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POTENTIAL OF CHILLI VARIETIES UNDER CHEMICAL AND ORGANIC AGRICULTURAL SYSTEMS IN THAILAND

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Abstract

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Thirty five varieties of hot chilli were evaluated under chemical and organic agricultural systems. The objectives of this study were to compare crop performance of chilli cultivars in terms of productivity and reactions to root and stem rot caused by *Sclerotium rolfsii* and piecing and sucking insect pests (thrips and aphids) and identify chilli cultivars that have good adaptation to chemical and organic agricultural systems. The chilli varieties were arranged in a Randomized Complete Block Design with four replications at two agricultural systems (chemical and organic agricultural) between December 2012 and June 2013. The results showed that there were highly significant ($p \leq 0.01$) by plant height, leaf width, leaf length, canopy width, branches/plant, stem width, fruit width, fruit length, fruits/plant and yields/plant in different chilli varieties. The highest number of quality fruit was found on Chee 519.42±14.27 and 512.69±12.35 fruits/plant under chemical and organic agricultural systems, respectively. The lowest number of quality fruit was observed on Labmeunang 27.63±6.10 and 19.89±5.78 fruits/plant under the chemical agricultural system and organic agricultural system, respectively. Chee produced the highest yields under the chemical and organic agricultural system 701.22±18.58 and 630.61±16.35 grams/plant, respectively. Labmeunang produced the lowest yield in two systems (38.41±12.25 and 26.45±10.05 grams/plant) under the chemical and organic agricultural systems, respectively. The lowest disease percentage was recorded 6.25 and 2.08% on Chee under organic and chemical agricultural system, respectively. Chee had the highest resistance to insect pests (trips and aphids) under both chemical and organic agricultural systems with leaf damage ratings of 0.09 and 0.25, respectively. The results indicated that Chee show potential for chilli production in both systems.

Key words: Capsicum spp.; yield; chemical agricultural system; organic agricultural system

Introduction

Chilli (*Capsicum* spp.) originated from South America (Nkansah et al., 2011). Chilli is closely related to 25 wild and 5 domesticated species belonging to genus *Capsicum* in Solanaceae family (Bosland and Votava, 2000; Khan et al., 2012; Jagtap et al., 2012a). Chilli was first introduced into Asia by Portuguese travelers during 15th century. Its cultivation became popular in the 17th century (Singh et al., 2014), and it is widely used as a universal spice in Asia including India, Thailand, Japan, China, Burma, Vietnam, Cambodia and Laos (Makari et al., 2009; Sangdee et al., 2011). Chilli is an important crop in preparation of many food recipes water in many countries (Jarret, 2008). The pungency associated with many forms of *Capsicum* makes the fresh or dried fruits a desirable spice, and many medicinal properties have been attributed to capsaicin and its analogs (Jarret, 2008). The nutritive value of chilli is excellent (Pawar et al., 2011; Jagtap

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et al., 2012b). Chilli is a rich source of vitamins especially for vitamins A, C, E and P that is useful for human diet (Mebratu et al., 2014). World production of chilli was 28.4 million tons in both dry and green fruits from 3.3 million hectares of land with annual growth rate of 0.5% (FAO, 2007).

Chilli is a valuable spice and also an important cash crop in Thailand. The area of about 100 000 hectares in all parts of the country including the North, the Northeast, the Central Plain and the South is under chilli cultivation, and the most important production area is in the South as most food recipes in the South are rather hot. With the increase in population, our compulsion is not only to stabilize agricultural production but also to increase it further in sustainable manner. Excessive use over years of agro-chemicals like pesticides and fertilizers has affected the soil health, leading to reduction in crop yield and product quality. Hence, a natural balance needs to be maintained at all cost (Ghaouti and Link, 2009). Chilli cultivars with good adaptation to organic agricultural systems have not been investigated in Thailand. It is also important to compare the crop performance of chilli cultivars in terms of growth, yield and reactions to diseases and insect pests under both organic and chemical production systems in order to provide recommendations to chilli growers. The objectives of this study were to compare crop performance of chilli cultivars in terms of productivity and reactions to diseases and insect pests and identify chilli cultivars that have good adaptation to chemical and organic agricultural systems. The information obtained in this study will be useful for providing recommendation to chilli growers in chemical and organic agricultural systems.

Materials and Methods

Plant materials and experiment conditions

Thirty five varieties of hot chilli used in this study were selected from different locations in Thailand. The chilli varieties were evaluated in a Randomized Complete Block Design with four replications at two agricultural systems (chemical and organic) at the Plant Science Department, Faculty of Technology and Community Development Thaksin University Phatthalung Campus, Phatthalung Thailand (7° 37′ 0″ N, 100° 5′ 0″ E) between December 2012 and June 2013.

