CHAPTER 6

DISCUSSION

6.1 Results of field survey

6.1.1 The climate of Oudomxay province

The climatic data for the study area was obtained from the meteorological station of Oudomxay province. Based on the Koppen system, the climate of the provinces is classified as a moist/dry monsoon tropical climate. The wet-season starts in May and extends to October. Heaviest rainfall is usually recorded in the months of August and September. The wet-season is followed by a 3-4 month period of cooler, dry conditions. Hot and humid conditions prevail in April, prior to the onset of the wet-season.

During the wet-season minimum and maximum temperatures are rather constant with mean temperature of about 25 °C, and an average temperature range from 20.6 to 29.5 °C. The mean temperature in December is round 17.1 °C. In the hottest month, April, the maximum temperatures can rise to in excess of 32 °C. Most annual crop production (rice, maize, sorghum, leguminous crops, vegetables, etc.) takes place during the wet-season. In the limited areas serviced by irrigation, there is some dry-season production of rice, peanuts, soybean, maize and vegetables.

6.1.2 Soil characteristics

The soils in the study area have been described in Chapter IV. Most of the soils throughout the study area are of low to moderate fertility, highly prone to erosion in sloping areas, and having relatively limited agricultural potential. With the exception of some upland areas under intensive slash-and-burn agriculture, soil organic matter can reach levels of between 4 and 5 %. Soil pH is moderately acid to slightly alkaline, with a reasonably high cation content. The moderately weathered soils in the narrow floodplains have a relatively high nutrient status.

6.1.3 Land use and cropping systems

In the Namkha study area, most cultivation is under upland conditions with the emphasis being on upland rice based mixed cropping and to a more limited extent, maize based mixed cropping. Field surveys have indicated a trend of declining productivity from year-to-year. Government policy is to stop most upland annual production, with a move to more sustainable agricultural practices in the upland environment.

The main cropping combinations in the area are mixtures cropping pattern such as rice/maize, maize legumes, maize/squashes and cucumbers, maize/sweet potato, etc. These crops and crop mixes are grown in a number of ways relay cropping, alternate cropping, intercropping and other crop rotations. A major constraint to production to all forms of upland cropping is the effects of weed competition and the associated labor inputs and financial cost of achieving weed control. The area, which individual households can farm, is determined by the level of weed ingress and associated level of labor availability.

Three categories of sloping land are recognized for agriculture in the study area sloping land 2-8 % slope; moderately sloping land with a 8-16 % slope, and medium sloping land with a 16-35 % slope. Within the study area, rice-based mixed cropping, maize based mixed cropping, and second cropping with cash and leguminous cropping, is found in all slope categories.

The results of study established that is it necessary to change the existing cropping patterns from upland rice-based mixture cropping to crop rotations such as maize following by leguminous crops and other cash crops. Whyte *et al*. (1969) also found that continuous cropping cereal crops or non-legume crops frequencies lead to depletion of some specific mineral nutrients and decreases the crop yields. However, when soybean is planted in rotation systems, beneficial effects are manifest in both economic terms and in improving the soil environment. One of the most beneficial systems is when soybean is intercropped in alternate rows or strip-cropping alternately with cereal crops. Combinations of soybean and maize can improved weed control and increase maize yield. Further, changes in the cropping patterns area also capable of bringing about higher soybean yields, as well as the improvements in yield and income from maize production. Maize is regarded as an attractive alternative to upland rice in the study area on account of its potential for raising farm incomes.

6.1.4 Manual weed control and labor use for weed control in maize and soybean

6.1.4.1 Manual weed control in maize and soybean

Manual or hand weeding remains the main means of weed control in crops of maize and soybean (and other crops) in the study area, with the critical period of control during the immature phase of crop growth. In the survey of production constraints in the study area, the majority of the respondents listed weeds are the important constraint in both maize and soybean production in rainfed upland mixed cropping systems. Most labor input into the cropping cycle is for weed control. The hand weeding that currently prevails uses a number of traditional implements such as spades, small hoes, and sickles. The most important weeds in declining order of significance are *Ageratum conyzoides* L, *Chromolaena odorata* (L), *Cyperyus rotundus* L, *Murdannia nudiflora* (L.). *Amaranthus spinosus* and *Eluesine indica* (L.) Geartn.

