Kasetsart J. (Nat. Sci.) 31 : 87 - 95 (1997)

Yield Gap Analysis in Soybean Production

Ambika Charan Shrivastava, Aphiphan Pookpakdi, Isara Sooksathan, and Ed Sarobol[1]

ABSTRACT

In the process of determining yield gap in soybean production, two types of experiments were conducted. The trials conducted at a research station in which Kamphaeng Saen was used as a site, simultaneously an on farm trials were conducted in the farmer's fields at Banpong district of Ratchaburi Province. Prior to performing the experiment conducted, site selection and agro-ecological analysis of the target area were done and recorded. The results of the study indicated that potential possibilities of growing soybeans at Banpong was high. This is due to the fact that in research managed trials conducted at Kamphaeng Saen and Banpong, the yield of soybean were 2.04 and 1.61 ton/ha were obtained, respectively, whereas the average farmers yield was 1.03 ton/ha. Yield gap between the trials conducted at Kamphaeng Saen and Banpong indicated the effect of environmental conditions which differed between the experimental station and in the farmer's field. Likewise, the different in yield between the research trial and farmers field at Banpong indicated that socio-economic constraints prevailed in soybean production. Due to the competitiveness of cropping system at Banpong, farmers give priority to the main staple crop such as rice, sugar cane and vegetables which they are more familiar with.

Key words : *Glycine max* L., agro-ecological analysis, rapid rural apraisal, yield gap analysis.

INTRODUCTION

Decreasing farm size, increasing population and declining rate of productivity are common trends of Asian agriculture, while agricultural land is gradually loosing its ability to sustain the growing population. The economic outcome from farming is declining and unstable, therefore farmer needs to find alternative sources of income to survive. Poonaperuma (1979) stated that small farmers cannot provide the management inputs required to extract the high yield potential of modern varieties. The popular pattern of intensive cultivation of double rice crop, sugar-cane, baby-corn with frequent use of pesticides and herbicides have resulted in insurgency of pests, disease and weed problems. While insects and weeds are acquiring resistance at alarming level due to intensifying monoculture cultivation, pesticides uses caused side effects such as fish kills, and increasing incidence of fish and shrimp diseases, cattle poisoning, and indirect impact on beneficial insects, pollinators and microbial soil organisms, Therefore soil is loosing its overall biological function and fertility. In restoring soil fertility and reducing the detrimental effects of chemical fertilizers, soybean *(Glycine max* L. Merrill) grown in rotation will be beneficial for restoring soil fertility by reducing the

1 Department of Agronomy, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand.

use of chemical fertilizer. By breaking the reproductive cycle of insect pests, nematodes and weeds, it significantly reduces the incidences of insect pests attack. There is also general agreement that legume such as soybean contributes considerable amount of nitrogen to the succeeding crops. Research results concluded that rotational cropping of soybean could increase the availability of nitrogen. Nitrogen fixation by soybean may vary from 57 to 94 kg/ha/year (Evans and Barber, 1977). With 40% protein in soybean seeds ,the crop is considered to be nutritional and provide cheap source of protein for human dietary. However, the wide gap of soybean yield exist between the experimental yield obtained and actual field condition . Yield gap has been influenced by several environmental factors, non-transferable technology and socio-economic determinants. According to Librero (1985), there are four general factors determining yield gap such as non-transferable technology, environmental differences, biological and socio-economic constraints. Analysing yield gap and identification of determinants which were the cause ,will help in bringing down this gap to a minimum level and elevation of soybean yield under farm conditions would be possible. In the present study, attempts had been made to identify possible determinants influencing the yield gap. Method used in this study composed of agro-ecological analysis of the target areas, experiment conducted by researcher in research managed trials at the experimental station and in the farmer's field plus an on-farm research through farmer participation. It is anticipated that the interpretation of the result of the study would lead into the identification of yield gap determinants at the target area. Therefore improvement of soybean yield through research and / or transfer of technology can be done.

MATERIALS AND METHODS

A general procedure for methodology of conducting yield gap analysis of the study were carried out as follows.

a. Agro-ecological analysis of the target area.

b. Experiments conducted at research station in conjunction with on farm research.

c. Evaluation of yield gap occurring between research conducted at the research station and the experiments conducted on-farm. Interpretation of yield gap between two types researches and attempt to analyze the causes of yield gap occurrence which are influenced by environmental and socio-economic determinants of the target-area. Formulation of guidelines for technology transfer to farmers in the target area using the result of yield gap analysis.

