483	1.68	0.072
Residual	54	304.400	5.637		
Total	89	636.400			

Appendix 7: Grain yield of cowpea

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	1069.1	534.5	2.62	
BLOCK.INTERCROP stratum					
INTERCROP	2	1818946.9	909473.4	4463.34	<.001
Residual	4	815.1	203.8	0.22	
BLOCK.INTERCROP.ENTRY stratum					
ENTRY	9	2186927.2	242991.9	257.21	<.001
INTERCROP.ENTRY	18	1911608.9	106200.5	112.42	<.001
Residual	54	51014.0	944.7		
Total	89	5970381.1			

Appendix 8: Biomass yield of cowpea

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	12430.	6215.	0.34	
BLOCK.INTERCROP stratum					
INTERCROP	2	11279511.	5639755.	308.51	<.001
Residual	4	73122.	18281.	1.53	
BLOCK.INTERCROP.ENTRY stratum					
ENTRY	9	54438867.	6048763.	504.63	<.001
INTERCROP.ENTRY	18	19901910.	1105662.	92.24	<.001
Residual	54	647267.	11986.		
Total	89	86353107.			

Appendix 9: Chlorophyll content of cowpea

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	28.40	14.20	0.13	
BLOCK.INTERCROP stratum					
INTERCROP	2	5517.49	2758.75	25.26	0.005
Residual	4	436.83	109.21	2.16	
BLOCK.INTERCROP.ENTRY stratum					
ENTRY	9	7796.91	866.32	17.15	<.001
INTERCROP.ENTRY	18	3042.59	169.03	3.35	<.001
Residual	54	2728.50	50.53		
Total	89	19550.72			

Appendix 10: Plant height of maize

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	1448.51	724.26	0.58	
BLOCK.INTERCROP stratum					
INTERCROP	2	6537.52	3268.76	2.62	0.187
Residual	4	4984.46	1246.12	1.33	
BLOCK.INTERCROP.ENTRY stratum					
ENTRY	10	6995.09	699.51	0.75	0.676
INTERCROP.ENTRY	8	7331.31	916.41	0.98	0.467
Residual	36	33668.12	935.23	14.03	
BLOCK.INTERCROP.ENTRY.*Units* stratum					
	3	200.00	66.67		
Total	65	61165.02			

Appendix 11: Grain yield of maize

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	115577.9	57788.9	3.10	
BLOCK.INTERCROP stratum					
INTERCROP	2	51592.5	25796.3	1.38	0.349
Residual	4	74509.7	18627.4	0.49	
BLOCK.INTERCROP.ENTRY stratum					
ENTRY	10	579178.5	57917.8	1.52	0.173
INTERCROP.ENTRY	8	387297.4	48412.2	1.27	0.290
Residual	36	1373303.6	38147.3	286.10	
BLOCK.INTERCROP.ENTRY.*Units* stratum					
	3	400.0	133.3		
Total	65	2581859.5			

Appendix 12: Cost of producing 1 ha of maize-cowpea row intercrop in northern Ghana

Item	Description	Cost GHC̸
Land preparation	harrowing@GHC̸200/ha ridging GHC200/ha	400
Fertilizer	125kg of compound fertilizer for maize@ 50kg for GHC̸80 125kg of compound fertilizer for maize@ 50kg for GHC̸80	400
Seeds	12.5 kg/ha@GHC̸250/ha for cowpea 25kg/ha@GHC̸125/ha for maize	250
Labour for planting	8 hands@GHC10/man/day for cowpea 15 hands@GHC̸10/man/day for maize	230
Labour for weed control	15 hands each @ 1st and 2nd weeding @GHC̸ 10/man/day	300
Spraying	2 hands each for 1st , 2nd and 3rd spraying @GHC̸10/man for cowpea 2 each for 1st and 2nd spraying @GHC̸10/man for maize	100
Insecticide	2litre @GHC̸40/250ml	320
Picking	8 hands each @ 1st and 2nd picking @ghc 10/man/day for cowpea 15 hands @ GHC̸10/man for maize	310
Drying	2 hands each at 1st and 2nd drying for 3 days each @GHC̸ 10/man/day for cowpea 2 hands for drying for 3 days each @GHC̸10/man/day for maize	180
Threshing, winnowing, selection and bagging	10 hands each at 1st and 2nd threshing, winnowing, selection and bagging of cowpea for 2 days each @GHC̸10/man/day 10 hands for threshing, winnowing, selection and bagging of maize @GHC̸10/man/day	300
TOTAL		2790

