Chapter 2

LITERATURE REVIEW

2.1 Why intercropping (?)

Intercropping is commonly practiced in the tropics especially by small scale, subsistence farmers (Francis, 1989; Vandermeer, 1989; Willey 1979). It is considered to be an important farm practice since it offers the possibility of yield advantages relative to sole cropping, either through yield stability and/or improved yields (Willey, 1979). Major contributors to yield advantages include: better use of growth resources (Trenbath, 1986) and better control of weeds, pests, or diseases (Willey, 1979).

A comprehensive review by Willey (1979) states that yield advantage in intercropping normally occurs because component crops differ in their use of growth resources in such a way that when they are grown in combination they are able to complement each other and so make better overall use of resources than when grown separately. In terms of competition, this means that in some way the component crops are not competing for exactly the same overall resources and thus inter-crop competition is less than intra-crop competition.

2.2 Indices used in evaluating intercrop advantage

Various indices are being used to evaluate intercrop advantage. In this review, only three indeces, Land Equivalent Ratio, Relative Yield Total, and Area-x-Time Equivalency Ratio, are considered since they are the most commonly used.

Land equivalent ratio (LER)

The measurement frequently used to judge the effectiveness of an intercrop is the land equivalent ratio (LER) (Trenbath, 1976; Vandermeer, 1989; Willey, 1979). It is an index of combined yield for evaluating the effectiveness of all forms of intercropping (Ofori and Stern, 1987a).

LER is defined as the total land area required under sole cropping to give the yields obtained in the intercrop mixture. It is expressed 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 (Hiebsch and McCollum, 1987).

When LER is equal or lesser than 1, there is no advantage to intercropping in comparison with sole cropping.

When LER is greater than 1, a larger area is needed to produce the same yields of sole crop of each component than with an intercropping mixture (Ofori and Stern, 1987a), and the implication is that the magnitude of LER quantifies the increase of biological efficiency achieved by intercropping (Hiebsch and McCollum, 1987).

Relative yield total (RYT)

RYT is used to evaluate intercrop advantage in replacement desisgn. Total plant density of the mixture must equal total plant density of pure stands of the mixture components (Hiebsch and McCollum, 1987).

The mixture yield of a component crop expressed as a proportion of its yield as a sole crop is the relative yield of the crop (Trenbath, 1976). The sum of the relative yields of component crops is called the relative yield total (RYT). When RYT is equal or less than 1, there is no intercrop advantage (Ofori and Stern, 1987a). Only when RYT is greater than one can mixed cropping give a yield benefit, because in part the species occupy different spaces.

Area-x-time equivalency ratio (ATER)

The area-x-time equivalency ratio was proposed by

Hiebsch and McCollum (1987) as a modification of LER. This takes into account the duration of the crop, that is, the time it occupies from planting to harvesting. It is an index used to evaluate effectiveness of intercropping at constant plant density. Plant population of each species in monoculture is assigned a density of 1.0; each component in the mixture is planted at a given fraction of its monoculture population; and the sum of the fractions for all species in the mixture equals 1.0 (Hiebsch and McCollum, 1987).

ATER is preferably used to evaluate the intercrop advantage when component crops do differ in maturity periods. ATER, then, defines yield as a function of both land area and time. It is calculated (Ofori and Stern, 1987a) as: ATER = (Liti + Ljtj)/T where, Li and Lj are relative yields or partial LER's 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.

When the ATER is more than 1, there is an intercrop advantage. For example, an ATER of 1.3 means it would require 1.3 ha-days of monoculture production to produce the same quantities of the same commodities as 1 ha-day of intercrop production (Wade and Sanchez, 1984).

2.3 Relative time of sowing component crops

Probably the main way that complementarity in intercropping can occur is when the growth patterns of the component crops differ in time so that the crops make their major demands on resources at different times (Willey 1979). This type of complementarity is said to give better temporal use of resources.

As Ofori and Stern (1987a) stated, the relative time of sowing component crops is a management variable that can be manipulated in cereal-legume intercrop systems. Willey (1979) 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 imoroves land productivity and minimizes competition for growth-limiting factors in intercropping.

The effects of staggered sowing on yield advantages merit some consideration and these have been examined in a number of studies. Some results revealed no effects, others positive effects to the intercrop system. Ofori and Stern (1987b) concluded from a maize - cowpea intercrop systems that staggered sowing of component crops at intervals of 10 or 21 days were of no advantage over sowing them simultaneously.

However, Nnko and Doto (1982) found that the highest cereal grain yield for both maize and millet (3,212 g/plot and 2,290 g/plot, respectively) were achieved by sowing soybean one week later compared with simultaneous sowing, or sowing soybean one or two weeks earlier than maize or millet. They concluded that sowing both legume and cereal at the same time (as commonly practiced) inevitably leads to lower cereal yield than would be obtained under cereal monoculture. Sowing the legume earlier than the cereal produced even lower cereal yield.