Prior to the setup of the experiment, the soil at two experimental sites was ploughed and sowed with sun hemp (*Crotalaria juncea* L.) as a green manure to improve soil conditions and provide fixed nitrogen to the crop. The soil was ploughed again at flowering of sun hemp or 60 days after sowing. For both trails, the seedlings were transplanted in the plots of 1.5×5 m (7.5 m^2) that could accommodate two rows with six plants for each row.

Therefore, each plot had 12 plants. Soil preparation and crop management for organic trail followed the regulations of the Organic Agriculture Certification Thailand (ACT, 2012) and the International Federation Organic Movement (International Federation Organic Movement, 2009). Briefly, the 30 day-old seedlings of 35 varieties were transplanted under field conditions. Soil content of chill planting was shown in Table 1.

Chemical fertilizer (formula 15-15-15 of NPK) was applied to the chemical trial at the rate of 650 kg ha^{-1}, and compost manure was applied to organic trial at the rate of 650 kg ha^{-1}. The full rates of the fertilizers (both chemical and manure) were applied in two splits at the 325 kg ha^{-1} at transplanting and at 28 days after transplanting (DAT). At first split, the fertilizers were applied at the bottoms of the hills shortly before transplanting.

At second split, the fertilizers were applied around the stems of the plants and hilled up by hoes (pilling soil up around the base of the plant). Manual weeding was practiced for both chemical and organic systems, and chemical control of insects and diseases was practiced under chemical system only, whereas biological control was practiced under organic farming systems.

Table 1
Soil content of chill planting

Parameters	Chemical		Organic		Method of analysis
	Before Planting	After Planting	Before Planting	After Planting	
Organic matter	1.16%	1.15%	1.02%	1.28%	Walkley-Black method
Nitrogen	0.15%	0.14%	0.15%	0.15%	McKenzie method
P_2O_5 (mg kg^{-1})	34.33	37.01	37.33	39.33	Flame photometric
K (mg kg^{-1})	82.35	65.01	41.67	31.67	Oxidation
pH (H_2O)	4.27	4.57	4.23	4.40	pH meter method
EC (dS/m)	0.08	0.07	0.06	0.07	

A.A.S: Atomic absorption Spectrometer Experimental set up

Data collection

Survival percentage and agronomic traits

Survival percentage was recorded at 30 DAT from total number of 48 plants in each plot. Plant height (cm), leaf width (cm), leaf length canopy width (cm), number of branches/plant, stem width (cm), fruit width (cm), fruit length (cm) and number of fruits/plant were measured for 60 fruits per a treatment.

In addition, fruit yield per plant was also recorded. The fruits of the crop were harvested for yield assessment at fully ripening stage as indicated by red color of the fruits, and yield was accumulated until three months after transplanting.

Disease and pest assessment

Thirty five varieties of hot chilli were evaluated under chemical and organic agricultural systems at eight weeks after transplanting (WAT) for reactions to root and stem rot caused by *Sclerotium rolfsii,* which causes severe yield loss in the South of Thailand (Gurung et al., 2012). The data were recorded for disease incidence from all plants in the plots (total number of 48 plants) using natural occurring disease infestation. The chilli varieties were also evaluated for damage caused by piercing-sucking insect pests (thrips and aphids) from 12 plants in the plots using 0-5 rating scales under natural infestation of insect pests at 8 WAT (Chiranjeevi et al., 2002) (Table 2).

Statistical analysis

Data for separate locations were analyzed statistically according to a Randomized Complete Block Design. All analyses were done using the statistical program of SPSS (Statistical Package for the Social Science for Windows) version 16.0. Significant treatment differences were separated using the Duncan's New Multiple Range Test (DMRT) at 0.01 probability level.

Results

Plant survival

Thirty five varieties of hot chilli were evaluated for plant survival at 30 DAT. The results showed that survival percentages ranging from 50.00 to 85.71% and 42.86 to 85.71% were recorded under chemical production system and organic production system, respectively (Table 3). Top star had the highest survival percentages of 85.71% under chemical and organic agricultural systems, whereas Labmeunang had the lowest survival percentages of 50% under chemical agricultural system and 42.86% under organic agricultural system. In general, chemical production system had higher survival percentage than organic production system.

