Kasetsart J. (Nat. Sci.) 35 : 271 - 283 (2001)

Yield Losses Assessment Due to Pests on Cotton in Lao PDR

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ABSTRACT

From 1985 to 1991 research on cotton protection was carried out in Lao PDR to determine the incidence of the major pests and the efficiency of the recommended protection program. Results showed that without any pest control, the development of the plants was very low and yield losses reached almost 70% of the potential production. The recommended program, with seven insecticide sprayings, reduced the incidence of the pests but was not enough to ensure the required production. Moreover, it increased the cost of production and was not profitable. Only the intensive program with a weekly insecticide application could protect the crop satisfactorily. To cope with this situation, an IPM strategy, aiming at reducing the cost of pest control, must be implemented.

Key words: cotton, pests, yield losses, Integrated Pest Management, Lao

INTRODUCTION

In Lao PDR, cotton is traditionally grown throughout the country in small family plots without inputs (Trébuil *et al.*, 1994). The average of the planted area per farmer is about 1,500 m^2 (Thirasack, 1994). Five main types of cotton plant are cultivated. They belong to three botanical species *Gossypium hirsutum* L. (Fai Niai), *G. arboreum* L. (Fai Noi, Fai Moui, Fai Mok) and *G. bardadense* L. (Fai Djan) (Tr?buil *et al*., 1994). These cultivars produce a short to medium size lint of 18 to 27 mm in length. The ginning out turn is about 30 %. The yields are low and the national average is around 500 kg/ha of seed-cotton (Castella *et al*., 1993).

Among the problems that must face the farmers are the attacks of several insect pests that reduce yield (Angladette, 1948). Over the crop season two main kinds of pest are recorded. The first are sucking insects represented essentially by the leafhopper *Amrasca biguttula* Ishida (Homoptera: Cicadellidae), and the cotton aphid *Aphis gossypii* Glover (Homoptera: Aphididae). Secondly there is the bollworm *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae) which larvae, according to the period of infestation, can damage either the squares, the flowers or the green bolls (Matthews and Tunstall, 1994). Moreover, *A. gossypii* transmits a viral disease called blue disease or leaf roll (Cauquil and Follin, 1983). Pests of minor importance are also recorded. The larvae of the semi-looper *Anomis flava* (F.) (Lepidoptera: Noctuidae) and of the leaf roller *Syllepte derogata* (F.) (Lepidoptera: Pyralidae) damage the foliage of the plants. Nymphs and adults of the whitefly *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) and of the cotton stainer *Dysdercus cingulatus* (F.) (Hemiptera: Pyrrhocoridae) are sucking insects. The former feeds on the leaves but can also contaminate the lint with honeydew and associated fungi. The latter feeds on immature as well as ripe cotton seeds. Its punctures can either

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cause the shedding of the young green bolls or the rotting of the developed bolls which produce seeds and lint of poor quality. Finally, the spiny bollworm *Earias vittella* (F.) (Lepidoptera: Noctuidae) and the pink bollworm *Pectinophora gosssypiella* (Saunders) (Lepidoptera: Gelechiidae) damage the flowers and the green bolls. Several other secondary pests are also present in the fields, but no data is available concerning these species.

Until the creation in 1987 of the Cotton Lao Factory in Vientiane (Kousol, 1994) cotton was usually grown for self-consumption (Trébuil *et al.*, 1994). Between 60 to 80 kg of seed-cotton, ginned by hand, are needed to meet a family’s fibre requirement (Mahdavi, 1995; Peutot, 1996). Nowadays the development of the textile industry, particularly in Thailand, opened new outlets (Fichet, 1995). But the exportation to these countries depends, among other things, on the fibre quality which must be adapted to the industrial spinning technology (Mahdavi, 1995). Consequently new varieties with high level of production and good fibre quality must be proposed to the farmers. In the 1960’s, new cultivars were tested with more intensive cultural practices; hence seed-cotton yield increased initially. But after a few years, the production started to decrease due to their susceptibility to *A. biguttula* and *H. armigera,* and to the augmentation of the cost of production generated by the numerous insecticide applications that the farmers must do to control these pests. This situation, which has continued until now (Castella *et al.*, 1993), demonstrates that the development of cotton production in Lao PDR must be accompanied by the implementation of technical itineraries which allow the growth of cotton without increasing the use of chemicals. This is possible with the setting up of an Integrated Pest Management strategy adapted to the local conditions of production which are specific to the country with regard to ecological and human environments, varieties, outlets and organisation of the cotton industry (Follin and Crozat, 1993). But the elaboration of such a strategy necessitates a thorough knowledge of the factors influencing the production, particularly the pests.

