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Impact of Pigeonpea Research in Enhancing Sugarcane Production in Thailand

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Abstract

Impact of pigeonpea research in enhancing sugarcane production in Thailand. This assessment study was undertaken by the Thailand DOA in collaboration with ICRISAT to assess the contribution of pigeonpea as a green manuring crop in specific locations of Thailand—Khon Kaen and Udon Thani. The adoption of green manuring pigeonpea in sugarcane production from 1996 was estimated at 3.7% of the study area, covering an area of 4400 ha. It is expected that the ceiling level of adoption will reach 15% of the study area in the year 2004, covering an area of 18 000 ha. Green manuring pigeonpea has the potential of reducing the use of chemical fertilizer in sugarcane production. It substitutes for 15-15-15 NPK fertilizer at the rate of 312.5 kg ha^{-1}. In comparison with the chemical fertilizer application at that rate, green manuring pigeonpea reduces unit cost by 4.3-8.4 %. By using the ceiling level of adoption of 15%, the net present value of benefits accruing to the study area is approximately 60-115 million baht, representing an internal rate of return of 65-82%. This study also provides lessons for future research and development policy.

Résumé

L'impact de la recherche concernant le pois d'angole sur l'accroissement de la production de la canne à sucre en Thaïlande. Cette étude d'évaluation a été réalisée par le DOA de la Thaïlande en collaboration avec l'ICRISAT en vue d'évaluer la contribution du pois d'angole en tant qu'engrais vert, dans des zones spécifiques de la Thaïlande—Khon Kaen et Udon Thani. La superficie concernée par l'adoption du pois d'angole en tant qu'engrais vert dans la production de la canne à sucre, à partir de 1996, est estimée à 3,7 % de la zone d'étude, soit 4400 ha. On s'attend à ce que l'adoption atteigne un niveau plafond de 15 % de la zone étudiée en 2004, soit 18 000 ha. Le pois d'angole, utilisé comme engrais vert, permet de réduire l'utilisation des engrais chimiques pour la production de la canne à sucre. Il remplace le15-15-15 NPK à un taux d'application de 312.5 kg ha^{-1}. Par rapport à l'application de cet engrais chimique au même taux, le pois d'angole réduit le coût unitaire de 4,3 à 8,4 %. En se basant sur un niveau plafond d'adoption de 15 %, la valeur actuelle nette des bénéfices qui seront réalisés dans la zone d'étude s'élève à environ 60-115 millions baht, soit un taux rentabilité interne de 65-82 %. Cette étude fournit également des leçons pour les études et les politiques de développement futures.

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Background

A study was undertaken by the Thailand Department of Agriculture in collaboration with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to assess the economic impact of pigeonpea research and development projects in Thailand. In particular, the study aimed to quantify the contribution of pigeonpea as a green manuring crop in Khon Kaen and Udon Thani provinces. The study was coordinated with other assessment projects underway at Kasetsart University, Bangkok, and funded by the Australian Centre for International Agricultural Research (ACIAR).

Research on pigeonpea was conducted under two projects, PN 8201 "Pigeonpea Improvement" and PN 8567 "Production System for Short-duration Pigeonpea", started in 1984 in Thailand to improve the yield potential and shorten the number of days to maturity of the traditional long-duration pigeonpea varieties. Results of research experiments undertaken under these two projects by the Land Development Department (LDD) and Chiang Mai University (CMU) of Thailand showed that pigeonpea has many advantages over other legumes. It has the ability to grow on low fertility soil; and it also enhances soil fertility through nitrogen fixation. In northeastern Thailand, where pigeonpea grain production remains insignificant, the research was able to demonstrate the important traits of pigeonpea such as drought tolerance and its potential use as green manure, which are essential crop attributes in the area.

PN 8201 and PN 8567 were part of the Overseas Collaborative Research Programs funded by ACIAR which commenced in 1982 in Fiji, Indonesia, and Thailand, with active involvement of the Thailand Department of Agriculture, ICRISAT, and the University of Queensland. In Thailand, the project was implemented by the Field Crops Research Institute (FCRI), Department of Agriculture, Kasetsart University, and Prince of Songkhla University. The project aimed at increasing the adaptation of higher yielding short-duration pigeonpea varieties to replace the traditional long-duration varieties.

Funding from ACIAR ended in 1989 but FCRI continued to collaborate with ICRISAT on conducting experimental trials to evaluate promising materials for higher grain yields and insect and disease resistance, and identify important cultural practices including recommended fertilizer application rates.

Research products were developed in the early 90s (e.g., up to 500 kg seed of well adapted materials), and these were provided to LDD, CMU, some agencies, and farmers for testing. Farmers showed preference for pigeonpea as a green manure crop rather than as a grain for cash sale, as the pigeonpea pods suffered serious damage from insects during the trials, resulting in low grain yield.

Starting in 1995, FCRI evaluated several promising improved varieties for use as a green manure crop and produced a total of 1 tonne of seed of two varieties – ICPL 270 and ICPL 304 – both appropriate for green manuring. A portion of this seed was provided to farmers in Udon Thani and Khon Kaen provinces, mostly sugarcane growers and seed producers. Seed requirements increased significantly as farmers became convinced of the potential of the crop for green manuring.

Research on pigeonpea in Thailand

Research on pigeonpea in Thailand was begun in 1984. The main implementing agency was the Field Crops Research Institute, Department of Agriculture. Most field experiments were conducted at Khon Kaen Field Crops Research Center.

The research involved implementation of a series of research activities under projects on firstly, pigeonpea improvement and secondly, production of early maturing pigeonpea. The research activities were classified under five categories: (1) varietal tests (yield trials), (2) field tests, (3) population density and sowing time, (4) fertilizer rates, and (5) climatic adaptation. The number of subprojects and trials in each category are listed in Table 1. The performance of entries evaluated from 1984 to 1995 under the variety improvement project is shown in Table 2a and that of entries under the resource management project in Table 2b.

Table 1. Number of subprojects and trials within the different categories of pigeonpea research activities conducted in Thailand.

	Number of subprojects	Number of trials
Variety testing and improvement	19	31
Short-maturing varieties	12	21
Long-maturing varieties	1	1
Pest resistance	2	2
Vegetable pigeonpea	1	3
For green manuring	3	4
Field test	4	7
Density and sowing time	10	10
Fertilizer	2	2
Environmental adaptation	3	3
Other	3	3
Total	**41**	**56**

Table 2a. The performance of pigeonpea varieties evaluated under the variety improvement project, 1984-1995.