In upland maize crops during the wet-season, hand weeding is undertaken 2-3 times, while for a single time of weeding for soybean is usually undertaken. In maize crops, most weeding is undertaken in June and July, which correspond with the V4 and V8 stages of growth. There is no use of herbicide in the study area. Despite the current hand weeding practices, weed competitions are still regarded as a significant potential constraint to production. More timely weeding is regarded as having the potential for both maximizing labor use efficiency and improving productivity (Shetty, 1980).

6.1.4.2 Labor use for weed control in maize and soybean

In many areas, a system of family labor exchange is followed in an attempt to meet the labor input requirements for weeding. However, with most households having high labor input needs for weed control at the same time, timely weeding cannot always be achieved. Estimates of labor inputs for maize and soybean have indicated a requirement of 232 and 207 labor-days ha^{-1} for maize and soybean, respectively. As already reported, this labor input is the equivalent of about 38 % and 31 % of the total labor input for maize and soybean, respectively, during the crop production cycle for these two crops. This compares with a labor input of 39 % the total, for weed control under estate conditions in Malaysia (Ayub, 1982). This high labor input for weeding can limit the area cropped in some farming systems (Armitage and Brook, 1976; Koch *et al*., 1982). Reichelderfer (1984) point out that if the labor required for weeding can be reduced, additional land can be area cultivated, thereby providing the potential for raising farm incomes.

6.1.5 The role of maize and soybean intercropping systems in the study site.

Most farmers in the Namkha study area are involved in upland rice-based mixed cropping, and maize-based mixed cropping with leguminous and other cash crops, under rainfed upland conditions. Most maize is grown in the wet-season under both upland and flood-plain conditions. The crops mixed with the maize are mostly leguminous crops and vegetable-squash. Due to the lack of irrigation facilities, there is little dry-season cultivation of maize or soybean, and only a small area of dry-season irrigated rice.

Planting of the upland maize crop usually commences with the onset of early wet-season rains in May, as soon as there is sufficient soil moisture. Soybean is planted near the end of the wet season, about August. The varieties of maize grown include a combination of traditional varieties including a 'Hmong' variety and the Vietnamese variety (VN10). The variety of soybean grown is simply known as the 'Hmong' variety.

As the national government of Laos has a policy of also increasing rice production to achieve food self-sufficiency, this policy is also reflected in the study area with most farmers attempting to increase rice production. However, there are many systems of rice-based cultivation under upland rainfed conditions, including rice-maize intercropping.

6.1.6 The role of maize/soybean intercropping for weed control

There were many legumes can be grown in combination with maize; these include mungbean, peanut, cowpea and soybean. Intercropping maize with a legume may protect the young maize crop against early weed competition thereby reducing the cost of weed control (in terms of both labor cost and cash outlays). The legume rapidly forms a dense leaf canopy beneath the maize and effectively shades out the weeds. Increased light interception in intercropping appears to be the vital element in reducing crop-weed competition, especially in the stages of crop growth when weed control is critical (Herrera, 1975).

Bantilan and Harwood (1973b) also report that when legumes are intercropped with maize, the legumes can protect the maize crop from competition during the first 40 days of growth. However, there are also exceptions to this expectation. Moody (1977a) stated that maize and peanut would benefit little, if any, in terms of weed suppression from being grown in combination. Different legumes differ in their capacity to reduce weed competition. Harrera (1975) reported that peanut was less effective in competing against weeds than mungbean.

Maize and mungbean are usually regarded as one of the best intercropping combinations for controlling weed competition (Moody, 1977b). In the Philippines, there several studies have reported the benefits of mungbean on weed competition when intercropped with maize (Bantilan and Harwood, 1973a, Batilan *et al*., 1974; Castin *et al*., 1976).

