CHAPTER 2

LITERATURE REVIEW

2.1 Intercropping- definition, importance and mechanism of yield advantage

2.1.1 Definition of intercropping

Intercropping is the practice of growing more than one crop in a field at the same time (Horwith, 1985). Crop intensification in the intercropping system occurs in both time and space dimension. Intercrop competition exists during all or part of crop growth. Intercropping may be of mixed, row, strip or relay depending upon the spatial or time arrangement (Francis, 1986).

2.1.2 Importance of intercropping

Intercropping has been a common practice in the tropics mostly by the small scale, subsistence farmers (Francis 1989; Vandermeer, 1989). It is considered to be an important farm practice since it offers the possibility of yield advantages relative to sole cropping.

Intercropping offers several advantages. It may be more efficient in using environmental factors such as light, nutrients, and water as well as providing a greater diversity of food and income sources. It may reduce the adverse effects of diseases, pests and weeds; it gives greater stability in production and greater insurance against crop failures; higher gross returns and productivity per unit area (Willey, 1979; Ssekabembe, 1984). Importance of intercropping have also been well documented in a number of literatures and published reports (Trenbath, 1976; Willey 1979; Nnko and Doto, 1982; Horwith,1985; Singh *et al.*, 1986; Rerkasem *et al.*, 1988; Clark and Francis, 1989; Caroll *et al.*, 1990 and Peoples *et al.*, 1989).

The cereal legume intercropping where crops are grown simultaneously on the same unit of land is perhaps the most wide spread intercropping systems in terms of land use efficiency and crop production (Ssekabembe, 1984). In this system in addition to the food (crop) product, crop residue and forage can also be obtained periodically throughout the growing season and serves with an excellent opportunity of providing human food and animal feed simultaneously (Topark-Ngarm, 1990)

In some intercropping patterns, the food crop is also protected from strong wind, rapid loss of soil moisture or soil erosion by the counterpart forage legume. Such advantage of cereal legume intercropping should benefit small holder farmers who normally have small-scale mixed crop-animal farming in their farms. However, success of such intercropping depends on factors like suitable combination of species and proper management of the crops which generally differ among locations and environments (Topark-Ngarm, 1990).

With the emphasis on increased food and feed production in subsistence oriented smallholder systems, cereal legume intercropping could be one viable alternative to achieve the goal. The techniques such as cutting and removing of some plant parts, detopping and defoliation of standing crops/ forages, biotectural manipulation by plant density and spatial arrangement of mixed, inter or relay cropping of food and forage legumes, should be adopted for increased fodder production. The scheme can produce food crops, animal feed and improve fertility status of the soil to increase the productivity (Miah *et al.*, 1990).

On the other hand, protein content of some cereals are generally too low for rapidly growing or lactating animals. Intercropping such cereals with legumes could help overcome this protein limitation. Along with this, such intercropping system may increase greater yield stability over different seasons, increased yields and or monetary returns and increased yields for subsequent crops.

2.1.3 Mechanism of intercropping yield advantage

Advantage in cereal legume intercropping system could be achieved due to low interspecific competition between the component crops for growth limiting factors. Growing component crops with contrasting maturities would complement rather than compete for the same resources at the same time (Ofori and

Stern, 1987). The authors in a detailed literature review further mentioned that, competition between component crops for growth limiting factors is regulated by basic morpho-physiological differences and agronomic factors such as proportion of crops in the mixture, fertilizer applications and relative time of sowing.

Willey (1979), later reviewed by Francis (1989) attempted to simplify the interactions in intercropping into three broad categories:

1. *Mutual inhibition*, in which the actual yield of each species is less than expected.

2. *Mutual cooperation*, in which the actual yield of each species is greater than expected.

3. *Compensation*, in which one crop produces more and the other produces less than expected.

A main reason of yield advantages is that intercropping better utilizes growth resources. This is because the component crops differ in their temporal and spatial use of resources; in their nutrient requirement, in the form of nutrients they can take up and in their abilities to extract nutrients from the soil. The component crops may have their peak demands for nutrients at different stages of growth. They may not compete for exactly the same overall resources and thus, inter-crop competition is less than intra-crop competition. The component crops may also exploit different soil layers via different rooting patterns, thus in combination they may exploit a greater total volume of soil. The better distribution of leafy areas over time and the proper arrangement of combined leaf canopy may take better use of light. The interaction between the rhizosphere micro-organisms of component crops could also benefit nutrient uptake of intercropped crops (Shantaram and Rangaswami, 1967 and Kibani *et al.*, 1976 adapted from Willey, 1979). Many studies have shown that the presence of legume in intercropping with nitrogen fixing ability, produces a greater yield of companion nonlegume crop than its in sole cropping (Willey, 1979; Ofori and Stern, 1987).

2.2 Evaluating intercrop advantage

Several methods are being used to evaluate intercropping advantage. To name some of them are; Land Equivalent Ratio, Area-X-Time equivalent Ratio, Relative Yield Total, Area Harvests Equivalency Ratio etc. This review will be comprised of in brief discussion of these indices.

