CHAPTER 2

LITERATURE REVIEW

2.1 Weed control concepts

Weeds are the plants, which grow where they are not wanted. Weeding is essential for successful crop production but is time and labor consuming and finally reduce the crop yields. Weeds deprive crop plants of nutrients and water, and often serve as hosts to insects and other pests detrimental to the crop.

Therefore, to increase agricultural production and to reduce the time and labor cost of weeding operations, there is an urgent need to improve hand weeding practices with simple tools and to develop and promote other weeding technology such as mix cropping, intercropping, crop rotation, multiple cropping system and other methods (FAO, 1997). One considering that intensification of cropping will be reduced weed problems (Hammerton, 1974) and other believing that weed problems will increase if cropping is intensified (Gill and Brar, 1972; Anderson and Whan, 1974; Hoque *et al*., 1976). Plucknett *et al*. (1977), while agreeing that some intensive cropping patterns will help reduce weed problems because of move vigorous crops, more intensive shading, more frequent tillage, crop rotation, and better water management, argue that each cropping or farming system has its own weed problems.

Weed management strategies for small farmers of tropical should involve combinations of crop production practices and specific weed control technologies. The aimed at reducing weed competition and should focus on the entire cropping system with emphasis on year-round and multi year management of weed populations. An understanding of crop-crop, crop-weed and crop-crop-weed interaction is essential in designing the habitat management approach. The conceptual model of a weed community cycle in a cultivated field presented by (Bantilan *et al*. (1974) pointed out the differences between the effect on the weed community of intensive cropping systems and that of a single crop system. Harwood and Bantilan (1974) also have demonstrated how such factors as light, nitrogen, crop density, and cropping pattern, can be manipulated to obtain better weed management.

2.2 Weed control in intercropping systems

Weed control in intercropping systems that have limited research results on weed control in intercropping in the Lao PDR. One of the reasons given for intercropping is weed suppression but there is little experiment evidence to support this conclusion. Many factors including the specific component crop, crop cultivars, plant population, and fertility determine the weed competitive ability of intercrops.

Weed controls in intercropping systems depend upon the weed population densities and weed competitive ability of the intercrop combinations. Control of weed may be a greater problem in intercropping than when the component crops are grown alone. Mechanical of weeding may be difficult or even impossible in certain spatial arrangements or when the row spacing of the component crops is too close to each other (Miller, 1976; Moody, 1980).

Moody (1977b) observed that if a number of crops are grown in such close proximity such that plant density is greater than in sole cropping (additive), there would be greater competition against weeds and less need for weeding. If the density of the intercrops is the same as that of the component crops when grown alone (substitutive) or if the crops are planted at their optimal densities, there may be little improvement in weed suppression due to intercropping.

In the some cases, weed growth in the intercrop may be as serious or even worse than in the sole crop (Moody, 1980). Thus, the need for weed control in intercropping may be as great as for sole cropping. Care should be taken in identification of intercrop combinations and environments where they may be grown if reduced weed growth is going to be a benefit.

2.3 Methods of weed control in intercropping

While crop diversity through intercropping may help in weed suppression (Litsinger and Moody, 1976), weed control in the some cases, may be a greater problem in the intercrop than in the component sole crops. That weeding was more difficult when crops were sown in the scattered or staggered pattern than when they were sole cropped or intercrop in separate rows.

Methods of controlling weeds in crop combinations are manual and mechanical (Moody, 1976). Because, there are few weeds in certain crop combinations, the time required for weeding these is probably less than that required in sole crop. Farmers on crop combinations do not use herbicides and herbicides have been tested on research stations for weed control and crop tolerance, and for possible use intercropping (Moody, 1976). The majors of weed control are dominated destructive methods, emphasizing to their economic characteristics. Weed control in intercropping systems practices can be groups into five general classifications:

1. Biological control methods. Biological control involves the utilization of natural enemies for the control of specific weed species. The objective of biological control is not eradication of the target weed species, but the reduction of its population and crop competitiveness to acceptable level under conditions involve. This may be achieved by direct or indirect action of biotic agent.

2. Physical and mechanical methods. There that is common practice in the farm. Hand weeding, tillage and mowing are among the most important methods of weed management today. Hand weeding and hoeing, although very laborious, are still the most important weed management methods in many agro-ecosystems.

Mechanical methods are those, which involve the use of mechanical devices to control, weed (i.e. removing, cutting and dredging). These can be done manually, using simple tools such as scythes, grass hooks, rakes, forks, knives, or harvesters.

3. Chemical methods. They are included many different types of chemical such as natural products, inorganic compounds, and a wide range of synthetic products applied to soil or foliage. Some are plant growth regulators, while other are toxins that selectively exert various effects on plant species.

4. Preventive methods. Prevention of movement of weeds and weed seed is critical in limiting the spread of weeds to new location. Regulatory and quarantine program from international to local levels conduct inspections to restrict certain weed species.

5. Cultural methods. Cultural control of weed utilizes practices common to good land and water management. These practices included manipulation of row spacing, crop cultivars, and crop populations, maintaining critical weed-free periods and using crop potations and smother crops.

2.4 Weed control in maize and soybean intercropping systems

2.4.1 Weed control in maize

Field legume, owing to their characteristically low-growing habits and their ability to supply their own nitrogen needs in the absence of adequate supply of soil nitrogen, are ideal intercrops for most major field crops.

Legumes are often effective in suppressing weed growth when grow as intercrops.