Subprojects	Number of trials/ location	Sowing date	Varieties	Grain yield (t ha^{-1})	Dry matter yield (t ha^{-1})	Harvesting (days after sowing)
Variety Testing						
• Genotypic Evaluation of Pigeonpea in the Northeast, 1984						
	1/Khon Kaen		QPL 58	3.90		124
			ICPL 155	3.80		

continued

Subprojects	Number of trials/ location	Sowing date	Varieties	Grain yield (t ha^{-1})	Dry matter yield (t ha^{-1})	Harvesting (days after sowing)
• Pigeonpea Preliminary Yield Trial (group I) 1987						
Group 1	1/Khon Kaen		ICPL 86008	2.66		125-138
			ICPL 83009	2.31		
			QPL 1070	2.27		
Group 2	1/Khon Kaen		ICPL 8324	2.40		135
• Pigeonpea Standard Yield Trial, 1987						
	4/ Mean of 4 locations		QPL 637	1.20		135
• Pigeonpea Regional Yield Trial, 1988						
	4/ Mean of 4 locations		QPL 637	2.00		
• Pigeonpea Locational Yield Trial, 1988 (early and medium)						
	1/Khon Kaen		ICPL 270	1.85		
			ICPL 151	1.40		
• Pigeonpea Preliminary Yield Trial from ICRISAT, 1991						
Group 1	1/Khon Kaen	29 Jul	ICPL 87101	3.10	8.2	120-130
			ICPL 88027	2.90	9.3	120-130
			ICPL 86005	2.89	6.8	120-130
Group 2	1/Khon Kaen	29 Jul	ICPL 88009	2.60	6.1	120-130
			ICPL 88015	2.50	6.4	120-130
• Pigeonpea Trial after Rice 1991						
	1/Khon Kaen	7 Dec	ICPL 87109	1.77	4.2	113
			ICPL 88027	1.72	5.6	113
• Pigeonpea Yield Trial 1992						
Group 1	1/Khon Kaen	8 Sep	ICPL 87105	3.19		110
			ICPL 85012	3.17		110
			ICPL 90013	3.11		110
			ICPL 88027	3.10		110
Group 2	1/Khon Kaen	8 Sep	ICPL 88017	2.94		110
			ICPL 90012	2.86		110
• Pigeonpea Yield Trial, 1993 (short-duration, and indeterminate)						
	1/Khon Kaen	6 Jul	ICPL 90053	3.58		134
	1/Ta Pra	6 Jul	ICPL 90046	3.57		134
• Extra Short-duration Pigeonpea Yield Trial, 1994 (extra short-duration, and indeterminate)						
Group 1	1/Khon Kaen	13 Jul	ICPL 92047	2.90	12.2	124
			ICPL 92042	2.56	8.7	124
Group 2	1/Khon Kaen	13 Jul	UPAS 120	2.24	7.7	124
			ICPL 88034	2.14	9.2	124
• Extra Short-duration Pigeonpea Yield Trial, 1995 (determinate)						
Group 1	1/Khon Kaen	22 Jun	ICPL 94020	2.35	10.0	118
Group 2	1/Khon Kaen	22 Jun	ICPL 94015	2.54	10.1	118
• Short-duration Pigeonpea Locational Yield Trial, 1995						
	1/Khon Kaen	16 Jun	ICP 8102	2.55	10.8	143
			ICP 8863	2.31	9.7	143

continued

Subprojects	Number of trials/ location	Sowing date	Varieties	Grain yield (t ha^{-1})	Dry matter yield (t ha^{-1})	Harvesting (days after sowing)
	1/Roi-et	13 Jun	ICP 8102	2.47	15.0	197,210
			ICP 8863	2.20	13.2	197,210
	1/Loei	7 May	ICP 8863	2.39		171,202
			ICP 8102	2.38		171,202
	3/Mean		ICP 8102	2.47	12.9	
			ICP 8863	2.30	11.4	
			ICPL 151 (control)	1.54	5.9	
• Pigeonpea Preliminary Yield Trial for Green Manure, 1995						
	2/Mean	19 May	ICPL 93001	3.43	13.4	210
		10 Jun	ICPL 95004	3.19	13.7	210
			ICPL 304	2.5	12.6	210
Pest Resistance						
• Pigeonpea Preliminary Yield Trial, 1987 (no insect control)						
	1/ Khon Kaen		ICPL 332	2.10		196
			ICPL 265	1.50		196
• Pigeonpea Standard Yield Trial , 1987 (insect control)						
	1/ Khon Kaen		ICPL 265	1.90		188
			ICPL 332	1.85		188
Vegetable						
• Pigeonpea Standard Yield Trial, 1987						
	3/Mean		ICP 7035	3.96		107-139

Table 2b. Performance of pigeonpea varieties evaluated under the resource management project, 1984-1995.

Subprojects	Results
Climatic Adaptation	
Serial Sowing Trial of Pigeonpea, 1984	
	Photo insensitive: NORMAN, HUNT, QPL 42, 1605. ICPL 1, ICPL 6, ICPL 26, PANT-A 3 and TC-F 6-2-7
	Photo sensitive: ROYES, C 322, BDN 1, ICPL 227, ICPL 265, ICPL 270 and ICPL 304
Field Test	
Pigeonpea Field Test, 1988	
	QPL 42, 2 locations, grain yield =0.81 t ha^{-1}, harvesting 130 days and 170 days, farm cost=15 708 baht ha^{-1}, insect control cost=33% of total farm cost
Pigeonpea Field Test, 1989	
	QPL 42, 2 locations, grain yield =1.97 t ha^{-1}, harvesting 133 days, farm cost=15 348 baht ha^{-1}, insect control cost=34% of total farm cost
Pigeonpea Field Test, 1990	
	ICPL 83009, 2 locations, grain yield =1.33 t ha^{-1}, harvesting 131 days, farm cost=14 580 baht ha^{-1}, insect control cost=30% of total farm cost

continued

Subprojects	Results
Population Density and Sowing Time	
The Effects of Genotypes and Population Density on the Productivity of Pigeonpea (short-duration varieties), 1984	Optimum density - Hunt 200 000 plant ha^{-1}, harvesting 94-118 days, 1.96 t ha^{-1} - 412, 200 000 plant ha^{-1}, harvesting 100-124 days, 3.2 t ha^{-1}
The Effects of Genotypes and Population Density on the Productivity of Pigeonpea (photosensitive varieties), 1984	Optimum density - ROYES 100 000-200 000 plant ha^{-1}, harvesting 145-153 days, 2.1-2.5 t ha^{-1} - ICPL 295 100 000 plant ha^{-1}, harvesting 145-153 days, 3.25 t ha^{-1}
The Effects of Different Spacing on the Productivity of Pigeonpea, 1985	Optimum density - HUNT 160 000-330 000 plant ha^{-1}, harvesting 110 days, 0.78-0.99 t ha^{-1} - QPL 42 160 000-330 000 plant ha^{-1}, harvesting 116 days, 1.0-1.26 t ha^{-1} - ROYES 100 000-200 000 plant ha^{-1}, harvesting 165 days, 0.9-1.04 t ha^{-1} - ICPL 265 100 000-200 000 plant ha^{-1}, harvesting 169 days, 1.3-1.5 t ha^{-1}
Study on the Optimum Spacing of Pigeonpea ICPL 270, Effect on the Growth and Yield, 1988	Optimum density - ICPL 270 60 000-100 000 plant ha^{-1}, harvesting 173 days mean 2.25 t ha^{-1} - ICPL 270 60 000 plant ha^{-1} (green manure use), 25.8 t dry matter ha^{-1}
Genotype × Sowing Time Trial, 1985	Varieties (QPL 17, QPL 42, QPL 130, QPL 58 and HUNT) Optimum sowing date – northeastern Thailand: mid July – northern Thailand: late June
Fertilizers	
The Effects of Phosphorus and Potassium Fertilizers on the Growth and Yield of Pigeonpea QPL 42, 1987	Grain yields increased from 1.56 t ha^{-1} with P37 kg ha^{-1} to 1.83 t ha^{-1} when applied with P75 kg ha^{-1}. Increasing K increased seed size
Effects of Different Rates of P and K Fertilizers on the Growth and Yield of Pigeonpea ICPL 83024, 1988	Grain yields increased from 1.18 t ha^{-1} without P application to 1.57 t ha^{-1} when applied with P 37 kg ha^{-1}. Increasing K increased seed size

25 baht = $US 1.