Morphological characters of chilli

Under chemical agricultural system, significant differences ($p \leq 0.01$) among chilli varieties were observed for leaf width, leaf length, canopy width, branch numbers, stem width and plant height (Table 4). Leaf widths ranged from 4.00±0.31 cm in Black hot to 10.88±0.32 cm in OP1, whereas leaf lengths ranged between 3.98±0.36 cm in Choypach and 10.45±0.61 cm in OP1. Chee had the widest canopy of 81.31±9.52 cm, whereas Labmeunang had the narrowest canopy of 26.83±7.95 cm. Chee also had the highest number of branches (6.09±2.36 branches/plant), whereas Labmeunang produced the lowest number of branches (1.20±0.84 branches/plant). Chee had the biggest stem of 2.34±0.09 cm and the smallest stem was observed in Labmeunang and Maliwan (0.68 cm for both varieties). Chee also had the tallest plants under chemical agricultural system (114.85±15.55 cm), whereas Maliwan was the lowest variety for plant height (47.20±11.03 cm).

Under organic production system, chilli varieties were significantly different ($P \leq 0.01$) for leaf width, leaf length, canopy width, branch numbers, stem width and plant height (Table 5). The highest leaf width (12.09±0.33 cm) was obtained from OP1 and the narrowest leaf width (4.12±0.35 cm) was obtained from Black hot. Chee and Choypach had the lowest leaf length of 4.75 cm for both varieties, and OP1 had the highest leaf lengths of 12.23±0.48cm.

Table 2
Rating scales for leaf damage by piercing-sucking insect pests

Scores	Symptoms
0	No symptoms
1	3-4 terminal leaves showing up eruptions in interval area of leaves
2	Terminal 3-4 leaves showing upward curling along leaf margin
3	Severe scorching of terminal and a few lower leaves
4	Stunted plants, leaves severely curled and leaf area greatly reduced
5	Plants with no leaves and only stem remaining

Table 3
Survival percentage (%) of chilli varieties under the fields

Variety	Survival percentage		
	Chemical system	Organic system	Difference[1]
Black hot	75.00	75.00	0.00
Chaiprakan	71.43	67.86	3.57
Chee	78.57	64.29	14.28
Choypach	67.86	64.29	3.57
Dehot	71.43	67.86	3.57
Dinamai	71.43	71.43	0.00
Dumnean	57.14	53.57	3.57
Haomkeaw	60.71	57.14	3.57
Hot het	85.71	82.14	3.57
Intira	75.00	67.86	7.14
Jindadang	57.14	53.57	3.57
Jindadum	85.71	78.57	7.14
Jomthong	82.14	75.00	7.14
Karang	71.43	71.43	0.00
Keenukaw	60.71	53.57	7.14
Keenuson	53.57	50.00	3.57
Kungsalad	53.57	46.43	7.14
Labmeunang	50.00	42.86	7.14
Maliwan	67.86	60.71	7.15
Manikhan	64.29	60.71	3.58
Mundum	82.14	78.57	3.57
Nheumkeaw	71.43	71.43	0.00
OP1	71.43	67.86	3.57
OP2	67.86	64.29	3.57
Patsiam	75.00	71.43	3.57
Pongpach	75.00	71.43	3.57
Pratadtong	85.71	82.14	3.57
Pretty	82.14	78.57	3.57
Redhot	75.00	71.43	3.57
Saoykai	64.29	64.29	0.00
Saoypet	67.86	60.71	7.15
Sriphai	53.57	53.57	0.00
Top green	67.86	67.86	0.00
Top star	85.71	85.71	0.00
Yhodtong	82.14	82.14	0.00

[1]plus sign indicates higher value of chemical production system than organic production system

Chee was with the highest values for number of canopy width (88.29±10.68 cm) and branches per plant (5.32±3.58 branches) and Labmeunang was with the lowest ones for these traits (33.81±9.57 cm for canopy width and 0.55±0.19 for branch numbers/plant). Chee was also with the highest values for stem width (2.87±0.08 cm) and plant height (107.53±16.35 cm), whereas Maliwan was the lowest ones for these traits (1.21±0.23 cm for stem width and 43.88±16.35 cm for plant height).

Fruit characters, fruit yield and yield components of chill

Under chemical agricultural system, chilli varieties were highly significantly different ($p \leq 0.01$) for fruit width, fruit length fruit numbers, fruit weight and fruit yield (Table 6). Means for fruit width ranged from 0.39±0.02 cm in Labmeunang to 2.21±0.35 cm in Saoypet, whereas means for fruit length were between 4.12±0.33 cm in Karang and 12.71±0.65 cm in Jomthong. Fruit numbers/plant ranging between 27.63±6.10 fruits in Labmeunang and 519.42±14.27 fruits in Chee. The fruit weights ranging between 0.98±0.08 g in Karang and 12.69±3.20 g in Nheumkeaw were recorded. The highest fruit yields/plant of 701.22±18.58g was obtained from Chee and the lowest fruit yield/plant of 38.41±12.25g was obtained from Labmeunang.

