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Research article

Extending indigenous knowledge on organic soil management to reduce papaya ringspot virus in Maha Sarakham Province, Thailand

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ABSTRACT

This research compared two crops for intercropping with papaya: banana and custard apple; and two types of soil cover: dry rice straw and natural grass, on organic farms in northeast Thailand. The research was conducted in Ban Bor Yai, Borabeu District, Maha Sarakham Province from October 2018 to September 2019. Data were collected on the prevalence and level of papaya ringspot virus (PRSV) and quantity and quality of papaya. Statistically significant differences were found in yield, weight per fruit, flesh thickness, total soluble solids, disease incidence and level of disease. Banana as a companion plant promoted papaya yield, while custard apple could minimize PRSV infection. Dry rice straw was the most suitable type of mulch.

Introduction

Economic and technological changes, and the rapid rise in the human population, are forcing small-scale traditional farmers to adapt their practices. When faced with expanding market opportunities, promotion of agricultural chemicals and household economic problems, many farmers give in to the temptation to use more chemicals for quick returns without thoroughly considering the impact on the natural environment and the balance of the agricultural system. Most agricultural research and agricultural extension work in the humid tropics has emphasized modern agricultural methods that rely on external inputs such as chemicals, hybrid seed, and machinery, with the aim of increasing yield. Modern agricultural methods have indeed been able to increase the amount of food produced on the earth, but in most cases this has come at the cost of decreased quality of life for small-scale farmers. In later years, more people have become aware of the social and environmental impact of post Green Revolution agriculture.

Meanwhile, small farmers have started to encounter problems from environmental degradation. Developers have thus shown interest in new alternatives to develop agriculture and upgrade the livings of small farmers, as well as halting further degradation of natural resourses and improving the state of the environment. This is the origin of “Sustainable Agriculture” (Panyakul, 2004). “Sustainable Agriculture” is a system of resources management for agricultural production which meets human needs, while simultaneously maintaining and reviving the environment and conserving natural resources (Panyakul, 2008).

Papaya ringspot disease is the most important problem in production papaya and it is caused by the papaya ringspot virus (PRSV). Once a tree has the virus it cannot be cured, but whether it will produced depends on the timescale of infection damaging the tree. PRSV is epidemic in the world’s important commercial

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papaya growing areas such as Hawaii, Brazil, Mexico, Malaysia, Taiwan and Australia. In Thailand the disease has spread to every region of the country with a severity of 100%. farmers deal with the epidemic by moving the cropped area, not growing papaya in a previously infected area for a year and a half, or uprooting and destroying infected trees. The Northeast region of Thailand is the country's major source of papaya, as people in this region consume "somtam," a type of salad made from unripe papaya, as a staple food. Almost every household in the Northeast grows papaya for subsistence. The PRSV epidemic has reduced production until it is insufficient to meet demand, causing more growers in the Central region to try to produce papaya commercially, shipping unripe fruit to sell in the Northeast and ripe fruit to sell overseas. However, the severe PRSV epidemic in the Central and Southern regions soon caused the fruit production volume and fruit quality to drop. This meant the supply of raw material for fruit canneries was insufficient and substandard. Growers stopped growing papaya and turned to other crops, or moved to new growing areas, such as in Chonburi, Rayong, Chantaburi and Trat. It became an urgent problem, just like in other countries that suffered impacts to the export of fresh papaya. Thailand's papaya exports had previously reached as much as 4,088 tons in 1987, and dropped to just 8 tons in 1995 and only 1% of the country's agricultural production in 2002. At present, despite state agencies and private organizations improving papaya cultivars to resist this disease, they cannot eradicate it entirely. Surveys of papaya growing areas, marketing and processing in three northeastern provinces found that farmers growing papaya commercially on a large scale used the method of moving the growing area or making a moveable papaya stand every year to avoid this epidemic.

Research of production in an integrated growing system by Jantasri (2002) found that growing papaya in an area surrounded by big trees had a prevalance of PRSV reduced by 10% compared to an open plot, where it is found to be approximately 100%. Research was conducted in the same year testing the planting of marigolds around the papaya trees to reduce the depredations of threadworms. It was found that papaya surrounded by marigolds had less threadworms and threadworm eggs than papaya without marigolds. Research into producing papaya organically by Jantasri (2007) found that organic papayas grown integrated with other crops showed prevalence of PRSV of only 1%. Papaya grown with rose-apples and bananas in an organic system did not suffer from PRSV.