Materials and methods

Information used in this assessment was gathered from both primary and secondary (see references) data sources. Primary data were obtained through reconnaissance surveys undertaken during 1998. Figure 1 shows the areas in which the surveys were conducted. Data sets on sugarcane farmers' practices, farm cost structure, adoption of green manuring and seed distributions were generated from these surveys. The first survey was conducted in November 1998 in the upper regions of northeast Thailand, where most of the work on pigeonpea was conducted. The survey interviews were conducted among pigeonpea farmers and respondents from Khon Kaen Field Crops Research Center (KKFCRC), Office of Land Development, Region 5, Khon Kaen (LDD5), Sugarcane Pest Control Center, Region 5, Udon Thani (SPCC5), and Kumpawapee Sugar Refinery, Udon Thani.

Data collected from this survey showed limited use of the green pods of pigeonpea. No data was obtained on dry seed use. Results of the survey also showed a significant increase in use of pigeonpea for green manuring in sugarcane in the region.

A follow-up survey was undertaken in December 1998, and focused on green manuring of pigeonpea in sugarcane in two districts of Udon Thani and one district of Khon Kaen province. A random sample of farmers who were members of the Sugarcane Planters' Association, were interviewed. Simultaneously, another survey was also conducted in Chiang Mai. Organizations interviewed included the Office of Extension and Cooperatives, Udon Thani; Office of Extension, Udon Thani; Sugarcane Center (NE), Udon Thani; Seed Center, Udon Thani; Office of Land Development, Region 5, Khon Kaen (LDD5); Office of Land Development, Region 6, Chiang Mai (LDD6); Kumpawapee Sugar Refinery, Udon Thani; Ream Udom Sugar Refinery, Udon Thani; Northeast Sugarcane Planters' Association, Udon Thani; Chiang Mai Field Crops Research Center, Chiang Mai; and Multiple Cropping Center, Chiang Mai University, Chiang Mai.

Analysis of dimensions of impact in northeastern and northern Thailand

The usefulness of pigeonpea in the farming systems of Thailand is in crop rotation and green manuring in sugarcane-producing land holdings. It is not significant for its dry seeds or as green vegetable. Green manuring of pigeonpea in sugarcane cropping systems was found common in the provinces of Khon Kaen and Udon Thani in the upper regions of northeastern Thailand.

Sugarcane is one of the most important crops in the northeast regions of Thailand. It occupies the third largest area grown to field crops, following cassava and corn (Table 3). The growth rate of sugarcane production in Khon Kaen and Udon Thani is quite high. The area grown to sugarcane more than doubled from 53 404 ha in 1985 to 119 213 ha in 1996 and production increased by more than three times from 2.14 million tonnes in 1985 to 7.5 million tonnes in 1996.

Most of the sugarcane farmers in Udon Thani and Khon Kaen normally replant sugarcane after harvesting the first ratoon. Yields of the second and subsequent ratoons are low due to a low percentage of shoot regeneration. After harvesting the first ratooned crop, farmers usually discard the stubble. In this region, sugarcane is mainly harvested from October to March and the land left fallow until the end of the rainy season (October). Pigeonpea can be planted at the beginning of the rainy season (May) and plowed down after four months in August (Figure 2), after which it is left for at least a month to decompose before the sowing of sugarcane, which is considered the main crop.

The survey data from northeastern Thailand indicates that there were two categories of people who adopted pigeonpea: (1) large-holder farmers who allocated more than 10 ha for sugarcane production; and (2) small-holder farmers, who allocated less than 10 ha for sugarcane production. Large-holder farmers comprised 27% of cane farmers in northeast Thailand (Prammanee et al., 1997), and achieved a higher rate of adoption of pigeonpea as a green manure than small-holder farmers. Cane farmers who owned more than 200 ha of sugarcane land were usually found to grow pigeonpea for green manure as well as for seed multiplication.

Extra seed is sold mainly to nearby farmers. Small-holder farmers prefer to buy seed every year. Although some seed producers multiply pigeonpea mainly for seed sale, the seed has remained insufficient for the seed buyers. The Khon Kaen Field Crops Research Center produces and distributes foundation seeds on the average of 1 tonne of seed a year.