According to Herrera (1975), maize is a slow-starting crop, making rapid internodes elongation about 1 month after planting, intercropping maize with a legume may provide it with early protection against weeds and often means less cash and energy allocation for supplementary weed control. The legume rapidly forms a dense out the weeds. Increase light interception in intercropping appears to be vital element in crop-weed competition, especially in the early growth stages when weed control is critical (Herrera 1975). Bantilan and Harwood (1973b) note that intercropping maize with legume may protect it from weed competition during the first 40 days after grown.

According to Harwood and Bantilan (1974), weed control is simplified in many intercrop combinations because that rapid establishment of the dense canopy reduces weed growth. Shade-sensitive weeds such as *Cyperus rotundus* and *Imperata cylindrica* (L.) Beauv may be eliminated entirely by an intercrop combination like maize-mungbean, which intercepts 90 % of the incident light after 50 days of growth. Maize as a sole crop intercepts only 80 % of the light. Continuous high-density intercropping will eventually eliminate all light sensitive weeds from the field.

2.4.2 Weed control in soybean

Herrera (1975) report that soybean was less competitive than mungbean against weeds when intercropped with maize. Soybean was more competitive at higher maize populations, Mercado *et al*. (1977) report that weeds caused a significant decrease in yield in sole-cropped of soybean but not in maize alone or in maize intercrop. Intercropping maize with soybean resulted in a threefold increase in maize yield compared to sole crop of maize. However, soybean yield was reduced by 58.5 % in the intercrop in the plot maintained weed free for 42 DAP compared to sole crop. In the un-weeded plot, soybean yield in the intercrop is 44 % more than the sole crop.

In one experiment, Responso *et al*. (1982) found that weeds were greatly suppressed when maize was intercropped with soybean. Because yields were not significant increased by hand weeding, the greatest returns were obtained in the un-weeded check. In other experiment, Responso *et al*. (1982) reported that weed weights were significantly lower in the plot that received two inter-row cultivations followed by two hand weeding than in the un-weeded check.

In a trial conducted in International Rice Research Institute (IRRI 1978) un-control weed growth caused a significant reduction in maize yield but soybean yield was un-affected by weed competition. Net returns over variable cost were greater when the plots were hand weeded twice. Furoc *et al*. (1977) reported that when soybean was intercropped with maize the presence of the soybean reduced weed growth markedly. Forty days after sowing, 4.0 tons ha^{-1} of weed were harvested from the sole crop plots, whereas only 0.5 tons ha^{-1} from the intercropped plots.

2.5 Weed species in intercrop

Bariuan and Mercado (1980a) examined the effect of different cropping systems on weed seed reserves at harvest. More weed seeds were found after a sole crop of soybean than after a sole crop of maize or maize and soybean intercropping. The growth of species such as *Cyperus rotundus* and *Echinochloa colona* (L) Link was reduced by maize. *Cleome rutidosperma* DC and *Commelina diffus* Burm.f.. Which were not observed in pre-plant samples was observed at harvest. *Cyperus diffusa* tolerated shade better than *Cyperus rutidosperma* and had a higher population in maize alone than soybean alone or the maize-soybean intercrop.

Weed species that are mentioned in different intercrop in the tropic region. Those mentioned in more than 50 % of the articles are (in order of number of times mentioned) *Cyperus rotundus*, *Eleusine indica* (L.) Gaertn, *Ipomoea triloba* L. *Echinochloa colona* (L) Link. *sanguinalis,* and R. *exaltata,* (IRRI, 1978).

If an intercropping combination is being considered for its weed suppressing abilities or a weed control program is being designed for an intercrop, these are the weeds that must be taken into consideration. Failure to suppress or control even one of these could lead to failure of intercrop.

Lao-IRRI, (1991) stated that the majority of respondents listed weed in rainfed upland rice-based mixture cropping systems in both province were Oudomxay and Luang Prabang province, there mention 10 species of important weeds are: *Chromolaena odonata* (L.) R.M. King & M. Robinson, *Ageratum conyzoides* L, *Lygodium flexuosum, Commelina diffusa* Burm. f. *Panicum cambogiense, Cyperus rotundus* L. *Panicum trichoides, Crassocephalum crepidiodes*, and *Conyza sumatrensis*.

According to the result of farm field survey, weed species in maize and soybean intercropping systems in the Namkha area, Houn district, Oudomxay province, Laos. There were founded many species of weeds in rainfed upland cropping areas, and some of weeds was difficultly to management by hand-weeding those mentioned *Cyperus rotundus. Ageratum conyzoides* L. *Chromolaena odonata* (L.) R.M. King & M. Robinson *Commelina diffusa* Burm.f.. *Murdannia nudiflor* (L.) Brenan. *Imperata cylindrica* (L.) Beauv etc, (SSLCC, 1997).

2.6 Hand weeding and labor use for weed control

2.6.1 Hand weeding/timeliness

Hand weeding is the most common weed control method used by small-scale farmers. It usually requires no capital outlay. This is a major advantage when cash is not readily available and labor is provided from the farmer's immediate family or through non-cash exchange, they had labor exchange by group. Hand weeding is intensive and slow compared to others methods.

A majority of the small-scale farmers in the tropics utilize manual weed control and may dedicate 35 to 70 % of their total agricultural labor to this task (Akobundu, 1980b, Okigbo, 1980; Wetala, 1980). Several authors suggested that yield losses were incurred because of untimely weed control, but they do not specify if farmers initiated weeding too late, or if weeding was late only on the last part of the area being weeded (Druijff and Kerkhoven, 1970a; Binswanger and Shetty, 1977; Minjas, 1980; Ngugi, 1980).

