

Present status of production and marketing of papaya for unripe consumption in Northeastern Thailand

Rapatsa Janthasri* and Wiwat Chaiyaboon

School of Agricultural Technology, Maha Sarakham Rajabhat University, 80 Nakhonsawan Road, Mueang Maha Sarakham, Thailand 44000

*Corresponding author: juntasri@hotmail.com

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Abstract

A questionnaire-based survey was made of 800 papaya growers in 8 provinces in northeastern Thailand in January to December 2014. The results showed that most of the growers were female, aged over 30, and educated to primary school level. They had an average of 11-15 years experience growing papaya. Most (72%) grew papaya on mixed plantations. Larger monocrop plantations were found mainly in Kalasin and Mukdahan Provinces. Both household and hired labor was used. The most popular cultivars were 'Khaeg Nuan' and 'Yellow Krang.' Most farmers saved their own seed and propagated papaya by seed, starting in plastic bag containers. A planting space of 1.7 × 1.7 m was commonly used on large plantations while on some of the mixed farms a wider planting space of 2 × 2 to 3 × 3 m was used. Most farmers used both chemical and organic fertilizer and over 75% relied on rain water for irrigation. They used both mechanical and chemical methods for weed control and pest control. The pest problems reported were red spider mites, aphids, mealy bugs, coccids, worms and snails. The most serious disease problem was Papaya Ring Spot Virus. As for production costs, in the pre-harvest period land rental accounted for the greatest proportion of costs for small-scale farmers and labor accounted for the least proportion of costs. During the harvest period, the highest costs for small-scale farmers were for the irrigation system, and the lowest were for chemical fertilizer. The large-scale farmers had the highest overall costs for chemical fertilizer. In all 8 provinces surveyed, the majority of growers (88%) sold their papaya in unripe form and none of them sold papaya to factories for processing. The prices paid to farmers for papaya were the highest in January, April and November and the lowest in July, February and August. Farm gate prices were higher in Kalasin and Nakhon Ratchasima than in the other provinces.

Highlights

- The majority of farmers surveyed grew papaya as part of an integrated farming system
- Most of the farmers are middle-aged and there appears to be a shortage of younger generations continuing in the farming business
- There is considerable seasonal variation in the prices paid to farmers for unripe papaya
- The Papaya Ring Spot Virus epidemic is a continued threat in this growing area

Keywords: *Carica papaya*, monoculture, mixed farming system, fruit production practice, farm produce marketing

Papaya (*Carica papaya*) is an important economic fruit crop of Thailand. Annual production in Thailand was about 215,000 tons in 2013 but has been generally declining since 2001 due to the outbreak of Papaya Ring Spot Virus. Thailand is ranked as the eighth largest papaya producer in

the world, and production still lags far behind the major producing countries, such as the world's largest producer, India, which produced more than 5,544,000 tons in 2013 (Factfish 2014). In fact, papaya production in India has been increasing as more farmers diversify from rice and other crops to papaya (Maske, 2013).



People in Southeast Asian countries tend to consume papaya most frequently in its unripe form, as a vegetable ingredient, rather than a table fruit. Although of South American origin, papaya (*Carica papaya*) has long been grown in Thailand until it has been closely integrated into the culinary tradition in most parts of the country. In its unripe form, green papaya is of particular importance to the cooks of the northeastern region as they use it to make the perennially popular spicy salad called “*som tam*,” a staple dish of most northeastern Thai households that is also popular with consumers throughout the country. Demand for papaya in the domestic market has risen steadily as it is not only consumed fresh but also utilized in the textile and tanning industries and as an ingredient in many chili sauce products produced on a commercial scale (Janthasri 2007). The Yellow Krang and Red Krang cultivars grown in Maha Sarakham Province and the Khaeg Nuan cultivar grown in Kalasin are especially in demand from som tam vendors because the flesh is crispy and tastes good when unripe compared to other cultivars. The 4 major papaya production centers in northeastern Thailand are in Pak Chong District in Nakhon Ratchasima Province, Kantaralak District in Si Saket Province, Lerng Nok Tha District in Mukdahan Province and Tha Phra District in Khon Kaen Province. These areas still cannot produce enough papaya to meet the demand for consumption in the northeastern region, so papaya is brought in from the central and southern parts of the country. The number of farmers producing papaya in the northeast has also dropped due to the Papaya Ringspot Virus (PRSV) epidemic (Janthasri 2004). PRSV has had a major impact on the amount of papaya produced in Thailand and has also affected industries that use papaya as a raw materials.

