KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
COLLEGE OF AGRICULTURE AND RENEWABLE NATURAL RESOURCES

FACULTY OF AGRICULTURE DEPARTMENT OF CROP AND SOIL SCIENCES

SPATIAL ARRANGEMENTS AND TIME OF INTRODUCING AN INTERCROP ON THE PRODUCTIVITY OF COMPONENT CROPS IN MAIZE (*Zea Mays* L) - SOYBEAN (*Glycine max* (L.) Merrill) INTERCROPPING SYSTEMS

BY ABDUL- RAHAMAN ISSAHAKU

JUNE, 2010

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(*Glycine max* (L.) Merrill) INTERCROPPING SYSTEMS

by Abdul-Rahaman Issahaku BSc (Agriculture Technology) A Thesis submitted to the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology in partial fulfillment of the requirements for the degree

of

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DECLARATION

I hereby declare that this submission is my own work towards the Master of Science degree and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the university, except where due acknowledgement has been made in the text

ABDUL- RAHAMAN ISSAHAKU	……………………	……………………
Student Name	Signature	Date

Certified by:

DR. J. SARKODIE ADDO	………………………	……………………
Supervisor's Name	Signature	Date

ABSTRACT

A field experiment was conducted, at the Faculty of Agriculture Farm (Plantation section), KNUST, Kumasi in the Kumasi metropolis of Ashanti region of Ghana during the 2009 growing season. The experiment examined the effects of seeding date (simultaneous with maize, 1 or 2 WAPM) at four levels of spatial arrangements; 1:1, 2:2, 3:3, and 4:4 on soil nutrient budget and performance of the component crops in maize *(Zea mays* l) - soybean (*Glycine max* (L) Merrill) intercropping systems. The maize was sown at a spacing of 80 x 40 cm and intercropped with the soybean planted at 0, 1 and 2 week after planting the maize (WAPM). The soybean was sown at a spacing of 60 x 5cm. Non-intercropped plots were made to serve as sole crop or control. The compound fertilizer, NPK (15-15-15) was applied to the sole maize 4 WAP at 60 kg/ha and top dressed with sulphate of ammonia at 50 kg N/ha at 8 WAP.

The results showed that intra- and interspecific competition in the system affected the performance of the crops with respect to yield and quality. The late intercrops grew poorly as an intercrop component, producing little or no grain. Leaf area, leaf area index, dry weights, crop growth rate, relative crop growth rate and the yield components decreased with delay in intercropping as results of competition of intercrop components for nutrients, light, and space. In the case of the maize, delay in intercropping resulted in increased grain yield. This implied that the early intercropped maize plants experienced greater competition than the late intercropped maize plants. Land equivalent ratio also decreased with delay in intercropping. It is recommended to intercrop soybean at 0 WAPM in 1:1 spatial arrangement combinations.

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DEDICATION

This thesis is dedicated to the late **Issahaku Fusein Gonje and Mahama Abibata**

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ACRONYMS

DAS…………Days after Sowing

DMY ………Dry Matter Yield

DM…………Dry Matter

DMP………. Dry Matter Production

CGR………..Crop Growth Rate

RCGR……...Relative Crop Growth Rate

KNUST…….Kwame Nkrumah University of Science and Technology

WAP……….Weeks After Planting

LA………… Leaf Area

LAI……….. Leaf Area Index

SW………… Seed Weight

WAPM……. Weeks After Planting Maize

GGDP ……. Ghana Grains Development Project.

LSD……..... Least Significant Difference

SRID……… Statistical Research and Information Directorate

MoFA…….. Ministry of Food and Agriculture

CHAPTER ONE

INTRODUCTION

Maize (*Zea mays* L) is believed to have originated from the high plateau of central Mexico. It belongs to the family Poaceae. It ranks second to wheat among the world's cereal crops in terms of importance and total production (Drisah, 2005). Maize is grown primarily for grain and secondly for fodder and raw materials. It features prominently in adult and infant weaning foods, feed for livestock and poultry. Maize fodder can safely be fed at all stages of growth without any danger of oxalic acid, prussic acid as in the case of sorghum (Dahmardeh *et al*., 2009). Maize is the most suitable fodder crop for making silage. Therefore, it is called the king of crops suitable for silage as reported by Muhammad *et al*. (1990).

In Ghana, maize is an important cereal produced in all the five agro-ecological zones, namely the Costal savanna, Forest, Transitional zone, Guinea and Sudan savannas (Obeng-Antwi *et al*, 2002). In Ghana, subsistence agriculture is the predominant occupation. Maize is the most commonly cultivated cereal according to Dowsewll *et al*. (1996).

Maize crop requires substantial amount of N for growth and development. It is very sensitive to weed competition. These problems and nutrient requirements serve as constraints to its growth and development (Drisah, 2005). The inherently low fertility of the soils especially in N and P and the problem of weeds in the past decades have resulted in falling agricultural productivity index (Dogbe, 1998).

In spite of the notable adoption of high yielding varieties of maize by small holders in Africa (33-50%), national per hectare increase in production is disappointing (Kumwenda *et al*,.

1996).The national average yield is estimated at 1.58 t/ha for the 2004 growing season (SRIDMoFA, 2005). To allow the "miracle varieties" to express their full yield potential, they are given adequate fertilizer and irrigation, which predispose them to disease and pest attack; in addition, the world-wide distribution of the same genetic types provides ideal conditions for the evolution of races of disease and pest organism to attack them. Varietal maize improvement will have a transitory impact on smallholder farming in Africa unless farmers address widespread declines in soil fertility. In view of the danger of widespread epidemics leading to calamitous yield losses, it is now being felt that heterogeneity should be reintroduced into the crop fields in some planned fashion.

Per- capital agricultural production is declining in sub-Sahara Africa (Sanchez *et al* 1996), probably owing to the above constraints and particularly due to low and depleted soil fertility (Vlek 1993; Bekunda *et al* 1997) and partly because production has expanded into drought-prone semi-arid areas. Most areas are suffering from declining yield and increasing production through opening of new lands has limited potential (Paul, 1997). Many farmers are caught in poverty trap (Barrett *et. al* 2003), where harvest is insufficient to meet urgent household food needs let alone generate enough income to invest in fertilizer. Increasing urbanization and deforestation due to high demographic pressure as well as ecological problems, particularly soil erosion has decreased the amount of arable land available to farmers (Chukwu, 1997). Increasing pressure on agricultural land and the subsequent abandonment of many traditional maintenance strategies for soil fertility has resulted in negative nutrient balance. Nitrogen is deficient in most soils and extremely limiting to crop production in larger areas of the southern African plateau. About 200 million hectares of crop land in Africa has lost 600, 75 and 450 kg/ N, P and K respectively primarily by removing crop harvest (Stoorvogel and Smaling, 1990). Much of Africa is experiencing the long term effect of degradation (Anderson, 2003).

Reversal of soil fertility depletion is required to increase agricultural production (Sanchez and Leakey, 1997). This has necessitated a rapid increase of fertilizer application in recent years to achieve high yield. Losses emanating from storage, handling and application of fertilizer are potential environmental problems which among others increase the risk of ground water nitrate pollution. Moreover prices of inorganic fertilizers have tripled in recent years, and coupled with unavailability, their use is limited (Brumby, 1991). It is further constrained by unstable prices of agricultural produce, scarce financial resources and lack of access to credit. The effects of soil nutrient depletion are felt beyond the farm. Organic inputs are commonly used in the maintenance of soil productivity (Bekunda and Woomer 1996). However, its use especially in intensive agriculture has been rendered less feasible by its bulkiness, difficulties associated with its transportation and application, coupled with the fact that organic resources sufficient to replenish nutrient losses through cropping are difficult to produce (African Fertilizer Summit 2006). Its use is also constrained by unavailability and high cost. Therefore, there is the need for alternative low-cost remote ameliorating measures for sustainable crop production. The shortage and ever increasing prices of food commodities have put greater pressure on research organizations to study the efficiency of farm inputs used for food production. Without such technology, the productivity of smallholder maize-based farming systems in Africa will fail to improve

Agronomists, physiologists, and ecologists are intrigued by the potential of extending resource use and the biological stability, improving self regulation within integrated crop protection in particular and integrated crop management in general. There is therefore the need to develop strategies that are economically viable in terms of input use efficiency and ecologically sustainable with the potential of controlling weeds, increasing soil fertility and increasing yield of maize. One of the copping strategies adopted by farmers is intercropping legumes with cereals as a means of securing food in times of crop failure. Legumes hold great potential as sources of high protein food and feed, and have received considerable attention from research organizations. Above all, because of their ability to fix significant amounts of atmospheric nitrogen, legumes become more important and offer an alternative for increasing nitrogen input in various cropping systems and soil management practices. Intercropping is practiced in many parts of the world (Francis, 1986). Steiner, (1984) estimated that intercrops cover over 75% of the cultivated area in the West African tropics because of some of the established and anticipated advantages such as greater yield stability (Jensen, 1996), greater land-use efficiency (Ofori and Stern, 1987), increased competitive ability towards weeds (Hauggaard-Nielsen *et al*., 2001a), improvement of soil fertility due to the addition of N by fixation (Hauggaard-Nielsen *et al*., 2001b; Jensen, 1996), and some favorable exudates from the component legume (Willey, 1979a; Ofori and Stern, 1987). Almost all published intercropping combinations with a significant yield advantage were nonlegume-legume combinations (Morris and Garrity, 1993). Compared with corresponding sole crops, yield advantages have been recorded in many nonlegume/legume intercropping systems, including maize (*Zea mays L*.)/soybean (Abdul-Rahaman, 2006; West and Griffith, 1992; Ghaffarzadeh *et al*., 1994), sorghum/soybean (Elmore and Jackobs, 1986), wheat (*Triticum aestivum* L.)/mungbean [*Vigna radiata* (L.) R. Wilczek] (Chowdhury and Rosario, 1994), barley (*Hordeum vulgare* L.)/medic (*Medicago* spp.) (Moynihan *et al*., 1996), canola (*Brassica* spp.)/soybean (Ayisi *et al*., 1997), groundnut (*Arachis hypogaea* L.)/pearl millet [*Pennisetum glaucum* (L.) R. Br.] (Ghosh and Devi Dayal, 1998), maize/faba bean (*Vicia faba* L.) (Li *et al*., 2001), pearl millet/cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.] (Yadav and Yadav, 2001), groundnut/cereal fodders

(Ghosh, 2004), barley/pea (*Pisum sativum* L.) (Chen *et al*., 2004), and faba bean/barley (Trydemanknudsen *et al*., 2004).