1. Target area

Banpong district of Ratchaburi province had been chosen as the target area. It is situated in the south western of Bangkok at the distance of 142 km. At Banpong, low land areas are cultivated to wet land rice production in rainy season and second rice production in dry season. Upland areas are devoted to sugarcane (*Saccharum officinarum.*) and babycorn (*Zea mays* L) production. Due to the availability of irrigation canals and shallow wells, short duration crops with high value of cash income such as babycorn, leafy vegetables, shallots and asparagus are being grown. The production of short duration crops are intensively cultivated with heavy use of chemicals. Likewise, accumulation of pests and diseases had been observed in the rice cultivation as the result of intensive monoculture of double rice cropping. Yield reduction *in second* rice has been observed during the previous years due to soil fertility declining and pest accumulation. Average previous decade rainfall indicated

consistency and gradual reduction of precipitation which modify the task of getting good crop of dry season with proper economic management.

2. Agro-ecological analysis

Agro-ecological analysis of Banpong district as well as Krupyai sub-district were conducted between November 1995 to January 1996. The latter had been selected as the research site due to numerous suitable on-farm research facilities .The first step of agro-ecological analysis were the collection of secondary data such as total cultivated land, prevailing cropping patterns, availability of irrigation water, rainfall amount and pattern. These secondary data were obtained from various governmental offices at Banpong as well as Regional Agricultural Extension Office, Royal Irrigation Department, and Office of Municipality. Data were compiled ,analyzed and summarized before interviewing of farmers in January, 1996 in order to establish the primary data on crop and animal productions, farm environment and socio-economics. Rapid rural appraisal (RRA) were used for farmers interviewing methods. Monitoring of crop performance planted by farmers were also done as part of primary data collection.

3. Field-experiments

Two types of field experiments were conducted simultaneously in this study, research station experiments were conducted at Kasetsart University, Kamphaeng Saen, while on-farm research was conducted at Banpong district of Ratchaburi Province. Experiments at Banpong composed of research managed trial in which researcher conducted experiments themselves as those done at the experiment station. Also at Banpong, superimposed trials were done by farmers as farmer participatory activity. Period of experimentation were between January to June 1996. The site for on-farm field research at Banpong was at KrubYai sub-district.

3.1 Research conducted at the experiment station

Experiment I : Cultivar evaluation at Kamphaeng Saen Campus

Five soybean promising lines such as " Leichhardt," VX 4-76-2, CPAC-150-76, CPAC 562-76, CPAC-55-76 were planted in randomized complete block design with three replications. Fertilizer was applied to all plots at the rate of 18.75, 56.25 and 37.50 kg/ha of N, P_2O_5 and K_2O. Seeds were inoculated with *Rhizobium japonicum* prior to planting. For data collection yield, yield components and some growth and phenological data were recorded.

Experiment II : Weed management vs soil fertility practices at Kampheang Saen Campus

Split plot design with three replications was used in this experiment. Two main plots composed of soybean seeds of cultivar Leichhardt inoculated with rhizobium without fertilizer given, and the application of $(NH_4)_2SO_4$ at the rate of 31.25 kg.N/ha prior to soybean planting. Sub-plots composed of no weeding (control), complete hand weeding, pre-emergence i.e., alachlor at the rate of 3.5 kg/ha and alachlor application plus one hand weeding at 40 days after emergence. Data on yield, growth of soybean, and weed infestation were collected.

3.2 Research management, on farm trial at Banpong

Experiment III : Soybean promising lines vs soil fertility practices.

Four soybean lines, i.e. Leichhardt, VX 4-76-2, CPAC-150-76, and CPAC-55-76 were planted in 2×4 factorial arrangement in randomized complete block design experiment with three replications First factor composed of nitrogen fertilizer applied as $(NH_4)_2SO_4$ at the rate of 31.25 kg/ha and seeds were inoculated with *Rhizobium japonicum*. Second factors composed of soybean cultivar and accessions. Data on growth and yield

of soybean were gathered accordingly.