The objective of this study is to quantify yield losses caused by insects, and the cost-effectiveness of the recommended management strategy.

MATERIALS AND METHODS

The experiment was conducted over a period of seven years, from 1985 to 1991, in farmer fields, except at Napok where it was carried out at the National Agricultural Research Station. These locations were in the following provinces: Luang Prabang, Sayabury, Vientiane with two places Napok and Ban Hai, Bolikhamxay and Savannakhet (Figure 1). This allowed researchers to collect results in various ecological conditions (Table 1). Cotton was grown during the rainy season from the end of

Table 1 Altitude and annual rainfall registered at the different experiment localities.

Localities	Altitude (m above sea level)	Annual rainfall (mm)
Bolikhamxay	180	2200-3000
Savannakhet	170	1400-1900
Vientiane	170	1400-1900
Sayabury	350	1400-1900
Luang Prabang	450	less than 1400

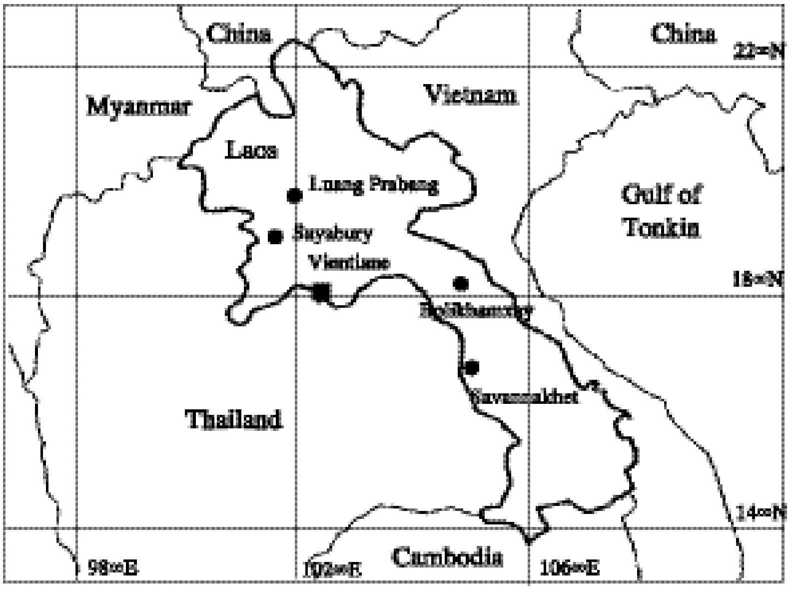

Figure 1 Map of Lao PDR with location of the experiments.

June to November. At Luang Prabang in 1985, Napok Research Station in 1985 and Ban Hai 1991, the sowing dates were on June 29th, July 1st and June 1st respectively.

According to the cropping season and the locality, several traditional and bred varieties were planted (Table 2).

No seed treatment either with insecticide or fungicide was used. Throughout the season three insect pest protection levels were compared as follows:

- No Treatment (NT): no insecticide application.

- Standard Protection (SP): 7 insecticide applications at 15 day intervals, starting from 21 days after sowing.

- Intensive Protection (IP): weekly application of insecticide starting from 16 days after sowing.

All insecticide applications were carried out by knapsack sprayer equipped with a single lance. Pesticides were used as follows: two applications for SP and four for IP with dimethoate were implemented at the rate of 375 to 560 g ai/ha depending on plants growth, followed by the applications of a mixture of dimethoate (as previous) and deltametrin at the rate of 7 to 10 g ai/ha. Dimethoate was applied to control early and late sucking pests whereas deltametrin was used to control bollworm.

For each experiment, during the whole cropping season, data were recorded using 40 plants in each plot. For aphids, this meant the number of plants with at least one individual. The populations of leafhoppers were estimated by counting together the number of nymphs and adults observed on five top leaves of each scouted plant. Finally the number of bollworm larvae encountered on the whole plant was recorded.

Two replications were implemented. Aiming to reduce environmental effects, the untreated plots were located at both extremities of the planted area whereas the plots with the intensive protection were situated in the middle of the experimental parcel. The standard program was applied between the two previous levels of protection (Figure 2). Elementary

Table 2 Yield and relative yield losses due to all pests in experiments carried out at different locations, from 1985 to 1991, and average per locality.