Provided that interference between component crops is weaker than that between crops and weeds, intercropping can suppress the growth of weeds more than sole cropping (Yih, 1982). Legumes can however become pest in an intercropping system by shading the component crops and thereby reducing yield (Osei-Bonsu and Asibuo 1997). Important factors affecting competition between the intercrop components for water, sunlight, space and nutrients and hence input use efficiency are the crop density, the relative proportion of component crops, the spatial arrangement (Daniel *et al*. 2001), and time of intercropping. According to Ghosh (2004), spatial arrangements of plants, planting rates and maturity dates must be considered when planning intercrops because they are some of the most important factors for better yield advantage (Singh and Yadave 1992). Spatial arrangements of intercrop components may create different micro climate in the stands. This is likely to have a profound influence on the performance of the intercrop components, though less is known of how stand composition affects yield despite its widespread significance especially in subsistence agriculture. Soybean is photosensitive; a change in planting date would expose plants to different photoperiods which can have a significant influence on its yield and that of the associated crop. Abdul- Rahaman (2006), Drisah (2005) and Osei-Bonsu and Buckles, (1993) observed a significant increase in maize grain yield with delay in intercropping contrary to that of Acheampong (2006) who reported a significant decrease in grain yield of maize with delay in intercropping. Optimum crop geometry is therefore one of the most important factors for higher productivity, by efficient utilization of ground resources and also harvesting as much solar radiation and in turn better photosynthate formation (Thavaprakaassh, 2005). The objectives of this study were to :

(1) identifying suitable and economically viable spatial arrangements for enhancing productivity of maize-soybean intercropping systems.

(2) Identify the appropriate time to introduce soybean into maize stands in order to maximize the economic yield required

(3) Examine whether there is possible advantage of growing mixed –crops, as mixed cropping is still widely practiced under conditions of primitive agriculture,

(4) Estimate the contribution/effect of the legume to the total nutrient budget of the soil

CHAPTER TWO

2.0.0 LITERATURE REVIEW 2.1.0 CROPPING SYSTEM

Davis and Wooley (1993) defined cropping system as the sequence of crops on one field and the way they are managed. Intercropping is a crop intensification practice in which two or more crops are interplanted on the field such that their growth cycle overlaps (GGDP, 1999). Andrew and Kassam, (1976) also define intercropping as the growing of two or more crops simultaneously on the same field.

2.1.1 CROPPING SYSTEMS IN GHANA

Common cropping systems include monocropping, crop rotation, relay cropping, mixed cropping and inter-cropping. Among these cropping systems, the one that receives much attention as far as research is concerned is intercropping.

2.1.2 SCOPE OF INTERCROPPING

It is the dominant practice among smallholder farmers in the semi arid tropics of West Africa (Fussell and Serafini, 1985). According to Ntare (1990), subsistence farmers with low inputs are particularly dependent on intercropping. Steiner (1984) estimated that intercrops cover over 75% of the cultivated area in the West African tropics.

2.1.3 CHARACTERISTICS OF INTERCROPPING SYSTEMS

According to Preston (2003) intercropping systems are characterized by the following:

1) Each of the many possible intercropping patterns is appropriate for a particular range of conditions and inappropriate for others.
2) Each intercropping pattern is usually chosen to alleviate a particular limitation in resources.
3) Intercropping is generally associated with small land holdings.
4) Intercropping systems make it difficult to cultivate between rows

2.2.0 INTERCROPPING ROW CONFIGURATIONS

In an intercrop system, row configurations (arrangements) alter the amount of light transmission to lower layers of the crops and affect the competition of species for light, water, and nutrients. There are four types of intercropping row configurations: (i) mixed intercropping, which grows component crops simultaneously in complete mixtures; (ii) row intercropping, which grows component crops simultaneously in different rows; (iii) strip intercropping, which grows component crops simultaneously in different strips; and (iv) relay intercropping, which grows component crops in relay so that growth cycles overlap

2.3.0 ADVANTAGES OF INTERCROPPING

In general, farmers give four principal reasons for intercropping: (i) Tradition, (ii) The need for food security, (iii) The need to maximize the return from a limiting factor of production such as labour and (iv) Beneficial effects of legumes on other crops (Norman, 1977).

2.3.1 MAXIMIZE THE ENVIRONMENT'S RESOURCES

David Gibbon *et al*. (1991) reported that the benefits of intercropping are to fully maximize the environment's resources over the course of the growing season, increase output per unit area and the diversification of the availability of food. Willey, (1979a) observed better use of light, and nutrients. Clark and Francis (1985) also reported that if a tall crop especially C_4 plants is intercropped with shorter C_3 plants, there is enhanced used of total light. In intercropping systems, the associated crop contrasting growth habit permits them to exploit time, rainfall and other resources better (Fussell and Serafini, 1986)

2.3.2 YIELD ADVANTAGES

Where intercropping systems have been studied, especially in West Africa, the findings as a whole indicate that there are yield advantages over the component crops grown as sole crops (Fussell and Serafini, 1985). Ofori and Stern, (1987), reported that intercropping produces higher and suitable yield in wide range of component combinations. According to Agboola and Fayemi (1977), intercropping maize with Phaseolus *aureu, Vigna anguiculata and Colopogonium mucunoids* increase its mean grain yield by 0.5 tons/ha over the control. Although intercropping reduces the yield of component crops but total productivity and net return has been found higher in intercropping system than sole cropping (Andrew, 1972; Nyambo *et. al* 1980). Goswami *et al.* (1999) reported that intercropping soybean with sorghum and arhar (*Cajanus spp.)* resulted in increased soybean equivalent yield and net return. Sherma *et al*. (2000) reported that sorghum – soybean based intercropping system gave higher yield (38 to 124%) than other cropping systems. Net returns were higher from a sorghum + soybean 30/90 cm paired row system with two rows of soybean. Rashid *et al.* (2005) reported that mungbean associated with sorghum substantially increased income than sole cropping of sorghum. Rashid *et al.* (2006) found that grain yield of sorghum with intercrops of mungbean or guar increased over sole cropping. Singh and Jha (1984) observed that intercropping of sorghum was more economical as compared to sole cropping system of either crop. Net return obtained from intercropping was 7 to 54 percent more than sole cropping. Shahapurkar and Patil (1989) recorded higher net income per hectare from paired rows of maize and soybean itercropping system compared to net income from maize crop alone .Barik *et al.* (1998) stated that sorghum and groundnut intercropping system appeared to be more advantageous from value of land equivalent ratio (LER), relative value total (RVT) and relative net return (RNR). Similarly, Singh and Balyan (2000) indicated that sorghum + clusterbean in paired row planting pattern (30/90 cm) proved as the best intercropping system with maximum total productivity and net return. Similarly, Singh and Balyan (2000) indicated that intercropping systems registered significant increase in total productivity (sorghum equivalent) over sole sorghum

2.3.3 WEED SUPPRESSION

Drisah (2005) reported that intercropping Mucuna and Canavalia in maize at six weeks after planting the maize gave good weed suppression and subsequently gave higher maize grain yield. According to Gupta (1998), intercropping helps in the suppression of at least the secondary growth of weeds that occurs after the intercrops have fully covered the ground. Bantilan and Harwood (1973), Shetty and Rao (1979) also reported that intercropping has proved to be superior to its single component crops in weed suppression and thus it provides an opportunity to utilize the crop as a tool for weed management.

2.3.4 BIOLOGICAL NITROGEN FIXATION (BNF)

In legume intercrop, there is nitrogen leaching from the legume to the associate crop (Aggarwal *et al*. 1992). Similarly, intercropping affects soil fertility maintenance through nitrogen fixation and differential uptake of nutrients (Redy *et al*., 1992). Willey (1979a) observed better use of light, nutrients as well as fixed nitrogen in legume-cereal intercropping system. Ofori and Stern (1986), Moreira (1989) and Cochran and Schlentner, *et al*. (1995) reported that total N accumulated by sorghum component in association with soybean was greater than that of monocrop. Pal and Shehu (2001) found that all legume crops contributed to yield and N uptake of maize either intercropped with legume or grown after legume as a sole crop. The beneficial effects of legumes on other crops have also been reported (Norman, 1977). In general, legumes provide free supply of 15-20 units of nitrogen per month during growing season due to nitrogen fixation (Charles – Marie, 1992).

2.3.5 REDUCTION IN INCIDENCE OF PESTS AND DISEASES

Andrews (1972) reported that intercropping reduces the damage caused by pests and diseases and therefore ensures greater yield stability. According to Perrin (1978), multiple cropping can be a powerful component of cultural pest control, provided that it satisfies the farmer's socioeconomic objectives. Baliddawa (1985) reported that population of several pests are depressed under plant species diversity. Risch (1984) found intercropping as a measure for the control of insect pests. The presence of two or more kinds of crop has several effects: fly paper effect, compensation effects, and microenvironmental effects which affect the host parasite in relationship in subtle ways - (a) by acting on the potentially attacked component changing its susceptibility (b) by acting directly on the attacking organism and (c) by influencing the populations of the natural enemies of the attacking organism

2.3.6 IMPROVEMENT OF THE FEEDING VALUE OF CROP RESIDUES

Growing forage legumes in association with food crops to improve the feeding value of crop residues is one option that has shown promise for low-resource farmers to feed their animals better (Abate *et al*., 1992; Umunna *et al*., 1997) while contributing to soil fertility.

2.3.7 BETTER PROTEIN YIELD OF THE ASSOCIATED CEREAL

Similarly, Khushawaha ad Chandel (1997) recorded maximum protein yield of sorghum under soybean plus sorghum system than sole sorghum. In many cereal- legume intercropping systems there is emanation of favourable exudates from the component legume to the associated cereal and this is suspected to have effects on the quality of the cereal in terms of protein yield

2.3.8 INSURANCE AGAINST TOTAL CROP FAILURE

Intercropping serves as an insurance against total crop failure in uncertain weather condition, increasing total productivity, equitable and judicial use of land resources and farming inputs including labour (Barik *et al* 1998).

3.3.9 STABILITY TENDS TO INCREASE WITH INCREASING DIVERSITY

The more complex and diverse communities become, the fewer the fluctuations in numbers of a given species, and the more stable the communities tend to be. As the number of species increases, so does the web of interdependencies (Savory, 1998). Monocultures are prone to major fluctuations. Disease outbreaks in plants and animals occur more frequently—as do outbreaks of weed, insect, bird, or rodent pests.

2.4.0 DISADVANTAGES OF INTERCROPPING 2.4.1 COMPETITION FOR GROWTH FACTORS

Roots of crops in association compete for growth factors such as nutrients, light and moisture which may affect the associated crop negatively (Wahua, 1983).

2.4.2 SHADING OF THE ASSOCIATED CROP

Osei Bonsu and Asibuo (1997) reported that legumes could become pest in an intercropping system by shading the components crop(s) and thereby reducing yield.

2.4.3 HARVESTING CHALLENGES

Most grain-crop mixtures with similar ripening times cannot be machine-harvested to produce a marketable commodity, since few buyers purchase mixed grains. Because of limited harvest options with that type of intercropping, farmers are left with the options of hand harvesting, grazing crops in the field with animals, or harvesting the mixture for on-farm animal feed. However, some intercropping schemes allow for staggered harvest dates that keep crop species separated.

2.5.0 FACTORS AFFECTING SUCCESSFUL INTERCROPPING

When two or more crops are growing together, each must have adequate space to maximize cooperation and minimize competition between them. To accomplish this, four things need to be considered: 1) spatial arrangement, 2) plant density, 3) maturity dates of the crops being grown, and 4) plant architecture.