Experiment IV : Soybean lines vs weed management practices

A split plot design were used with three replications in this experiment, having four different weed management practices as main plots. Weed management treatment plots were the same as those in experiment II. Five promising cultivars and accessions similar to those in Experiment I were used as sub-plot. Other management were the same as to other three experiments described. Data on growth, yield of soybean, and dry matter of weeds were recorded.

3.3 Superimposed, on-farm trial at Banpong

Two replications of superimposed trials were carried out by two farmers, each managing one replication of trial. Soybean cultivar, Liechhardt, was planted on plots having two different fertility practices, (NH4)2SO4 at the rate of 31.35 kg/ha without rhizobium inoculum and plot receiving rhizobium inoculum without fertilizer. Two weed management treatments, pre-emergence herbicide of alachlor only and alachlor with one hand weeding were applied and compared in each of the fertility practice plots. Apart from yield data, economic assessments such as cost of input and output were also recorded in this superimpose trials.

4. Yield gap analysis

Yield gap analysis were calculated using the formulae provided by Sarobol *et al.*, 1989, as followed :

Comparing yield from experimental station trial and research managed trial in an on-farm research, Gap I can be assessed as followed:

$$\text{GAP I} = \frac{\text{YP} - \text{YMF}}{\text{YP}} \times 10$$

While comparing between yields from research managed trial and farmers managed trial, Gap II can be assessed by calculating from this formula.

$$\text{GAP II} = \frac{\text{YMF} - \text{YF}}{\text{YMF}} \times 10$$

Where, YP = Yield obtained from experiment at the research station.

YMF = Yield obtained from research management trial conducted in the farmer's field.

YF = Yield obtained from super imposed trial conducted in the farmer's field as farmer participatory activity.

RESULT AND DISCUSSION

1. Agro-ecological analysis

According to agro-ecological analysis and farm survey, it was obvious that agricultural production at Banpong was very intensive. Land areas have been cultivated with monoculture crop such as double rice cropping in the lowland area and continuously cropping of baby corn in the upland areas, while other portions of upland are devoted to sugarcane and vegetable production. Intensiveness of cropping lead into heavy use of chemical fertilizer and pesticide. Farmer skill in crop technology are high, they are readily to accept new technology if extended. Market possibility is also high in this area.

It was felt necessary that rotational cropping of grain legumes such as soybean with base crops should be introduced to Banpong. For soybeans, due to its capability of improving soil status and maintaining stability and sustainability to agricultural system through its biological nitrogen fixation process, therefore, soybean production at Banpong was proposed as the crop planted after rice in rice-soybean cropping system. Obviously, it may also be planted in rotation with baby corn. Rotational effect derived from soybean production may remedy the problem of pest infestation as well

as restoring soil fertility in both paddy and upland areas of Bangpong district. Since it had been suggested through agro-ecological analysis that soybean need to be introduced to the agricultural system at Banpong, field experiments were conducted in order to find the way in which proper cultivation methods of soybean which fit with environmental and socio-economic of farm be derived.

2. Field Experiments

2.1 Research conducted at Kamphaeng Saen campus

Figure 2 showed the result of the experiment conducted at Kamphaeng Saen campus in which the yield of five soybean promising lines such as Leichhardt, VX 4-6-2, CPAC 150-76, CPAC 562-76 and CPAC 55-76 were compared. The results showed that line CPAC 55-76 gave significantly higher yield than other four accessions. ($P < 0.05$). When Leichhardt was grown in the split plot design experiments in which two main plots were the inoculation of rhizobium in comparison with $(NH_4)_2SO_4$ fertilizer and the sub plot were different weed management. It was found that the average yield of soybean in the plot where inoculation of rhizobium had been applied to the seeds was 2,607 kg/ha which was higher than the yield of 2,407 kg/ha from the plot in which nitrogen fertility was applied. Among weed management treatments, hand weeding gave the highest yield of soybean followed by application of alachlor plus hand weeding, and the application of alachlor alone while no weeding gave the lowest yield among other treatments (Figure 3). Significant differentce in soybean yield derived from weed management treatments were obtained ($P < 0.05$). This finding is similar to that reported by Pookpakdi (1990).