Land Equivalent Ratio (LER)

Land Equivalent Ratio (LER) is the most frequently used measurement to evaluate the effectiveness of an intercrop (Ofori and Stern, 1987; Trenbath, 1976; Vandermeer, 1989; Willey, 1979). It is an index of combined yield to evaluate the all forms of intercropping effectiveness (Ofori and Stern, 1987). As an index of combined yield, LER provides a quantitative evaluation of the yield advantage due to intercropping (Willey, 1979).

LER is defined as the total land area required under sole cropping to give the yields obtained in the intercropping mixture. Hiebsch and McCollum (1987) define Land equivalent ratio as LER= (Yi1/ Ym1) + (Yi2/ Ym2) where, Y is the yield per unit area, Ym1 and Ym2 are sole crop yields of the component crops 1 and 2, and Yi1 and Yi2 are intercrop yields.

When LER is equal or less than 1, there is no advantage to intercropping in comparison to sole cropping. When LER is greater than 1, a larger area of land is needed to produce the same yield of sole crop of each component than with an intercropping mixture. Difference in competitive ability affect the relative performance of component crops and thus the LER values of different cereal-legume intercrop systems (Ofori and Stern, 1987) and the implication is that the magnitude of LER quantifies the increased in biological efficiency achieved by interplanting (Hiebsch and McCollum, 1987).

Relative Yield Total (RYT)

Replacement series design is used to evaluate the intercrop advantage through RYT. For this, total plant density of the mixture must equal total plant density of pure stands of the mixture components.

The mixture yield of a component crop expressed as a proportion of its yield as a sole crop from the same replacement series is the relative yield of the crop (Trenbath, 1976). The sum of the relative yields of component crops is called the Relative Yield Total and is denoted by RYT. Ofori and Stern (1987), revealed that when the RYT is equal to or less than 1, there is no advantage of intercropping. A species is consider to perform better in intercrop than monoculture when its relative yield is greater than its share of the population in intercrop.

Area-X-Time Equivalent Ratio (ATER)

Considering the situation that, duration of land occupancy by an intercrop is often longer than production-cycle duration for one or more of intercrop species, an Area-X-Time Equivalent Ratio was proposed by Hiebsch and McCollum (1987). In actual sense, ATER is the modification of the LER. ATER takes into account the duration of the crop, i.e, the time it occupies from planting to harvesting.

ATER defines yield as a function of both land area and time. ATER = (Liti + Ljtj)/T where, Li and Lj are relative yields or partial LERs of component crops i and j, ti and tj are the durations (days) for crops i and j, and T is the duration (days) of the whole intercrop system (Ofori and Stern, 1987). When the ATER is more than 1, intercropping is considered advantageous.

Area Harvests Equivalency Ratio (AHER)

Area Harvest Equivalency Ratio for measuring efficiency in multi season intercropping is an another indic of evaluate intercropping, proposed by Balasubramanian and Sekayange, (1990). It is based on the concept that, both area and time factors have to be considered to quantify resource-use efficiency in multi season intercropping. AHER ratio incorporates the time factor in the form of number of possible harvests of each component crop in a system that could be obtained during the full intercrop period, if each component was monocropped.

$$AHER = Yi1/ Ym1ni + Yi2/ Ym2ni$$

This is same to the LER, except number of harvest. Here, ni denotes total number of possible harvests of crop i, that could be obtained during the full intercrop period, if crop i, was monocropped. In the form of ni, AHER gives a practical definition to the time factor. Values of ni will always be in whole numbers because fractional harvests of crop are not appropriate. By using ni, AHER assumes that sole crop yields of component species in successive seasons are the same, which may not always be the case. By definition, AHER = LER when ni = 1 (e.g., single season associations).

2.3 Nitrogen fixation and the intercrop system

The legume component of an intercrop system, because of its ability to fix N2 from the air, is a good source of soil nitrogen (LaRue and Patterson, 1981). There are evidences to indicate that legumes when incorporated in a cropping system increase the nitrogen content of the soil (Singh, *et al.*, 1986). However, the contribution depends upon the effectiveness of the N-fixing system. The legume may either increase the soil N status through fixation, or in the absence of an effective N-fixing system, it may compete for soil N (Trenbath, 1976). The amount of nitrogen fixed by a legume also depends on the efficiency of the symbiosis, which is limited genetically by the growth of the host and environmentally by the nitrogen status of the soil (Piha *et al.*, 1987).

2.3.1 Nitrogen fixation by the legume

The quantity of nitrogen fixed by the legume component in cereal-legume intercropping depends on the species, morphology, density of legume in mixture, the type of management and the competitive abilities of the component crops (Ofori and Stern, 1987), and establishment of effective symbiosis (Weber, 1986). Similarly, the levels of nitrogen fixation depend on water supply, inoculation, crop management practices, including applications of fertilizer nitrogen and soil nitrogen fertility (Peoples and Herridge, 1990). Differences in the competitive abilities of the component crops for soil nitrogen can result in a stimulation of nitrogen fixation and ultimately lead to a increased nitrogen yield in the intercrop relative to the legume and cereal monocrops. Cropping systems also makes differences in N fixation. Proportion of legume nitrogen derived from nitrogen fixation was found higher in rice bean grown in association with maize than when grown in sole crop (Rerkasem and Rerkasem, 1988). Some 19.5% increase in the grain yield of a maize crop in India was observed when intercropped with soybean (Singh *et al.*, 1986).