2.5.1 RELATIVE TIME OF SOWING COMPONENT CROP

Probably the main way that complementarity in an intercropping system can occur is where growing pattern of the component crops differ in time so that the crops make their major demand on resource at different times (Willey 1979a). This type of complementarity is said to give better temporal use of resources. Ofori and Stern (1987) stated that the relative time of sowing component crops is a management variable that can be manipulated in cereal-legume intercropping systems. Willey (1979a) and Marandu (1977) also supported that varying the time of sowing of the component crops may be a way to improve yield advantage because it improves land productivity and minimize competition for growth limiting factors.

2.6.0 NITROGEN ECONOMY OF THE INTERCROPPING SYSTEM

The legume component of an intercropping system, because of ability to fix N_2 from the air, is a potential source of soil N (LaRue and Patterson 1981). However this contribution depends on the efficiency of N fixing system. The legume may either increase the soil N status through fixation or in the absence of an efficiency of N fixing system it may compete for N (Trenbath, 1976).

2.6.1 N_2 FIXATION BY THE LEGUME COMPONENTS.

Peoples and Herridge (1990) stated that the level of fixation depends on water supply, inoculation, crop management practice, including application of fertilizer N, and soil N fertility. There is an inverse relationship between the level of plant available soil N and the proportion of N derived from fixation. The contribution of N_2 fixation to the total N per plant is increased by nodulation levels of combined N (soil and fertilizer) but decline at high-levels, reflecting the depression of N_2 fixation caused by the high levels of either soil or fertilizer N (Marschner and Roemheld 1986). Levels of fixation achieved by crops in the field may be high, to offset the harvested seed.

The quantity of N_2 fixed by the legume component in cereal - legume intercropping depends on the species, morphology, density of legume in the intercrop mixture, the type of crops management and the competitive ability of the component crops (Ofori and Stern 1987, Peoples and Herridge 1990).

Difference in the competitive ability of the component crops for soil N can result in the stimulation of N_2 fixation and ultimately lead to an increase in N yield in the intercrop relative to the legume and cereal monocrops (Rerkasem *et. al*, 1988). Legume with indeterminate growth and a climbing habit are generally more efficient (Ofori and Stern 1987) and more successful (Peoples and Harridge 1990) than determinate type in terms of N fixation.

2.6.2 NITROGEN TRANSFER

Many commonly occurring intercrop systems involve a nodulating legume, and total intercrop yield are better relative to their monocultural components (Trenbath, 1976). It is suspected that nitrogen is somehow involved. Evidence in the literature suggests that N_2 fixed by the intercrop legume may be available to the associated cereal in the current growing season (Agboola and Fayemi, 1972) or as a residual for the benefits of a succeeding cereal crop (Ofori and Stern, 1987). Both forms of N transfer are considered to be important and could improve the N economy of various legumes – based intercrop system. The degree to which N from intercrop legume may benefit a cereal crop depend on the quantity and concentration of the legume N, microbial degradation (mineralization) of the legume residues, utilization of these residue, and the amount of N_2 fixed by the legume (Henzell and Vallis, 1977) cited from Ofori and Stern, (1987).

2.6.3 RESIDUAL N OF LEGUME CROPS

The total amount of N in a legume crop comes either from N_2 fixation or from uptake of mineral N from the soil (Peoples and Herridge 1990). The intercrop legume may accrue N to the soil and this may not become available until after the growing season, improving soil fertility to benefit a subsequent crop (Ofori and Stern 1986). Reported benefits of tropical crop legume to subsequent cereal crops are consistent and substantial and may persist several seasons (Peoples and Herridge 1990) regardless of whether the legume was grown in monoculture or intercrop.

From a comprehensive review made by Peoples and Herridge (1990), improvement in cereal yield represents around 30% to 35% increases over yield in cereal – cereal cropping systems. Peoples and Herridge (1990) also pointed out that the potential for legume leaves to contribute N to a subsequent crop can be considerable since they represent the single largest source of vegetative N remaining in the residue, and because of their high N content and low C:N ratio favour mineralization.

To maximize the contribution of legume N to a following crop, it is necessary to maximize total amount of N in legume crop, the proportion of N derived from N_2 fixation, the proportion legume N mineralized and the efficiency of utilization of this mineral N (People and Herridge 1990). Unfortunately, it is not always possible to optimize these factors. However the quantity of N and N concentration in the legume material returned are likely to be higher than when seed is removed from a food legume.

2.7.0 ADAPTING INTERCROPPING TO A FARM

Intercropping has been important in the U.S. and other countries and continues to be an important practice in developing nations. In traditional systems, intercropping evolved through many centuries of trial and error. To have persisted, intercropping had to have merit biologically, environmentally, economically, and sociologically. To gain acceptance, any agricultural practice must provide advantages over other available options in the eyes of the practitioner. Many of the impediments to adoption of new strategies or practices of diversification are sociological and financial than technological.

2.8.0 ESTIMATING ADVANTAGE OF INTERCROP

Intercropping in many instances resulted in the combined crop yield being greater than the sum yield of individual crops grown in monoculture on the same total land area (Willey, 1979a). Willey (1979a) attributed this to the results of more efficient utilization of environmental resources such as solar radiation, water and nutrients. An index for evaluating the efficiency of an intercropping system is the Land Equivalent Ratio (LER). LER is defined as the total land area required under sole cropping to give the yields obtained in the intercrop mixture at the same management level (Hiebsch and McCollum, 1987). It is the sum of fraction of the yields of component crops relative to their sole crop yield (Francis, 1986). An LER greater than 1 indicates that the intercrop is more productive than the comparative monocrops. On the other hand, when LER is equal to 1 or less than 1 there is no advantage to intercropping in comparison to sole cropping.

CHAPTER THREE

3.0.0 MATERIALS AND METHODS 3.1.0 EXPERIMENTAL SITE

The experiment was conducted at the Faculty of Agriculture Farm, KNUST, Kumasi in the Kumasi metropolis of Ashanti region of Ghana during the 2009 growing season. The area is characterized by forest and natural vegetation, representative of forest agroecological zone of Ghana. Rainfall distribution in this eco-zone is bimodal with mean annual rainfall of 1302mm. The area has a mean lowest and highest temperature of 24.6^0C and 28.8^0C respectively. Mean relative humidity is 77%. The area has an annual evapotranspiation of

1234mm with monthly values ranging from 107 to 144mm in the major dry season and 71 to 118mm in the rainy season. The area lies on latitude $6^{0}41'$N and longitude $1^{0}38'$W (Mensah *et.al* 2008). The soil are generally sandy loam, medium to coarse textured, with fairly high moisture holding capacity.

3.1.1 LAND PREPARATION

The vegetation was cleared, and the land was ploughed, harrowed and divided into 56 plots. Each plot was 5m x 5m with 0.5 and 1m between plots and treatment blocks, respectively

3.1.2 EXPERIMENTAL FIELD LAYOUT

The experimental plots were laid out in a randomized complete block design (RCBD) with fourteen treatments and four replications for each treatment

3.1.3 SPATIAL ARRANGEMENTS AND SOWING DATES

3.1.3a FACTOR 1: SPATIAL ARRANGEMENTS

Four maize-soybean spatial arrangements were tested:

One row of maize and one row of soybean (MS 1:1),

Two rows of maize and two row of soybean (MS 2:2),

Three rows of maize and three row of soybean (MS 3:3) and Four

rows of maize and four rows of soybean (MS 4:4).

3.1.3b FACTOR 2: TIME OF INTRODUCTION OF SOYBEAN

The soybean introduction times were

Simultaneous planting (0 WAPM),

One week after planting maize (1 WAPM) and

Two week after planting maize (2 WAPM)

Non-intercropped plots, Sole Maize (SM) and Sole Soybean (SS) were made to serve as sole crop or control

3.2.0 PLANTING MATERIALS

Seeds of both crops were obtained from the Seed Unit of Ministry of Food and Agriculture (MoFA). The maize variety was Obatampa and the Anidaso variety of soybean was used.

3.2.1 PLANT CULTURE

The maize was sown at a spacing of 80 x 40 cm and intercropped with the soybean at 0, 1 and 2 week after planting the maize (WAPM). With the exception of 1:1 intercrop row configuration the soybean was sown at a spacing of 60 x 5cm. The spatial arrangements of the intercrop components were 1:1, 2:2, 3:3, and 4:4.

SPATIAL ARRANGEMENTS

One row of maize to one row of soybean

Two rows of maize to two row of soybean

Three rows of maize to three row of soybean

Four rows of maize to four rows of soybean

3.3.0 WEED CONTROL.

Weed control was done manually by hoeing. Two weeding were done at 3rd and 7th week after planting the maize.

3.4.0 FERTILIZER APPLICATION

The compound fertilizer, NPK (15-15-15) was applied to the sole maize 4 WAP at 60 kg N ha^{-1}, 60 kg P ha^{-1} and 60 kg K ha^{-1} and top-dressed with sulphate of ammonia at 8 WAP at 50 kg N ha^{-1}

3.5.0 PARAMETERS MEASURED

The parameters measured were weekly maize plant height, maize stem diameter, nodule count, number of days to fifty percent flowering by the soybean component, number of days to fifty percent tasselling by the maize component, dry matter production by both crops, number of pods per plant, and hundred seed weight. The following were computed from the data: Leaf Area, Leaf Area Index, Crop Growth Rates, Relative Crop Growth Rate, Land Equivalent Ratio and yield of the maize and soybean (kg ha^{-1} and kg m^{-2})

3.6.0 PLANT DRY MATTER

Four plant samples from each plot were collected for growth analysis at 4, 7 and 10 WAP. Samples were oven-dried at 80°C for 72 h until a constant weight and dry weight were recorded. Crop growth rate (CGR), the increase in dry weight per unit ground area of crop in a unit time, was calculated using the following formula as proposed by

Gardener *et al* (1985)

$CGR = (W_2 - W_1) / (T_2 - T_1)$ ……………………………………………………………1

Where W_1 and W_2 are dry weights at times T_1 and T_2 respectively, and expressed as $gm^{-2} d^{-1}$. A measure of the efficiency of a plant as a producer of new dry matter can only be made if the initial size of the plant is taken into account. Relative growth rate (R) is used to measure the efficiency of dry matter production and it was calculated using the following formula as proposed by Gardener *et al* (1985).

$$R = (\log_e W_2 - \log_e W_1) / (T_2 - T_1) \quad \ldots\ldots 2$$

Where W_1 and W_2 are dry weights taken on two successive occasions at T_1 and T_2 respectively.