Localities	Years	Varieties	NT yield (kg/ha)	SP yield (kg/ha)	IP yield (kg/ha)	Losses in NT (% of IP)	Losses in SP (% of IP)
Napok	1985	DI.5	12	507	2623	99	81
Station	1986	DI.5	8	816	1160	99	30
(Vientiane)	1989	SR 2	742	2125	2700	73	21
		Fai Niai	175	236	436	60	46
	1990	SR 2	66	281	862	92	67
		KK 1	650	752	1377	53	45
	average		276	786	1526	80	49
Ban Hai	1987	Fai Niai	1035	1570	1530	32	0
(Vientiane)	1991	KK 1	846	1847	2445	65	25
	average		941	1709	1988	53	14
Bolikhamxay	1991	KK 1	355	1503	2247	84	33
		Fai Niai	569	1091	1474	61	26
	average		452	1297	1861	76	30
Sayabury	1991	KK 1	298	1466	2180	86	33
		Fai Niai	558	1040	1400	60	26
	average		428	1253	1790	76	30
Savannakhet	1991	KK1	437	1491	2095	79	29
		Fai Niai	760	966	1542	51	37
	average		599	1229	1819	67	32
Luang Prabang	1985	DI.5	339	1665	1685	80	1
	Average of all the trials		457	1157	1717	73	33

NT	SP	IP	IP	SP	NT
No Treatment	Standard Program	Intensive Protection	Intensive Protection	Standard Program	No Treatment

Figure 2 Experimental design used to compare the three levels of protection.

plots consisted of 16 rows of 25 m long of 1 m apart (400 m^2).

Correlation analysis was performed by Statitcf Version 5 (Institut Technique des Céréales et des Fourrages) and the curves were plotted using Excel 97 software (Microsoft).

RESULTS AND DISCUSSION

The incidence of the pests varied from an experiment to experiment. Presented below are the main results, obtained when pest populations were important enough to reveal differences between

Table 3 Yield obtained with the three levels of protection, and losses in NT and SP programs according to the potential production (IP yield) and the varieties (average over locations and years).

Varieties	NT kg/ha	SP kg/ha	IP kg/ha	Losses in NT (% of IP)	Losses in SP (% of IP)
DI.5	120	996	1823	93	45
SR 2	269	802	1187	77	32
KK 1	517	1412	2069	75	32
Fai Niai	619	981	1364	55	28

treatments or trials.

a) Plant growth

According to the incidence of pests the development of the plants showed important differences.

At Luang Prabang in 1985, early pest incidence was low and no difference in plant growth was noted. Plant development was gradual and similar in the three treatments (Figure 3). At the end of the season, the plants reached 140 cm.

At Napok station in 1985, significant difference was observed between NT and SP as well as SP and IP (Figure 4). With IP program up to 90 days after sowing, the plant growth was normal and the result obtained was rather similar to the one of Luang Prabang. After this date the rains stopped early affecting the plant growth. With the standard protection, the plant development slowed down after the beginning of the season and the maximum height was only 50 cm. Finally, when no insecticide was applied the plants remained small and did not exceed 20 cm in height.

Hence, at Napok station, plant growth was directly affected by insect pest incidence and varied according to insecticide control level. The difference of plant growth was essentially due to leafhopper damage because populations of other early pests remained low. Important populations of these homopterous insects could affect the plant

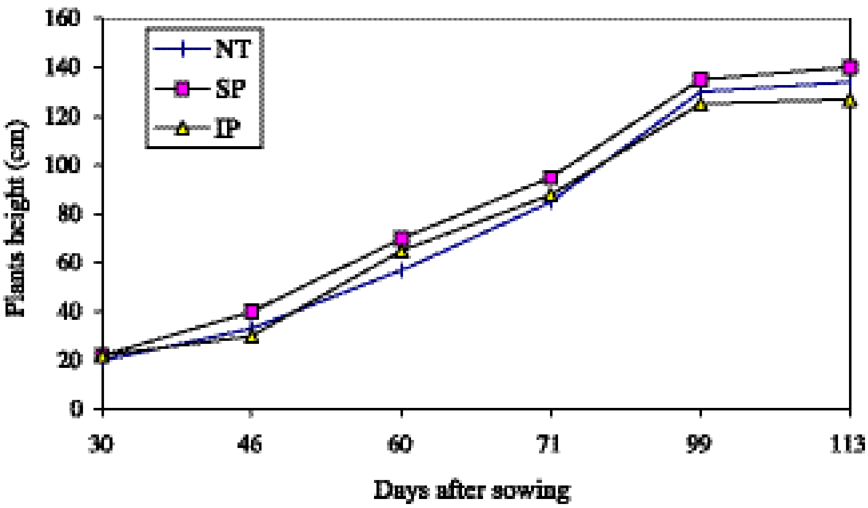

Figure 3 Plant growth at Luang Prabang in 1985 (sowing date June 29).

development considerably. Apart from leaves drying, the punctures of leafhoppers induce a shortening of the inter nodes. Moreover, only the IP program yielded a satisfactory control of the pest. The standard program, with spraying rate of 15 day intervals could reduce the incidence of pests but was not enough to allow a normal plant development.