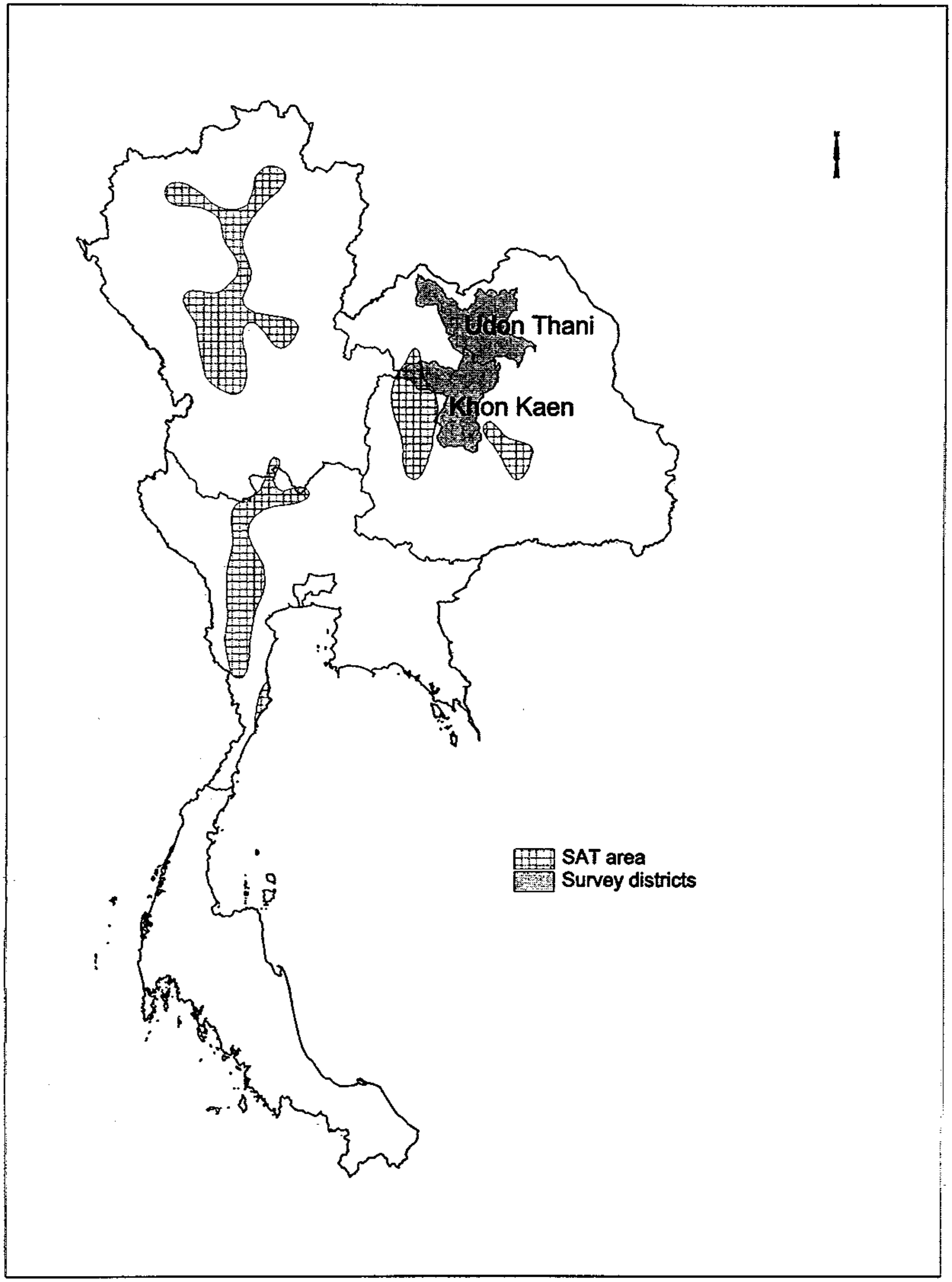

Figure1. Map showing the survey area in northeastern Thailand.

Table 3. Area (ha) planted to the most important field crops in northeastern Thailand compared with the national area, 1996.

	Northeast	*Country*
Cassava	752 531	1 228 144
Corn	332 212	1 263 400
Sugarcane	310 520	985 004
Kenaf	67 104	70 047

Source: Center for Agricultural Statistics, 1996.

The surveys also revealed that farmers of Chiang Mai intercrop pigeonpea with *Leucaena* spp. as a hedgerow to reduce soil erosion in sloping lands. The Land Development Department Region 6 (LDD6) produces 10 tonnes pigeonpea seed per year in an area of about 800 ha to supply farmers who grow it as hedgerow. The multiple cropping center at Chiang Mai University, after evaluating a number of different legume crops, also established that pigeonpea is the only legume that could grow well and improve the soil nutrients of the poor soils in the area (high acidity and low phosphorus levels). This finding is very significant considering that farmers in the highlands who cultivate upland rice obtain only 1.2 t ha^{-1} even after leaving their land fallow for a year.

Measuring Impact

Adoption

The analysis of adoption and impact of pigeonpeas in northeastern Thailand focused on benefits derived from green manuring for sugarcane production. In this case, the 119 000 ha of sugarcane

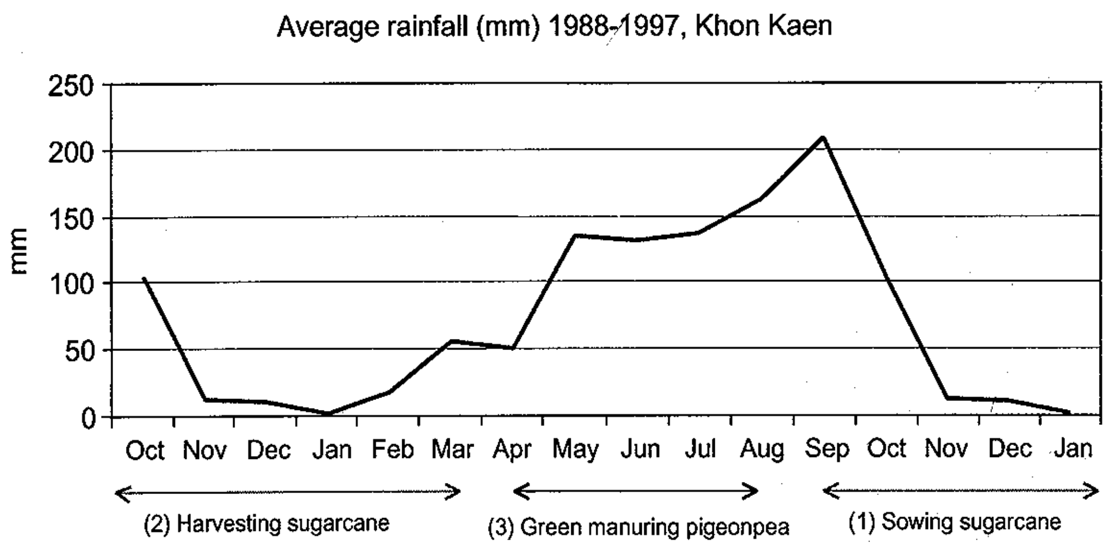

Figure 2. Average rainfall and corresponding cropping patterns of sugarcane and pigeonpea in Khon Kaen, 1988-97.

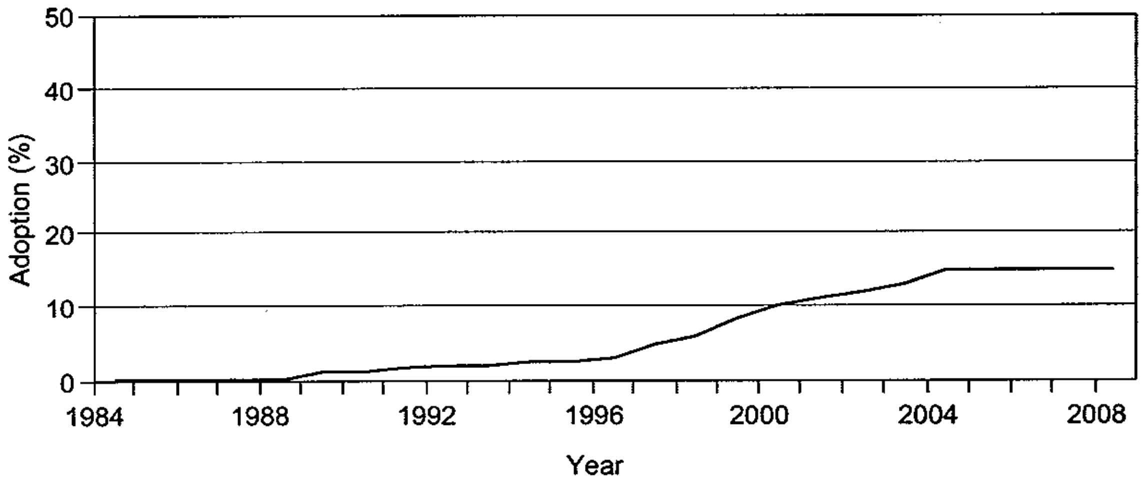

Figure 3. Adoption of green manuring pigeonpea in Khon Kaen and Udon Thani, 1984-2008.