3.6.1 LEAF AREA AND LEAF AREA INDEX

3.6.1a SOYBEAN LEAF AREA AND LEAF AREA INDEX

Leaf Area Index (LAI) was determined by destructively sampling three plants at random from each plot and 50 discs of known diameter (1.0cm) were perforated on leaves picked from different levels on the plants (i.e. Lower, middle and top). The imperforated leaves and leaves discs were weighed. The area of the 50 discs per plot was obtained from the formula proposed by Andres (2004).

$$LA = \frac{M \times \pi r^2 \times Nd}{m} \quad \ldots\ldots 3$$

Where LA= Leaf area (m^2)

M = Weight of the imperforated leaves

m = Weight of discs Nd= number of

discs r = Radius of the discs (m)

$\pi = 3.14$

The total area of leaves per plot was then obtained by extrapolation and the leaf area index was calculated using the formula below:

$$LAI = \frac{\text{Green leaf area } (s)}{\text{Ground area (G)}} = \frac{[M \times \pi r2 \times Nd]}{m} /A \ldots\ldots\ldots\ldots\ldots\ldots 4$$

3.6.1b MAIZE LEAF AREA AND LEAF AREA INDECES

The formula proposed by Krishnamurthy et al (1974) was used to determine leaf area and leaf area index. It is given as:

Leaf area= k (l x w) ……………………………………………………………………5

Where,

l= leaf length w=

leaf width

k= factor (in cereals= 0.75). Leaf area index was calculated by dividing the total area of leaves by total land area it occupied.

LAI= k (l x w) /A ……………………………………………………………………..6

Where A= Total land area occupied by leaves

3.6.2 NUMBER OF PODS PER PLANT

Pods from four plants per plot selected randomly were counted at maturity and mean values were used as the number of pods/plants

3.6.3 HARVESTING

Maize and the serially introduced soybean were harvested at physiological maturity. Proper sampling procedures were employed at the time of harvesting by picking samples randomly and thereby ensuring that no particular treatment is consistently favored or handicapped

3.6.4 LAND EQUIVALENT RATIO

To study competition effects between the crops and to evaluate intercrop performance, the competition function; Land Equivalent Ratio (LER) was calculated. The LER is an accurate assessment of the biological efficiency of the intercropping situation. For treatments to be analyzed as an additive series, the land equivalent ratio (LER) was calculated. The LER, which was first described by Mead and Willey (1980), is calculated according to the following;

$$LER = (Y_{1,2} / Y_{1,1}) + (Y_{2,1} / Y_{2,2}) \quad \text{……………………………………………………..7}$$

Where Y is the crop yield and the suffixes 1 and 2 denote crop 1 and crop 2 in the mixture. Thus $Y_{1,2}$ is the yield of crop 1 when grown in mixture with crop 2, and $Y_{1,1}$ is the yield of crop 1 when grown in monoculture. The LER characterizes the performance of an intercrop by giving the relative land area under sole crops, required to produce the yields achieved in intercropping.

3.7.0 SOIL SAMPLING

Soil samplings were done prior to planting and immediately after harvest. Soil samples were collected from each of the replicated experimental plots to estimate the contribution of the associated legume to the total nutrient budget of the soil. Samples were taken from 0-15cm, and 15-30 cm depth.

3.8.0 SOIL ANALYSIS 3.8.1 DETERMINATION OF SOIL pH

The hydrogen ion concentration (pH) of soil was determined electrometrically. 10g air dried soil in 100ml beaker. 25ml distilled water was added and vigorously stirred for 20 minutes. After allowing suspended clay to settle out from the suspension a pH meter was calibrated at pH of 4 and 7 respectively. Electrode of pH meter was inserted into the suspension and read off (Motsara and Roy 2008).

3.8.2 DETERMINATION OF % TOTAL NITROGEN

Percentage total Nitrogen was determined by digestion, distillation and titration. 10ml distilled water was added to 10.0g of air dry soil in a 500ml Kjeldahl flask and allowed to moisten for 10 minutes. One spatula full of Kjeldahl catalyst and 30ml concentrated H_2SO_4 was added. This was digested for 1½hours, followed by dispense of 20 ml of 40% NaOH. Distillation was done by taking 10 ml aliquot of digest and 4% Boric acid with mixed indicators. A conical flask was used to trap the distillate. With the addition or dispense of 20ml of 40% NaOH. The distillate was titrated with 0.1 N HCl and percent nitrogen determined (Pellet and Young1980).

3.8.3 DETERMINATION OF % ORGANIC CARBON

Percent Organic carbon was determined by Walkley-Black oxidation method. 2.0g of soil sample was weighed into a 500 ml flash. From a burette, exactly 10ml of 1.0 N Potassium dichromate was added, followed by 20 ml of con. H_2SO_4. The mixture was swirled and allowed to cool for 30 minutes. 200 ml of distilled water and 10ml of orthophosphoric acid was added and titrated with 1.0 N ferrous sulphate solution (Walkley and Black1934).

3.8.4 DETERMINATION OF AVAILABLE PHOSPHORUS

Available phosphorus was determined colorimetrically or spectrophotometrically. 20ml of Bray Pl extracting solution was added to 2.0g of soil in 50ml bottle. It was shaken and filtered into a 100ml flask and 10ml of filtrate was pipetted into a 25ml flask. 1.0ml each of molybdate agent and reducing agent was added and made up with distilled water to the 25ml mark followed by vigorous shaking and allowed to stand undisturbed for 30 minutes for color development. Measurement of percentage transmittance at 600nm was done on a spectrophotometer (Bray and Kurtz1945).

3.8.5 DETERMINATION OF EXCHANGEABLE CATIONS

Exchangeable metallic cations or bases (Ca^{2+}, Mg^{2+}, K^{+}) were determined after extraction and bringing them into solution. 100ml of 1.0 N NH_4OAc (PH 7) solution was added to 10.0g soil in extraction bottle. The mixture was shaken for 1 hour followed by filtration and the aliquots of the filtrate were used for the determination of Ca, Mg, K and Na (Motsara and Roy 2008).

3.8.6 PARTICLE SIZE ANALYSIS

Particle size was analyzed by weighing 51.0g of air-dried soil into a bottle and 100ml of distilled water was added and swirled. 20ml and 50ml of 30% H_2O_2 and 5% sodium hexametaphosphate respectively were added. Amyl alcohol was added and shaken for 2 hours. The content was transferred into a 1000ml sedimentation tube and water washings of all soil particles were added and made up with distilled water. Readings were record using a thermometer and hydrometer (Motsara and Roy 2008).

3.9.0 DATA ANALYSIS

All data was analyzed with the Analysis of Variance (ANOVA) using the Genstat 5 statistical package (Numerical Algorithms Group, Oxford, England) (Payne *et al*., 1987). The Least Significant Difference (LSD) procedure was used to determine treatment differences. The significant differences between the treatments were compared with the critical difference at a 5% level of probability.

Treatment	Week 4 (g/plant)	Week 7 (g/plant)	Week 10 (g/plant)

CHAPTER FOUR

4.0 RESULTS 4.1 MAIZE DRY MATTER YIELD

Results of maize dry matter yield (DMY) are presented in Table 1. During sampling at week 4, the 4:4 spatial arrangement significantly ($P<0.05$) produced greater DMY than that of the l:1

arrangement only. All other treatments differences were statistically similar. Introducing soybean at 2 WAPM also resulted in significantly greater DMY than those of other periods.

At week 7, the DMY of the various spatial arrangements were not significantly different from one another ($P>0.05$). Additionally, time of introduction of the intercrop legume component did not significantly ($P>0.05$) affect maize dry matter production. The maize dry matter yield during sampling at week 10 was not significantly affected ($P >0.05$) by both spatial arrangement and time of the introduction of the intercrop.

The results of the experiment also showed that the sole maize plots gave the highest DMY at week 4, 7 and 10 and this effect was significantly higher than all other treatment effects

Spatial arrangement			
MS (1:1)	21.47	52.70	73.70
MS (2:2)	24.04	42.40	66.20
MS (3:3)	24.82	50.50	70.00
MS (4:4)	27.02	49.40	80.70
L S D (5%)	5.25	NS	NS
CV (%)	5.10	7.80	9.50
Time of intercropping			
0 WAPM	22.60	44.80	67.20
1 WAPM	22.41	45.60	67.80
2 WAPM	28.01	55.90	82.90
L S D (5%)	4.55	NS	NS

CV (%)	5.10	7.80	9.50
Sole crop	30.4	61.2	87.9

Table 1. Effects of intercropping on maize dry matter yield sampled over three different periods

NS= No significant difference

4.2 SOYBEAN DRY MATTER YIELD

Soybean DMY results are presented in Table 2. Spatial arrangement did not significantly affect soybean dry matter at week 4. Soybean planted at 0 WAPM and 1 WAPM were not different in their effect on soybean dry matter, but either effect was significantly greater than when the soybean was introduced at 2 WAPM.

At week 7, both spatial arrangement and time of introducing the soybean did not significantly affect soybean DMY ($P>0.05$). Sampling at week 10 showed that spatial arrangement did not significantly ($P> 0.05$) affect Soybean DMY. Soybean dry matter yield was greatest when soybean was introduced at 0 WAPM, and this effect was significantly higher than all other treatment effects (Table 2).

The results of the experiment also indicated that the sole soybean plots gave the highest DMY at week 4, 7 and 10 and this effect was significantly higher than all other treatment effects

Table 2. Effects of intercropping on soybean dry matter yield sampled over three different periods

Treatment	Week 4 (g/plant)	Week 7 (g/plant)	Week 10 (g/plant)
Spatial arrangement			
MS (1:1)	7.91	12.79	18.56
MS (2:2)	8.43	13.15	21.14
MS (3:3)	8.67	13.17	20.62
MS (4:4)	8.36	13.50	18.92
L S D (5%)	NS	NS	NS
CV (%)	12.10	11.80	12.50
Time of intercropping			
0 WAPM	9.58	14.45	23.92

1 WAPM	9.13	13.64	19.28
2 WAPM	6.32	11.37	16.22
L S D (5%)	1.95	NS	4.25
CV (%)	12.10	11.80	12.50
Sole crop	10.9	11.9	26.45

NS= No significant difference

4.3 CROP GROWTH RATE AND RELATIVE CROP GROWTH RATE The effects of cropping system on crop growth rate and relative growth rate are presented in Tables 3. The results indicated that both spatial arrangements and time of introduction of the soybean did not significantly (P>0.05) affects maize crop growth rate at 28-49 DAS. Also both spatial arrangements and time of introduction of the soybean did not impact significantly (P>0.05) on relative growth rate (RGR) of the maize component at 28 – 49 DAS.

For the soybean, spatial arrangement did not significantly (P>0.05) affects crop growth rate at 28– 49 DAS. However soybean growth rate was greatest when soybean was introduced at 0 WAPM and this effect was significantly (P<0.05) higher than all other treatment effects (Table 3) .Time of introduction of the soybean and spatial arrangement did not impact significantly (P>0.05) on soybean Relative Growth Rate at 28 – 49 DAS.

The results of the experiment also showed that the sole maize plots and the sole soybean plots gave the highest CGR and RGR and this effect was significantly higher than all other treatment effects at 28 – 49 DAS.