6.2 Results of field experiment

6.2.1 Weed population density

The interaction between critical timing of weeding and intercropping had effected to the weed population density reducing in the maize and soybean intercropping combinations. Generally, the weed population was greatest in the single cropping treatments, and for these treatments was greatest in the sole cropped maize relative to the sole cropped soybean (when no weeding was undertaken). In the both maize and soybean intercropping treatments (single row of maize and single row of soybean M: SB 1:1 and single row of maize and double rows of soybean M: SB1: 2) the intercropping had a very marked impact in suppressing weed growth, even in the no-weeding treatment. In term, there was relatively little difference in the weed population between the two weeding treatments. Further, there was slightly difference in weed density between the two weeding treatments V4+8 and V4+8+12. Weed population density in the weeding-V8 treatment was generally greater than for all other timing-of-weeding treatments under all cropping regimes (i.e. in terms of weed density, V8 was the least effective in suppressing weed growth). Mercado and Bariuan (1978a) found that at 20 DAP weed density was higher in maize than either soybean or maize-soybean intercrop. By 80 DAP, the weed density in the intercrop was as greater as that in maize sole crop; soybean was more competitive.

6.2.2 Weed species

The major weed species at the experimental site (the Irrigated Agriculture Research Station of Chiang Mai University) were, by weed category, as follows: (i) broadleaved weeds: *Ageratum conyzoides* L. *Alternanthera sessilis* (L.) DC. *Eclipta prodstrata* (L.) L. *Cleome rutidosperma* DC. *Mimosa pudica* L. *Ludwigia octovalvis* (Jacq.) Raven. *Sesbania sesban* (L.) Merr. *Physalis angulata L.* (ii) sedges: *Staria geniculata* (Lmk.) P. Beauv. *Cyperus imbricatus* Retz. *Cyperus rotundus* L. *Scripus grosses* L. f. *Fimbristylis miliacea* (L.); (iii) grasses: *Echinochloa glabrescens* Munro ex Hook. f. *Eleusine indica* (L.) Gaertn. *Panicum maximum* Jacq. *Poa annua* L. *Elephantopus tomentosus* L. *Oryza stiva* L. *Paspalum conjugatum* Berg. *Leptochloa* *chinensis* (L.) Nees. *Cynodon dactylon* (L.) Pers. *Phyllanthus amarus* Schum. & Thonn. *Chloris barbata Sw*. *Pennisetum polystachyon* (L.) Schult. *Pennisetum purpureum* Schumach. Among these, the five most important weeds were *Eleusine indica* (L.). *Ageratum conyzoides* L. *Echinochloa glabrescens* Munro ex Hook. f. *Cynodon dactylon* (L.), and *Oryza stiva* L. Generally the grass weeds were more important than broadleaf and sedges.

6.2.3 Total dry matter yield of weeds

The interaction between timing-of-weeding and cropping all treatments had reflected to the total dry matter of weed in the sole cropping of soybean is much more susceptible to weed ingress than sole cropping of maize in the no-weeding and weeding-V4+V8 treatments. However, the single of weeding treatments for weeding-V4 and V8 had the TDM of weed for sole cropping of maize. Generally the level of weed ingress (as reflected by the TDM in the intercropping combinations was less than in the sole crop situations for each weeding treatment. However, with early and or frequent weeding (V4, V4+V8, V4+V8+V12), the differences in TDM were not statistically significantly different from the sole crop treatments.

The TDM in the two intercropping treatments showed very slightly difference for the V4 treatment. However, there were significant differences for weeding treatments V8, V4+V8 and V4+V8+V12 t for when a single row of maize was intercropped with a double row of soybean (M: SB 1: 2), for which treatment the TDM was approximately 24 % less than for the single row of soybean intercrop (M: SB 1: 1) treatment. The TDM generally reflected the relative weed population densities, timing-of-weeding and cropping systems, including rows spacing arrangements. Many authors (Bantilan *et al*., 1974; Castin et al., 1976; Shetty and Rao, 1977) have reported that the weight of weeds growing in association with intercrops such as maize/mungbean, maize/soybean, sorghum/pigeon pea, sorghum/cowpea, and sorghum/mungbean is as low or lower than that growing in association with the sole crops.