Jantasri (2009) tested the effects of various materials to cover the base of the main papaya stem and found that mulch made from dried Moringa oleifera leaves could reduce damping off disease and increase fruiting per plant better than any other covering materials.

Jantasri (2010) found that mycorrhyza fungus on the root systems had the effect to increase essential trace elements absorption by the plants, and so increase production of fruit from healthier papaya trees that were better able to endure PRSV infection. Besides this, applying the local techniques of managing the soil by protecting the dry soil surface with natural grasses, reducing herbicide use, and growing herbal plants with a strong odour can prevent an outbreak of PRSV by up to 90%. A local technique among papaya growers in Srisaket Province is to cover the base of the plants with dry straw to increase trace elements in the soil and increase the vigor of the papaya plants to reduce the prevalence of PRSV.

Therefore, this study aimed to build on local soil management techniques to reduce PRSV together with chemical-free planting, to contribute to the body of knowledge about papaya growing in Thailand. We chose to compare 'Kluai Namwa' banana (Musa ABB group) and custard apple (Annona squamosa) as possible partner plants for intercropping to see which was more suitable, and we compared dry rice straw mulch (a readily available agricultural by-product) with natural grass mulch. This study provides a guideline for developing a future sustainable system that can be applied for producing papaya or other crops.

Material and methods

The research was conducted in Ban Bor Yai, Borabeu District, Maha Sarakham Province (16° N, 103° E) from October 2018 to September 2019. Plowing and plot preparation: The experimental plots were laid out in an open area with rows running North to South to maximize exposure to sunlight, which is an important factor for both photosynthesis and pathogen reduction. Each plot was 2 metres wide and the length according to the size of the area in each place. Legumes such as mung bean (*Vigna radiata*) and pigeon pea (*Cajanus cajan*) were planted as a green manure cover crop. Then anti-insect herbs were planted around the outside: neem tree (*Azadirachta indica*), climbing wattle (*Acacia pennata*), citronella grass (*Cymgopogon winterianus*) and galangal (*Alpinia galanga* (L.) Willd.), planted about 2 metres apart around the area. Inside, the insect repellant planting at the next lowest level consisted of holy basil (*Ocimum tenuiflorum*), Thai basil (*O. basilicum* var. thyrsiflora), and citronella grass (*Cymgopogon winterianus*) planted every 3 metres, alternating all around the inside area. After the anti-insect plants were established, the plots were plowed to created raised berms and the soil in the growing area was treated with dried manure raked in throughout the soil and left for 7 days before planting.

Integrated planting system and mulch: the experimental plots were plowed two more times before manure and fresh compost were applied all over the growing area. Holes were prepared for planting the alternating companion plants (banana and custard apple), with the size of the hole matching the size of the plant. The soil was left to dry in the sun for a week. A soil mixture was prepared for filling in the holes comprising compost, burnt rice husks, dried rice husks, bonemeal and a 1:1 thorough mixture of bat manure and dolomite. Then the intercropping plants were planted and the soil was covered with mulch (natural grass or dry rice straw) as specified all over the planting holes. Manure and compost were applied in alternating months throughout the experimental period.

Papaya seedlings were prepared by soaking papaya seeds in warm water at a temperature of approximately 50ºC for 24 hours. The seeds which floated were discarded. The remaining seeds were wrapped in thin white cloth or stored in tightly closed plastic bags, and stored in the shade for 3-5 days. When the seed casing started to break and show the white radical protruding, the seeds were then germinated in black 2 by 6-inch plastic bags, each bag with one seed planted at 1 cm deep in the germinating material soil, burnt rice husks and manure, in a ratio of 2:3:1. After 20 days, they were nourished with liquid organic fertilizer at the rate of 5 cm^3 per plant. They were transplanted to the field when the seedlings were 40 days old. A 50 cm planting hole was dug for each papaya plant (between the previously planted companion plants) and left to sun-dry with soil for a week. A soil mixture was prepared for the hole which comprised compost, burnt rice husks, dried rice husks, bonemeal and a 1:1 thorough mixture of bat manure and dolomite. Then the papaya seedlings were planted with two seedlings for each hole. The hole was completely covered with straw or grass. After the seedlings were aged 4 months, hermaphrodite plants were selected to leave one plant per hole. They were watered and given fertilizer every month. Before the daily watering, a natural insecticide was administered consisting of shredded citronella grass leaves, holy basil leaves, Thai basil leaves and galangal leaves. Extract of neem tree was sprayed on every week until the fruit was harvested in the 8th month.