Table 3. Effects of intercropping on crop growth rate (CGR**) and relative growth rate** (RGR)

Treatment	MAIZE		SOYBEAN	
	CGR ($gm^{-2}d^{-1}$) 28-49 DAS	**RGR ($gg^{-1}d^{-1}$) 28-49 DAS**	**CGR ($gm^{-2}d^{-1}$) 28-49 DAS**	**RGR ($gg^{-1}d^{-1}$) 28-49 DAS**
Spatial arrangement				
MS (1:1)	0.94	0.0342	0.267	0.0258
MS (2:2)	1.08	0.0400	0.367	0.0283
MS (3:3)	0.85	0.0317	0.350	0.0275
MS (4:4)	1.35	0.0308	0.342	0.0317
L S D (5%)	NS	NS	NS	NS
CV (%)	9.2	6.3	16.7	9.9
Time of intercropping				
0 WAPM	0.93	0.0319	0.475	0.0300
1 WAPM	1.20	0.0363	0.312	0.0313

2 WAPM	1.03	0.0344	0.206	0.0238
L S D (5%)	0.48	NS	0.1572	NS
CV (%)	9.2	6.3	16.7	9.9
Sole crop	2.2	0.038	0.5	0.093

NS= No significant difference

4.4 LEAF AREA AND LEAF AREA INDICES OF MAIZ AND SOYBEAN

Results of the effects of spatial arrangements and time of introduction of soybean on Leaf Area (LA) and Leaf Area Index (LAI) are presented in Table 4. The results showed that both spatial arrangements and time of introduction of the soybean did not significantly (P>0.05) affect both maize leaf area and maize leaf area index.

With regard to the soybean, spatial arrangements did not significantly influence leaf area (P>0.05). However, time of introduction of the legume component significantly (P<0.05) influenced leaf area. Leaf area was greatest when soybean was introduced at 0 WAPM and this effect was significantly higher than that of other treatments. The highest leaf area index was recorded in the MS (1.1) spatial arrangement and this effect was significantly (P<0.05) higher than the effects of MS (4:4) arrangements only. Other treatment differences were not significant. Time of introduction of soybean significantly (P<0.05) affected leaf area index. The highest LAI was recorded when soybean was introduced at OWAPM which was significantly greater than that of other treatments. Other treatment differences were not significant at 5% level of probability.

The results showed that the sole maize plots and the sole soybean plots gave the highest LA and

LAI and this effect was significantly higher than all other treatment effects

Table 4. Effects of intercropping on leaf area and leaf area indices of maize and soybean

Treatment	MAIZE		SOYBEAN	
	LEAF AREA (cm^2)	LEAF AREA INDEX	LEAF AREA (cm^2)	LEAF AREA INDEX
Spatial arrangement				
MS (1:1)	601.0	2.00	1991.0	6.50
MS (2:2)	608.0	2.13	1700.0	5.63
MS (3:3)	568.0	1.99	1649.0	5.40
MS (4:4)	643.0	2.22	1871.0	4.94
L S D (5%)	NS	NS	NS	1.52
CV (%)	4.0	5.1	11.8	16.6
Time of intercropping				
0 WAPM	609.0	2.10	2266.0	6.85
1 WAPM	574.0	1.99	1604.0	5.17
2 WAPM	633.0	2.17	1539.0	4.84
L S D (5%)	NS	NS	549.9	1.31
CV (%)	4.0	5.1	11.8	16.6
Sole crop	669.9	2.5	1925.2	6.6

NS= No significant difference

4.5 TASSELLING AND FLOWERING DATES, STEM DIAMETER AND NODULE COUNT

The effect of spatial arrangement and time of introduction of the legume component on number of days to 50% tasselling by the maize, maize stem diameter, number of days to 50% flowering by the soybean plants and number of effective nodules produced by the soybean plants is presented in Table 5. Spatial arrangements significantly ($P<0.05$) influenced the number of days to 50% tasselling (Maize). Spatial arrangement 3:3 produced the greatest influence and this was statistically higher ($P<0.05$) than that of 1:1 and 2:2 treatment combinations. Differences in all other treatment combinations were not statistically significant ($P>0.05$). Time of introduction of soybean statistically influenced number of days to 50% tasselling by the maize. Tasselling date was greatest when soybeans was introduced at 2 WAPM and this was significantly different from the other treatments ($P<0.05$).

The greatest maize stem diameter was recorded in the MS (4:4) arrangements and this was significantly ($P<0.05$) higher than all other spatial arrangements. All other treatment effects were statistically similar. Stem diameter of maize was significantly higher when soybean was introduced at 2 WAPM than in all other times. Indeed there was no differences observed at 0 WAPM and 1 WAPM

Neither the spatial arrangement nor the time of introduction of the soybean resulted in significant ($P>0.05$) influence on the number of days to 50% flowering by the soybean plants.

Spatial arrangement did not have any significant ($P>0.05$) influence on nodule count. The lowest number of nodules per plant was obtained when soybean was intercropped at 2 WAMP and it was significantly ($P<0.05$) lower than that of other sowing dates. There was however no significant ($P>0.05$) difference between O WAPM and 1 WAPM.

Spatial arrangement MS (2:2) gave the highest number of effective nodules and this was significantly ($P<0.05$) different from that of MS (1:1) treatment only. Time of introduction of soybean significantly ($P<0.05$) influenced nodule number. The highest was obtained when soybean was intercropped at 0 WAMP which was significantly ($P<0.05$) higher than those of other treatments. The effect of the 1 WAPM treatments was also significantly higher than that of the 2 WAPM treatments.

Table 5 Effects of intercropping on tasselling and flowering dates, stem diameter and nodule count

Treatment	MAIZE		SOYBEAN		
	Days To 50% Tasselling	Stem Diameter (cm)	Days To 50% Flowering	Nodule count	Effective Nodules
Spatial arrangement					
MS (1:1)	57.66	7.38	57.33	13.0	7.00
MS (2:2)	57.75	7.56	57.50	12.75	8.42
MS (3:3)	58.16	7.22	58.17	13.42	7.75
MS (4:4)	57.83	7.95	57.58	12.15	7.42
L S D (5%)	0.37	0.37	NS	NS	1.18
CV (%)	0.3	3.0	0.7	10.12	5.4
Time of intercropping					
0 WAPM	57.62	7.08	57.50	13.75	9.75
1 WAPM	57.50	7.43	57.88	12.15	7.31
2 WAPM	58.43	8.08	57.56	9.0	5.88
L S D (5%)	0.32	0.32	NS	1.93	1.02
CV (%)	0.3	3.0	0.7	10.12	5.4

SM/SS	56.00	9.00	57.00	15.0	11

NS= No significant difference

4.6 MAIZE GRAIN YIELD

The effect of cropping system on yield of maize in maize–soybean intercropping system is shown in Table 6. Yield estimated in kilograms of grain per hectare showed that the spatial arrangement MS (1:1) produced the greatest maize grain yield (2524.0 kg/ha) and this was statistically higher than that of other spatial arrangements. All other spatial arrangement treatment combinations were statistically (P>0.05) similar. Time of introduction of the soybean did not, however, produce any significant (P>0.05) difference.

Table 6. Effects of intercropping on maize grain yield

Treatment	**kg ha^{-1}**
Spatial arrangement	
MS (1:1)	2524.0
MS (2:2)	1783.0
MS (3:3)	1415.5
MS (4:4)	1749.5
L S D (5%)	654.3
CV (%)	6.8
Time of intercropping	
0 WAPM	1722.5
1 WAPM	2010.0
2 WAPM	1871.5
L S D (5%)	NS
CV (%)	6.8
SM	3781.0

NS= No significant difference

4.7 SOYBEAN GRAIN YIELD

The effects of spatial arrangement and time of introduction of soybean on soybean grain yield are presented in Table 7. MS (2:2) gave the highest number of pods per plant and this differed significantly ($P<0.05$) from that of MS (1:1) and MS (3:3) treatment combinations only. MS (4:4) ranked second to MS (2:2) in terms of number of pods per plant and this was statistically ($P<0.05$) higher than the MS (1:1) only. All other treatment combinations were statistically similar. The highest number of pods per plant was obtained when the soybean was introduced at 0 WAPM and this differed significantly ($P<0.05$) from the rest of the sowing dates. There was no significant ($P>0.05$) difference between 1WAPM and 2 WAPMS.

Spatial arrangement of component crops did not significantly ($P>0.05$) affect soybean 100 seed weight. However, time of introduction of the soybean significantly influenced soybean 100 seed weight. The highest value of 9.70 grams of grain per plant was obtained when soybean was introduced at 0 WAPM and this value was statistically ($P<0.05$) higher than that of the rest of treatments. There was, however, no significant ($P>0.05$) difference between the effects of 1 WAPM and 2 WAPMS.

Both spatial arrangement and time of introduction of the soybean significantly ($P<0.05$) affected soybean grain yield. The MS (1:1) gave the greatest grain yield of 2,040.0 kg ha^{-1} and this was significantly ($P<0.05$) higher than that of MS (3:3) and MS (4:4) arrangements. Other treatment combinations were statistically similar. Introducing the soybean at 0 WAPM gave the highest grain yield and this was significantly ($P<0.05$) greater than the rest of the sowing dates. 1 WAPM and 2 WAPM introductions statistically gave similar results.

Table 7. Effects of intercropping on soybean yield

Treatment	**Pods/Plant**	**100 Seed Weight (g)**	**kg ha^{-1}**
Spatial arrangement			
MS (1:1)	30.1	9.15	2040.0
MS (2:2)	44.6	9.34	1667.0
MS (3:3)	34.7	9.13	1419.5
MS (4:4)	39.3	9.43	1376.5
L S D (5%)	8.95	NS	553.0
CV (%)	5.3	2.5	15.3
Time of intercropping			
0 WAPM	62.9	9.70	2056.0
1 WAPM	27.6	9.13	1428.0
2 WAPM	21.0	8.96	1393.0
L S D (5%)	7.76	0.526	479.1
CV (%)	5.3	2.5	15.3
SS	52.5	10.5	3572.0

NS= No significant difference

4.8 LAND EQUIVALENT RATIO

The results of the spatial arrangement and time of introduction of soybean on land equivalent ratio are shown in Table 8. The highest land equivalent ratio value of 1.672 was recorded on MS (1:1) arrangement and this was significantly ($P<0.05$) higher than that of MS (3:3) and MS (4:4) treatment combinations. The treatment effect of MS (2:2) was significantly ($P<0.05$) greater than that of MS (3:3) treatment only. All other treatments were statistically similar.

Time of introduction of the soybean did not significantly influence the land equivalent ratio values (Table 8).