b) Pest control

Control of aphids

At Napok station the number of plants infested by aphids increased gradually throughout the growing season with noticeable fluctuations (Figure 5). In NT and SP plots, the development of the colonies was almost the same. Two main peaks

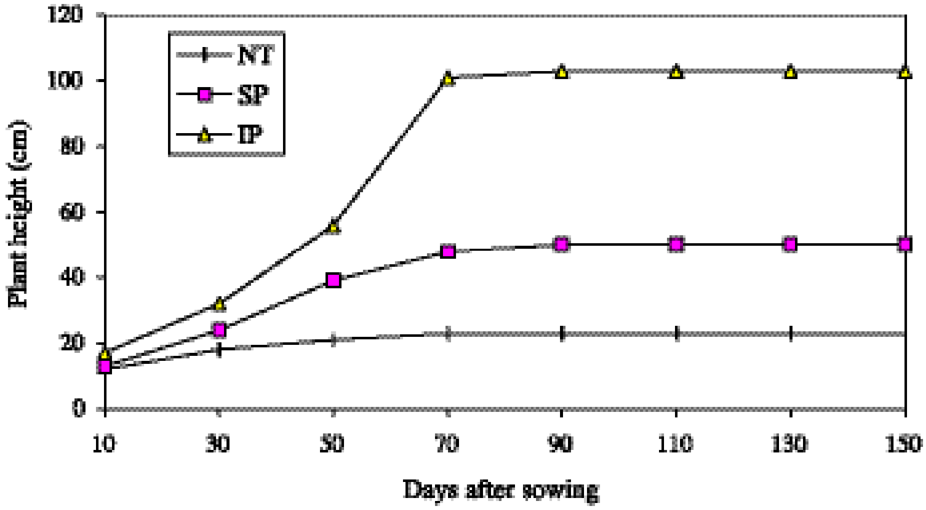

Figure 4 Plant growth at Napok in 1985 (sowing date July 4).

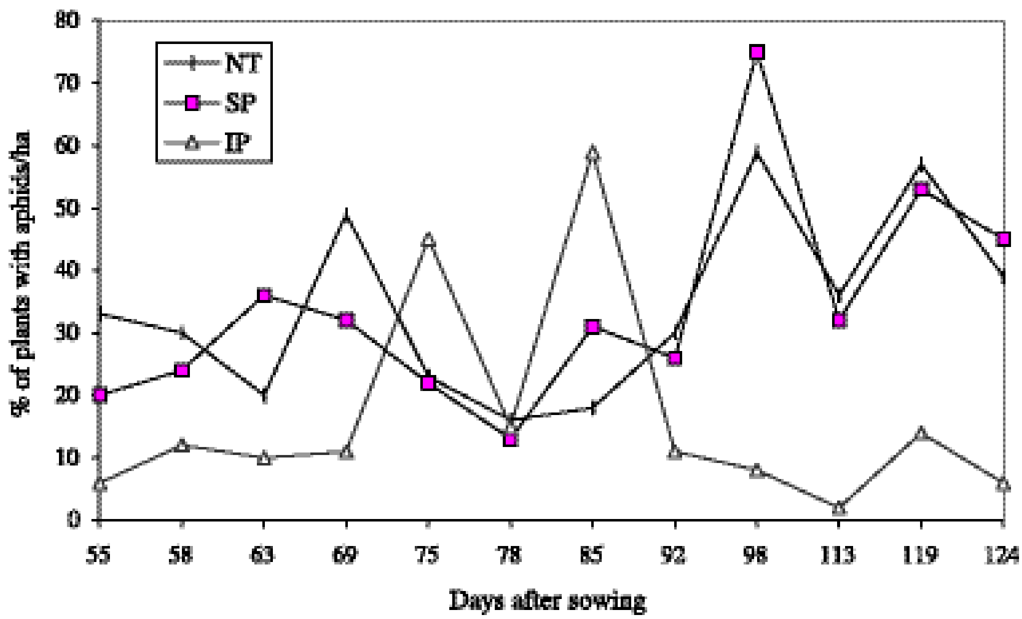

Figure 5 Plant infestation by aphids at Napok in 1985 (sowing date July 4).

of infestation were recorded at the middle of September (almost 69 days after sowing) and the beginning of October (98 days after sowing) with almost 50 % and 75 % of plants attacked, respectively. With IP program, except at 75 and 85 days after sowing, the rate of infested plants remained lower than in NT and SP. This was particularly true during the month of October (from 92 days after sowing) where the infestation decreased quickly with IP program, and affected in most of cases less than 10 % of the plants.