2.2 On farm research conducted at Banpong. research management trials.

Cultivar evaluation in the farmers' fields at Banpong district showed similar results with those conducted at the experiment station at Kamphaeng Saen. Accession CPAC 55-76 gave the highest yield among cultivar and accessions tested. There was no significant different in yield of soybean when grown in the plots in which inoculation of rhizobium and the application of fertilizer were compared. (Table 1)

Figure 4 showed the yield of soybean cultivar Leichhardt which was grown in the plot in which different weed management treatments were

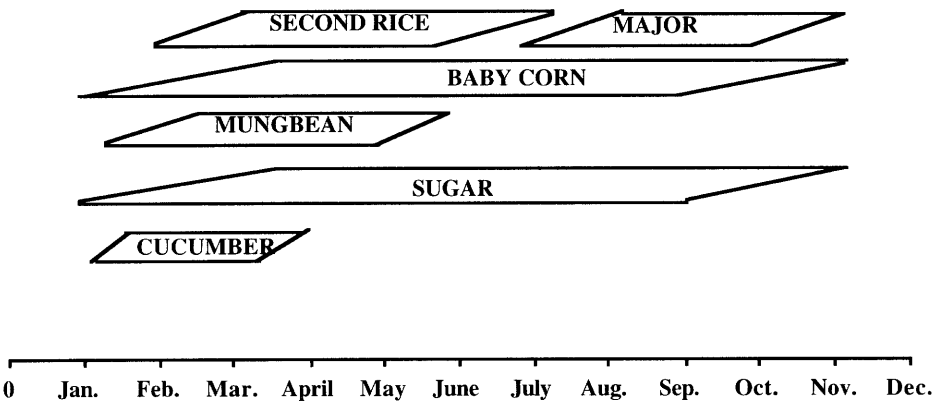

Figure 1 Existing cropping patterns at Banpong district, Ratchaburi Province in 1992. (Source: Statistical - Communication Office, 1994)

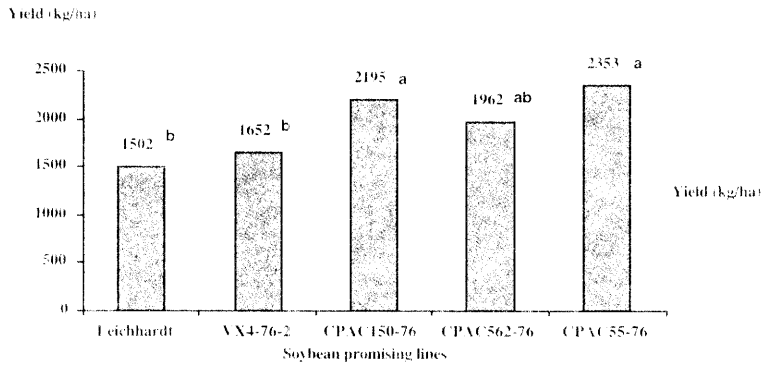

Figure 2 Yield (kg/ha) of different soybean lines grown at Kamphaeng Saen, dry season 1996.
Note: Numbers followed by different small letters were significantly different at 5% level of probability.

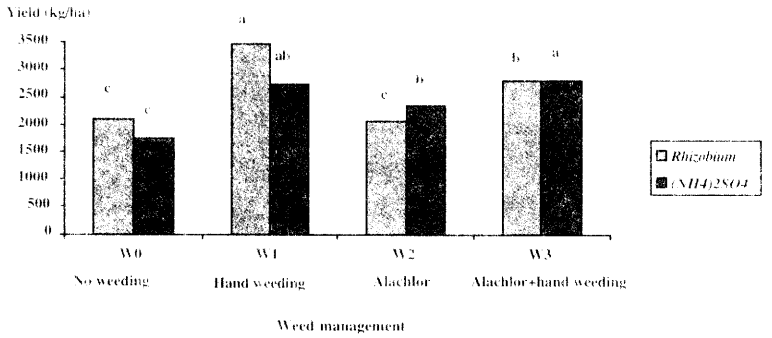

Figure 3 Effect of different weed management practices on yield of soybean at two fertility levels.
Note: Different small letters on the top of bars indicated significant different in soybean yield as affected by fertility and weed management.