which lies in Khon Kaen and Udon Thani was targeted for this analysis. The estimated area of adoption was 850 ha (0.7% of study area) in 1990. The adoption from 1996 was estimated based on two data sources; (1) seed distribution, assuming an average seed rate of 25 kg ha^{-1} and (2) the area of large-holder farmers producing seed, covering an area of 4400 ha which is 3.7% of the study area. Considering the seed use of 120 tonnes per year during 1996-1998 and the quantity of seed required, excess demand is clear. It is expected that the ceiling level of adoption will reach 15% of the study area in the year 2004; about 18 000 ha which requires 450 tonnes of seed (see Figure 3).

Cost Reduction

Nutrient compositions and biomass of long-duration pigeonpea varieties are shown in Tables 4 and 5. Data presented in Table 6 show that green manuring pigeonpea has the potential to reduce the use of chemical fertilizer in sugarcane production. Pigeonpea can substitute for 15-15-15 NPK fertilizer at the rate of 312.5 kg ha^{-1}. With green manuring, sugarcane yields were 77.25 t ha^{-1}, which was 53% higher than when no fertilizer was applied. Data (Table 6) derived from on-station trials indicated a yield adjustment rate of 20%; these adjusted yields may be used to reckon yield rates on-farm.

Table 4. Nutrient compositions (kg ha^{-1}) and dry matter masses of pigeonpea sown in early rainy season, Khon Kaen, Thailand, 1994.

	Dry mass (125 days) (kg ha^{-1})	N	P (kg ha^{-1})	K
Stem	8256	33.02	8.26	42.11
Leaf	2862	89.87	8.01	30.34
Root	2606	14.85	2.34	13.81
Leaf (fall)	956	11.76	0.96	3.13
Total	14680	149.50	19.58	89.39

Source: Paiboon Sirisangtagoon, 1996.

Table 5. Nutrient compositions (kg ha^{-1}) and dry matter masses (kg ha^{-1}) of pigeonpea sown in late rainy season, Khon Kaen, Thailand, 1994.

	Dry mass (125 days) (kg ha^{-1})	N	P (kg ha^{-1})	K
Stem	2332	32.46	0.86	35.9
Leaf	471	19.07	0.26	7.15
Root	592	8.33	0.38	8.98
Total	3395	59.86	1.50	52.03

Source: Wimolrat Sukarin, 1996.

Table 6. Yield of sugarcane (t ha^{-1}) at Khon Kaen, 1994.

Treatment	Yield (t ha^{-1})	Adjusted yield (t ha^{-1})
1. No fertilizer application	50.62 b[2]	40.50
2. 15-15-15 NPK[1]	74.25 a	59.40
3. Green manuring pigeonpea	77.25 a	61.80
4. 2 + 3	85.93 a	68.74

1. 15-15-15 NPK at a rate of 312 kg ha^{-1}.
2. Numbers followed by the same letter are not statistically significantly different at $P<0.05$.
Source: Paiboon Sirisangtagoon, 1996.

Tables 7 and 8 present a cost analysis for sugarcane production using pigeonpea green manuring based on input data from on-farm surveys and output data given in Table 6. A comparison was made of yield and input use among sugarcane farmers with and without pigeonpea green manuring. Data collected from the on-farm surveys show that all sugarcane farmers in the study area applied chemical fertilizer. Most of them applied 15-15-15 NPK chemical fertilizer (Prammanee 1997). Two cases were considered for the cost analysis.

Case 1: Comparison of cane farmers who used green manuring pigeonpea compared with cane farmers who did not use green manuring pigeonpea; both groups applied fertilizer (15-15-15 NPK) at the rate of 312.5 kg ha^{-1}.

Case 2: Comparison of cane farmers who used green manuring pigeonpea and did not apply fertilizer and cane farmers who did not use green manuring pigeonpea and applied fertilizer (15-15-15 NPK) at the rate of 312.5 kg ha^{-1}.

The cost analysis indicated that using green manuring pigeonpea reduced the unit cost of sugarcane production by 4.3% or 20.65 baht per tonne of sugarcane (case 1) and by 8.4% or 39.12 baht per tonne of sugarcane (case 2).

Research and extension costs and returns

Data on costs of pigeonpea research were derived based on salaries of members of the research team, and the proportion of each scientist's time spent on pigeonpea research. The cost of workers was estimated from annual budgets spent on pigeonpea. Extension costs (covering seed multiplication and distribution) were also included (see Tables 9 and 10).

Table 7. Cost analysis of research impact of pigeonpea as green manure in producing sugarcane (case 1).

	Unit	Unit price (baht)	Technology before research Fertilizer[1] Quantity	Technology before research Fertilizer[1] Cost (baht)	Technology after research Fertilizer + pigeonpea[2] Quantity	Technology after research Fertilizer + pigeonpea[2] Cost (baht)
Fixed Costs[3]						
Land - rental costs				3375.00		3375.00
Variable Costs[3]						
Labor costs						
Sowing	ha	3172.00	1.00	3172.00	1.00	3172.00
Broadcast (pigeonpea)	days	100.00	0.00	0.00	1.56	156.00
Weeding	days	100.00	6.25	625.00	6.25	625.00
Pesticide application	days	180.00	2.08	374.40	2.08	374.40
Fertilizer application	days	100.00	3.13	312.50	3.13	312.50
Harvesting costs	tonne	86.70	59.39	5149.11	68.73	5958.89
Tractor						
Land preparation	no. times	750.00	2.00	1500.00	2.00	1500.00
Eradication of the old stool	no. times	750.00	1.00	750.00	1.00	750.00
Plow down (pigeonpea)	no. times	750.00	0.00	0.00	1.00	750.00
Seed costs (sugarcane)	tonne	600.00	7.18	4308.00	7.18	4308.00
Seed costs (pigeonpea)	kg	25.00	0.00	0.00	25.00	625.00
Fertilizer costs						
15-15-15	kg	9.20	312.50	2875.00	312.50	2875.00
Pesticides						
Post-emergence (2 times)	kg	117.50	12.50	1468.75	12.50	1468.75
Transportation	tonne	100.00	59.39	5939.00	68.73	6873.00
Total Cost[3]				29848.76		33123.54
Total value of Output[4]	tonne	600.00	59.39	35634.00	68.73	41238.00
Unit Cost	baht tonne^{-1}			502.59		481.94
Unit Cost Reduction	baht tonne^{-1}					20.65

1. Applied fertilizer 15-15-15 NPK with rate 312.5 kg ha^{-1}.
2. Used green manuring pigeonpea and applied fertilizer 15-15-15 NPK with rate 312.5 kg ha^{-1}.
3. Costs expressed in ha^{-1} year^{-1}.
4. Output expressed in ha^{-1} year^{-1}.
Source: On-farm survey by FCRI, DOA, 1998.