Most of the research done on papaya in Thailand has focused on breeding programs (Janthasri *et al.* 2007), technology and management methods to increase production, and disease control methods. Comparative data on production area, production methods, and the market system in different parts of the country have not been systematically collected. The objective of this research was to study the status of papaya production and marketing for unripe papaya consumption in northeastern Thailand, covering the 8 provinces of Roi Et, Maha

Sarakham, Khon Kaen, Kalasin, Si Saket, Sakon Nakhon, Mukdahan and Nakhon Ratchasima. The data should be useful for farmers, extension workers and policymakers in planning and developing sustainable papaya production in the future.

Materials and methods

Extent of the survey

A meeting was held with field researchers and local agricultural extension officials to designate the study areas and plan the data collection. The target areas were districts where papaya is grown to be sold in its unripe form.

Survey method

Production data were collected in the study areas in the 8 provinces of Roi Et, Maha Sarakham, Khon Kaen, Kalasin, Si Saket, Sakon Nakhon, Mukdahan and Nakhon Ratchasima, comprising data on the cultivars planted, seed selection method, production system (planting seeds, transplanting, maintenance, fertilization, irrigation, weed control, disease control, pest control, harvesting and marketing) and problems faced by the farmers as well as the solutions they found. A questionnaire was used to collect the data.

Demographic data on the farmers were collected using both questionnaires and an interview form.

A market survey was done, also using a questionnaire, to collect data on sales of ripe and unripe papaya, grading, price setting, packaging, processing, place of sale, transportation, annual sales volume, and payment methods.

Fruit quality analysis

To assess papaya quality, 2 sets of samples were taken. First, for both unripe and ripe papaya, one specimen of each cultivar was randomly selected from one farm in each district. Second, for unripe papaya only, 3 specimens about 2 months old were taken of each cultivar from every farm. Data were recorded on fruit weight, shape, peel color, flesh thickness, flavor, and consumer preference, rated by having 100 random som tam customers/som tam vendors rate the unripe fruit's taste on a scale of 1 to 5.

Statistical analysis

All the data (farmer demographics, production data, fruit quality data and market survey data) were statistically analyzed by SPSS.

Results

Farmer demographics

Data were collected from a sample of 800 farmers, 100 from each province. The 100 farmers in Roi Et came from 15 sub-districts in 4 districts. The 100 farmers in Kalasin came from 20 sub-districts in 2 districts. The 100 farmers in Maha Sarakham came from 16 sub-districts in 3 districts. The 100 farmers from Khon Kaen came from 11 sub-districts in 6 districts. The 100 farmers from Mukdahan came from 4 sub-districts in 2 districts. The 100 farmers in Si Saket came from 6 sub-districts in 3 districts. The 100 farmers in Nakhon Ratchasima came from 6 sub-districts in 4 districts. The 100 farmers in Sakol Nakhon came from 4 sub-districts in 1 district.

In every province except Si Saket, the majority of farmers were female (Table 1). Most of the papaya farmers in the 8 provinces surveyed were in the age range of over 30. In the provinces with the most commercial papaya production (Mukdahan and Kalasin), most of the farmers were in the 30-49 age

group (36.71% and 28.91%, respectively), followed by the over 50 group. No farmers in the less-than-30 age group were found in any of the provinces surveyed (Table 1).