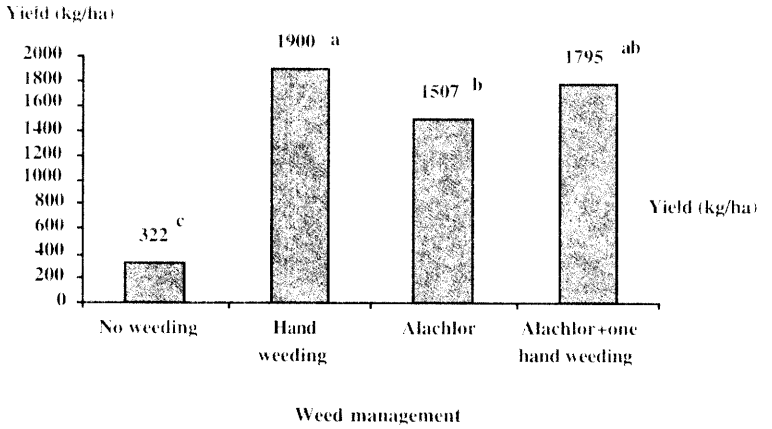

Figure 4 Seed yield (kg/ha) of soybean cultivar Leichhardt under different weed management.
Note: Means followed by a common letter are not significantly different at 5% level of probability.

imposed. Similar result had been obtained from this experiment in comparison with the experiment conducted in the experiment station at Kamphaeng Saen. Sult stop not colon Handweeding gave the highest yield of soybean while the application of alachlor plus one hand weeding at 40 DAE, the application of alachlor alone ranked second and third respectively. Likewise, no weeding gave the lowest yield as expected (Figure 4).

2.3 Superimposed farmer participation trials

Results of superimposed trial conducted by two farmers were showed in Table 2. Due to socio-economic differences and incentiveness to cultivate soybean crops by two farmers, the yield of 1,459 and 617 kg/ha were obtained from the two farmers respectively. As expected, the plot in which the application of alachlor plus one hand weeding produced higher soybean yield than the use of alachlor alone in both farmers' plots. The application of rhizobium and $(NH_4)_2SO_4$ fertilizer did not cause much difference in yield between two farmers' trials and the difference was not consistent also indicating that application of fertilizer and rhizobium by two farmers may also be differed.

3. Yield gap analysis

Table 3 showed the result of yield gap which was calculated from the yield of soybean in experiments conducted at Kamphaeng Saen campus which were used as trials conducted at the experiment station in comparison with two different on-farm trials conducted at Banpong district, Ratchaburi province i.e. research management trials and superimposed, farmer participating trials. As it was indicated earlier GAP I represented the effect on environmental difference between experimental station and farmer's fields while GAP II showed socio-economic and lack of technology which are the cause of the difference in yield between trial conducted by researcher and farmers under on farm conditions.

Yield gap derived from soybean cultivar performance

From the result showed in Table 3 it can be seen that based on the use of soybean cultivar Leichhardt, GAP I and II were not very much different suggesting that while the environment between the experiment station and under on farm condition prevailing in yield drop of soybeans, the

Table 1 Yield (kg/ha) of different soybean promising lines grown under application of rhizobium and fertilizer at Banpong, dry season 1996.

Variety	Fertility		Mean	Diff.
	$(NH_4)_2SO_4$	Rhizobium		
Leichhardt	1,856 ab	1,893 ab	1,874 ab	-37
VX 4-76-2	2,099 ab	1,707 ab	1,903 ab	382
CPAC 150-76	1,341 b	1,346 b	1,343 b	-5
CPAC 55-76	2,476 a	2,443 a	2,459 a	33
MEAN	1,943	1,847	1,895	96

Note: Figures followed by different letter in the same columun were significantly different at 5% level of probability.

Table 2 Yield of soybean under application of rhizobium and fertilizer and weed management practices in farmer management trial at Banpong, dry season 1996.

Item	Farmer A	Farmer B
Soybean yield (kg/ha)	1,458	617
Weed management		
Alachlor	1,245	571
Alachlor+1 Hand weeding	1,672	663
Soil Fertility		
Rhizobium	1,644	622
$(NH_4)_2 SO_4$	1,272	611

Table 3 Yield gap derived from different yield performance of soybean at the experimental station when compared with two type of on-farm trial experiments.