At Ban Hai in 1991 the infestation of aphids was important at the beginning of the growing season, before the application of insecticide, particularly in IP and NT plots (Figure 6). Therefore, the number of infested plants decreased quickly, including in NT plot where no insecticide was applied. Nevertheless, the results showed differences between the treatments. During the whole season the highest level of infestation was recorded in NT plot and the lowest in IP plot.

The data collected at Napok in 1991 indicated that in case of serious infestation of aphids, the standard program of protection was not sufficient to control the development of the aphid colonies.

Control of leafhoppers

Leafhoppers appeared very early, from the second week after the emergence of seedling and the infestation continued until harvesting time. At Napok station in 1985, the populations recorded on NT and SP increased gradually and remained high during the entire crop season (Figure 7). Three peaks of infestation could be observed, at the beginning of July (35 days after sowing) and August (59 days after sowing), and at the end of October (87 days after sowing) with a population of more than 1,200,000 leafhoppers per ha in SP. Only with the intensive protection the density of leafhoppers was lowered to reach a maximum of almost 200,000 leafhoppers per ha in July (43 days after sowing).

At Ban Hai in 1991, the results were not similar to those of Napok (Figure 8). The most important damaging populations were recorded in NT plots. The standard protection, in spite of good efficiency at the beginning and the end of the crop season, could not control leafhopper infestation from 45 to 60 days after sowing.

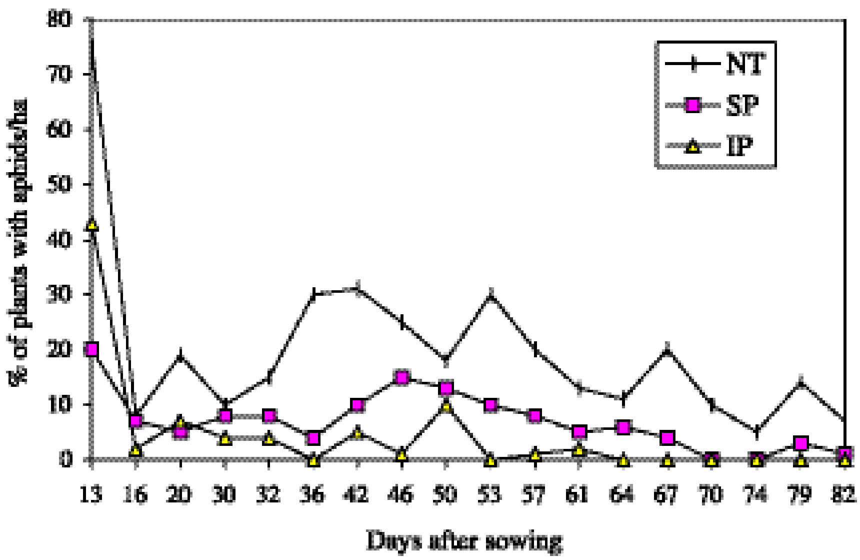

Figure 6 Plant infestation by aphids at Ban Hai in 1991 (sowing date June 1).

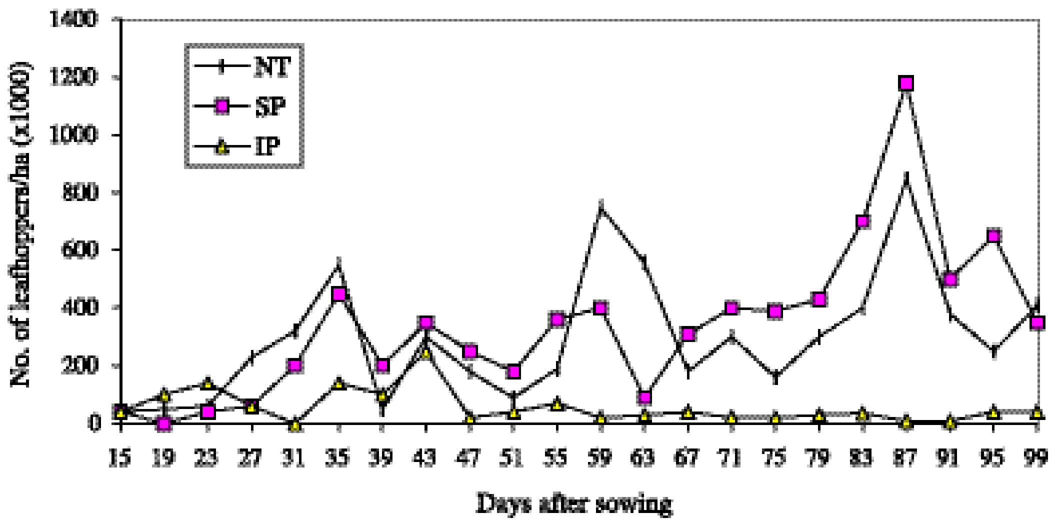

Figure 7 Plant infestation by leafhoppers at Napok in 1985 (sowing date July 4).