Most of the farmers (91.51%) were educated to primary school level. Only 7.60% were educated to secondary school level and 0.89% to post secondary school level. Bachelor's degree was the highest education level recorded. The largest number of farmers surveyed said they had 11-15 years of experience growing papaya (48.21%). The least number had less than 5 years experience (2.74%). None of the farmers in Kalasin or Mukdahan provinces had less than 5 years experience. In all 8 provinces the minimum number of years experience reported was 2 years experience and the maximum was 25 years experience (data not shown).

About half (49.53%) of the farmers surveyed grew papaya as their main occupation. The vast majority (72.19%) planted papaya along with other crops in mixed plantation systems, while 27.81% grew only papaya. The labor used in papaya production included both household labor and hired labor. Of the farmers in this survey, 79.54% reported using one or two household laborers and 20.46% used more than two laborers (data not shown).

Table 1: Sex and age range of papaya farmers in the 8 provinces of the study area

Sex/Age	Roi Et Province (%)	Kalasin Province (%)	Maha Sarakham Province (%)	Khon Kaen Province (%)	Si Saket Province (%)	Mukdahan Province (%)	Sakon Nakhon Province (%)	Nakhon Ratchasima Province (%)
Sex								
-Male	30	14	41	44	63	34	48	32
-Female	70	86	59	56	37	66	52	68
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Age								
≤ 30 years	-	-	-	-	-	-	-	-
30-49	77	68	19	30	21	81	12	44
≥ 50 years	23	32	81	70	79	19	88	56
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Production system data

The cultivars that most of the farmers grew were Khaeg Nuan (52.18%), Yellow Krang (19.69%), Red

Krang (18.43%) and Khaeg Dam Damnern (9.70%). One hundred per cent of the farmers in Kalasin and Mukdahan, and most of the farmers in the other provinces, collected their own seed for each



subsequent crop. Almost all (99.85%) produced their own seedlings. Most (89.48%) planted seeds in plastic bags filled with planting material and transplanted the seedlings to the field when they were big enough, but 10.52% planted the seeds directly in the field.

Large monoculture plantations growing exclusively papaya were found in Kalasin and Mukdahan provinces. In all the other provinces, most farmers grew papaya along with other crops in mixed farming systems. In the monoculture plantations, a planting space of 1.7×1.7 was generally used in order to maximize production per unit area. In the mixed farming systems the planting space was also less than 2×2 meters on 86.21% of farms but was 2×2 or 3×3 meters on some.

Most of the farmers in the study area (75.49%) relied exclusively on rainwater for growing papaya. On the commercial plantations, mini sprinkler systems were used for irrigation about once a week starting in late November. The farmers applied fertilizer at three stages-- before planting, during fruiting and after planting-- using organic fertilizer, chemical fertilizer or a mixture of both. The most common practice in all 8 provinces was to use a mixture of organic and chemical fertilizer before planting (65.62%) and during fruiting (34.38%) and all of the farmers (100%) used organic fertilizer in the period after planting. The organic fertilizer used was mainly chicken manure.

Most of the farmers (86.94%) used a combination of mechanical and chemical weed control methods, while 7.10% used only mechanical weed control and 5.96% used only herbicide.

The pests most commonly found in the study area were red spider mites, aphids, mealy bugs, coccids, worms and snails. Most of the farmers (80.41%) used a combination of mechanical and chemical pest control methods, while 5.27% used only mechanical pest control and 14.32% used only chemical pest control.

The most common disease encountered in the study area was PRSV. Most of the farmers (74.61%) did not use any PRSV protection methods but simply allowed it to spread throughout the plantation and then destroyed all the trees, to be replaced with new seedlings. Another 12.04% of farmers said they used chemical control methods, while 13.35% said they used a mixed method.