Experimental design: The experiment was planned as factorial in RCBD, with two levels of factors: Factor A: Type of mulch: natural grass and dry rice straw Factor B: Type of intercropping plant: bananas and custard apple Therefore, there were 5 treatments using the experimental plot of 400 square meters as follows:

1. Planting papaya alternating with bananas, dry rice straw mulch
2. Planting papaya alternating with bananas, natural grass mulch
3. Planting papaya alternating with custard apples, dry rice straw mulch
4. Planting papaya alternating with custard apples, natural grass mulch
5. Planting papaya alone in open soil with no mulch (control)

Data collection:

Unripe fruit

Data were collected on the quality of papaya fruit being consumed unripe. Three fruit were collected per plant, harvested randomly during the unripe phase at about 2 months from anthesis. Data were collected in respect of: Number of fruit per tree,Weight of each fruit (kg), Length of each fruit (cm),Thickness of flesh (cm) , Percentage of hollow space inside the fruit, Number of seeds per fruit,

Ripe Fruit

For collecting data on the quality of papaya fruit when consumed ripe, fruit were randomly harvested in the phase that yellow tips appeared, covering about 0.5% of the skin area. Six fruit were harvested per tree. Two harvests were made, each one collecting three fruit as follows:

After storage at room temperature until the skin was yellow in 75% of the total skin area: number of days from harvest to when the fruit was ripe for consumption, the shape of the fruit, the weight of the fruit, the percentage of the skin which was diseased, the colour of the skin, the thickness of the flesh, the amount of total soluble solids, and the colour of the flesh.

For recording the results of resistance to PRSV, the amount of PRSV was determined according to the scale of Prasartsee et al, 2009, where PRSV has five levels as follows:

Level 0 = (no symptoms) Very good resistance to PRSV

Level 1 = (very mild mottling) Mottling at only 1-25% of the leaf area. Leaves have the symptoms of ring spot.

Level 2 = (mild or moderate mottling) Average motlling of 26-50% of the leaf area. Small ring spots on the fruit, smooth skin of fruit, may or may not have bruising or streaks on the leaf stems, medium resistance to PRSV.

Level 3 = (mottling) Leaf area is 51-75% mottled, clear ring spots all over the fruit, bruising or streaks on leaf stems and main stem, small resistance to PRSV.

Level 4 = (severe mottling) Leaf area is 75-100% mottled, leaves brittle or distorted, leaf area shrunk to just the leaf stem (severe leaf distortion), clear ring spots all over the fruit, blisters scabbed over, distorted shape of fruit, rough skin, flesh hardened with bitter taste, no resistance to PRSV (Prasartsee, 2009)

$$1)\ \%\ disease\ prevalence\ = \frac{Number\ of\ infected\ plants \times 100}{Number\ of\ plants\ planted}$$

2) Levels of PRSV in papaya

Level 0 = No symptoms of PRSV

Level 1 = Very mild mottling at only 1-25% of the leaf area. Symptoms of PRSV unclear

Level 2 = Mild or moderate mottling of 26-50% of the leaf area. Small symptoms of PRSV, smooth skin

Level 3 = Mottling of 51-75% of leaf area. Clear symptoms of PRSV

Level 4 = Severe mottling of 75-100% of leaf area. Clear and thorough symptoms of PRSV, Blisters scabbed over, distorted shape of fruit

Results

Suitability of the intercropping plant types and mulches for PRSV control

We studied two other tropical fruit crops to be grown in an intercropping system with papaya: namwa bananas and custard apples, with insect repellent herbal plants also grown in the plots. In most typical farms, papaya is normally grown as a monocrop in small or large stands with only natural grass growing between trees and rows. It was found that alternating namwa bananas with papaya caused the papaya to develop better than planting custard apple as the intercrop. This is likely because banana is a plant with broad leaves which shade the papaya plant when it is small, reducing damage from solar heat which may even burn the leaves. Also, banana has the ability to trap moisture around its stem at a high rate, allowing the papaya to receive some parts of this moisture. Even in an area of water shortage, papaya can grow well when planted close to banana. However, the banana plants should be planted 3 months before the papaya, so the banana plant has time to establish itself and produce leaves to shade the papaya.