Appendix 13: Cost of producing 1 ha of maize-cowpea strip intercrop in northern Ghana

Item	Description	Cost GHȻ
Land preparation	harrowing@GHȻ200/ha ridging GHC200/ha	400
Fertilizer	62.5kg of compound fertilizer for maize@ 50kg for GHȻ80 62.5kg of compound fertilizer for maize@ 50kg for GHȻ80	200
Seeds	12.5 kg/ha@GHȻ125/ha for cowpea 12.5kg/ha@GHȻ 62.5/ha for maize	187.5
Labour for planting	8 hands@GHC10/man/day for cowpea 8 hands@GHȻ10/man/day for maize	160
Labour for weed cont	15 hands each @ 1st and 2nd weeding @GHȻ 10/man/day	300
Spraying	2 each for 1st , 2nd and 3rd spraying @GHȻ10/man for cowpea 2 each for 1st and 2nd spraying @GHȻ10/man for maize	100
Insecticide	2litre @GHȻ40/250ml	320
Picking	8 hands each @ 1st and 2nd picking @ghc 10/man/day for cowpea 8 hands @ GHȻ10/man for maize	240
Drying	2 hands each at 1st and 2nd drying for 3 days each @GHȻ 10/man/day for cowpea 2 hands for drying for 3 days each @GHȻ10/man/day for maize	180
Threshing, winnowing, selection and bagging	5 hands each at 1st and 2nd threshing, winnowing, selection and bagging of cowpea for 2 days each @GHȻ10/man/day 5 hands for threshing, winnowing, selection and bagging of maize @GHȻ10/man/day	150
TOTAL		2237.5

Appendix 14: Cost of producing 1 ha of maize in northern Ghana

Item	Description	Cost GH₵
Land preparation	Harrowing@GH₵200/ha	400
	Ridging GHC200/ha	
Fertilizer	125kg of compound fertilizer @ 50kg for GH₵80	200
	125kg of compound fertilizer @ 50kg for GH₵80	
Seeds	25kg/ha@GH₵125/ha	125
Labour for planting	15 hands@GH₵10/man/day	150
Labour for weed control	15 hands each @ 1st and 2nd weeding @GH₵ 10/man/day	150
Spraying	2 hand each for 1st and 2nd spraying @GH₵10/man	40
Insecticide	1litre @GH₵40/250ml	160
Picking	15 hand @ GH₵10/man	150
Drying	2 hands for drying for 3 days each @GH₵10/man/day	60
Threshing, winnowing, selection and bagging	10 hands for threshing, winnowing, selection and bagging @GH₵10/man/day	100
TOTAL		1535

Appendix 15: Cost of producing 1 ha of cowpea in northern Ghana

Item	Description	Cost GHȻ
Land preparation	harrowing@GHȻ200/ha	400
	ridging GHC200/ha	
Seeds	25 kg/ha@GHȻ250/ha	250
Labour for planting	15 hands@GHC10/man/day	150
Labour for weed control	15 hands each @ 1st and 2nd weeding @GHȻ 10/man/day	300
Spraying	2 each for 1st , 2nd and 3rd spraying @GHȻ10/man	60
Insecticide	1litre @GHȻ40/250ml	160
Picking	15 hands each @ 1st and 2nd picking @ghc 10/man/day	300
Drying	2 hands for drying for 3 days each @GHȻ10/man/day	60
Threshing, winnowing, selection and bagging	10 hands each at 1st and 2nd threshing, winnowing, selection and bagging of cowpea for 2 days each @GHȻ10/man/day	200
TOTAL		1880

Appendix 16: Maize and cowpea yield, number of bags obtained, cost per bag, revenue, gross monetary return, net monetary return and return on investment.