Production costs

Average production costs per month on monoculture plantations with no raised berms were divided into pre-harvest costs and during harvest costs. In the pre-harvest period, farmers said the largest proportion of their costs were for the factors of fertilizer, chemicals, labor and land rent. Land rent costs were usually the highest, but varied each year. In the period when the papaya trees were producing fruit for harvest, fertilizer, chemicals and labor costs constituted the greatest proportion of the farmers' costs. The lowest expenditure was for water costs, because virtually every plantation in the study area had access to water from natural sources such as ponds or underground water.

Average production costs per month on mixed plantations with no raised berms were divided into pre-harvest costs (for the first 5 months) and during harvest costs (for the next 13 months of the one-and-a-half-year production cycle). Irrigation costs accounted for the greatest proportion of pre-harvest costs and labor costs accounted for least, because most mixed farming systems relied primarily on (unpaid) household labor. The mean production costs per month in the pre-harvest period were 941 baht in Roi Et, 980 baht in Si Saket, 1,340 baht in Sakon Nakhon, 1,512 baht in Maha Sarakham, 2,210 baht in Khon Kaen, 2,300 baht in Nakhon Ratchasima, 4,560 baht in Kalasin, and 5,600 baht in Mukdahan. In general, mixed farms used less chemical inputs than monoculture farms did. During the harvest period, fertilizer accounted for 65.19% of costs while other chemicals accounted for 18.73% and fuel accounted for 16.08%. In the period when fruits were being harvested, fertilizer costs accounted for the lowest proportion of the cost. On mixed plantations during the harvest period, the lowest reported monthly cost was 540 baht and the highest was 5,820 baht. In general, farmers' costs were higher during the harvest period than during the pre-harvest period, because when the papaya trees grew larger they required more fertilizer and more input to control pests and diseases.

Table 2 shows the mean production costs in each province during one 18-month production period, divided into costs for land preparation, seeds/seedlings, irrigation, fertilization, chemicals, labor, fuel and land rent. The highest production costs were reported in Kalasin Province (547,500 baht),



Table 2: Average cost of production in 8 provinces (per 18-month crop cycle)

Activity	Roi-Et		Kalasin		Maha Sarakham		Khon Kaen		Si Saket		Mukdahan		Sakon Nakhon		Nakhon Ratchasima	
	Cost (baht)	(%)	Cost (baht)	(%)	Cost (baht)	(%)	Cost (baht)	(%)	Cost (baht)	(%)	Cost (baht)	(%)	Cost (baht)	(%)	Cost (baht)	(%)
- Land preparation	2,600	10.66	20,000	3.65	2,000	2.27	15,000	11.67	4,000	19.7	38,000	8.18	5,000	10.02	15,000	8.90
- Seeds/seedlings	1,000	4.10	-	-	5,000	5.68	10,000	7.78	3,000	14.78	-	-	2,000	4.01	3,000	1.78
- Irrigation	1,500	6.15	4,500	0.82	42,000	47.68	30,000	23.35	4,800	23.65	22,500	4.84	10,900	21.84	20,500	12.17
- Fertilization	2,900	11.90	400,000	73.06	10,900	12.38	56,900	44.28	5,000	24.63	300,000	64.59	5,000	10.02	60,000	35.61
- Chemicals	890	3.64	32,000	5.84	16,690	18.94	9,600	7.47	500	2.46	54,000	11.63	20,000	40.08	25,000	14.84
- Labor	3,000	12.30	7,000	1.27	5,000	5.68	3,000	2.34	2,000	9.85	12,000	2.58	4,000	8.02	9,000	5.34
- Fuel/oil	500	2.05	24,000	4.38	2,000	2.27	4,000	3.11	1,000	4.93	18,000	3.88	1,000	2.00	6,000	3.56
- Land rent	12,000	49.20	60,000	11.00	4,500	5.10	-	-	-	-	20,000	4.30	2,000	4.01	30,000	17.80
Total	24,390	100	547,500	100	88,090	100	128,500	100	20,300	100	464,500	100	49,900	100	168,500	100