Type of experiments	Gap I (%)	Gap II (%)
1. Cultivar testing	18.79	36.22
2. Use of rhizobium inoculum	27.42	40.09
3. Fertilizer application	22.88	49.24
4. Use of pre-emergence herbicide	31.26	41.81
5. Use of pre-emergence herbicide plus one hand weeding	36.16	34.92

socio-economic of farmers such as time in taking care of the crop and proper cultural practices given to their soybean such as the use of right plant populations and planting methods were also an importance causes of yield difference between two type of on-farm trials.

Soil fertility practices

Based on two level of fertility practices, i.e. the use of rhizobium inoculum alone and the application of fertilizer $(NH_4)_2SO_4$, GAP I was very much less than GAP II, suggesting that in the trials conducted at the experiment station and research management trials, the cause of yield difference would probably be only lying with soil heterogeneity between two experimental sites. However, application of rhizobium inoculum and fertilizer application in term of the rate, time of application, and methods were the same as they were done by the same researcher. Therefore GAP I for rhizobium inoculum and fertilizer application were found to be similar (27.42 and 22.88% respectively).

On the same level of fertility practices, it was found that GAP II for rhizobium inoculation was 40.09% and fertilizer application was 49.24% respectively. GAP II was found to be very much wider gap, suggesting that the farmer may apply

either rhizobium inoculum or fertilizer or both not at the right time or not using the proper methods. In both treatments, ample soil moisture are generally required prior to immediately after the application of rhizobium inoculation or fertilizer application. The farmer may not irrigate their plots properly.

Weed management practices

Yield gap based on weed management practices, either the use of alachlor alone or alachlor with one hand weeding at 40 DAE or both revealed that GAP I were high up to 31.26 and 36.16% percent for the use of pre-emergence herbicide and pre-emergence herbicide plus one hand weeding respectively. This may suggest that weed problem at Banpong was generally severe and weed infestation was the major cause in yield drop when soybean was grown at Banpong. GAP II which reflected the general performance of farmer in the application of herbicide were not much higher than GAP I, suggesting that the farmer realized the importance of proper weed control as a successful measure to obtain higher crop yield.

CONCLUSION

This study showed that the possibility for extending soybean production in Banpong was rather promising as it can be seen from the yield performance of soybean of 1,618 kg/ha under on-farm condition. Generally two major constraints caused the yield gap in soybean performance when they were compared from experiment conducted at the research station and on-farm environments. Environmental factors caused the yield drop under farm conditions were weed infestation, soil heterogeneity and non-transferable technologies such as different methods of tillage and irrigation. Socio-economic factors prevail which may be due to the lack of certain technologies by farmers, improper or failure of imposing technology such as the application of fertilizer or seed inoculum using the right method or applying at the right time due to their engagement in other activities. Also, their limited times and resources prevented them from concentrating on proper planting methods and using proper plant populations. Both environmental and socio economic factors caused yield constraints may be remedied by more on-farm research and initiation of simple farmer training programs for improving their technology know how in soybean production.

LITERATURE CITED

Evans, H. J. and L. E. Barber. 1977. Biological nitrogen fixation for food and fibre production. Science. 1977: 332-339.

Librero, A. R. 1985. Socio-economic constraints and research priorities on maize in the Philippines, pp 15-31. *In* Research Implications of Exampled Production of Selected Upland Crops in Tropical Asia. Bogor: CGPRT centre.

Poonaperuma, F. N. 1979. IR 42, a rice variety for small farms of south and south east Asia. Agronomy Abstract. A. S. A. Madison Wis. 46 p.

Pookpakdi, A. 1990. On farm research and technology transfer in soybean production for the central plain region of Thailand, Oil-Crop Development Project. No. 201-89. 56 p.

Sarobol, N., N. Potan, V. Benjasil, P. Setarath, and S. Dechates. 1989. Preliminary Survey on Soybean Yield Gap Analysis in Thailand. The CGPRT centre publication, Bogor, Indonesia. 57 p.

Statistical Communication Office, Banpong, 1994. Banpong Agricultural District Office (mimeo). 29 p.