Table 8. Cost analysis of research impact of pigeonpea as green manure in producing sugarcane (case 2).

	Unit	Unit price (baht)	Technology before research Fertilizer[1] Quantity	Technology before research Fertilizer[1] Cost (baht)	Technology after research Pigeonpea[2] Quantity	Technology after research Pigeonpea[2] Cost (baht)
Fixed Costs[3]						
Land - rental costs				3375.00		3375.00
Variable Costs[3]						
Labor costs						
Sowing	ha	3172.00	1.00	3172.00	1.00	3172.00
Broadcast (pigeonpea)	days	100.00	0.00	0.00	1.56	156.00
Weeding	days	100.00	6.25	625.00	6.25	625.00
Pesticides application	days	180.00	2.08	374.40	2.08	374.40
Fertilizer application	days	100.00	3.13	312.50	0.00	0.00
Harvesting costs	tonne	86.70	59.39	5149.11	61.80	5358.06
Tractor						
Land preparation	times	750.00	2.00	1500.00	2.00	1500.00
Eradication of the old stool	times	750.00	1.00	750.00	1.00	750.00
Plow down (pigeonpea)	times	750.00	0.00	0.00	1.00	750.00
Seed costs (sugarcane)	tonne	600.00	7.18	4308.00	7.18	4308.00
Seed costs (pigeonpea)	kg	25.00	0.00	0.00	25.00	625.00
Fertilizer costs						
15-15-15	kg	9.20	312.50	2875.00	0.00	0.00
Pesticides						
Post-emergence (2 times)	kg	117.50	12.50	1468.75	12.50	1468.75
Transportation	tonne	100.00	59.39	5939.00	61.80	6180.00
Total Cost[3]				29848.76		28642.21
Total Value of Output[4]	tonne	600.00	59.39	35634.00	61.80	37080.00
Unit Cost	baht tonne^{-1}			502.59		463.47
Unit Cost Reduction	baht tonne^{-1}					39.12

Notes:
1. Applied fertilizer 15-15-15 NPK with rate 312.5 kg ha^{-1}.
2. Used green manuring pigeonpea.
3. Costs expressed in ha^{-1} year^{-1}.
4. Output expressed in ha^{-1} year^{-1}.
Source: On-farm survey by FCRI, DOA, 1998..

Table 9. Salary and operating costs of pigeonpea research, 1984-1998.

	Research cost (baht)								
Year	Salary for scientist	% time	Cost	Salary for research assistance	% time	Cost	Workers	Operating	Research cost
1984	120 000	40	48 000	40 000	60	24 000	80 000	32 000	184 000
1985	120 000	20	24 000	40 000	60	24 000	40 000	16 000	104 000
1986	120 000	20	24 000	40 000	60	24 000	40 000	16 000	104 000
1987	120 000	70	84 000	40 000	60	24 000	140 000	56 000	304 000
1988	180 000	50	90 000	60 000	60	36 000	100 000	40 000	266 000
1989	180 000	10	18 000	60 000	60	36 000	20 000	8 000	82 000
1990	180 000	10	18 000	60 000	60	36 000	20 000	8 000	82 000
1991	180 000	50	90 000	60 000	60	36 000	100 000	40 000	266 000
1992	180 000	20	36 000	60 000	60	36 000	40 000	16 000	128 000
1993	216 000	40	86 400	72 000	60	43 200	80 000	32 000	241 600
1994	216 000	40	86 400	72 000	60	43 200	80 000	32 000	241 600
1995	216 000	40	86 400	72 000	60	43 200	80 000	32 000	241 600
1996	216 000	20	43 200	72 000	60	43 200	40 000	16 000	142 400
1997	216 000	20	43 200	72 000	60	43 200	40 000	16 000	142 400
1998	216 000	20	43 200	72 000	60	43 200	40 000	16 000	142 400
Total	2676 000	32	820 800	892 000	60	535 200	940 000	376 000	2 672 000

Table 10. Extension (seed multiplication) and total costs, 1984-1998.

	Extension cost (baht)					Total cost (baht)		
	KKFCRC		SPCC5					
Year	Tonne[1]	Baht	Tonne[2]	Baht	Total	Research cost	Extension cost	Total
1984						184 000		184 000
1985						104 000		104 000
1986						104 000		104 000
1987	0.3	12 000			12 000	304 000	12 000	316 000
1988	0.3	12 000			12 000	266 000	12 000	278 000
1989	0.3	12 000			12 000	82 000	12 000	94 000
1990	0.3	12 000			12 000	82 000	12 000	94 000
1991	0.3	12 000			12 000	266 000	12 000	278 000
1992	0.3	12 000			12 000	128 000	12 000	140 000
1993	0.3	12 000			12 000	241 600	12 000	253 600
1994	1.0	40 000			40 000	241 600	40 000	281 600
1995	1.0	40 000			40 000	241 600	40 000	281 600
1996	1.0	40 000	4.0	100 000	140 000	142 400	140 000	282 400
1997	1.0	40 000	5.0	125 000	165 000	142 400	165 000	307 400
1998	1.0	40 000			40 000	142 400	40 000	182 400
Total	7.1	284 000	9.0	225 000	509 000	2 672 000	509 000	3 181 000

1. Foundation seed.

2. Certified seed.

Rates of return analysis

Applying the economic evaluation model developed by ACIAR, as described by Lubulwa and McMeniman (1998), the benefit from pigeonpea research projects in Thailand was estimated. Two simulations were made considering the unit cost savings reflected under the two cases (see Tables 7 and 8 and two cases presented in page 10).

Case 1: Unit cost saving by 4.3%, assuming an expected ceiling of adoption of 15% of study area in 2004;

Case 2: Unit cost saving by 8.4% and the expected ceiling of adoption of 15% of study area in 2004.

Furthermore, estimates of key parameters of the assessment model were made as follows:

- Base price of sugarcane of 600 baht per tonne
- Discount rate of 8%
- Supply elasticity of 0.75
- Demand elasticity of 0.75.

Considering the estimated adoption rates depicted in Figure 3, and total research and extension costs presented in Table 10, the net present value of benefits from pigeonpea research in Thailand is approximately 60 million baht in case 1 and 115 million baht in case 2. These represent an internal rate of return of 65% for case 1 and 82% for case 2. Noting that sugarcane farmers continued to apply chemical fertilizer along with green manuring pigeonpea, case 1 is considered as a more realistic case than case 2. Simulation of case 2, however, indicates the potential for higher benefits of using green manuring pigeonpea even without chemical fertilizer application.