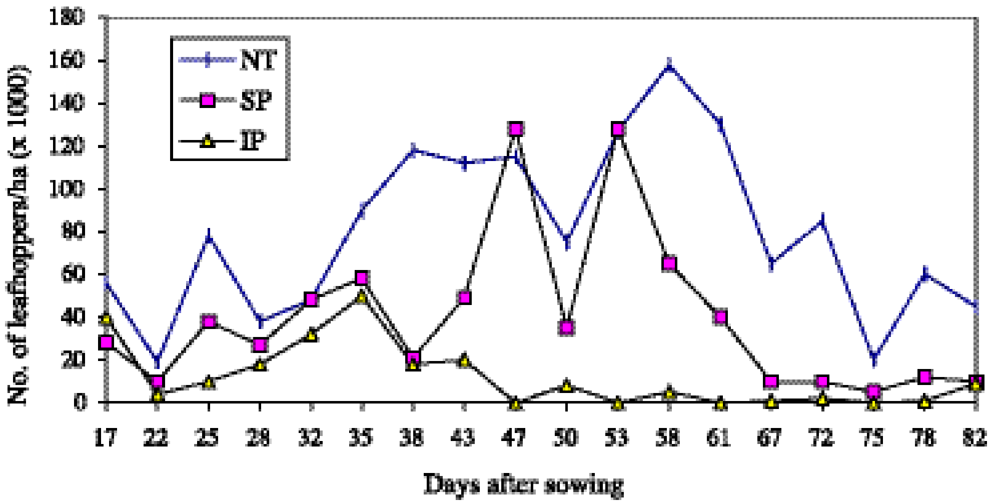

Figure 8 Plant infestation by leafhoppers at Ban Hai in 1991 (sowing date June 1).

Control of bollworm

Bollworm infestation was recorded only in Ban Hai in 1991 (Figure 9). The first larvae were observed at the beginning of the flowering period. The data collected showed that with no insecticide application the population of larvae increased quickly starting from 60 days after sowing and could exceed 10,000 larvae/ha. In SP plots the dynamic of population was almost the same as in NT plot, but with lower density of larvae which did not exceed 3,000 larvae per ha. In IP plots very few larvae were recorded. The population increased at the end of the growing season, around 80 days after sowing, in the three programs of protection. But the level of population depended on the level of protection.

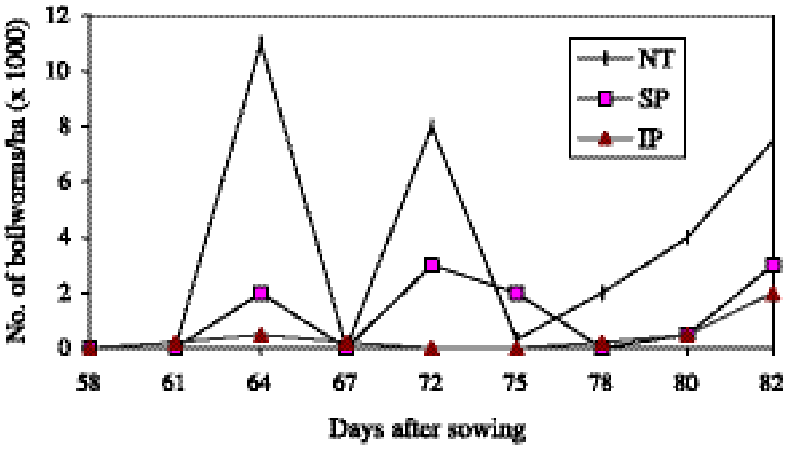

Figure 9 Dynamic of population of bollworm at Ban Hai in 1991 (sowing date June 1).

b) Seed-cotton yield

The production of seed cotton depended on several factors such as climate, soil, variety and pest incidence. Therefore, to estimate the losses caused by insect pests it was necessary to compare the production obtained in NT plot with the one in IP plot which is not significantly correlated with pests incidence (P>>0.05; R^2 = 0.0596). Similarly, the efficiency of the standard program was estimated comparing the productions obtained in SP and IP plots.