6.2.4 Labor use for weed management

Labor use for weeding was significant for the interaction between time-of-weeding and cropping, for all treatments. The labor use for weeding, as to be expected, reflected the frequency of weeding. The highest labor input was associated with the weed-free treatment.

Among the different cropping treatments, the highest labor input for weed control was associated with the sole crop soybean treatments. In the intercrop treatment single row maize and single row soybean (M: SB 1:1), and the treatment single row maize and double row soybean (M: SB 1:2) the labor input for weeding was approximately 16 and 30 % less, respectively, than for the sole soybean crop. The labor input for weed control in the sole maize crop treatment was about 6 % less than for the sole soybean crop

While crop diversity through intercropping may help in weed suppression (Litsinger and Moody, 1976), weed control in intercrop situations may be more difficult to achieve than in sole crop situations.

In a comparison of the labor input for weeding in the weed-free treatments, relative to the different weed frequencies, the labor input was reduced for the latter by the order of 78.6; 75.7; 61.8 and 43.5 % for the weeding treatments V4, V8, V4+V8 and V4+V8+V12, respectively. Similar results to those reported for this study have been reported Paller and Vega, (1972b).

6.2.5 Crop growth and yield

6.2.5.1 Plant height of maize and soybean, and number of soybean branches

Plant height of maize as measured at harvest, reflected of affects for timing-of weeding and intercropping treatments. There was an effect on maize plant height in all the intercrop treatments was higher than for the sole maize crops. The tallest maize plants were in the no-weeding treatment, and the single row maize: double row soybean (M: SB 1:2) treatment. The shortest maize plants were in the V8 weeding treatment for the sole maize crop.

For soybean plant height, differences were manifest between the different intercropping treatments. The tallest soybean plants were in the unweeded treatment, and for the V4 weeding treatment when two rows of soybean were intercropped to each row of maize (M: SB 1:2). The shortest soybean plants height were recorded in the different weeding treatments for the sole soybean crop treatments. It is apparent from these results that light competition from either the intercrop maize or weeds, helped determine the soybean crop height. When there was light competition from either intercropped maize or weeds, the net result was for the soybean plants to elongate. Ibrahim *et al*. (1977) report that in similar intercropping studies, soybean plant height was not influenced by maize density, soybean density or by intercropping. On other hand, Tsay *et al*. (1988) reported that the relative plant height of the component crops appears to be an important factor in determining the growth of each crop.

In relation to soybean branching (measured at harvest), the greatest level of branching occurred in the sole soybean crops, irrespective of the weeding treatments. An exception to this was in the no weeding treatment where, in addition to the level of branching being reduced as a result of weed competition, there was slightly or no difference from the single row of maize and single row of soybean (M: SB 1:1) intercropping treatment. The effects of timing of weeding in the weeding-V4+V8 and weeding-V4+V8+V12 treatments, the net effect was to increase the level of soybean branching when the soybean was sole cropped.

The level of soybean branching was also related to plant height. Generally the degree of branching was inversely related to plant height (i.e. shorter plants had higher levels of branching).

The level of soybean branching was obviously related to the level of shading. Shading which resulted in elongation as a result of competition for light generally resulted in reduced levels of branching. Reduced levels of branching (as a result of weed competition) resulted in reduced grain yield. This is consistent with the relationship reported by Srivastaya *et al*. (1980).

6.2.5.2 Leaf area index of maize and soybean

Fukai (1993) reports a complex of relationships in crop and weed competition relationships that influence leaf area index (LAI).

In this study, all time-of-weeding treatments and intercropping treatments affected the LAI for both maize and soybean. Generally, LAIs for each crop were highest in the respective sole crop treatments for all weed control regimes, while the LAI for each crop was also higher in the different weeding treatments relative to the no weeding treatment. Generally, the LAI for both corn and soybean was suppressed by both weed competition and intercropping.