followed by Mukdahan (464,500 baht) and Nakhon Ratchasima (168,500 baht). The lowest production costs were reported in Si Saket Province (20,300 baht). The highest land rent cost (49.20% of total costs) was reported in Roi Et Province, while farmers in Khon Kaen and Si Saket did not have land rent costs. The highest costs for chemical fertilizer were reported in Kalasin Province (400,000 baht), followed by Mukdahan (300,000 baht), Nakhon Ratchasima (60,000 baht), and Khon Kaen (56,900 baht). In these areas, papaya was mainly grown intensively in large plantations. The farmers in Kalasin and Mukdahan did not report any seed or seedling costs because they produced all their own seedlings from seeds they collected themselves.

Papaya fruit quality

Most of the farmers surveyed sold all their papaya in unripe form, but some of the farmers in Roi Et, Khon Kaen, Sakon Nakhon and Maha Sarakham sold both ripe and unripe papaya. When asked if the papaya fruits they produced were true-to-type, the majority of farmers said they matched from 2 to 5 of the 5 points given for the description of the cultivar (green petiole, leaves with 7-11 lobes, rod-shaped fruit, with light yellow flesh when unripe). The largest number (38.75%) said their fruits matched 2 of the standard cultivar characteristics.

As for fruit size, most of the fruits (63.18%) were classed in the 500-999 grams category. The largest mean fruit size was 1,240 g and the smallest mean fruit size was 370 g. Fruits from hermaphrodite flowers were elongated, pear-shaped or rod shaped. The most common fruit shape was elongated; 52.08% of the sample fruits analyzed (Khaeg Dam, Yellow Krang, Red Krang and Khaeg Nuan cultivars) were

of elongated shape and the fewest (20.32%) were rod shaped. The peel color of most of the unripe papaya was dark green (39.84%), followed by light green (37.79%) and medium green (22.37%). The flesh color of unripe papaya was mainly whitish-yellow to medium yellow (46.41%), followed by clear-transparent white (25.61%), opaque white (18.24%) and light yellow (9.74%). The crispiness of unripe fruits in 5 provinces (Roi Et, Sakon Nakhon, Mukdahan, Nakhon Ratchasima and Si Saket) was mainly classified as “medium crispy,” while fruits with “very crispy” flesh were found in Kalasin, Khon Kaen and Maha Sarakham. In Roi Et, Sakon Nakhon, Khon Kaen, Nakhon Ratchasima, Si Saket and Maha Sarakham, 87.26% of the fruits had flesh that was 1.0-1.5 cm thick on average. Fruits with thicker flesh in the range 2.5-3.0 cm were found in some of the fruits (12.74%) from Kalasin and Mukdahan (data not shown).

Market and processing data

In most of the study area, 88.21% of the papaya was sold in unripe form. In Roi Et, Maha Sarakham, Khon Kaen, Si Saket and Sakon Nakhon, about 5.38% of the papaya was sold as ripe papaya. None of the farmers surveyed sold ripe papaya to factories for processing. Large-scale or small-scale middlemen came to buy the fruits at the plantations every day.

The price paid for papaya varied every month. The highest average price was 9.3 baht/kg in January, followed by 8.6 baht/kg in April and 7.4 baht/kg in November. The lowest prices were paid in July, August and February (1.9, 2.4 and 2.9 baht/kg, respectively). The highest prices were paid in Kalasin and Nakhon Ratchasima Provinces (Table 3).

Table 3: Farm gate prices paid for unripe papaya (Yellow Krang and Khaeg Nuan cultivars) in northeast Thailand by month