Constraints to adoption

The survey provided valuable insights regarding the uptake of new technologies by farmers in northeastern Thailand. Feedback from farmers indicated utilization of pigeonpea for grain production and green manuring. Specific feedback on constraints to adoption from sugarcane farmers of Khon Kaen and Udon Thani are as follows:

For grain production:

- Pigeonpea grain is not preferred for domestic consumption.
- Insect problems present difficulties in producing pigeonpea grain in Thailand. The data collected from three years of on-farm field testing showed that the cost of insect control is up to 34% of total cost.

For green manuring:

- Nonavailability of pigeonpea seed;
- Information on utilization of pigeonpea for green manuring and seed multiplication does not reach farmers.

Conclusions and lessons for the future

This study has shown that there is a high potential for improving the welfare of sugarcane farmers through utilization of green manuring pigeonpea. This technology has been shown to enrich soil fertility in Thailand, particularly in the northeastern regions characterized by infertile soils, where organic matter is less than 1% in an area of 7.42 million hectares, representing 80% of the total agricultural area in that region.

Soil improvement has been the first priority for research and development by the LDD. Research at LDD and CMU indicates that among many green manuring crops, pigeonpea is accepted as one of the most appropriate crops in the uplands of northeastern Thailand. In addition, cultivation of pigeonpea as hedgerows in the sloping highlands enhances soil conservation. The pigeonpea leaves can be used as forage for animal feed, and the stems for fuel wood.

Further upscaling of the utilization of pigeonpea as a green manure crop as well as a green vegetable for local consumption will require new institutional arrangements to expand the delivery of critical information and inputs of this technology to farmers. Seed multiplication initiatives by the Seed Center of the Department of Agricultural Extension and Land Development Department remain critical. Collaborative efforts with Chiang Mai University, Khon Kaen University, the Department of Agriculture, Land Development Department and Department of Agricultural Extension should ensure the delivery and uptake of research and development generated technologies to farmers of northeastern Thailand.

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Appendix

Abstract of pigeonpea research at Khon Kaen Field Crops Research Center from 1984 to 1990

1984

1. Genotypic evaluation

A study on genotypic evaluation of pigeonpea in northeastern Thailand was carried out at Khon Kaen in 1984, when 19 cultivars were determined and classified into 2 groups; early-maturing cultivars (76-86 days) and medium-maturing cultivars (115-128 days). Grain yields of 3.9 t ha^{-1} and 3.8 t ha^{-1} were obtained from QPL 58 and ICPL 155, 43% higher than the local variety (NORMAN). *Maruca testulalis* and fusarium wilt caused grain yield reductions of 25%.

2. Population density (early-maturing cultivars)

The highest grain yields of 1.96 t ha^{-1} and 3.1 t ha^{-1} were obtained from Hunt and 412 with a density 200 000 plants ha^{-1} (50 × 10 cm). The mean annual rainfall in Khon Kaen over 10 years was 1200 mm, starting in February and ending in November with the peak of 240 mm in September.

3. Population density (medium-maturing cultivars)

A study on optimum density of medium-maturing cultivars (145-155 days), cv ROYES and ICPL 295, was carried out at Khon Kaen. Grain yields of ROYES did not significantly differ with the population densities between 100 000 to 200 000 plants ha^{-1} with an average of 2.0 t ha^{-1} .The highest grain yield of ICPL 295 was 3.2 t ha^{-1} with the density of 100 000 plants ha^{-1} at the planting date of late August, and 2.2 t ha^{-1} with the density of 200 000 fitted for the planting date in early October.

4. Serial sowing trial

A study on pigeonpea climatic adaptation was carried out at Khon Kaen using 17 varieties sown at 2 week intervals from August 1983 to August 1984. Among those NORMAN, HUNT, QPL 42, 412,

1605, ICPL 1, ICPL 6, ICPL 26, PANT-A 3 and TC-F 6-2-7 were photoinsensitive varieties. Seven photosensitive varieties (ROYES, C 322, BDN 1, ICPL 227, ICPL 265, ICPL 270 and ICPL 304) sown during late August to early January reached 50% flowering 70-90 days after emergence, but when sown during late January to April it required 170 to 280 days from emergence to reach 50% flowering.

1985

1. Genotype × sowing time trial

This study was carried out at Khon Kaen (KK), Ubon Rachatanee (UB), Chiang Mai (CM) and Rayong (RY) in 1985, using pigeonpea varieties QPL 17, QPL 42, QPL 130, QPL 58 and HUNT. Three plantings were done at monthly intervals, beginning in mid June at KK, UB and in late May at CM and RY. Planting in mid July at KK and UB and planting in late June at CM and RY gave the highest grain yields. QPL 130 gave the highest grain yields of 2.3 and 3.7 t ha^{-1} at UB and CM, QPL 58 gave 1.6 t ha^{-1} at KK and QPL17 gave 1.32 t ha^{-1} at RY. HUNT produced the lowest grain yield of 1.37 t ha^{-1}. The mean of this experiment was 1.66 t ha^{-1}.

2. Population density

Early-maturing cultivars, HUNT and QPL 42, were grown at Khon Kaen using three population densities: 160 000, 330 000 and 660 000. Days to flowering, maturities (113 days) and grain yields did not differ among densities. QPL 42 gave a higher grain yield than HUNT (1.2 t ha^{-1}) compared with HUNT 0.96 t ha^{-1}.

Medium-maturing cultivars, ROYES and ICPL 265, were grown at Khon Kaen using three population densities: 50 000, 100 000 and 200 000: The densities of 100 000 and 200 000 gave higher grain yields than that of 50 000. Days to flowering and maturity (167 days) did not differ among densities. ICPL 265 was less damaged by insects and diseases than ROYES.

1987

1. Preliminary yield trial (early cultivars), group I

Eighteen pigeonpea cultivars were sown in a field trial at Khon Kaen in the late rainy season of 1987. The highest yielding cultivars (>2 t ha^{-1}) were ICPL 86008, ICPL 83009 and QPL 1070. The 100-seed masses ranged from 8.92 g (QPL 1086) to 13.30 g (QPL 1082). ICPL 83009 showed the outstanding determinate type and nonshattering characteristic. Days to maturities ranged from 125 to 138 days.

2. Preliminary yield trial (early cultivars), group II

Ten pigeonpea cultivars (135 days) were sown in a field trial at Khon Kaen in 1987. ICPL 8324 gave the highest grain yield of 2.4 t ha^{-1}, 43% higher than HUNT (control). The 100 seed masses ranged from 5.8 g (ICPL 4) to 15.2 g (ICPL 8324).

3. Preliminary yield trial (pest resistance)

Nine medium-maturing pigeonpea cultivars (196 days) were evaluated without pest control at Khon Kaen in 1987. ICPL 332 (*Heliothis*-resistant line from ICRISAT) gave the highest grain yield (2.1 t ha^{-1}), 86% higher than ICPX 79083-NDT 2 (a susceptible line). ICPL 265, which was the high-yielding cultivar under pest control, produced 1.5 t ha^{-1} of grain yield. However, the insect population that year was not serious.