Cropping pattern	Genotype	Cowpea (kg/ha)	Maize (kg/ha)	Cowpea number of bags (100kg)	Maize number of bags (100kg)	Total cost of production (cowpea + maize)	Cost per bag of cowpea	Cost per bag of maize	Revenue	Gross monetary return	Post harvest expenses	Net monetary return (NMR)	Return on investment (ROI)
Row	CB27	338.8	4378	3.388	43.78	2790	320	120	6337.76	3547.76	256.168	3291.592	1.1797821
Row	M008	271.1	4537	2.711	45.37	2790	320	120	6311.92	3521.92	256.671	3265.249	1.1703401
Row	M043	353.1	4251	3.531	42.51	2790	320	120	6231.12	3441.12	251.391	3189.729	1.143272
Row	M048	293.4	4436	2.934	44.36	2790	320	120	6262.08	3472.08	254.074	3218.006	1.1534072
Row	M055	365.3	4556	3.653	45.56	2790	320	120	6636.16	3846.16	267.983	3578.177	1.2825007
Row	M076	267.7	4309	2.677	43.09	2790	320	120	6027.44	3237.44	244.897	2992.543	1.0725961
Row	M118	308.4	4089	3.084	40.89	2790	320	120	5893.68	3103.68	238.374	2865.306	1.0269914
Row	M154	262.4	4344	2.624	43.44	2790	320	120	6052.48	3262.48	246.064	3016.416	1.0811527
Row	M176	287.6	4550	2.876	45.5	2790	320	120	6380.32	3590.32	259.136	3331.184	1.1939728
Row	SARC 1-57-2	564.2	4611	5.642	46.11	2790	320	120	7338.64	4548.64	292.612	4256.028	1.5254581
Strip	CB27	801.3	2201	8.013	22.01	2237.5	320	120	5205.36	2967.86	198.193	2769.667	1.23784
Strip	M008	1022.8	2152	10.228	21.52	2237.5	320	120	5855.36	3617.86	220.108	3397.752	1.5185484
Strip	M043	874.5	2144	8.745	21.44	2237.5	320	120	5371.2	3133.7	203.395	2930.305	1.3096335
Strip	M048	1437.3	2240	14.373	22.4	2237.5	320	120	7287.36	5049.86	270.103	4779.757	2.1362042
Strip	M055	1426.7	2236	14.267	22.36	2237.5	320	120	7248.64	5011.14	268.737	4742.403	2.1195097
Strip	M076	786.1	2083	7.861	20.83	2237.5	320	120	5015.12	2777.62	190.621	2586.999	1.1562007
Strip	M118	675.2	2172	6.752	21.72	2237.5	320	120	4767.04	2529.54	182.872	2346.668	1.0487902
Strip	M154	1072.1	2207	10.721	22.07	2237.5	320	120	6079.12	3841.62	228.281	3613.339	1.6149001
Strip	M176	846.5	2183	8.465	21.83	2237.5	320	120	5328.4	3090.9	202.265	2888.635	1.2910101
Strip	SARC 1-57-2	1041.9	2150	10.419	21.5	2237.5	320	120	5914.08	3676.58	222.109	3454.471	1.5438977
Sole	CB27	1638.2		16.382		1880	320		5242.24	3362.24	180.202	3182.038	1.6925734
Sole	M008	2015.7		20.157		1880	320		6450.24	4570.24	221.727	4348.513	2.3130388
Sole	M043	1503.1		15.031		1880	320		4809.92	2929.92	165.341	2764.579	1.4705207
Sole	M048	2501.3		25.013		1880	320		8004.16	6124.16	275.143	5849.017	3.1111793
Sole	M055	2610.1		26.101		1880	320		8352.32	6472.32	287.111	6185.209	3.2900048
Sole	M076	1644.6		16.446		1880	320		5262.72	3382.72	180.906	3201.814	1.7030926
Sole	M118	1359.6		13.596		1880	320		4350.72	2470.72	149.556	2321.164	1.2346617
Sole	M154	2047.4		20.474		1880	320		6551.68	4671.68	225.214	4446.466	2.3651415
Sole	M176	1528.7		15.287		1880	320		4891.84	3011.84	168.157	2843.683	1.5125973
Sole	SARC 1-57-2	1343.7		13.437		1880	320		4299.84	2419.84	147.807	2272.033	1.2085282
Sole	maize (wangdataa)		4448		44.48	1535		120	5337.6	3802.6	222.4	3580.2	2.3323779

Revenue = Price of produce per bag × Number of bags (kg/ha)

Gross monetary return = Revenue-Total cost of production

Other expenses = other period cost incurred in producing eg. Storage, selling and distribution. Administrative expenses etc.

Net Monetary Return = Gross benefit - Other expenses

$$\text{Return on Investment (ROI)} = \frac{Net\ monetary\ return}{Total\ cost\ of\ production}$$

Benefit Cost Ratio (BCR) = $\frac{Net\ monetary\ return}{Total\ cost\ of\ production+other\ expenses}$

Monetary advantage index (MAI) = value of combined intercropped yield x (LER -1)/LER