Differences in LAI between the weed free and no weeding treatments for the sole cropped maize were generally greatest at the V12 stage of crop development. However, differences between the cropping treatments (sole crop, M: SB 1:1 and M: SB 1:2) were greatest for the V4+V8 weeding treatment at the VT stage of crop development.

In the case of soybean, LAI at the R2 and R5 stages of reproductive development were differed among the time-of-weeding and intercropping treatments.

LAI of soybean at R2 was at a maximum for all time-of-weeding treatments (but not for the weed free or no weeding treatments). Maximum LAI was achieved in the weeding treatments V4 and V4+V8. LAI was also higher in the sole crop soybean relative to the different intercrop treatments.

The relationship of LAI to the different weeding and intercrop treatments for soybean at the R5 stage of reproductive growth was generally similar to that for the R2 stage of development.

The relationship between LAI and weed competition has been distributed by Sucharin (1981) and Trenbath and Fukai (1993). The reduction of LAI as a result of either weed competition or intercropping can result in a reduction in photosynthetic activity, resulting in a reduction in crop yields in both sole crop and intercrop associations.

6.2.5.3 Light intensity and light interception

The interaction between timing of weeding and intercropping had affected for light intensity and light interception obtain level at the V12 stages of growth for maize. There was indicated significant effect in the intercropping, the highest levels of light intensity and light interception at V12 were obtained in the single row of maize and single row of soybean intercrop (M: SB 1: 1) treatment. The lowest light intensity and light interception was found in the sole crop of maize, due to leaf area and canopy in the single crop was larger than maize intercropping treatment. Thus light transmission to the ground was smaller than maize intercrop treatment.

At the VT stage of growth, greatest light intensity and light interception occurred in the intercrop treatments relative to the sole crop treatments. Further, light intensity and light interception in the no weeding and early weeding treatments (V4) for sole crop of maize was generally higher than maize intercrop treatments. The levels of light intensity and light interception in the different treatments were generally reflected in maize growth and development through both leaf area and canopy development. All maize intercropping at three timing-of weeding treatment, included weed-free treatment was obtained light intensity and light interception level higher than sole crop of maize treatment.

In the case of soybean, light intensity and light interception at two stages of reproductive growth, R2 and R5, differed for both time-of-weeding and intercropping treatments. In all sole soybean crops, light intensity was greater than in the intercrop treatments. In the sole soybean crops, highest light intensity was measured in the V4 weeding treatment at the R2 stage of growth, and in the V8 treatment at R5. However, light interception by soybean in the intercrop treatments was generally greater than for when soybean was sole cropped. This applied for almost all weeding treatments with the exception of V4 at R2 and V8 at the R5 stage of growth. The increased light interception in the intercropping treatments appears to be the vital element in crop-weed competition, especially in the early growth stages when weed control is critical (Herrera, 1975).

6.2.5.4 Total dry matter yield of maize and soybean

Significant differences in total dry matter (TDM) yield for maize were recorded for the effects of time-of-weeding and the intercropping treatments, at the V12 and VT stages of crop development.

At the V12 stage of development, highest TDM was recorded in the sole crop treatment and when a single row of maize was intercropped with two rows of soybeans (M: SB 1:2). Most time-of-weeding treatments also gave a higher maize TDM than the no weeding treatment.

At the VT stage of growth, the no weeding and early weeding (V4) treatments were associated with the lowest TDM. The highest TDM was recorded for the four treatments at V8, V4+V8, V4+V8+V12, and the weed-free treatment. Generally the sole maize crop treatment gave higher TDM than the two-intercrop treatments, at this stage of crop development. However, some of the differences between these treatments were not statistically significantly different.

At harvest, the highest TDM was also associated with more frequent weeding and was reduced when the maize was intercropped with soybean (in both intercropping treatments). Generally, TDM accumulation for maize was reduced at all stages of growth in the no-weeding treatments, and in those treatments based on a single weeding, and when the maize was intercropped with soybean. This association of increased TDM production with reduced competition (whether as a result of maize plant population pressure or being intercropped or bordered by less competitive crops, has been reported by several authors (Alexader and Genter, 1962; Pedleton *et al*., 1963; Crookston and Hill, 1979).