Table 8. Effects of intercropping on land equivalent ratio

Treatment	Land Equivalent Ratio	Remarks(s)
Spatial arrangement		
MS (1:1)	1.672	advantageous
MS (2:2)	1.436	advantageous
MS (3:3)	0.975	not advantageous
MS (4:4)	1.185	advantageous
L S D (5%)	0.3661	
CV (%)	32.2	
Time of intercropping		
0 WAPM	1.526	advantageous
1 WAPM	1.215	advantageous
2 WAPM	1.210	advantageous
L S D (5%)	NS	
CV (%)	32.2	

NS= No significant difference

4.9a SOIL NUTRIENT BUDGET

The effects of spatial arrangements and time of introduction of soybean on soil nutrient budget are presented in Table 9. Spatial arrangement significantly ($P < 0.05$) affected the level of carbon in the soil. MS (3:3) gave the highest % C and this was significantly ($P < 0.05$) higher than that of other spatial arrangement combinations. The rest of the spatial arrangement combinations were statistically ($P>0.05$) similar. Time of introduction of the soybean significantly ($P < 0.05$) affected % C. 1WAPM gave the highest % C and this was significantly ($P < 0.05$) greater than that of other sowing dates. Indeed 0 WAPM and 2 WAPM did not show any significant ($P>0.05$) difference.

Spatial arrangement significantly ($P < 0.05$) affected percent organic matter (% OM). MS (3:3) gave the highest % OM and this was significantly ($P < 0.05$) greater than all other spatial arrangement treatments. All other spatial arrangement treatments were statistically ($P > 0.05$) similar. The highest % OM was obtained when the soybean was introduced at 1WAPM and this was significantly ($P < 0.05$) higher than that of other sowing dates. 2 WAPM was also significantly greater than 0 WAPM.

Indeed both spatial arrangements and time of intercropping did not significantly ($P >0.05$) affect percent nitrogen (% N), percent calcium (% Ca) and percent Magnesium (% Mg).

The spatial arrangement MS (4:4) recorded the highest percent potassium (% K) and this was significantly ($P < 0.05$) higher than MS (3.3) only. All other spatial arrangements treatment were statistically ($P > 0.05$) similar. Time of introduction of the soybean did not significantly ($P > 0.05$) affect % K.

Spatial arrangement significantly affected percent phosphorus (% P). MS (4:4) gave the highest % P and this was significantly ($P < 0.05$) greater than MS (1:1) and MS (3:3) only. All other spatial arrangements treatment combination were statistically ($P > 0.05$) similar. Time of introduction of the soybean did not significantly ($P > 0.05$) affect % P.

The spatial arrangement MS (1:1) gave percent pH value which was significantly smaller ($P > 0.05$) than all other spatial arrangement treatment combinations. All other spatial arrangement treatment combinations were statistically ($P > 0.05$) similar. Indeed time of introduction of the soybean did not significantly ($P > 0.05$) affect % PH.

Generally, the presence of the legume in the cropping system had increased the amount N, P, K, Ca, and organic matter (before planting *vs* after harvest analysis) content of the soil

Table 9 Effects of intercropping on soil nutrient budget

Treatment	C %	OM %	N %	Exchangeable cations (cmol/kg)			P (Mg/kg)	pH
				Ca	Mg	K		
Spatial arrangement								
MS (1:1)	0.673	1.17	0.132	3.97	1.658	0.45	11.6	5.319
MS (2:2)	0.674	1.14	0.134	3.63	1.887	0.25	15.0	5.502
MS (3:3)	0.898	1.53	0.129	3.82	1.958	0.20	12.0	5.520
MS (4:4)	0.702	1.21	0.130	4.60	2.032	0.99	17.0	5.648
LSD (5%)	0.132	0.23	NS	NS	NS	0.742	4.6	0.178
CV (%)	2.6	1.4	15.9	3.2	2.7	3.8	12.9.	0.6
Time of intercropping								
0 WAPM	0.623	1.04	0.134	3.71	1.753	0.16	13.0	5.435
1 WAPM	0.859	1.48	0.130	4.19	1.968	0.49	15.1	5.561
2 WAPM	0.729	1.27	0.129	4.11	1.931	0.78	15.0	5.496
LSD (5%)	0.114	0.20	NS	NS	NS	NS	NS	NS
CV (%)	2.6	1.4	15.9	3.2	2.7	3.8	12.9.	0.6

Before planting	0.56	0.97	0.07	2.20	1.20	0.08	10.6	5.62

4.9b PARTICLE SIZE ANALYSIS

The spatial arrangement and time of intercropping on soil particle size is presented in Table 10. Spatial arrangements did not significantly (P > 0.05) affect percent sand, but time of introduction of the soybean significantly (P < 0.05) affected % sand. The highest value of 84.44% was obtained when soybean was introduced at 2 WAPM and this was significantly (P < 0.05) greater than that of other sowing dates. Indeed there was no significant difference between 0 WAPM and 1 WAPM.

MS (3.3) gave the greatest percent silt and this was significantly (P < 0.05) greater than that of MS (2:2) only. All other spatial arrangement treatments were statistically (P > 0.05) similar. Time of introduction of the soybean did not significantly (P > 0.05) affect % silt.

Spatial arrangement did not significantly (P > 0.05) affect percent clay (% clay), however, time of introduction of soybean significantly (P < 0.05) affected % clay. 1 WAPM and 0 WAPM gave the highest % clay of 8.20% and 8.18% respectively and these were significantly (P < 0.05) higher than that of 2 WAPM. There was no significant (P > 0.05) difference between 0 WAPM and 1 WAPM.

Table 10 Effects of intercropping on soil particle size

Treatment	% sand	% silt	% clay
Spatial arrangement			
MS (1:1)	83.51	8.42	7.99
MS (2:2)	84.15	8.04	7.81
MS (3:3)	83.61	8.73	7.83
MS (4:4)	83.83	8.33	7.67
LSD (5%)	NS	0.67	NS
CV (%)	0.3	1.9	0.3
Time of intercropping			
0 WAPM	83.54	8.28	8.18
1 WAPM	83.34	8.52	8.20
2 WAPM	84.44	8.34	7.09
LSD (5%)	0.66	NS	0.38
CV (%)	1.1	9.7	14.0
Before planting	84.4	9.8	7.8

CHAPTER FIVE

5.0 DISCUSSION

This study has shown that yield and yield components of the intercropped components varied significantly with time of introduction of the legume component and spatial arrangements. The performance of the associated legume appeared to have been affected by the growth of maize and its associated micro climatic changes. This is reflected in the significant differences among treatments in terms of grain yield.

5.1 DRY MATTER YIELD

Because of the differences in canopy height of soybean and maize, the two species not only competed for nutrient and water but also for sunlight (Hauggaard-Nielsen *et al*., 2001b; Ghosh, 2004). The shading effect of tall intercropped maize may have adversely affected photosynthesis and hence reduction in biomass yield of intercropped soybean relative to that of the monocrop plots. The present results agree with Acheampong (2006) who reported a decrease in dry matter yield with delay in intercropping cowpea with maize. The results do not differ from that of OseiBonsu (1998) who reported that the legume cover crop mucuna gave higher shoot biomass 4 WAP than 10 WAP maize in a maize - mucuna intercrop trial. The reduction in dry matter yield in the intercrops relative to that of the sole crops buttresses the fact that light energy is needed to initiate photosynthesis and hence dry matter accumulation.

5.2 LEAF AREA, LEAF AREA INDEX AND FLOWERING

The LA and LAI's of intercropped legume were lower than LA and LAI's of legume monocrops, which suggests that grain legumes were dominated by corn. This may be the reason for depressed yields of intercropped legume. The differences in LA and LAI can be attributed to different canopy configuration giving rise to differences in LA (Adams *et, al* 1976). Important factors affecting the competitive ability of species and genotypes are the leaf area dynamics, plant height, root growth dynamics, and resource use efficiency (Kropff and Lotz, 1993) Optimizing the crop performance in an intercrop system is a question of maximizing complementarity and minimizing the competition between the two component crops (Willey, 1979a). The higher total LAI in maize/legume intercrops indicate a greater interception of incoming solar radiation by intercrops than by monocrops, and this may also be the reason for increased total biomass production/ha in intercropping systems relative to their monocultural counterparts.

Days to first tassel and flower are plant encoded (governed predominantly by genetic make-up of the plant). However, the above agronomic alternations also impacted significantly on flowering and tasselling dates (Table 5). This could be attributed to the contrasting growth habits of the associated crops and its micro environmental changes

5.3 NODULATION

The intercropped maize significantly affected nodulating ability of soybean (Table 5). Limited ability to obtain sunlight by the soybean shoots might translate into major competitive limitation (Midmore, 1993) that strongly influences the interspecific competitive ability. The reduced light energy affects nodulation by restricting photosynthesis and the energy supply to roots, thereby reducing nodulation (Nambiar *et al.,* 1986). The decrease in nodule number with delay in intercropping could also be due to suboptimal development of soybean plants which lowered their potential for nodule formation. The decrease in nodule number with delay in intercropping is also in conformity with study done by Acheampong (2006) who reported a decrease in nodule number with delay in intercropping cowpea with maize.

5.4 YIELD COMPONENTS

The seed yield of intercropped maize and soybean was lower than the sole crops (Table 6 and 7). Soybean did not benefit from the intercropping to the same degree as maize. Thus, the results ascertain that maize was the major contributor to the mixture yield. The reduction in yield components of the legume is in conformity with work done by Acheampong (2006) who observed a decrease in yield component of the legume with late sowing. The reduction in the yield of the associated cereal can be attributed to competition of intercrop component for growth resources. Similar observation was made by Drisah (2005) who reported a significant reduction in maize grain yield intercropped with mucuna and canavalia. The results, however, contradicts that of Acheampong (2006) and Ghaffarzadeh *et al.* (1994) who observed a decrease in yield component of the cereal with late introduction of the legume component. The gradual reduction in yield of the soybean crops was largely due to interspecies competition for factors of growth especially light. Mark (1992) concluded from his studies that sowing of soybean should be staggered in such a way as to minimize the demand for light by the two crops at the same time. The greater ability of the cereal component to absorb limited soil factors increased the interspecific competition in the intercrop (Trenbath, 1976) thereby reducing soybean yield components.

This is similar to contramensalism (one species increased and the other decreased) in microorganism communities (Hodge and Arthur, 1996). The coexistence of positive and negative interactions in the same ecosystem has also been found in forests between *Abies lasiocarpa* and *Pinus albicaulis* (Callaway, 1998), in the shrub *Reama sphaerocarpa* and herb *Marrubium vulgare* community (Pugnaire *et al.*, 1996), in other ecosystems (Callaway, 1998), and in field crops wheat and maize or wheat and sorghum (Li *et al*., 2001).

The observations on competition indicators in the present study corroborated the Crimes theory of competitive success in which the species with greater capacity for resource capture will be the superior competitor (Grace, 1990). Accordingly, maize was the superior competitor during the experiment. The number of soybean pods produced per plant decreased with delay in intercropping probably due to corresponding decrease in photosynthate production. The reproductive sink size of the soybean plant and its relative strength appear to have an innate bearing on photosynthesis and consequently the seed yield. Duncan *et al*. (1978) observed partitioning of photosynthate to pods as the most influential physiological factor in yield determination. The early intercropped legume performed better because they had a long period of time to assimilate organic matter and to fill their grains (Climpson, 1994). Legume yield was also found to be suppressed by cereals in other studies (Mohta and De, 1980; Lesoing and Francis, 1999; Hauggaard-Nielsen and Jensen, 2001).