First of all it was noted that the yield varied accordingly with the year and the locality (Table 2). For instance, at Napok station in NT plot, with the same variety SR 2, the production was 742 kg/ha and 66 kg/ha in 1989 and 1990, respectively. This difference was due, in part, to the level of pests incidence, particularly leafhopper. In NT plot in1985 with the variety DI.5 the production was 12 kg/ha at Napok and 339 kg/ha at Luang Prabang. The same variation was observed in 1991 with the variety KK1 planted in four locations, Ban Hai, Savannakhet, Bolikhamxay and Sayabury. In this case the pest incidence was the highest at Sayabury, with 86 % of losses in NT comparing with IP, and was the lowest at Ban Hai with 65 % of losses. In spite of these important variations, the results showed that in Lao PDR, if no insecticide protection is administered, the average losses due to pests could reach about 70 % of the potential production of the crop (Table 2). This estimation is almost identical to the one obtained in Thailand, where the average loss of production due to all the pests fluctuating between 70 % and 80 % of the potential production (Genay, 1994). With the standard program, the average loss decreased to around 30 % in comparison with IP program (Table 2). It indicated that, even if the yield obtained with SP program was positively correlated with the yield obtained with IP (P< 0.01) (Figure 10), with seven sprays of insecticide it was not possible to reach the potential production. Moreover, the average loss of seed cotton between NT and SP is 700 kg. Actually the price of dimethoate 400 g ai/l and deltametrin 12.5 g ai/l is US $ 9/l and US $ 22/l respectively, whereas the kg of seed cotton bought to the farmers is almost 22 cents. That means that a program of 7 insecticide applications, 2 with dimethoate followed by 5 with dimethoate mixed with deltametrin, costs approximately the equivalent of 800 kg of seed-cotton and is not profitable. If all the results are taken into account, the efficiency of SP program was not significantly influenced by pests incidence (P>0.05) (Figure 11). Nevertheless, the tendency showed by the curve (Figure 11) is confirmed if the data recorded at Luang Prabang in 1985 is not taken into account (P< 0.05; R? = 0.3276). In this case, the more important the pests incidence, the less efficient the standard protection.

The comparison of seed-cotton yield among varieties showed that without pest control the variety mostly affected was DI.5, with 93 % yield losses, and the least damaged was Fai Niai, with only 55 % yield losses (Table 2). Even though these results

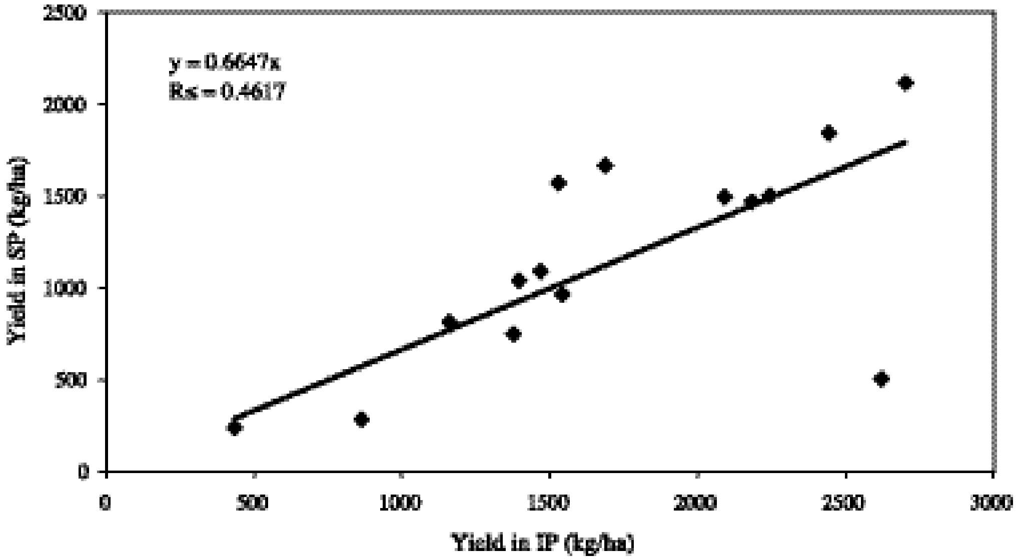

Figure 10 Corellation between the yields obtained with IP and SP programs.