In northeast Brazil, small-scale farmers initiated the first weeding of maize and bean 17 DAP, which generally enabled them to avoid the critical periods of competition in these crops (Young and Miller, 1976). Weeding time with the heavy 2 to 2.5 kg hoe commonly use [very similar to the traditional hoe in Kenya, described by Druijff and Kerkhoven (1970c)] was 12.7 days/ha. Inter-row cultivation with animal drawn cultivator required 2.4 days, and when supplemented with manual inter-row weeding, the total labor requirements were reduced 40 %. 9.8 days/ha/weeding (Shenk *et al*., 1976) perhaps the time required for this supplemental weeding could be reduced significantly to 7.4 days/ha if the traditional hoe was replaced with an improved implement (Druijff and Kerrkhoven, 1970c). Nevertheless, with the abundance of hand labor encountered in the region, most families made timely weeding in their food crops.

2.6.2 Labor use for weed control

Frequently, by the time a farmer finished the first weeding of manual crop, it is necessary to again remove weeds in the area where they began. This is especially true if a family has a lager area under crop or do not have an abundance of family labor. Such delays frequently result in serious weed infestations and reduced yields (Druijff and Kerkhoven, 1970b; Ogborn, 1976).

In other cases, the labor supply may be adequate, but adverse weather conditions, may prevent timely manual or mechanical weeding operations, which may subject the crop to significant weed competition during the critical period, (Cancian, 1972; Hammerton, 1974; Jansen and Kock, 1982). Armstrong et al. (1969) Report that timely mechanical weeding was more economical than chemical weed control in maize in central United States. However, if cultivation was delayed only 5 days, this practice was less economical than chemical control.

On other hand, Harwood and Price (1976) content that in tropical regions, annual production per unit area responds more positively to management at higher rate of application than in temperate climates. And the resulting economic incentive to increase the intensity of management has directly contributed to a reduction in farm size in tropical Asia.

According to the result of the assessment and eco-economy programming on the agro-ecosystem of Nahom area, Beng district, Oudomxay province LaoPDR, by (Chen, 1997), reported that the labor use for hand weeding in this area was the peak for labor force of their family, the labor use for weeding was covered to 33-48% of total labor used in the maize crop growth.

Roder (1991) stated that the majority of constraints of upland rice-based mixture cropping systems in northern part of Laos were weeded control. That is a limited of upland cropping, because it has spent a lot of times and labors use. Generally, farmers used the total input all of activities in upland rice cultivation, the average 159 days ha^{-1}, and a labor input of 294 labor days ha^{-1}, but weeding covered of 54 % of total labor input.

2.7 Crop-weed interaction

2.7.1 Crop-weed competition

Competition between plants for the capture of the essential resources for plant growth such as light, water, and nutrients is a critical process in natural, semi-natural, and agricultural ecosystems. Although farmers must have recognized competition effects in their systems as soon as they started to shape ecosystems to meet their needs, the first scientific reports on competition were published in the 14th century. Since then, competition has been regarded as on of the major forces behind the appearance and life history of plants and the structure and dynamics of plant community (Grace and Tilman, 1990).

In agricultural systems, crops are grown at moderate to high resource levels. In many of these systems large amount of resources (water, sunlight, and nutrients) are adds to the system to maximize yields. Competition in these systems could be defined as the process of capture and utilization of share resources by crop and its associated weeds. In the specific situation of crop-weed competition that is on the effect of resource capture by weeds on crop growth and production. Those resources of which the supply cannot meet the demand are of major interest, as they determine the attainable yield of crop. If weeds capture such resources, crop growth will be reduced resulting in the yield losses.

2.7.2 Competition and weed management

World wide a 10 % loss of agricultural production can be attributed to the competitive effect of weeds, in spite of intensive control of weeds in most agricultural systems (Zimdahl, 1980). Without weed control, yield losses range from 10 – 100 %, depending on the competitive ability of the crops (van Heemst, 1985). Therefore, weed management is one of the key elements of most agricultural systems. The use and application of herbicides was one of main factors enabling intensification of agriculture in past decades.

However, increasing herbicide resistance in weeds, the necessity to reduce cost of inputs, and widespread concern about environmental side effects of herbicides, have resulted in great pressure on farmers to reduce the use of herbicides. This led to the development of strategies for intergraded weed management based on the use of alternative methods for weed control and rationalization of herbicide use. Rather than trying to eradicate weeds from a field, emphasis is on the management of weed population.

Weed control is generally not needed to reduced yield loss in the current crop, but only to avoid problems in future crops (Lotz *et al*., 1990). The development of such weed management systems requires thorough quantitative insight in behavior of weeds in agroecosystems and their effects. This involves both insights in crop-weed interactions within the growing season as well as the dynamics of weed populations over growing seasons.

Several attempt have been made to weed control advisory systems, using thresholds for weed control, i.e. the level of weed infestation which can be tolerated based on specified criteria which are generally based on economics (cf. Niemann, 1986; Aarts and de Visser, 1985; Wahmhoff and Heitefuss, 1988). A number of concepts for thresholds for tactical (within season) and strategic (long-term) decision-making in weed management have been developed (Cousens, 1987).