As for the appropriate mulch for papaya, dry rice straw should be chosen, as it degrades into organic materials that are more beneficial for the development of the papaya than using natural grass (Table 1). A covering of dry straw also traps more moisture in the soil, enabling beneficial micro-organisms in the soil to thrive and help make the soil friable and suitable for the plant's development. This is consistent with the research of Jantasri (2009) which studied the viability of growing papaya in an organic system at the Ban Lad Organic Agriculture Center in Mahasarakham, which found that planting organic papaya alternated with 'Kluai Namwah' banana using a dry straw mulch could increase the survival rate of papaya when seedlings were transplanted to an area of water shortage, with growth continued and not curtailed, while also being able to increase the amount of fruit per plant and the weight of each fruit, compared to planting papaya alone.

Table 1 shows that between the different intercropping systems compared, there were significant differences at a level of 0.01 in the amount of fruit per plant and the weight of each fruit, while the size of each fruit and the number of seeds per fruit were not significantly different in all 5 systems. The system of growing papaya alternated with banana with dry straw mulch and alternated with banana with natural grass mulch gave more fruits per plant and greater weight of each fruit than other treatments. This may be because when papaya is grown alternated with banana, it receives moisture from the base of the banana plant, and there is reduced damage from the heat of sunlight, enabling the plant to grow better than when alternated with other plants. Thus the number of fruits per plant was higher, because in an integrated growing system, plants help each other. Banana is a plant which can trap high rates of moisture (Badillo, 1983) enables the papaya to receive moisture from around the base of the banana plant and some shade from the banana leaves, which promote the growth of micro-organisms in the soil. This enables the papaya to grow better than when it is planted alone (Jantasri, 2004).

Amount and quality of papaya fruit, both unripe and ripe.

The amount and the quality of the papaya is considered from thickness and density of flesh, hollow space inside the fruit, and the amount of total soluble solids. It was found that all 5 formats of integrated planting yielded statistically significant differences of thickness and density of flesh, and amount of total soluble solids. As for the percentage of hollow space inside the fruit, there was no difference between the 5 growing formats (Table 2). Papaya mulched with rice straw received nutrients from the degradation of the straw, enabling growth to be higher than all the integrated formats, resulting in large fruit, thick and dense flesh, and higher amount of total soluble solids than a natural grass mulch. As for the percentage of hollow space inside the fruit, this quality is genetically controlled and does not change with the environment, so no differences were detected among the intercropping systems tested. This study on buildings on local wisdom to manage soil resources to prevent PRSV in an organic production system for papaya in Mahasarakham found that it was highly possible to reduce or eliminate chemicals at every stage of papaya production and manage soil resources by replacing chemical fertilizers and insecticides with organic compounds or micro-organisms. The most important infectious disease in growing papaya is PRSV. When the papaya has this disease, it cannot be cured. Initial prevention is possible by preventing papaya from being infected when the plant is still young. If this cannot be prevented, the papaya may still grow to give fruit, but

Table 1 Number of fruit per tree, fruit weight, fruit length and number of seeds per fruit of papaya grown in various integrated states in the growing area of Maha Sarakham

Intercropping format	Number of fruit per tree	Mean fruit weight (kg)	Mean fruit length (cm)	Number of seeds per fruit
papaya alternating with bananas, dry rice straw mulch	95.10[a]	1.50[a]	42.40	367
papaya alternating with bananas, natural grass mulch	90.58[a]	1.29[a]	41.34	361
papaya alternating with custard apples, dry rice straw mulch	76.50[ab]	0.54[b]	40.16	365
papaya alternating with custard apples, natural grass mulch	71.42[b]	0.21[b]	41.20	362
Papaya only, no mulch	60.18[b]	1.03[a]	40.10	361
F-test	**	**	ns	ns
CV%	18.12	8.10	8.36	4.31

Note: Mean values in a single column with the same superscript are not statistically different by Least Significant Difference (LSD) at confidence level 0.01

the quality will not be as good as that from papaya plants without the disease. The five integrated papaya production formats we tested (intercropping with banana or custard apple, with or without dry rice straw mulch) may help avoid the disease in papaya and enable the production of organic papaya with no reliance on insecticide. As for the efficiency of preventing PRSV in all 5 formats of organic papaya, the research results are as follows:

Level of PRSV damage

Statistically significant differences were recorded in the prevalence of PRSV and the levels of infection among the 5 intercropping systems tested. Growing 'Yellow Krang' papaya alternating with custard apples and mulched with rice straw gave the lowest incidence of PRSV (66%), and the level of PRSV was less than in all the formats studied (2.25 points). Growing papaya alternated with 'Kluai Namwah' banana and mulched with dry rice straw was able to prevent the disease better than growing papaya alone (Table 3). The key factor to disease control in the intercropping system in which papaya was grown with custard apple and mulched with rice straw may have been the prevention of aphids, which are a vector of PRSV. The custard apple tree is not a habitat plant of this type of aphid, and custard apple leaves have a distinctively strong odour that is disagreeable to aphids. Thus it is possible that these insects were deterred from coming into the papaya stand, or when the aphids entered the inner plot of papaya they did not carry the PRSV, so the papaya showed only small symptoms of the infection (Purcifull et al. 1984). Meanwhile, large stands of papaya as a monocrop can become infected easily and quickly compared to training the plant and planting it alternated with banana (Jantasri and Jantasri, 2005). In the prevention of PRSV, it is highly possible to be able to reduce or eliminate chemicals in every stage of papaya production and use organic substances or micro-organisms instead of chemical fertilizer and insecticides. However, this must start from considering the selection of the growing area, which must be free of PRSV. This is most important because papaya is very sensitive to this disease and it may spread to the whole stand from just a few plants (Janthasri and Katengam, 2007). For instance, the area must also be free of insects such as termites and ground beetles, as well as earthworms and nematodes; and it should be an area surrounded by forest on all 4 sides. After that, the papaya plants must be nurtured to be strong by applying arbuscular Mycorrhyza fungus for the roots to increase the efficiency of phosphorus absorption. After that, the plant must be mulched with rice straw to cause the breakdown of food for micro-organisms, and the mirco-organisms will promote the development of the papaya. Papaya plants should be fertilized every month, with cow and ox manure, or other organic fertilizer at 2 kg per plant. Bio-fluid fertilizer or liquid compost should be put in furrows next to the plant. If a plant is found with PRSV, it should be uprooted and destroyed outside the plot, which greatly reduces the incidence of infection.

Discussion

This research on utilizing local wisdom of soil resource management to prevent PRSV in an organic production system found that suitable management of the soil together with intercropping could prevent PRSV efficiently. The application of suitable mulching material and the planting of suitable companion crops promotes papaya growth so the plants are vigorous and more resistant to PRSV. Our results indicated that

Table 2 Flesh thickness, flesh density, percentage of seed cavity, and total soluble solids of papaya grown in different intercropping systems in Maha Sarakham

Intercropping format	Flesh thickness (cm)	Flesh density (N)	% of hollow space inside the fruit	Total soluble solids (B^0)
papaya alternating with bananas, dry rice straw mulch	3.5[a]	4.3[a]	61.35	13[a]
papaya alternating with bananas, natural grass mulch	3.3[ab]	5.5[a]	60.78	11[ab]
papaya alternating with custard apples, dry rice straw mulch	3.6[a]	5.7[a]	65.01	10[b]
papaya alternating with custard apples, natural grass mulch	2.3[b]	6.9[b]	60.29	11[ab]
Papaya only, no mulch	2.1[b]	6.1[b]	64.32	10[b]
F-test	**	**	ns	**
%CV	7.12	10.38	7.38	5.39

Note: Mean values in a single column with the same superscript are not statistically different by Least Significant Difference (LSD) at confidence level 0.01