Yields were drastically affected by spatial arrangements because the proportion of the component crops in mixture is closely linked to the spatial arrangement.This findings contradicts that of Mohta and De (1980) who reported that yield of maize and sorghum was unaffected in either single or double alternate row configurations in maize–soybean and sorghum–soybean systems.

The reason for this phenomenon is more of environmental than genetical.

5.5 YIELD ADVANTAGE

In general, the non legume crop is considered a suppressing crop in legume/nonlegume associations like sorghum/pigeonpea (Tobita *et al*., 1994, 1996), groundnut/cereal fodders (Ghosh, 2004), and berseem (*Trifolium alexandrinum* L.)/barley (Ross *et al*., 2004). This was shown to be true in soybean/maize intercropping in the present study as indicated by the yield and yield components (Table 7).

The LER gives an accurate assessment of the biological efficiency of the intercropping situation. The trade-off between increasing the yield of suppressing species and decreasing that of the suppressed species has three possible outcomes for intercropping systems, i.e., yield advantage (LER > 1), yield disadvantage (LER < 1), and the intermediate result (LER = 1) (Vandermeer, 1989). The results of the present experiment showed crop complementarities in soybean/maize intercropping and yield advantage, as LER values are greater than unity (Table 6). This corroborated the findings of Willey (1979a) and Reddy and Willey (1981). Spatial arrangements however had a significant impact on yield. Yield of maize and soybean was negatively affected in MS (2:2), MS (3:3), and MS (4:4) row configurations owing to reduction in plant population densities and variation in the utilization of resources.

The findings as a whole indicate that there are yield advantages over the component crops grown as sole crops (Fussell and Serafini, 1985). This also agrees with work done by Ofori and Stern, (1987), who reported that intercropping produces higher and suitable yield in wide range of component combinations. The findings does not differ from that of Agboola and Fayemi (1977), who reported that intercropping maize with Phaseolus *aureu, Vigna anguiculata and Colopogonium mucunoids* increase its mean grain yield by 0.5 tons/ha over the control. The findings which agree with that of Andrew, (1972), and Nyambo *et. al* (1980) indicated that, although intercropping reduces the yield of component crops but total productivity and net return has been found higher in intercropping system than sole cropping. The present results do not differ from work done by Goswami *et al.* (1999) who reported that intercropping soybean with sorghum and arhar (*Canjanus spp.)* resulted in increased soybean equivalent yield and net return. Sherma *et al.* (2000) reported that sorghum –soybean intercropping system gave higher yield (38 to 124%) than other cropping systems. Net returns were higher from a sorghum + soybean 30/90 cm paired row system with two rows of soybean. Similarly Rashid *et al.* (2005) had reported that mungbean associated with sorghum substantially increased income than sole cropping of sorghum. Rashid *et al.* (2006) found that grain yield of sorghum with intercrops of mungbean or guar increased over sole cropping. Singh and Jha (1984) also observed that intercropping of sorghum was more economical as compared to sole cropping system of either crop. Net return obtained from intercropping was 7 to 54 percent more than sole cropping. Shahapurkar and Patil (1989) recorded higher net income of per hectare from paired rows of maize + soybean intercropping compared to net income from maize crop alone. Barik *et al.* (1998) stated that sorghum and groundnut intercropping system appeared to be more advantageous from value of land equivalent ratio (LER), relative value total (RVT) and relative net return (RNR). Similarly, Singh and Balyan (2000) indicated that sorghum + clusterbean in paired row planting pattern (30/90 cm) proved as the best intercropping system with maximum total productivity and net return. The yield advantage of intercropping had also been reported by Singh and Balyan (2000) who indicated that intercropping systems registered significant increase in total productivity (sorghum equivalent) over sole sorghum

5.6 SOIL NUTRIENT BUDGET

The results of the present study augment some of the evidence and speculation about the possibility of maintaining soil productivity through the inclusion of legumes in cropping systems. The positive impact on available soil nutrient budget can be attributed to beneficial effects of legumes in intercropping systems. Aggarwal *et al.* (1992) had reported that in legume intercrop, there is nitrogen leaching from the legume to the associate crop. Similarly, Redy *et al.*, (1992) reported that intercropping affects soil fertility maintenance through nitrogen fixation and differential uptake of nutrients. The findings does not differ from that of Willy (1979) who observed better use of light, nutrients as well as fixed nitrogen in legume-cereal intercropping system. Furthermore, Ofori and Stern, (1986), Moreira, (1989) and Cochran and Schlentner, (1995) had reported that total N accumulated by cereal component in association with soybean was greater than that of monocrop. Pal and Shehu (2001) found that all legume crops contributed to yield and N uptake of maize either intercropped with legume or grown after legume as a sole crop. In general, some legumes provide free supply of 15-20 units of nitrogen per month during growing season due to nitrogen fixation (Charles – Marie, 1992).

5.7 IMPROVEMENT OF THE INTERCROPS

Optimizing the crop performance in an intercrop system is a question of maximizing complementarity and minimizing the competition between the two component crops (Willey, 1979a). Intercrop performance can be improved with respect to temporal and spatial complementarity, and also by improving the compatibility of genotypes used as components of the mixture (Willey, 1979b). Staggering the relative planting time of the crops would be an example to account for temporal differences in resource use by the crops. Studies at the International Rice

Research Institute (Anonymous, 1973) and by Osiru and Willey (1976) showed increasing yield advantages due to staggered sowing of the component crop.

From a point of view of practicability, a plant mixture beyond a row-based replacement design is, however not realistic. Hence, optimization of the spatial arrangement should focus on row distance and in-row distance between plants. In this optimization process, practicability and options for mechanization should be taken into account. The proportion of the component crops in mixture is closely linked to the spatial arrangement.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS 6.1 CONCLUSION

The present study showed that crop growth rate, relative crop growth rate, leaf area index, nodule number and yield component of soybean decreased with delay in intercropping. The decrease in these parameters was mainly attributed to interspecific competition for nutrients, light, and space. In the case of maize, delay in introducing the legume component resulted in a progressive increase in yield components. This implies that the early intercropped maize plants experienced greater competition for growth factors. Staggering the relative planting time accounted for temporal differences in resource use by the crops and planting the component crops simultaneously or introducing the legume component not later than a week gave highest yield. Intercropping resulted in more returns than sole crops and growing of maize and soybean in 1:1 gave better yield returns than all other spatial arrangement combinations. It can therefore be concluded that optimization with respect to spatial arrangements and relative planting time of intercrop components can contribute to an improved complementarities of the crops in the mixture.

6.2 RECOMMENDATIONS

It is recommended to intercrop soybean not more than a week after planting the maize in 1:1 combination. With respect to improved spatial and temporal complementarities, information is needed about ecophysiological characteristics determining intra-and interspecific competition of a specific genotype. Ecophysiological crop growth models simulating interplant competition can help to find the most suitable combinations of genotypes, spatial arrangements, and relative planting times. Optimization of the spatial arrangement should focus on row distance and in-row distance between plants. In this optimization process, practicability and options for mechanization should be taken into account. Extensive field research using suitable experimental designs and appropriate statistical analyzing packages can help to improve the performance of intercrops with respect to yield and quality.

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APPENDICES

ANALYSIS OF VARIANCE OF MAIZE STEM DIAMETER

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	1.8790	0.6263	3.12	
Spatial arrangements (A)	3	3.5073	1.1691	5.82	0.003
Time of intercropping (B)	2	8.2400	4.1200	20.50	<.001
Interaction (A X B)	6	0.9433	0.78	0.1572	0.590
Residual	33	6.6335	0.2010		
Total	47	21.2031			

ANALYSIS OF VARIANCE OF NUMBER OF DAYS TO 50% FLOWERING

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	6.562	2.188	0.84	
Spatial arrangements (A)	3	4.729	1.576	0.60	0.617
Time of intercropping (B)	2	1.292	0.646	0.25	0.782
Interaction (A X B)	6	6.208	1.035	0.40	0.876
Residual	33	86.187	2.612		
Total	47	104.979			

ANALYSIS OF VARIANCE OF NUMBER OF DAYS TO 50% TASSELLING

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	1.3958	0.4653	2.24	
Spatial arrangements (A)	3	1.7292	0.5764	0.057	2.78
Time of intercropping (B)	2	8.2917	4.1458	19.96	<.001
Interaction (A X B)	6	1.7083	0.2847	0.255	1.37
Residual	33	6.8542	0.2077		
Total	47	19.9792			

ANALYSIS OF VARIANCE OF EFFECTIVE NODULE COUNT

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	6.062	2.021	1.01	
Spatial arrangements (A)	3	12.896	4.299	2.14	0.114
Time of intercropping (B)	2	122.792	61.396	30.61	<.001
Interaction (A X B)	6	1.042	0.174	0.09	0.997
Residual	33	66.188	2.006		
Total	47	208.979			

ANALYSIS OF VARIANCE OF MAIZE DRY MATTER YIELD AT WEEK 4

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	56.09	18.70	0.47	
Spatial arrangements (A)	3	189.47	63.16	1.58	0.213
Time of intercropping (B)	2	322.95	161.47	4.04	0.027
Interaction (A X B)	6	84.52	14.09	0.35	0.903
Residual	33	1318.31	39.95		
Total	47	1971.33			

ANALYSIS OF VARIANCE OF MAIZE DRY MATTER YIELD AT WEEK 7

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	525.4	175.1	0.44	
Spatial arrangements (A)	3	710.8	236.9	0.60	0.621
Time of intercropping (B)	2	1229.3	614.7	1.55	0.227
Interaction (A X B)	6	1777.1	296.2	0.75	0.615
Residual	33	13066.4	396.0		
Total	47	17309.1			

ANALYSIS OF VARIANCE OF MAIZE DRY MATTER YIELD AT WEEK 10

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	1728.5	576.2	1.18	
Spatial arrangements (A)	3	1377.3	459.1	0.94	0.433
Time of intercropping (B)	2	2516.9	1258.5	2.57	0.091
Interaction (A X B)	6	2402.4	400.4	0.82	0.563
Residual	33	16130.5	488.8		
Total	47	24155.5			

ANALYSIS OF VARIANCE OF SOYBEAN DRY MATTER YIELD AT WEEK 4

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	36.851	12.284	1.67	
Spatial arrangements (A)	3	3.691	1.230	0.17	0.917
Time of intercropping (B)	2	100.035	50.017	6.82	0.003
Interaction (A X B)	6	13.045	2.174	0.30	0.934
Residual	33	242.137	7.337		

Total	47	395.758			

ANALYSIS OF VARIANCE OF SOYBEAN DRY MATTER YIELD AT WEEK 7

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	86.30	28.77	1.48	
Spatial arrangements (A)	3	3.02	1.01	0.05	0.984
Time of intercropping (B)	2	81.25	40.63	2.09	0.139
Interaction (A X B)	6	81.45	13.57	0.70	0.652
Residual	33	640.33	19.40		
Total	47	892.34			