	Province/month												Mean
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	
Khon Kaen	.0	2.0	2.0	8.0	5.0	3.0	2.0	2.0	3.0	5.0	7.0	6.0	4.9
Kalasin	17.0	4.0	4.5	10.0	6.0	4.0	2.0	2.5	4.0	8.0	10.0	9.0	6.8
Maha Sarakham	2.0	2.5	2.0	7.0	5.0	4.0	1.0	2.0	3.0	7.0	8.0	7.0	5.0
Roi Et	10.0	1.5	1.0	8.0	5.0	3.0	1.5	2.0	3.0	5.0	7.0	7.0	5.5
Mukdahan	4.0	3.0	4.0	10.0	5.5	3.0	2.	3.5	3.5	8.0	10.0	9.0	5.5
Si Saket	5.0	2.0	3.0	7.0	4.0	2.5	1.5	2.0	3.0	7.0	7.0	8.0	4.3
Sakon Nakhon	8.0	3.0	3.0	5.0	5.0	3.5	2.0	2.0	3.0	5.0	5.0	7.0	4.3
Nakhon Ratchasima	15.0	5.0	5.0	14.0	10.0	3.0	3.0	3.0	2.0	5.0	5.0	5.0	6.3
Mean	9.3	2.9	3.1	8.6	5.7	3.3	1.9	2.4	3.0	6.3	7.4	7.3	



Market patterns

Three major pathways for marketing papaya in northeastern Thailand were identified. 1) Papayas brought into the study area from Loeng Nok Tha District, Yasothon Province, were distributed through Phanwee Fresh Market in Mueang District, Roi Et Province, to different districts in Roi Et and Kalasin Provinces. However, most consumers in the area acquired papaya from local growers at a stable price. 2) Farmers of Huai Phueng District and Khao Wong District in Kalasin Province produced a large amount of unripe papaya that was distributed to buyers in Khon Kaen, Udon Thani and Maha Sarakham Provinces. Some of the papaya in the main markets of Kalasin Province also came from farms in Sakon Nakhon Province. At the same time, markets in Kalasin, Yasothon and Maha Sarakham also sold ripe papaya that was transported in from Nakhon Pathom and Ratchaburi Provinces in the central region of Thailand. 3) Wholesalers aggregated unripe papaya from growers in Si Sa Ket Province with those from farms in Pak Chong District in Nakhon Ratchasima to take them to Talad Tai wholesale market in Rangsit District, Pathum Thani (a suburb of Bangkok) to distribute to the Bangkok market.

Discussion

One interesting finding of our survey was that 61.75% of the papaya farmers surveyed were female. The gender distribution was the most markedly skewed in Kalasin Province, where 86% of the papaya farmers were female. There were more female than male papaya farmers in every province surveyed with the exception of Si Saket, where only 37% were female. Similarly, a survey by Janthasri and Arimatsu (2010) on the status of papaya production in the 3 provinces of Kalasin, Roi Et and Maha Sarakham, found that 67.60% of papaya growers were female and only 32.40% male. The reason that more of the papaya farmers were female than male is probably because papaya growing was only a sideline occupation for the families. Most of the work involved is not extremely strenuous, so the male members of the household would mostly grow rice or work as hired laborers and would only help the women with the papaya plantation when extra workers were needed for fertilizing, irrigation, weeding and harvest. The prevalence of

women may not be very exceptional for Asia, where women tend to play a large role in the agriculture sector, although in developing countries overall the Food and Drug Administration found that women account for only 43% of the agricultural labor force (FAO, quoted in Villarreal 2013). By comparison, Paul *et al.* (2015) found that in integrated farming systems in Tripura, India, men tended to handle most of the land preparation work (84% male labor), irrigation (78% male labor), application of fertilizer and pesticide (94% male labor), and marketing of produce (84% male labor), while women contributed mainly to care of livestock along with weeding (82% female labor) and harvesting (80% female labor). In contrast, Stone, Netting and Stone (1990) reported that in the Benue Valley region of Nigeria, the male/female division of farming labor was readily interchangeable and particular farming tasks or crops were not rigidly assigned to a single sex.