Staggered sowing may be one way of ensuring yield advantage in intercrop system since temporal use of resources of component crops differ, inter and intra-crop competiton is minimal for growth-limiting factors.

Despite reports on yield advantages of various cereal-legume intercropping studies, only a few had been reported on yield advantages of intercropping upland rice with legumes. A recent study in India (Mandal et al., 1990) had shown upland rice to be less competitive in intercrop with legumes such as rice bean and blackgram. The total yield of upland rice and blackgram in the intercrop was only 89% of the highest monocrop (rice) yield. When the sowing of blackgram was delayed 30 days after sowing rice, the depression in total yield was lessened by only 2%. The authors suggested that the deferred sowing of the legume lessened the competition from the legume on rice by diverting demand for nutrients, water, etc. at different periods.

Important practical points here are that when temporal differences are increased by staggered sowing, this increases the total growing period; that there maybe a potential for greater yield advantages; that an earlier sown crop becomes more competitive and a later sown one less competitive than when they are sown simultaneously (Willey,1979). Harper (1977) also supported that the earlier sown component crop usually becomes more aggressive than when both crops are sown simultaneously.

2.4 Nitrogen economy of the intercrop system

The legume component of an intercrop system, because of its ability to fix N2 from the air, is a potential source of soil N (LaRue and Patterson, 1981). However, this 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).

2.4.1 N2 fixation by the legume component

Peoples and Herridge (1990) stated that the levels of fixation depend on water supply, inoculation, crop management practices, including applications 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 (Pfix). The contribution of N2 fixation to the total nitrogen per plant is increased by moderate levels of combined N (soil and fertilizer N), but declines at high levels, reflecting the depression of N2 fixation caused by the high levels of either soil or fertilizer N (Marschner, 1986). Levels of fixation achieved by crops in the field may be high, but are not always sufficient to offset the harvested seed.

The quantity of N2 fixed by the legume component in cereal-legume intercropping depends on the species, morphology, density of legume in the intercrop mixture, the type of crop management and the competitive abilities of the component crops (Ofori and Stern, 1987a; Peoples and Herridge, 1990).

Differences in the competitive abilities of the component crops for soil N can result in a stimulation of N2 fixation and ultimately lead to an increased N yield in the intercrop relative to the legume and cereal monocrops

(Rerkasem and Rerkasem, 1988; Rerkasem et al., 1988).

Legumes of indeterminate growth with a climbing habit are generally more efficient (Ofori and Stern, 1987a) and more successful (Peoples and Herridge, 1990) than determinate types in terms of N2 fixation. Rerkasem et al. (1988) concluded that the proportion of legume N derived from N2 fixation was higher in rice bean grown in association with maize than when grown as a sole crop. The authors concluded further that the stimulation of symbiotic activity and suppression of uptake of soil N by rice bean contributed to an increase in total crop N in maize-rice bean intercrop.

However, with shorter bushy type legumes like groundnut when intercropped with tall cereals like maize, its yield and N2 fixation activity were reduced due to shading by tall maize crops (Nambiar et al., 1983).

2.4.2 Nitrogen transfer

Many commonly occuring intercrop systems involve a nodulating legume, and total intercrop yields are better relative to their monocultural components (Trenbath, 1976). It is suspected that nitrogen is somehow involved. Evidence in the literature suggests that the N2 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 benefit of a succeeding cereal crop (Ofori and Stern, 1987a). Both forms of N transfer are considered to be important and could improve the N economy of various legume-based intercrop systems.

The degree to which N from intercrop legume may benefit a cereal crop depends on the quantity and concentration of the legume N, microbial degradation (mineralization) of the legume residues, utilization of these residues, and the amount of N2 fixed by the legume (Henzell and Vallis, 1977 and Herridge, 1982 quoted from Ofori and Stern, 1987a). When the quantities of N involved in plant growth, in N2 fixation and in seed are calculated for food legume crops, it is apparent that the net N balance is often low and in some instances negative (Peoples and Herridge, 1990).

2.4.3 Residual N of leguminous crops

The total amount of N in a legume crop comes either from N2 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 cereal crop (Ofori and Stern, 1987a).

Reported benefits of tropical crop legumes to subsequent cereal crops are consistent and substantial and may persist for several reasons (Peoples and Herridge, 1990), regardless of whether the legume was grown in monoculture or intercropped. From a comprehensive review made by Peoples and Herridge (1990), improvements in cereal yield represent around 30% to 350 % increases over yields in cereal-cereal cropping sequences.

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 trash, and because their high N content and low C:N ratio favor 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 N2 fixation, the proportions of legume N mineralized and the efficiency of utilization of this mineral N (Peoples 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.