4. Standard yield trial

Fourteen early pigeonpea cultivars were compared in field trials at four locations. Grain yields ranged from 1.2 t ha^{-1} in cv OPL 566 to 1.8 t ha^{-1} in cv QPL 17 at Khon Kaen, from 0.5 t ha^{-1} in cv QPL 734 to 1.4 t ha^{-1} in cv QPL 652 at Ubon, from 0.3 t ha^{-1} in cv QPL 42 to 0.9 t ha^{-1} in cv QPL 702 at Rayong, and from 0.7 t ha^{-1} in cv QPL 58 to 1.1 t ha^{-1} in cv QPL 827 at Chiang Mai. QPL 637 was the highest-yielding cultivar on average of four locations (1.2 t ha^{-1}) and was a well-adapted cultivar.

5. Standard yield trial (pest resistance)

Eight medium pigeonpea cultivars (188 days) were evaluated under pest control at the economic level. ICPL 265 which gave 1.9 t ha^{-1} of grain yield did not significantly differ from ICPL 332 (*Heliothis*-resistant line), 1.85 t ha^{-1}. ICPX 79083-NDT 2 (susceptible line) gave the lowest grain yield of 1.2 t ha^{-1}.

6. Standard yield trial (vegetable pigeonpea)

Six pigeonpea cultivars (107-139 days) were tested in field trials at three locations. Fresh pod yields ranged from 5.5 t ha^{-1} in cv ICPL 211 to 8.25 t ha^{-1} in cv ICPL 8324 at Khon Kaen, from 1.22 t ha^{-1} in cv ICPL 7035 to 1.88 t ha^{-1} in cv ICPX 79083-NDT 2 at Rayong, and from 2.67 t ha^{-1} in cv ICPL 211 to 3.96 t ha^{-1} in cv ICPL 7035 at Chiang Mai. ICPL 7035 was suitable for fresh pod consumption based on edible quality and high fresh pod yield on the mean of three locations (3.96 t ha^{-1}).

7. Fertilizers

In a field trial at Khon Kaen in 1987, pigeonpea cv QPL 42 was grown on infertile soil (OM = 0.36%, available P = 13 mg kg^{-1} and exchangeable K = 20 mg kg^{-1}). Nine treatment combinations of 3 rates of P and K (37, 56 and 75 kg ha^{-1}) were applied. Grain yields increased with P applications from 1.56 t ha^{-1} up to 1.83 t ha^{-1}. Increasing K increased seed size and grain yield. Both P and K had no effect on days to 50% bloom, plant height or plant dry weight at 100 days after sowing.

1988

1. Fertilizers

In a field trial at Khon Kaen in 1988, pigeonpea cv ICPL 83024 was grown on infertile soil (OM = 0.37%, available P = 7.5 mg kg^{-1} and exchangeable K = 10.0 mg kg^{-1}). Sixteen treatment combinations of four rates of P and K (0, 37, 56 and 75 kg ha^{-1}) were used. Grain yields increased from 1.18 t ha^{-1} with no P application up to 1.57 t ha^{-1} when applied with P at 37 kg ha^{-1} and from 1.16 t ha^{-1} with no fertilizer application up to 1.62 t ha^{-1} when applied with K at 37 kg ha^{-1}. Increasing K increased seed size, but both P and K had no effect on days to flowering, days to maturity and plant height.

2. Population density (green manure)

An indeterminate pigeonpea cv ICPL 270 (173 days) was sown with 3 densities (60 000, 80 000 and 100 000 plants ha^{-1}) at Khon Kaen in 1988. Grain yields did not differ significantly among densities with a mean of 2.25 t ha^{-1}. With the densities 60 000, 80 000 and 100 000 plants ha^{-1} produced 25.8, 27.0 and 24.7 tonnes dry matter ha^{-1} respectively. For seed cost saving, the optimum plant density for green manure was 60 000 plants ha^{-1}.

3. Regional yield trial

Twelve pigeonpea cultivars were compared in field trials at four locations. The highest yielding cultivars were QPL 637 (1.86 t ha^{-1}) at Rayong, QPL 702 (2.41 t ha^{-1}) at Chiang Mai, QPL 652 (1.76 t ha^{-1}) at Ubon and ICPL 86008 (2.67 t ha^{-1}) at Khon Kaen. QPL 637 gave the highest grain yield of 2.0 t ha^{-1} as a mean of four locations.

4. Locational yield trial

Eight medium and four early pigeonpeas were sown at Khon Kaen in 1988. ICPL270 gave the highest yield of 1.85 t ha^{-1} (170 DAE), ICPL 151 harvested at 130 DAE was the highest yielding cultivar among early pigeonpea (1.40 t ha^{-1}). Plant heights ranged from 1.4–1.7 m among medium cultivars and 0.90–1.20 m among early cultivars.

5. Field test

In a field test in 1988, QPL 42 was sown with a density of 300 000 at two locations in Khon Kaen. Grain yield on the average of two locations was very low (0.8 t ha^{-1}) due to damage by *Maruca (testulalis) vitrata* (Geyer) *and Helicoverpa (Heliothis) armigera* (Hübner) in the flowering period. Farm costs were high, up to 15 708 baht ha^{-1}, with 33% of total cost being insecticide applications.

1989

1. Field test

In a field test in 1989, QPL 42 was sown with a density of 400 000 plants ha^{-1} at two locations in Khon Kaen. Grain yield harvesting at 133 DAE for the mean of two locations was 1.97 t ha^{-1}. Farm cost was 15 347 baht ha^{-1}, 34% of total cost being insecticide applications.

1990

1. Field test

In a field test in 1990, ICPL 83009 was sown with densities of 300 000 and 400 000 plants ha^{-1} at two locations in Khon Kaen. Grain yield harvesting at 131 DAE for the mean of two locations was 1.33 t ha^{-1} and did not differ among densities. Farm cost was 14 580 baht ha^{-1}, 30% of total cost being insecticide applications.

Cost of pigeonpea (baht ha^{-1}) in field tests at Khon Kaen from 1988 to 1990.

	1988	1989	1990
Land Preparation	875.00	875.00	875.00
Plow	500.00	500.00	500.00
Harrow	375.00	375.00	375.00
Labor Cost	7 359.38	7 265.63	6937.50
Sowing	1500.00	1 250.00	1 250.00
Herbicide application	234.38	130.21	250.00
Fertilizer application	1 500.00	1 458.33	1 125.00
Weeding	2 250.00	1 093.75	1 125.00
Insecticide spraying	937.50	1 302.08	937.50
Harvesting	750.00	1 458.33	1 500.00
Threshing	187.50	572.92	750.00
Material Cost	7 474.00	7 207.00	6 768.00
Seed	250.00	468.00	250.00
Fertilizer N	350.00	350.00	350.00
P	1 187.00	1 187.00	1 187.00
K	437.00	437.00	437.00
Herbicide	1 063.00	885.00	1 063.00
Insecticide	4 187.00	3 880.00	3 481.00
Total (baht ha^{-1})	15 708.38	15 347.63	14 580.50

About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the semi-arid tropics. ICRISAT's mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.