Similarly, total dry matter yield of soybean was measured at the R2 and R5 stages of reproductive growth, and at harvest. There were significant differences for total dry matter (TDM) between all the cropping treatments at both R2 and R5. At harvest, it was significant different for the interaction between timing of weeding and cropping treatments. Highest TDM yield for soybean at both the R2 and R5 growth stages was recorded in the sole cropping treatment. The lower TDM for soybean recorded in the intercropping treatments did not differ significantly between whether one or two soybean rows was intercropped to each row of maize

The TDM at harvest for soybean was approximately 40 % less than that recorded at the R5 stage of reproductive growth (the reduction coming as a result of leaf drop at maturity). However, at this stage of growth, the TDM in the sole soybean crop was higher than for the intercropping treatments, for all time-of-weeding treatments. Further, the TDM in the three time-of-weeding treatments (V4, V8, V+V8 treatments) was higher than for both the weed-free and no-weeding treatment. The lowest of soybean TDM accumulation was associated with the interrow cropping of a single row of maize with double rows of soybean in the weeding-V4 treatment; however not all the differences between treatments were statistically significantly different. The results of the study clearly indicated that the level of plant competition, either weeds or other soybean plants in inter and intra row situations, determined the TDM of soybean. Similar results have been reported by Sivarkumar, 1980, Tsay *et al*., 1988, and Bohringer *et al*. (1994). High soybean dry matter accumulation is correlated with high seed yield (Veerawudh, 1974; Pookpakdi, 1997).

6.2.6 Yield components and grain yield of maize and soybean

6.2.6.1 Yield components of maize

The yield components of maize, which were observed, were number of rows per ear, seed number per row, seed number per ear, and 1,000 seed weight. There were significant differences in response to the treatments for most of the yield components, however, sometimes at the different treatments affected different components. Weeding treatment affected number of rows per ear, number of seeds per row and number of seeds per ear, while the intercropping treatments affected number of seeds per row, number of seeds per ear and 1,000 seed weight. The interaction between weeding and intercropping treatments was significant only for numbers of rows per ear and seeds per row (Table 38).

Differences in number of rows per ear, seeds per row and seeds per ear, were depended upon the effects of timing-of-weeding and cropping treatments.

Weeding treatment affected number of rows per ear and was highest for the weed-free treatment when maize was sole cropped. The lowest number of rows per ear was recorded in the weeding treatment V4+V8 when each single row of maize was intercropped with a single row of soybean (M: SB 1:1).

The highest for number of seeds per row was associated with the weeding treatment V4+V8+V12 for the sole maize crop treatment, and declined significantly when the maize was intercropped with a single row of soybean (M: SB 1:1) for all weeding treatments. The number of seeds per ear was highest in the weed-free treatment for the sole maize crop. The lowest number of seeds per ear was observed in the no-weeding situation when maize was intercropped with a double row of soybean (M: SB 1:2) treatment.

The 1000 seed weight of maize was significantly different only for the cropping treatments. The sole crop of maize gave highest of 1000 seed weight, while the lowest was associated with the intercropping of a single row of maize with a single row of soybean (M: SB 1: 2) treatment. The reduction of 1000 seed weight was associated with a reduced maize grain yield per unit's area. Overall, it was apparent that yield components in the sole maize crop treatments were higher than for any of the intercrop treatments. This results if consistent with the findings of Myers and Foale (1981).

The yield components of soybean, which were examined, were number pods per plant, number of filled-pods per plant, percent of un-filled-pods per plant and 100 seed weight. Overall, the main affects on some of these yield components were associated with the intercropping treatments (Table 44). Fageria *et al*. (1991) have also shown that yield component variation is also related to cultivars, row spacing, fertilizer and climatic conditions. Plant spacing and density are particularly important in affecting yield components. Increased plant density and decreased light intensity can result in a reduction in photosynthesis, causing a reduction in the number pods per plant and the number filled pods per plant.