However, the approach has hardly been used in practice (Cousens, 1987; Norris, 1992). Besides problems related to accuracy in yield loss predictions, good quantitative data on effects of specific weeds in specific crops are sparse as well as reliable simple assessment methodologies. These problems have resulted in major constraints to the development and implementation of weed control advisory systems (H.F.M. Aarts, Research Station for Arable Farming and Field Production of Vegetables, Lelystad; and

B. Gerowitt, Institute for Crop Protection, Gottingen, personal communications).

2.7.3 Economic threshold of weed control

Weed economic thresholds help in determining if weed density and interference is sufficient to justify control measures, i.e., if the yield loss avoided is greater than the cost of weed control. The time at which weeds emerge relative to the crop is a major determinant of yield loss. Early weeds that emerge at the same time as the crop cause more yield loss than weeds emerging after the crop is established. Estimation of effects on crop yield, most estimates of effects on crop yield are based on relationships between weed density and final crop yield (Zimdahl, 1980).

Though dry weight of weeds is better than density as an index of competitive ability, since weeds vary in size, there are practical difficulties in harvesting and drying large amount of weeds, and as a rule, doing so involve crop destruction. Hence, the weight of weeds might only be determined at harvest. Weed density has the advantage that it can be determined early in the life of the crop, when decisions on weed control have to be taken.

The relationship between density of a weed and crop loss is species specific, so that a competition index can be applied for each species. The relationship between crop yield and weed density may be affected by environmental conditions (Chisaka, 1977), time of sowing (Reeves, 1976), crop density (Medd *et al*., 1985), and another agronomic factors (Dew, 1972; Medd *et al*., 1985).

2.8 Intercropping concepts

The basic definition of intercropping is the planting of two or more crops simultaneously in the same unit of land. Intercropping is a common form of multiple cropping, which is defined as “the intensification and diversification of cropping in the same time and space dimensions” (Francis, 1986). There are many different kinds of intercropping systems. Some of which are more common than others, crops can be planted either as mixture, in a field (no rows), or as alternate rows, or strip, and relay cropping are species examples of intercropping. When two or more crops are growing together, each must have adequate space to maximize cooperation and minimize competition between the crops.

Andrews and Kassan (1976) identified four main types of intercropping as:

1. Row intercropping - growing two or more crops at the same time with at least one crop planted in rows.

2. Strip intercropping - growing two or more crops together in alternating strips or blocks on the same piece of land at the same time, wide enough to permit separate crop production using machines but close enough for the crops to interact.

3. Mixed intercropping - growing two or more crops together in no distinct row arrangement on the same piece of land at the same time or with a short interval.

4. Relay intercropping - planting a second crop into a standing crop at a time when the standing crop is at its reproductive stage but before harvesting

A primary and direct way of increasing the alpha diversity of an agroecosystem is to grow two or more crops together in mix that allow interaction between the individual of different crops. Intercropping can add temporal diversity through the sequential planting of different crops during the same season and the presence of more than one crop adds horizontal, vertical, structural, and functional diversity. Whenever two or more crops are plant together in the same cropping system, the resulting interactions can have mutually beneficial effects and effectively reduce the need external inputs. The today of information documenting these interactions has grown considerably in recent year (Fracis, 1986), and several authors have discussed how ecological approach to multiple cropping research can provide an understanding of how the benefits of intercropping come about (Hart 1984, Trenbath 1976; Beets 1982).

The most successful intercropping systems are know from the tropics, where a high percentage of agricultural production still is grown in mixtures. Because smaller scale farmers in the tropics have limited access to purchased inputs, they have developed intercropping combinations that are adapted to low external input management (Gliessman et al 1981; Altieri & Anderson 1986).

Moody (1977a) stated that intercropping gave increased productivity, insurance, reduced weed growth, reduced pest problems and reduced labor as examples of why farmers prefer to intercrop rather than sole crops than which will be produced by weeds. Intercropping should not be regarded as a panacea for all problems. Many people have the mistaken impression that intercropping always help to reduce weed growth.

Intercropping, compared with sole cropping, possible advantages of intercropping are higher yields in a given season and greater stability of yields in different season (Willey, 1979b). In this case of higher yield in a given season, apart from the better use of resources, one of the ways in which yield advantages can be brought about is trough a reduction in weeds, pests, and diseases.

2.9 Indices for evaluation productivity and efficiency of intercropping

2.9.1 Land equivalent ratio

Land equivalent ratio (LER) is an important tool for the study evaluation of intercropping system is the land equivalent ratio. LER provides all-other-things-being-equal measure of yield advantage obtained by growing two or more crops as an intercropping compared to growing the same crops as a collection of separate monocultures. LER thus allows going beyond a description of the pattern of diversity into an analysis of advantages of intercropping. The land equivalent ratio is calculated using the formula.

$$LER = f \frac{Y_{P_i}}{Y_{m_i}}$$

Where: Yp is the yield of each crop in the intercrop or polyculture, and Ym is the yield of each crop in the sole or monoculture. For each crop (i) a ratio is calculated to determine the partial LER for that crop, then the partial LERs are summed to give the total LER for intercrop. An LER value of 1.0 is the bleak even point, indicating no difference in yield between the intercrop and the collection of monoculture. Any value greater than 1 indicates a yield advantage for intercrop, a result called over yielding. Gliessman, (1988).

Land equivalent ratio may be defined as the relative land area under sole crops that is required to produce the yield achieved intercropping. It is usually stipulated that the "level of management' must be the same for intercropping as for sole cropping (Willey, 1979b). He has also explained that LER = 1.10 meant the mixture yield by growing pure stands would require 10% more land.