As more generations of young people opt for jobs in cities or the industrial sector, the aging of the farming population has become an issue of concern in most parts of the world. For instance, Zagata *et al.* (2015) reported that the average age of farmers in the European Union is increasing due to the minimal presence of younger entrepreneurs in the agricultural sector. Our survey confirmed this trend, as we found that 44.0% of the farmers surveyed were in the 30-49 age group (with a high of 81% in Mukdahan and a low of 12% in Sakon Nakhon) while 56% were in the 50 and over age group. Significantly, none of the farmers surveyed were in the under 30 age group. The previous survey of Kalasin, Roi Et and Maha Sarakham Provinces by Janthasri and Arimatsu (2010) revealed that 63.60% of the papaya farmers surveyed were in the 30-49 age group and 36.40% were in the 50 and over age group. Similarly, in a survey of 105 mixed system farmers in Nan Province, Thailand, Kunsit (1999) found that all of the samples (100%) were in the 40-50 year age range.

Our data show that most papaya production relies on household labor more than hired labor. This is consistent with the results of the smaller survey by Janthasri and Arimatsu (2010) on the status of papaya production in the 3 provinces of Kalasin, Roi Et and Maha Sarakham, which also found that 87.60% of the farms used 1-2 household workers and only 12.40% used more than 2 workers. In



the present study, we also found that in Maha Sarakham, Roi Et, Khon Kaen, Si Saket, Sakol Nakhon and Nakhon Ratchasima, in many villages whole family clans would group together to produce papaya. In that case, they would pool their labor to join in weeding and harvesting together. Similar examples of community work pooling can be found in other countries. For example, Stone, Netting and Stone (1990) made a survey of farming labor input throughout the year in the Kofyar community in Nigeria and found that household labor was supplemented by assistance from large work groups of neighbors who were recompensed with millet beer provided by the host household. The Kofyar believed that such exchanges were more cost effective and insured higher quality work than hiring unknown outside laborers (Stone, Netting and Stone 1990).

One salient feature of the papaya production conditions we found in Northeast Thailand was that most of the farmers surveyed produced papaya along with other crops in mixed plantations, although some large, monoculture plantations growing exclusively papaya were found in Kalasin and Mukdahan Provinces. Mixed cropping allows papaya farmers to make the best use of the land (Janthasri and Janthasri, 2005), helps reduce financial risk, and reduces the spread of the PRSV epidemic. The farmers in our survey area were able to harvest green papaya for a long period of 18-24 months. This is consistent with the results of the smaller survey by Janthasri and Arimatsu (2010) on the status of papaya production in the 3 provinces of Kalasin, Roi Et and Maha Sarakham, which also found that only 24.00% of the farmers grew papaya as a monocrop and only 16.80% considered papaya growing their primary occupation, while 76.00% grew papaya along with other crops in mixed plantations. The advantages of mixed cropping and integrated farming to farmers are many. Integrated farming systems have been shown to be capable of delivering both higher average net returns and higher benefit to cost ratio, as demonstrated by Desai et al at the University of Agricultural Sciences, Raichur, Karnataka, India, where an experimental integrated farming system gave better financial returns in contrast to a conventional farming system growing cotton as a monocrop (Desai *et al.* 2013).

In more intensive commercial papaya plantations,

a planting space of 1.7×1.7 was generally used in order to maximize production per unit area and to create more dense leaf coverage, which helps reduce the need for labor costs involved with weeding, since not much sunlight can reach the earth underneath and between the trees. In the mixed farming systems a wider planting space was sometimes used, which theoretically allows each tree to grow larger due to reduce competition for water and nutrients.

Most of the farmers surveyed utilized both chemical and organic fertilizers and counted chemical fertilizer as one of their significant input costs. The organic fertilizer used was mainly chicken manure, because it was easily available and cheap. Many farmers believed that cattle or water buffalo manure would cause Papaya Ring Spot Virus. They used only dry chicken manure, because if it was moist it would have an unpleasant odor would and attract too many flies. This is consistent with the results of the smaller survey by Janthasri and Arimatsu (2010) on the status of papaya production in the 3 provinces of Kalasin, Roi Et and Maha Sarakham, which also found that most growers used a combination of both chemical and organic fertilizer. The use of organic fertilizer is not only environmentally friendly, but also promises substantial cost-benefit savings. For instance, farmyard manure application was found to improve the fruit quality of lemon (Savreet and Bal, 2016).