The results of this study found that the number of pods per plant and number of filled pods per plant were both affected by timing-of -weeding and intercropping treatments. Generally, it was found that sole cropping of soybean resulted in higher pod number per plant and higher number of filled pods per plant, than for the different intercrop treatments. This is consistent with the findings of Kuo *et al*. (1977) who showed soybean pod number per plant was reduced when plants were continuously shaded and that 100 seed weight was reduced during the pod filling stage under such conditions.

The highest of number pods per plant and filled pods per plant were recorded in the weeding treatment V4+V8 treatment, for the sole soybean crop treatment. The lowest for number of pods per plant and filled pods per plant was recorded in the no-weeding treatment when double rows of soybean were intercropped to single rows of maize (M: SB 1:2). The percentage of unfilled pods per plant was higher in the intercrop treatments than when soybean was sole cropped. Although the 100 seed weight of soybean was highest in the sole soybean crop treatment, the difference with that recorded for the intercrop treatments was generally quite small.

Weed competition reduces soybean yield by reducing the number of pods/plant, number seeds/m^2 (Isidro, 1977; Malapaya and Robles, 1979, Sucharin, 1981), number of branches/plant, number of leaves per plant, number of seeds per pod, seed weight and dry weight of plant (Malapaya and Robles, 1979). However, Sucharin (1981) reported that number of branches/plant, seed weight, and number of seeds/pod were not affected be weed competition.

6.2.6.2 Yield of maize and soybean

Crops yield is a function of its yield components and related to physiological development. As might be expected, highest maize grain yield was associated with weed free treatment and lowest associated with no weeding. Highest yields were also associated with sole cropping of maize in all the time-of-weeding treatments. Maize grain yield in the two-intercrop treatments was reduced by between 12 and 14 % relative to the sole cropped maize. There was no statistically significant difference between the two-intercrop treatments for maize grain yield. The basis for the yield reduction is association with competition for nutrients, water and sunlight and alternate row spaces (Kurtz *et al*., 1952; Pedleton et al., 1963; Enyi, 1973).

Mercado *et al*. (1977) reported that weeds cause a significant decrease in yield in sole cropped soybean but not in maize alone or in a maize-soybean intercrop. Intercropping maize with soybean resulted in a threefold increase in maize yield compared to the sole crop of maize. However, soybean yield was reduced by 58 % in the intercrop situation, when the plots were maintained weed free for 42 days after planting (DAP), compared to sole crop treatments. In the un-weeded plots, soybean yield in the intercrop was 44 % greater than that in the sole crop situation

Similarly, soybean grain yield in this study was significant different between timing-of-weeding and cropping treatments. The grain yield in sole the soybean crop was higher than for soybean in the intercrop treatments. The highest grain yield was recorded that in the weeding treatment V4+V8+V12. In the weed-free treatment, there was a slightly yield increase over the treatment with a single weeding (treatments V4 and V8). The lowest of soybean grain yield was observed that in the no-weeding treatment where it dropped to 16.5 % of that in the frequently weeded treatment V4+V8+V12. However, soybean grain yield in both intercrops treatments was significantly lower than the sole crop soybean, the decline being of the order of approximately 66 and 38 %, respectively for the single row and double row intercrops treatments. Roquib et al., (1973) reported yield reductions in all instances where soybean was intercropped with several different crops. In most tropical countries, yield losses due to uncontrolled weed growth in soybean range from 50 to 60 % (Moody, 1973b).

When total grain yield is considered (maize plus soybean), highest yields were obtained in the intercrop treatments. Generally the highest total grain yields were achieved with one row of maize was double cropped with two rows of soybean (M: SB 1:2) treatment. In the treatment where a single row of maize was intercropped with a single row of soybean, total grain yield declined by about 32%. The lowest overall total grain yields were obtained for the sole crop treatments. This result is consistent with the reports of Herrera and Harwood (1973).