growing papaya alternated with banana and mulched with dry rice straw could promote higher yield and increased fruit weight more than growing papaya alternated with custard apples with a dry rice straw mulch. Overall, dry rice straw gave better results than natural grass as a mulch material. As for planting papaya with custard apple and dry rice straw mulch, this system could reduce destruction by PRSV more than growing papaya with banana or as a monocrop. Besides helping reduce the destruction of PRSV, integrated growing, or managing the growing of multiple crops in one stand, can also reduce production risks. Alternating papaya with banana can reduce the farmer’s risk because if a papaya becomes diseased and cannot fruit, there is still additional income and food for the family from banana. Indirect benefits are also obtained after harvest, because papaya fruit harvested from this growing system tends to have a longer shelf life, because the fruit received less sunlight than when grown alone without the shading from banana plants. However, planting integrated crops requires more complicated management than growing only one variety. Increased production costs may accrue from the need for specialized management of fertilizer and nutrients for each crop. In the first phase of development, there may be competition for nutrients, which is solved by choosing crops that are in symbiosis, such as the large leaves of banana and its moist stem base being beneficial for newly planted papaya nurseries. The leaves can be used to shade the papaya seedlings and improve soil moisture retention during the first phase of growth. When the banana has grown a large leaf area, it can prevent and resist some kinds of insects coming into the papaya stand. Therefore, when choosing the crops to grow in an integrated stand, they should interact beneficially and not compete for nutrients, or impede each other’s development. Growing papaya by training the stem is another format that can prevent PRSV to some degrees, as changing the growth to be small and short can help avoid some groups of insects, enabling papaya to be free of some diseases. It also reduces risk in areas with the problem of high wind speeds. This technique was adapted from papaya growing in Taiwan, where it is used to control the risk of PRSV and broken stems from a storm. This growing method has the drawback that production may be less than an untrained papaya, as the training tends to reduce the area of flowering and fruiting in a papaya to be less than a free-standing plant, giving less fruiting flowers. This can be solved by looking after the stem to grow longer than usual, to give more space for fruit.

The problems of growing papaya are mostly the prevention and elimination of disease, especially PRSV. Thus most papaya production emphasises the ability to prevent this disease. Intercropping with suitable companion plants and herbs with insect repellant properties may help prevent this disease. This must start from choosing a growing area free of PRSV, which is important as young papaya are very vulnerable to PRSV, which can spread throughout the stand from just a few plants (Janthasri and Katengam, 2007). Ideally, it should be an area surrounded by forest on 4 sides. For better soil management, the area around the stem should be mulched with rice straw to cause degradation into nutrients for microorganisms which will promote growth of the papaya. Monthly fertilization may comprise cow and ox manure, or various organic fertilizers including bio-fluid fertilizer or liquid compost. If a plant is found with PRSV, it should be uprooted and destroyed outside the plot. The format of papaya production driving this research can respond to the problems of papaya production in the future.

Producing crops in an organic system makes the elimination of diseases and insect pests much more challenging, because it is not possible to use chemicals

Table 3 Prevalence and level of PRSV in papaya grown in different intercropping systems in Mahasarakham

Intercropping format	Prevalence of PRSV[1/]	Level of PRSV[2/]	Note
papaya alternating with bananas, dry rice straw mulch	85[c]	3.32[b]	Other diseases found such as bacterial stem rot
papaya alternating with bananas, natural grass mulch	80[c]	3.58[b]	Bacterial stem rot present
papaya alternating with custard apples, dry rice straw mulch	66[a]	2.25[a]	Other diseases found such as bacterial stem rot, mottled leaves
papaya alternating with custard apples, natural grass mulch	70[b]	2.44[a]	Bacterial stem rot present
Papaya only, no mulch	90[d]	4.18[c]	-
F-test	**	**	
% CV	13.70	6.32	

Note: Mean values in a single column with the same superscript are not statistically different by Least Significant Difference (LSD) at confidence level 0.01

as in a conventional farming system. The fruit obtained may be outwardly unattractive, with worm channels and unattractive skin. However, the selling price, is usually higher than for fruits produced using chemicals. In this experiment, when papaya was infected with PRSV we used the method of uprooting and destroying the plant at any stage of its development to prevent infection to other plants in the stand. This required a large amount of repair planting, which caused harvesting to be out of synchrony, and this may have affected the data on fruit quality. Therefore, for future research we recommend choosing the location very caretully to ensure that the experimental plot is well prepared in terms of climate, disease factors, insects and labor availability.

The main factor for all organic crops is the environment, whether the weather, moisture, amount of rain, wind, diseases, insects and the fertility of the soil in that area. Choice of a suitable environment should contribute more than half to the success of the venture, because factors apart from these can be controlled, such as cultivars, nutrients, production volumes, fruit quality and harvesting.

Conclusion

Statistically significant differences were found in yield, weight per fruit, flesh thickness, total soluble solids, disease incidence and level of disease. Banana as a companion plant promoted papaya yield, while custard apple could minimize PRSV infection. Dry rice straw was the most suitable type of mulch.

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