The most common disease encountered in the study area was PRSV. This is not surprising because the PRSV epidemic is one of the most serious problems facing papaya growers in Southeast Asia. Janthasri and Arimatsu found in their survey of the papaya growing situation in Kalasin, Roi Et and Maha Sarakham provinces (Janthasri and Arimatsu, 2010) that PRSV was the most prevalent disease. The farmers in that area mainly combated it by cutting down and disposing of the diseased plants. It was observed that PRSV was less of a problem in papaya plantations that were located far from residential communities and were surrounded by forest or by sugar cane, cassava or banana plantations. It is possible that PRSV does not spread easily to more remote plantations because the aphid vectors might clean the virus from their stylets by feeding on other plants before reaching the papaya plants (Yimsawat, 1995). A cause for concern is that global warming



may make aphid-spread plant diseases an even more serious threat to farmers. Ayyogari et al (2014) reported that climate change may enable insects with short life cycles such as aphids to reproduce more quickly and increase their populations at a higher rate.

Papaya is an open pollinated crop, which may bring about genetic variation. The largest number of farmers in this survey (38.75%) reported that the fruits from their seed-grown papaya matched at least 2 out of 5 of the characteristics of the original cultivar. In general, for papaya fruits that were sold unripe, the buyers did not pay much attention about whether or not the fruits were true-to-type. Normally most of the fruits sold unripe are either Khaeg Nuan cultivar or Krang cultivar, and they are generally grown in separate areas where the risk of cross pollination is minimal compared to papaya plantations in the central region of Thailand, where a larger number of different cultivars are grown.

Almost all the farmers in the present research (99.85%) produced their own seedlings. The major reason that most farmers kept their own seed is that papaya seed is expensive, and a large amount of seed is required for each crop. They chose trees with a large number of well formed, large fruits from which to collect the seeds (Chaiyaboon and Janthasri, 2013).

The farm gate prices paid for papaya varied every month in the study period, ranging from a low of just 1 baht/kg up to a high of 15 baht/kg. Various factors affect the prices paid to farmers, including the volume of production, fruit quality and distance from the orchard to the market. In the present study, our data showed that the price differed from place to place, depending mainly on consumer demand. Demand tends to be higher in November, when rice farmers are harvesting their fields and usually get together in groups and have parties at which they eat "som tam" or green papaya salad. Demand is also higher in April because more people are on holiday during the school vacation and may eat som tam on picnics or for get-togethers at home. Similarly, in a report on unripe papaya prices in the 3 provinces of Roi Et, Kalasin and Maha Sarakham, Janthasri (2012) found that the farm gate price ranged from 1.50 baht/kg to 8 baht/kg for mixed grade fruits. The highest mean prices were in the period October to January, while the lowest mean prices were in the period July to September. The

mean price paid for Khaeg Dam cultivar was higher than for Khaeg Nuan.

Conclusion

Many papaya production practices were almost the same on all the farms surveyed. Most farmers used a relatively small planting space, which maximized yield per unit area and helped keep costs down during the pre-harvest period. The farmers were often able to begin selling unripe papaya in as short as 6 months after transplanting and could continue harvesting for about 18 months. However, the disease problem forced many farmers to shift their papaya planting area frequently, and land rent costs were a variable that had a strong impact on profits for many of the farmers who did not own their own land or had limited space.

It is notable that most small-scale papaya producers grew papaya along with other crops in mixed plantation systems. This practice helps reduce the incidence of transmittable plant diseases, keeps down insect pest populations and reduces farmers' economic risk, as well as providing increased year-round nutritional security for the family. Farm inputs such as fertilizer can also be pooled with those for the other crops grown. Mixed farming is a sustainable option that should be promoted.

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