The LER term is usually applied to combined intercrop yields but can be applied equally usefully to the intercrop yield of each crop. An important concept enhance in the use of LER is that different it crops, whatever their types or level of yield are put on a relative and directly comparable basis (Bergh, 1968; Hall, 1974).

The problem in relating LER advantage into meaningful practical terms at the farmer's level arise because the proportion of sole crops with which the combined intercrop yield is effectively compared, is determined as a consequence of intercrop competition; this exact proportion may be something of a "theoretical" concept rather than a realistic cropping alternative for a farmer who has to decide has proportions of crop at sowing time (Wiley, 1979b).

Mohta and De (1980) studied a maize and soybean intercropping for different planting geometries for the year 1970-1974. It has been noted that by maintaining a plant population of 65,000 plants per hectare, no significant difference in maize yield occurred whether the rows were placed 60 or 120 cm apart. In the intervening space, soybean was planted, which increased the LER by 54 %. With proportional planting, LERs of 1.3 and 1.6 have been report in the land equivalent ratio is the most frequently to determine the effectiveness of intercropping relative to growing crops separately. Generally, the value of LER is determined by several factors including density and competitive abilities of the component crops in the mixture crop morphology, duration and management variables that affect individual crop species (Willey, 1981).

2.10 Light interception

Light is one of most important factors in intercropping systems. Light differed from other recourses in that it could be regarded as a reservoir from which demands could be made as require. Solar radiation is continuously available and has to be "instantaneously intercepted" as it is to be used for photosynthesis.

Light interception in mixed canopies is determined by the leaf area index of the species, plant height, and light absorption characteristics of the leaves. If a leaf is positioned above another leaf it will absorb a large amount of radiation. A strong correlation between plant height and competitive ability has been demonstrated for many crop species (review by Berkowitz, 1988). Modeling the light interception process is regarded as the most promising approach to understand light capture by species in mixed canopies (Berkowitz, 1988).

It is possible to have sparse canopy, such as tall in cereal, for the high light intensities at top of canopy and a more course canopy, such as compact legume, for the lower intensities at the bottom. There is also the possibility of combining crops, which have different, inherent response to light. Thus the top of the canopy could consist of a component with a high light requirement and the bottom a component with a low light requirement an obvious example here would be a tall C4 crop combined with a short C3 one (Crookston and kent, 1976).

Light interception by sole crop is affected the positions of the light sources, the leaf area index and the inclination and distribution of leaves. Light penetrating a plant stand is diminished through interception and absorption by the leaves and other part of shoot systems. The potential shares of the light will be grained by the efficiency of their interception and absorption of light (Trenbath, 1979).

Willey (1979b) also pointed out that if there was to be better spatial use of light, which had probably to be achieved through more efficient use of light rather than greater light interception. That could be theoretically occur if light was better distribution over the leaves, either because of better leaf inclination or because of better leaf dispersion.

Experiment in which have been taken at a few point in time (IRRI, 1973, Fisher, 1975) and form which it has been reported that intercrops intercepted more light, might be difficult to intercept in the spatial sense because it was not usually possible to compare peak values of interception. In has been reported that narrow rows improved the performance of many crops in humid regions or under irrigations through maximizing the capture of incoming solar radiation (Kanemasu and Arkin, 1974).

The way intercropped species change each other's environments and physiological responses to change are closely related. Thus, the disadvantage of one component in competition for nutrients may increase its root/shoot ratio so that extra respiratory load per leaf area will reduce its efficiency of conversion of light to dry matter or yield (Trenbath, 1979). The success of intercrops has been shown to be associated with complementarily in time and possibly of higher plant population pressure, both of which result in grater light interception (Fisher, 1975).

Beets, (1976) studied this in mixed cropping systems of maize and soybean by measuring the "canopy cover" which is closely related to LAI. Showed that the percent canopy cover. This is illustrated the soybean canopy cover is plotted as a percentage of the total canopy cover (maize + soybean), from planting to physiological maturity. In the monoculture system the canopy cover increases to 100 percent. In the all mixed cropping systems, the soybean cover increases initially, but from the seventh after sowing all covers decrease, except for the system with only a small proportion of maize. The decrease in cover is due to over shading of maize and is greatest for the most intimate system. The yield results of trial show that the yield performance of the mixed cropping system was negatively correlated with the degree of over shading of the soybeans.

2.11 Some agronomic factors in fluencies productivity and economic efficiency of intercropping systems

The productivity and efficiency of cereal and legume intercropping systems are affected by various agronomic variables that affect crop yields. Productivity per unit area is increased through the use of suitable crops with higher yield stability and adoption of appropriate intercropping systems (Mandal *et al*., 1986).

Compared with sole cropping, intercropping diversifies production while serving as a security practice against possible crop failure as a result of adverse condition. In addition to achieve higher yield than sole cropping in a given season, the practice stabilizes variability of annual returns while at the same time results in a more uniform use of labor throughout the season (Willey, 1979b).

There is a number of report in which reducing the height of a dominant cereal has resulted in higher yields of associated crop (Andew, 1974; Vorasoot *et al*., 1976). Faris *et al*. (1979) also reported that the cereal crops several reduced the legume yield and that the intercropping system was more productive than the sole crop.