6.2.7 Land equivalent ratio (LER) in maize and soybean intercropping systems

The LER exceeded 1.0 in all intercropping treatments and in all weed control treatments within the intercropping treatments. The highest LER was registered in the intercropping combination of one row of maize and two rows of soybean (M: SB 1:2), exceeding that for the combination of each row of maize being intercropped with a row of soybean (M: SB 1:1). This difference in LER largely reflected the higher soybean population in the former treatment relative to the latter. Within the M: SB 1:2 intercropping treatment, the highest LER came from the double hand-weeding treatment V4+V8. For the same intercropping combination, the no weeding treatment reduced the LER by about 25 %. The lowest LER came from the single weeding V8 treatment when a single row of maize was intercropped with a single row of soybean (M: SB 1:1) (the LER in this treatment was lower than in the no-weeding treatment). In general, the results demonstrated that frequent weeding was associated with a higher LER and a resulting higher final total grain yield.

Crookston and Hill (1979), when evaluating soybean and maize intercropping combinations showed that there was an association between reduced soybean yields and increased maize yields in responses to changes in LER values. The observation in this study that all the intercropping treatments had an LER in excess of 1.10 indicated that intercropping systems are generally more advantageous than sole crop systems.

Similar results for soybean and maize intercropping in relation to LER have been reported by Alexander and Genter (1962).

6.2.8 Economic considerations

Economic efficiency analysis is the final step necessary for the assessment of crop production output and investment efficiency in intercropping systems. In this study, the economic returns to labor use for weeding differed among treatments relating to timing of weed control, and among of maize and soybean intercropping systems. The results of the evaluation have been reported in table 57.

The economic analyses shows that almost all timing of weeding and maize/soybean intercropping treatments gave better returns to labor than the sole crops of maize and soybean. Intercropping resulted in positive gross margins per unit area and to labor input (days) for weed control. There are numerous reports of intercropping resulting in increases in total productivity per unit area (Willey, 1979; Rajat and Singh, 1979; Chowdhury, 1979).

The results of the economic analyses in this study indicated that the no-weeding treatment had the highest of gross margin, while the lowest was found in the weed-free treatment. In a comparison of the treatments for 'time-of-weeding' the four treatments V4, V8, V+V8 and V4+V8+V12 whole, higher gross margins than the weed-free treatment. Generally, the total revenue, gross margin per unit area and per labor days were higher in both intercropping treatments (M: SB 1:1 and M: SB 1:2) than for the single crop treatments, for all time-of-weeding treatments.

The highest total gross margin per unit area was obtained in the no-weeding treatment for the intercropping treatment when each row of maize was intercropped with a double row of soybean; the estimates was Baht 24,242 ha^{-1}. However, the highest gross margin per labor used for weeding was obtained in the intercropping treatment of single row of maize and double rows of soybean (M: SB 1: 2) treatment, which was Baht 380 per labor -day, in the weeding at V4 treatment.

The relatively low gross margin was from the weed-free treatment for all cropping treatments. However, the lowest gross margin per unit area and per labor use for weeding were occurred in the sole crop of maize and soybean treatment, which were negative to (Baht - 3568 ha^{-1} and Baht (- 9247) ha^{-1}, respectively. For labor use for weeding were Baht (-16 per labor-day) in the maize crop and Baht (- 41 per labor - day), for sole soybean, respectively. The comparative figures for the weed free treatments were approximately Baht 32 ha^{-1} and Baht 6 Ld^{-1} day^{-1}.

In contrast, the gross margin for treatments relating to time-of-weeding indicated that the treatments V4, V8, V4+V8 and V4+V8+V12 had up to 99.7% higher gross margins to labor input for weeding, than for the weed free treatment. The highest gross margins were obtained in response to the weeding treatments at V4 stage of maize growth, for in the intercrop treatment of each row of maize being intercropped with two rows of soybean (M: SB 1:2).

The results indicate that highest returns to farmers will come from the maize and soybean intercropping combination of 1 row of maize being intercropped with two rows of soybean.