Morpho-physiological characteristics of plants also determines the level of nitrogen fixation. Legumes of indeterminate growth with a climbing habit are more efficient and successful than determinate types considering the amount of nitrogen fixation (Ofori and Stern, 1987; Peoples and Herridge, 1990). However, with shorter stature legumes such as soybean and groundnut, shading by tall cereal crops can reduce both yield and nitrogen fixation (Nambiar *et al.*, 1983).

2.3.2 Nitrogen transfer

The total intercrop yields are greater, relative to their monocultural components in intercropping systems (Trenbath, 1976). It is suspected that nitrogen is somehow involved. Evidence in the literature suggests that nitrogen fixed by the intercrop legume may be available to the associated cereal in the current season (Agboola and Fayemi, 1972). This form of nitrogen transfer could improve the nitrogen economy of various legume based intercrop systems. However, the degree of nitrogen benefit by a cereal crop from its companion legume depends on the quantity and concentration of legume N, mineralization of the legume residues and the amount of nitrogen fixed by the legume (quoted from Ofori and Stern, 1987).

2.3.3 Effects of cereal/ legume intercrop on subsequent crops

Legume may contribute N to the soil which is normally become available to the subsequent cereal crop (Ofori and Stern, 1987) from a cereal legume intercropping system. From a comprehensive review made by Peoples and Herridge (1990), improvement in cereal yield represent around 30 % to 350 % increase over yields in cereal cropping sequences.

Peoples and Herridge (1990), also pointed out that, the potential for legumes leaves to contribute N to a subsequent crop can be considerable since leaf-fall during crop legume development and nodulated roots can each contain up to 40 Kg N-ha. On the other hand, legume leaves, because their high N content and low C:N ratio favor mineralization process.

2.4 Maize as a component species in a cereal legume intercrop

Several researchers have reported that, maize could be a potential component in a cereal-legume intercropping. Wahua (1983) found maize as a dominant species, which was more benefitted in terms of nutrients uptake in a maize-cowpea intercropping. Tsay, 1985, adapted from Ofori and Stern, (1987) stated that, taller component suppresses the companion legume through shading, that also favor maize crop in an intercropping with legumes. Similarly, Ayeni *et al.*,(1984) reported that, performance of intercropping relative to sole cropping was enhanced by weed competition in a maize cowpea intercropping. Several other evidences have been found in which maize could be a potential intercrop species (Allen *et al.*,1983; Wahua, 1984; Francis *et al.*, 1982 b adapted from Ofori and Stern 1987).

2.5 Effect of cutting on regrowth of Swards

Many investigators have indicated that, defoliation lowers the carbohydrate reserves, that affects on regrowth of swards. Defoliation of plants decreased total soluble-carbohydrate was insufficient to account for regrowth and respiration losses (Mcilroy, 1967). Different factors play role in the regrowth of swards. Alberda, 1957, adapted from Mcilroy, (1967), reported that, light intensity and temperature can influence regrowth after cutting by influencing carbohydrate reserves. The author in an experiment found that, higher the light intensity, the higher the carbohydrate level in the stubble at the time of cutting. Eveas *et al.*, (1972) stated that, the rate of regrowth of a forage plant after defoliation is influenced by remaining leaf area on the stubble and the amount of carbohydrate reserves in the roots, crown and stubble. The authors further mentioned that, carbohydrate reserves may play a more important role in regrowth than remaining leaf area immediately after defoliation. However, Ward *et al.*,(1961); May (1960), reported that carbohydrate reserves may be important for only a brief period after defoliation. On the other hand, Younger *et al.*, (1976) suggested that the role of photosynthesis after defoliation may be as important as carbohydrate reserves. Frequency of cutting also make differences in regrowth. If very little is removed each time, frequency is unimportant. But, if most of the plant is removed, long intervals are required for the plants to recover (Spedding 1971). Whiteman *et al.*, (1974) mentioned that, defoliation that caused reduction in the number of bud sites will usually reduce the rate of regrowth. The legume especially stylo have few basal branches and susceptible to defoliation damage. The authors further reported that, defoliation reduces root growth, root size, which is positively related to defoliation frequency and negatively related to the leaf area index remaining after defoliation. Defoliation which removes the older leaves may affect the labile pool of nutrients in the plant; after defoliation leaves are not available to provide re-export to other parts of the plant.

Brann *et al.*, (1974) reported that, cutting at different heights generally had no effect on activation of axillary buds but, wide variation in axillary bud activity exist among plants under similar field conditions. The authors further mentioned that, time of cutting affect regrowth. When the first cutting of crownvetch was taken in late vegetative stage, crown buds were not as active as when the first cutting was taken earlier.