In field experiment at Dharwad, India during rainy season, maize was intercropped with groundnut, soybean, cowpea, and mungbean. Maize yields were not significantly affected by the intercrops. Intercropping gave higher gross monetary return than maize growing alone but net returns were not significantly different (Shahapurkar and Patil, 1989).

2.11. 1 Crop component and planting patterns

There are two important of cropping system to considerations should be made:

The cropping pattern should allow available farm resources to be used efficiently. They should be designed in such a way that the available farm resources are adequate for satisfactory production to labor used and or needs.

An understanding of the sharing of resources among component crops will help identify more appropriate agronomic manipulations and cultivates for intercrop (Trenbath and Fukai, 1993). Growing different crop species in various combination in space and time or with different duration, growth and developmental patterns, spatial distribution leaf size, shape and orientation and plant height resulted in great diversity and structural complexity in intercrop (Keating and Carberry, 1993).

Need for choice of component crop suitable for an intercrop, in many instances, is predetermined by local need for particular crop species. In choosing component crops to be intercropped, the important aspects to consider are the extent of competition between the crops and variation in competition ability among cultivars.

Choice of crops with contrasting growth patterns and complementary use of the same resource pool results in better intercrop productivity. The typical example is to intercrop short C3 and high C4 type plants, which differ in efficiency in use of tropical sunlight (Midmore, 1993).

Intercrop productivity depends on the genetic constitution of crop components, growth environment and agronomic manipulations of microenvironment. Farmers can choose crops, which differ in competitive ability in time, and space and they make management decision when to plant, at what arrangement (Trenbath and Fukai, 1993).

There many factors of crop management which can affect the competitive relationship between the crop components of an intercrop like relative planting date, density and spatial arrangement, fertility and water availability, pest and diseases. Choices of suitable crops, proper time and space to intercrops are of important and factors in successful intercropping system (Davis and Woolley, 1993).

Planting pattern of crop components plays an important role in maximizing the productivity of intercropping system. Choice of planting dates is relative timing of component crops, can contribute greatly to the crop yield of intercrop systems (Midmore, 1993). Choice of cropping patterns can also affect their efficiency.

According to many research results in the world show that the planting pattern legumes with cereal crop was provided high profit. The success of intercrop farming systems with legumes depends initially on effective nitrogen fixation and more nitrogen balance in intercropping systems that consist of legumes growing with another crop is considered in terms of nitrogen fixation (Stern, 1987)

2.11.2 Spacing and crops population

The amount of light intercepted by the component crops in intercrop system depends on the geometry of crops and foliage architecture. Generally, taller cereal shades legumes and at high densities cause reduced growth and yield of the companion legumes (Trenbath, 1986 and Tsay, 1985). In plant populations competition is defined as the situation in which each of two or more plants growing together in the same area seek the same growth factor. The overall intercrop densities and the relative proportions of component crops are important in determining yield and production efficiency of cereal/legume intercropping systems (Willey and Osiru, 1972).

According to research results of Herrera *et al*. (1975). They found that crops density has great effect on competitive ability of crop components for available resources. Weed control, insects and diseases occurrence and severity due to change in microenvironment and hence, yield of component crops. The relationship between population density and biomass yield which may be written as linear relationship between density and the correlative of individual plant weight (Spitters, 1980)

In intercropping choice of row spacing and row ratio are also an important factor that affects productivity of component crops. Row arrangement in contrast to arrangements of crop component within rows, improve amount of high transmitted to the lower legume canopy. Such arrangements can enhance legume yield and efficiency in cereal/ legumes intercrop systems (Francis, 1989). The several studies, it would appear that the yield of cereal component is usually less affected by component densities and arrangement of spacing between component crops (Tsay, 1985).

Fisher (1977) studied corn and bean intercropping system at varying densities which at harvesting were 13,700, 27,000, and 47,700 plants ha^{-1} of corn combined with 23,300; 56,300 and 121,000 plants ha^{-1} of bean receptively, designated as low, medium and high densities. At each density, the yield of intercrop corn did not differ from those of the sole corm. However, intercrop bean yield significantly increased with a rise in bean density. The arrangement of component crops in alternate row is more beneficial than in the same rows. The use of double rather than single alternate row arrangements of component crops improve the yield and light penetration to the canopy of legume component.

2.12 Maize production in Laos and Oudomxay provionce, Lao PDR

2.12.1 Maize production in the Lao PDR

The secondary data from Ministry of Agriculture and Forestry (MAF, 2000) showed that maize is as well as adapted to tropical climate and at the present maize were grown in many parts of Lao country as showed in Figure 2.