ANALYSIS OF VARIANCE OF SOYBEAN DRY MATTER YIELD AT WEEK 10

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	222.28	74.09	2.12	
Spatial arrangements (A)	3	57.63	19.21	0.55	0.652
Time of intercropping (B)	2	482.58	241.29	6.90	0.003
Interaction (A X B)	6	182.81	30.47	0.87	0.526

Residual	33	1154.35	34.98		
Total	47	2099.64			

ANALYSIS OF VARIANCE OF MAIZE LEAF AREA

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	20679	6893.	0.69	
Spatial arrangements (A)	3	34108.	11369.	1.13	0.349
Time of intercropping (B)	2	27302.	13651.	1.36	0.270
Interaction (A X B)	6	11539	1923	0.19	0.977
Residual	33	330645.	10020		
Total	47	424273			

ANALYSIS OF VARIANCE OF MAIZE LEAF AREA INDEX

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	0.40229	0.13410	1.38	
Spatial arrangements (A)	3	0.43729	0.14576	1.50	0.233
Time of intercropping (B)	2	0.26542	0.13271	1.36	0.270
Interaction (A X B)	6	0.26958	0.04493	0.46	0.831
Residual	33	3.21021	0.09728		

Total	47	4.58479			

ANALYSIS OF VARIANCE OF SOYBEAN LEAF AREA

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	1625672.	541891.	0.93	
Spatial arrangements (A)	3	890241	296747	0.51	0.680
Time of intercropping (B)	2	5183013.	2591506.	4.43	0.020
Interaction (A X B)	6	1805454.	300909.	0.51	0.793
Residual	33	19289305	584524.		
Total	47	28793685.			

ANALYSIS OF VARIANCE OF SOYBEAN LEAF AREA INDEX

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	31.169	10.390	3.09	
Spatial arrangements (A)	3	15.397	5.132	1.53	0.226
Time of intercropping (B)	2	37.261	18.631	5.54	0.008
Interaction (A X B)	6	17.412	2.902	0.86	0.532

Residual	33	110.894	3.360		
Total	47	212.133			

ANALYSIS OF VARIANCE OF MAIZE CROP GROWTH RATE

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	0.3440	0.1147	0.25	
Spatial arrangements (A)	3	1.7306	0.5769	0.307	1.25
Time of intercropping (B)	2	0.5904	0.2952	0.64	0.534
Interaction (A X B)	6	3.0762	0.5127	1.11	0.376
Residual	33	15.2135	0.4610		
Total	47	20.9548			

ANALYSIS OF VARIANCE OF MAIZE RELATIVE GROWTH RATE

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	0.0001667	0.0000556	0.18	
Spatial arrangements (A)	3	0.0006167	0.0002056	0.67	0.579
Time of intercropping (B)	2	0.0001542	0.0000771	0.25	0.780
Interaction (A X B)	6	0.0012458	0.0002076	0.67	0.672

Residual	33	0.0101833	0.0003086		
Total	47	0.0123667			

ANALYSIS OF VARIANCE OF SOYBEAN CROP GROWTH RATE

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	0.11062	0.03687	0.77	
Spatial arrangements (A)	3	0.07062	0.02354	0.49	0.690
Time of intercropping (B)	2	0.58625	0.29313	6.13	0.005
Interaction (A X B)	6	0.13875	0.02313	0.48	0.815
Residual	33	1.57688	0.04778		
Total	47	2.48312			

ANALYSIS OF VARIANCE OF SOYBEAN RELATIVE GROWTH RATE

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	0.0002833	0.0000944	0.26	
Spatial arrangements (A)	3	0.0002167	0.0000722	0.897	0.20
Time of intercropping (B)	2	0.0005167	0.0002583	0.71	0.501
Interaction (A X B)	6	0.0002639	0.0015833	0.72	0.635
Residual	33	0.0120667	0.0003657		

Total	47	0.0146667			

ANALYSIS OF VARIANCE OF SOYBEAN POD COUNT

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	138.2	46.1	0.40	
Spatial arrangements (A)	3	1393.5	464.5	4.00	0.016
Time of intercropping (B)	2	16213.2	8106.6	69.74	<.001
Interaction (A X B)	6 0.33	230.0	38.3	0.916	
Residual	33	3835.8	116.2		
Total	47	21810.7			

ANALYSIS OF VARIANCE OF MAIZE GRAIN YIELD IN KILLOGRAMS PER HECTOR

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	2308160.	769387.	0.31	
Spatial arrangements (A)	3 .	31508335.	10502778	4.23	0.012
Time of intercropping (B)	2	2637806.	1318903.	0.53	0.593
Interaction (A X B)	6	1870431.	11222586.	0.75	0.611

Residual	33	81900076.	2481820		
Total	47	129576964.			

ALYSIS OF VARIANCE OF SOYBEAN HUNDRED SEED WEIGHT

Source	d.f	S.S	M.S	V.R.	F pr.
replication	3	2.0042	0.6681	1.25	
Spatial arrangements (A)	3	0.8042	0.2681	0.50	0.684
Time of intercropping (B)	2	4.8388	2.4194	4.52	0.018
Interaction (A X B)	6	1.5296	0.2549	0.48	0.821
Residual	33	17.6558	0.5350		
Total	47	26.8325			

ANALYSIS OF VARIANCE OF SOYBEAN GRAIN YIELD IN KILLOGRAMS PER

HECTOR

Source	D.F	S.S	M.S	V.R.	F pr.
replication	3	8877077.	2959026	1.67	
Spatial arrangements (A)	3	13333894.	4444631.	2.51	0.076
Time of intercropping (B)	2	17844823.	8922411.	5.03	0.012

Interaction (A X B)	6	10798164.	1799694.	1.01	0.433
Residual	33	58542586	1774018		
Total	47	109396544			

ANALYSIS OF VARIANCE OF LAND EQUIVALENT RATIO

Source	D.F	S.S	M.S	V.R.	F pr.
replication	3	6.4849	2.1616	11.13	
Spatial arrangements (A)	3	3.2987	1.0996	5.66	0.003
Time of intercropping (B)	2	1.0502	0.5251	2.70	0.082
Interaction (A X B)	6	1.1817	0.1969	1.01	0.433
Residual	33	6.4103	0.1943		
Total	47	18.4258			

ANALYSIS OF VARIANCE OF PERCENT SILT

Source	D.F	S.S	M.S	V.R.	F pr.
replication	3	3	0.9590	0.3197	0.48
Spatial arrangements (A)	3	2.9140	0.9713	1.47	0.240
Time of intercropping (B)	2	0.4850	0.2425	0.37	0.695
Interaction (A X B)	6	5.8517	0.9753	1.48	0.216

Residual	33	21.7635	0.6595		
Total	47	31.9731			

ANALYSIS OF VARIANCE OF SAND

Source	D.F	S.S	M.S	V.R.	F pr.
replication	3	1.6956	0.5652	0.66	
Spatial arrangements (A)	3	2.9088	0.9696	1.12	0.354
Time of intercropping (B)	2	10.9047	5.4524	6.32	0.005
Interaction (A X B)	6	20.9424	3.4904	4.05	0.004
Residual	33	27.5902	0.8622		
Total	47	63.8928			

ANALYSIS OF VARIANCE OF PERCENT CARBON

Source	D.F	S.S	M.S	V.R.	F pr.
replication	3	0.01371	0.00457	0.18	
Spatial arrangements (A)	3	0.42334	0.14111	5.58	0.003
Time of intercropping (B)	2	0.44786	0.22393	8.85	<.001
Interaction (A X B)	6	0.24255	0.04043	1.60	0.179

Residual	33	0.83457	0.02529		
Total	47	1.96203			

ANALYSIS OF VARIANCE OF PERCENT CALCIUM

Source	D.F	S.S	M.S	V.R.	F pr.
replication	3	0.603	0.201	0.15	
Spatial arrangements (A)	3	6.349	2.116	1.55	0.221
Time of intercropping (B)	2	2.087	1.043	0.76	0.475
Interaction (A X B)	6	2.133	0.356	0.26	0.952
Residual	33	45.188	1.369		
Total	47	56.359			

ANALYSIS OF VARIANCE OF PERCENT POTASIUM

Source	D.F	S.S	M.S	V.R.	F pr.
replication	3	0.0114	0.0038	0.00	
Spatial arrangements (A)	3	4.7386	1.5795	1.98	0.136
Time of intercropping (B)	2	3.1043	1.5522	1.94	0.159
Interaction (A X B)	6	3.8739	0.6457	0.81	0.571

Residual	33	26.3579	0.7987		
Total	47	38.0862			

ANALYSIS OF VARIANCE OF PERCENT MAGNESIUM

Source	D.F	S.S	M.S	V.R.	F pr.
replication	3	0.0921	0.0307	0.06	
Spatial arrangements (A)	3	0.9422	0.3141	0.66	0.585
Time of intercropping (B)	2	0.4230	0.2115	0.44	0.647
Interaction (A X B)	6	5.8649	0.9775	2.04	0.088
Residual	33	15.8184	0.4793		
Total	47	23.1406			

ANALYSIS OF VARIANCE OF NITROGEN

Source	D.F	S.S	M.S	V.R.	F pr.
replication	3	0.0157956	0.0052652	23.96	
Spatial arrangements (A)	3	0.0001722	0.0000574	0.26	0.853
Time of intercropping (B)	2	0.0002595	0.0001298	0.59	0.560

Interaction (A X B)	6	0.0014270	0.0002378	1.08	0.393
Residual	33	0.0072512	0.0002197		
Total	47	0.0249055			

ANALYSIS OF VARIANCE OF PERCENT ORGANIC MATTER

Source	D.F	S.S	M.S	V.R.	F pr.
replication	3	0.01206	0.00402	0.05	
Spatial arrangements (A)	3	1.15656	0.38552	4.91	0.006
Time of intercropping (B)	2	1.57591	0.78796	10.03	<.001
Interaction (A X B)	6	0.87074	0.14512	1.85	0.120
Residual	33	2.59142	0.07853		
Total	47	6.20668			

ANALYSIS OF VARIANCE OF PERCENT PHOSPHORUS

Source	D.F	S.S	M.S	V.R.	F pr.
replication	3	96076	32025	1.03	
Spatial arrangements (A)	3	92197	30732	0.99	0.408

Time of intercropping (B)	2	63759	31880	1.03	0.368
Interaction (A X B)	6	180886	30148	0.97	0.458
Residual	33	1021715.	30961		
Total	47	1454633.			

ANALYSIS OF VARIANCE OF P^H

Source	D.F	S.S	M.S	V.R.	F pr.
replication	3	0.03740	0.01247	0.27	
Spatial arrangements (A)	3	0.66102	0.22034	4.77	0.007
Time of intercropping (B)	2	0.12755	0.06377	1.38	0.266
Interaction (A X B)	6	0.49918	0.08320	1.80	0.129
Residual	33	1.52495	0.04621		
Total	47	2.85010			