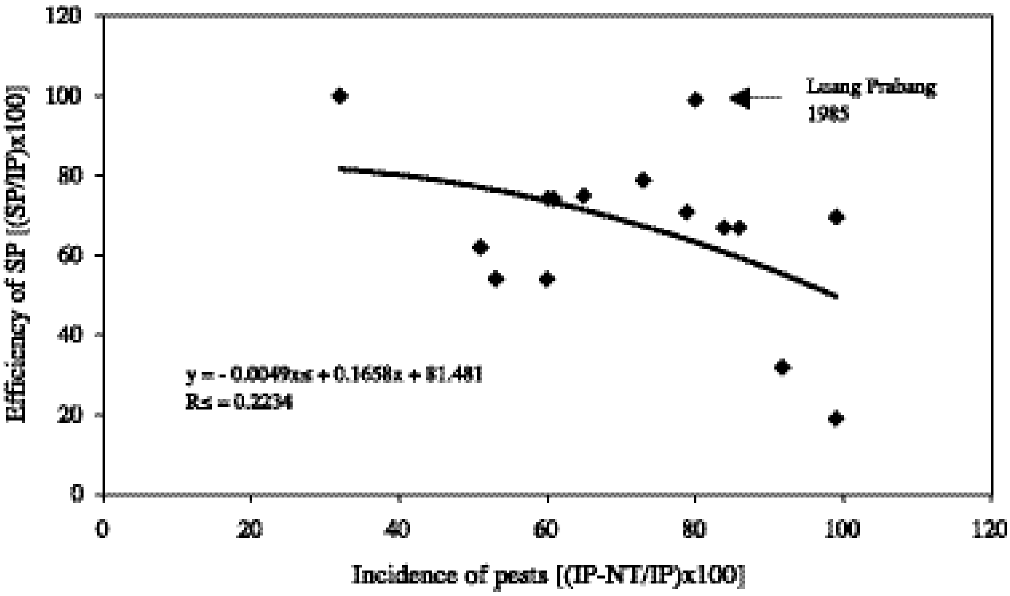

Figure 11 Relationship between the incidence of pests and the efficiency of SP program.

must be confirmed by more experiments, it is interesting to note that the two varieties, DI.5 and SR 2, are almost glabrous whereas KK 1 and over all Fai Niai are hairy. Consequently, this variation of productivity can be explained, at least in part, by the degree of sensibility to leafhoppers. As demonstrated by Parnell *et. al.* (1949) the pubescent varieties are resistant to this pest whereas the glabrous ones are highly affected. More recently, studies carried out in Thailand pointed out the implication of hairiness in the control of *A. bigittula* and the importance of this variety character for the improvement of Integrated Pest Management Strategies in South-east Asia (Castella, 1995; Renou, 1999).

CONCLUSION

The most important pests of cotton recorded from Lao PDR were the leafhopper *A. biguttula* and the bollworm *H. armigera*. But the damages caused by these insects were widely variable among locations and from one year to another. Nevertheless, the trials carried out for seven years in different regions of the country showed that the losses of production could reach an average of 70 % of the potential production when no insecticide was applied. The standard program of seven insecticide applications recommended to the farmers could help reduce the losses to 30 % on average, but its efficiency depends on the rising level of pest incidence and on the capacity of the variety to resist to leafhoppers attack. Moreover it increases the cost of production too much, and it is not profitable. Consequently, the chemical solution to control insect pests, appears to be very expensive and unsuitable according to the conditions of production encountered in Lao PDR.

To face this situation, it is important to develop in Lao PDR an Integrated Pest Management strategy aiming at reducing the pest incidence but maintaining a low production cost. As shown by the experiments, the first step to reach such a goal is to plant hairy cotton varieties with high resistance to leafhopper. This alternative should eliminate the insecticide applications to control this homoptera. Nevertheless, as it was demonstrated in Thailand whatever the cultivar, cotton leaf is more suitable for leafhopper egg deposition during the two first weeks of plant development, before the appearance of hairs. Moreover, in Lao PDR the field infestation by early pests like leafhoppers and aphids can take place during this period. From these observations it is possible to recommend to treat the seeds with an insecticide to control the early pests. This technique avoids insecticide sprayings at the beginning of the season and consequently leads to a better preservation of the beneficial species. As mentioned above, the other main pest encountered in Lao PDR was the bollworm *H. armigera*. No variety character seems to be efficient enough to avoid attack of *Helicoverpa*. Neither morphological character like atrophied or absent bracts (frego bracts) which can hinder oviposition (Angelini *et al*., 1965; Matthews, 1989), high gossypol which have an antibiotic effect on bollworm (Vaissayre *et al*., 1997), nor the combination of both (Khalifa, 1979) result in a satisfactory level of protection. Consequently, the control of this pest is until now mainly based on insecticide applications. But, the creation of genetically modified cotton varieties able to produce toxin of the bacteria *Bacillus thuringiensis* to control bollworm offers new possibilities. This has already been applied on a large scale in some countries, principally the U.S.A. (more than 70% of cotton acreage in 2000) and China (more than 10% of cotton acreage in 2000) (Giband *et al*., 2001). This alternative to chemical control could be experimented in Lao PDR within the framework of an integrated pest management strategy.

Finally, some additional measures, like planting date or intercropping could be of interest for Lao production, and should be tested.

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Received date : 4/07/01
Accepted date : 28/09/01