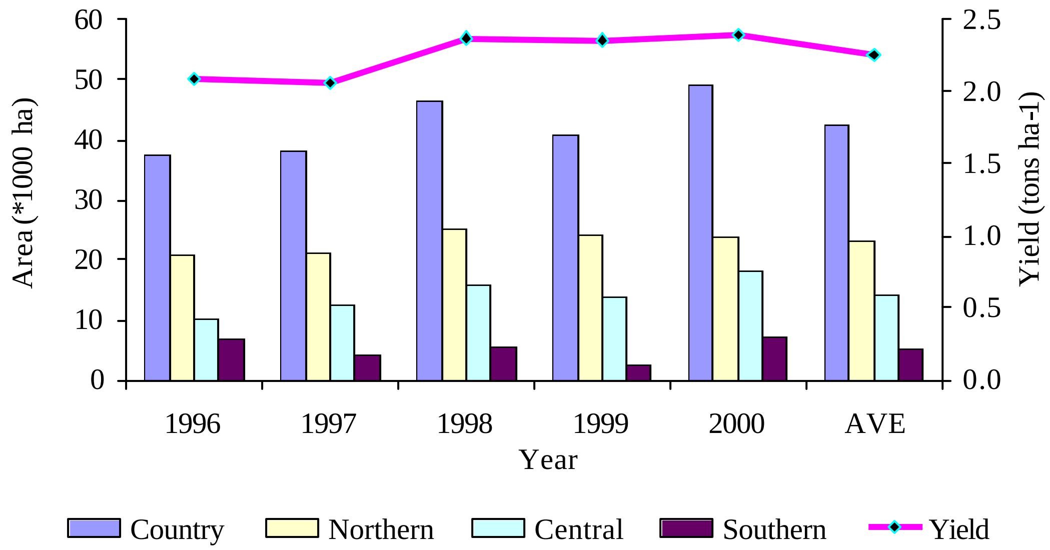

Figure 2. Area and yield of maize cultivated in the Lao PDR, 1996 – 2000.

Source: Department of agriculture, MAF, 2000.

Maize was the second stale food crop and also major cash crop in Laos. Maize had long been grown in distribution many parts in Laos, with the total area of maize cultivated of 49,000 ha in 2000. Average area in around 5 years (1996-2000) was of 42,302 ha, but the largest area of maize cultivated was in the northern part, covered 54.4 %. On average area of maize cultivation in each part of 23,042 ha, in northern part, 14,104 ha, for central, and 5,158 ha in the southern apart of country respectively. The average of maize yield was 2.3 tons per hectare, if compare in the South East Asia, the maize yield in Laos was very lowest.

2.12.2 Maize production in Oudomxay province

According to the agriculture statistics of Oudomxay provincial, agriculture and forestry office (DAFO, 2000). Found that the areas and yields of maize have been changed by year to year. The area and yield of maize production in Oudomday province were decreased from 1996 to 1999, and in year 2000 was increased that show in Figure 3.

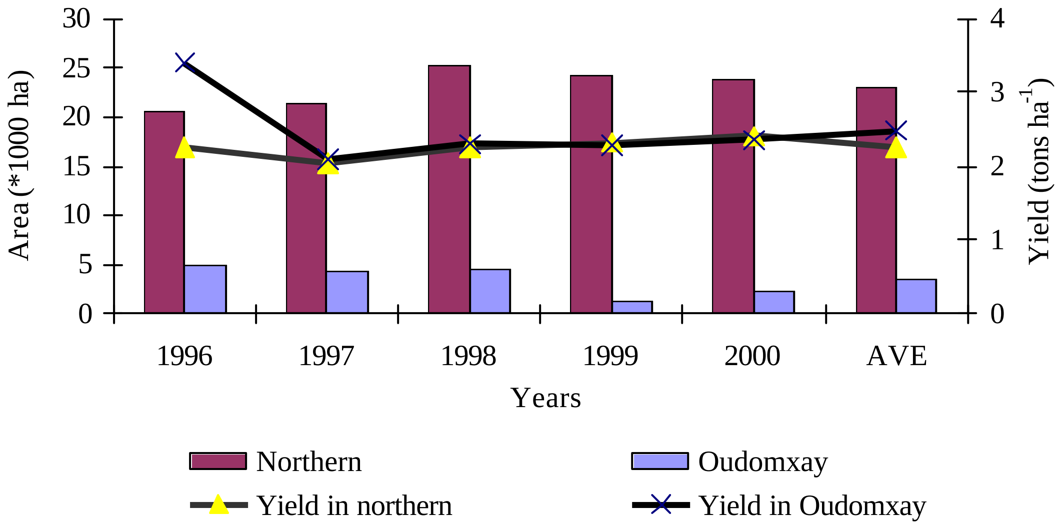

Figure 3. Area and yield of maize cultivated in Oudomxay province 1996 – 2000.

Source: Department of agriculture and Forestry Office, DAFO, 2000.

The average area around five years of maize cultivated in Oudomxay province was of 3,420 ha, and distribution about 14.8 % of total area in northern part of country. However, the yield of maize in Oudomxay province was higher than other province in the country. Average yield of maize was 2.48 tons ha^{-1}.

2.13 Soybean production in Lao and Oudomxay province, Lao PDR

2.13.1 Soybean production in the Lao PDR

General, agriculture statistical (MAF, 2000) the data of soybean production in the Lao PDR showed that soybean is well adapted to tropical climate and suitability to growing in many parts of Laos as showed that in Figure 4.

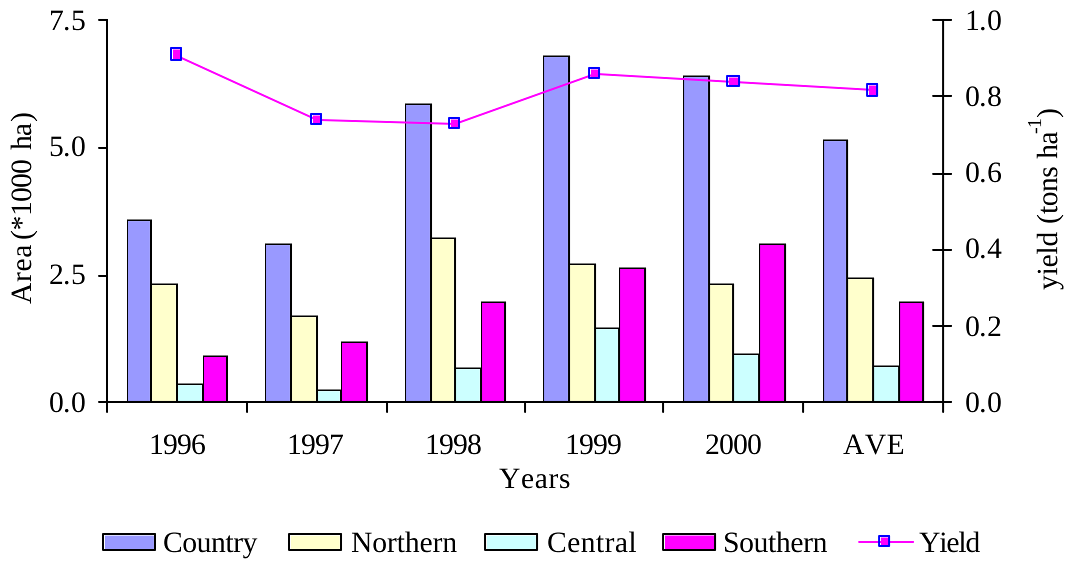

Figure 4. Area and yield of soybean cultivated in the Lao PDR, 1996 – 2000.

Source: Department of agriculture, MAF, 2000.

Soybean is a cash crop can be grown in many parts of Laos, especial in rainfed upland areas in northern part of country. The total area of soybean cultivated of 6,400 ha, in 2000. On average area in year 1996 to 2000 of soybean-cultivated was 5,154 ha. The average soybean yield was about 0.8 tons ha^{-1}; the soybean yield is very lowest if compared with Southeast Asia. The areas and yield in many parts of country was difference, and the highest was in northern part covered about 47.7 % of total area of soybean had grown in Laos.

2.13.2 Soybean production in Oudomxay province

According to the result of data based of agriculture and forestry office in Oudomxay province (DAFO, 2000). The area and yield of soybean cultivated was lowed in northern part and other province in Laos. An area of soybean average around 5 years was about 176 ha, covered about 7.2 % of total area in northern part. The average of soybean yield was higher than other province in north including in the country, the yield of soybean about 0.95 tons ha^{-1} that showed in Figure 5.

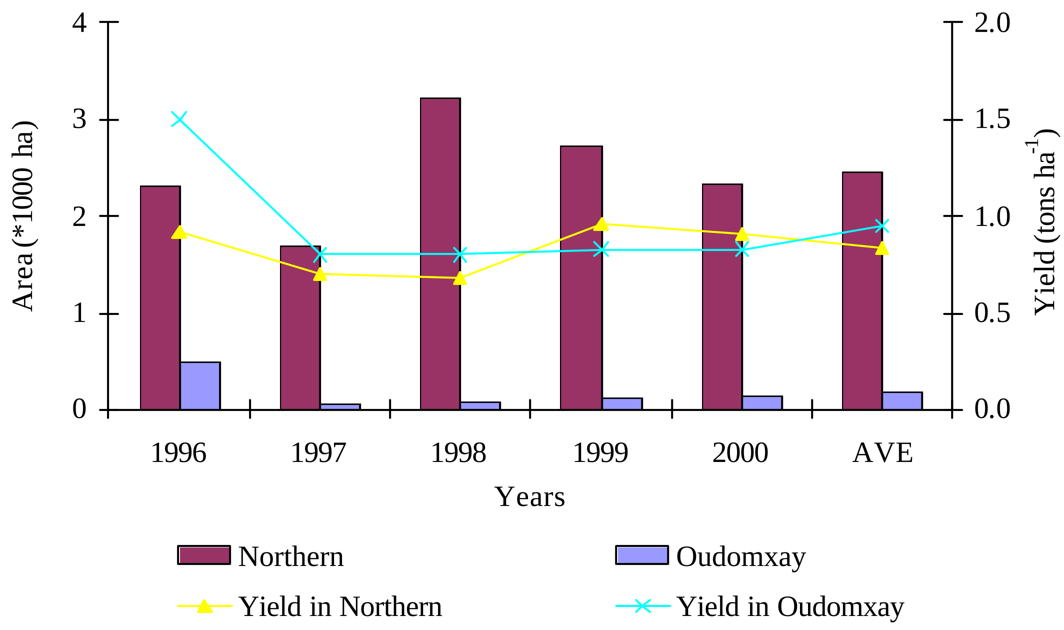

Figure 5. Area and yield of soybean cultivated in Oudomxay province 1996 – 2000.

Source: Department of agriculture and Forestry Office, DAFO, 2000.

2.14 Limitation of maize and soybean production in Laos and Oudomxay province, Lao PDR

Many constrains involved to maize and soybean cultivation in Laos and Oudomxay privince, in the Lao PDR. In duration of farm field survey, interview and secondary data collection, the major constraints or limitation of maize and soybean cultivations were investigated with two aspects as biophysical and socio-economical factors and weather conditions. The field survey, and interview with farmers and villagers for maize and soybean production constraint in Oudonxay province, Laos. Generally, most farmers are lack of technologies, poor internal inputs, and lack of markets, the market oriented was depend on foreign countries, the price was depended on mid-trader and high transportation costs as well as price policy are factors limiting with maize and soybean production. Lack of application of manure fertilizers as well as and also varieties of maize and soybean were imported from Thailand, Vietnam and China. Both maize and soybean are important for economic of household income, and can be to improved agro-economic system in the rural development areas.