Under organic production system, chilli varieties were highly significantly different ($p \leq 0.01$) for fruit width, fruit length fruit numbers, fruit weight and fruit yield (Table 7). Means for fruit width were between 0.33±0.05 cm in Labmeunang and 2.16±0.12 cm in Saoypet, whereas means for fruit length were between 4.10±0.54 cm in Karang and 14.90±0.42 cm in Nheumkeaw. Chee had the highest fruit numbers/plant (512.69±12.35 fruits) and Labmeunang was the lowest fruit numbers/plant (19.89±5.78 fruits). Nheumkeaw was the variety with the highest fruit weight (12.61±3.28 g) and Karang was the variety with the lowest fruit weight (0.89±0.07 g). The highest fruit yield per plant (630.61±16.35 g) was obtained from Chee, while the lowest fruit yield was obtained from Labmeunang (26.45±10.05 g).

Figure 1 showed that chemical production system had higher fruit number and fruit yield than organic production system for all chilli varieties. The differences between production systems for fruit numbers were between 5.74 fruits in Karang and 31.74 fruits in Jindadum, whereas the differences between production systems for fruit yield were between 8.72 g in Keenuson and 189.44 g in Jomthong.

It is interesting to note here that Chee had the highest fruit numbers and fruit yields but the differences between chemical and organic production system for fruit numbers and fruit yields were rather low in this variety (6.73 fruits for fruit number and 70.61 g for fruit yield) indicating that the performance for these traits of this variety was rather stable.

Disease incidence and leaf damage from insect pests

Percentages of root and stem rot disease (disease incidence) caused by *Sclerotium rolfsii* were low under

Table 4
Means for leaf and stem characteristics of chilli planted under chemical agricultural system

Variety	Leaf width (cm)	Leaf length (cm)	Canopy width (cm)	Branches / plant	Stem width (cm)	Plant height (cm)
Black hot	4.00±0.31d	6.90±0.65bc	54.80±4.32cd	3.80±0.98bcd	1.44±0.20cd	81.00±11.32cd
Chaiprakan	4.46±0.43d	4.56±0.87e	52.98±12.05cde	2.98±0.26de	1.25±0.32cde	67.09±12.68ef
Chee	5.96±0.21cd	3.98±0.68f	81.31±9.52a	6.09±2.36a	2.34±0.09a	114.85±15.55a
Choypach	5.60±0.42cd	3.98±0.36f	46.97±8.68def	2.87±0.25de	1.34±0.08cde	74.93±12.36de
Dehot	6.32±0.35bcd	8.22±0.65ab	53.61±6.43cde	2.40±0.55f	1.20±0.28cde	77.20±7.07de
Dinamai	5.60±0.56cd	6.64±0.42cd	39.62±3.97ef	3.40±0.14cd	0.82±0.28ef	73.20±6.10de
Dumnean	5.94±0.35cd	6.89±0.54bc	53.98±11.58cd	3.01±1.02de	1.12±0.21cde	68.75±13.58ef
Haomkeaw	6.52±0.21bcd	6.26±0.92cd	45.20±9.33def	3.60±1.20cd	1.24±0.14cde	89.64±21.35cd
Hot het	6.00±0.20bcd	6.42±0.48cd	48.73±7.56cdef	3.21±2.19cde	0.98±0.15ef	104.40±15.83ab
Intira	6.02±0.31bcd	5.98±0.68cde	42.09±12.58def	2.89±1.20de	0.98±0.01ef	58.98±8.69fgh
Jindadang	5.00±0.42cd	6.20±1.09cde	36.60±6.79ef	3.80±1.10bcd	0.96±0.22ef	70.40±8.80def
Jindadum	5.80±0.43cd	7.02±0.61abc	65.90±7.19bcd	4.80±2.17bc	1.22±0.41cde	93.50±9.07bcd
Jomthong	8.31±0.26bc	9.16±0.81a	71.20±12.50bc	5.60±2.51bc	1.58±0.28bcd	67.20±14.89ef
Karang	4.60±0.49cd	9.12±0.98a	68.09±15.85bcd	6.01±2.35a	1.07±0.80de	98.99±12.25bcd
keenukaw	5.56±0.37cd	7.33±0.87abc	59.87±13.32cd	3.87±1.02bcd	0.99±0.06ef	76.32±14.35de
Keenuson	6.14±0.24bcd	8.51±0.98ab	61.35±13.58cd	2.97±0.98de	1.02±0.25de	65.12±11.25fg
Kungsalad	4.76±0.36cd	6.26±1.03cd	57.10±7.32cd	4.80±1.36bc	1.20±0.25cde	77.48±4.78de
Labmeunang	8.79±0.35ab	8.98±0.62ab	26.83±7.95g	1.20±0.84g	0.68±0.13g	66.00±7.26efg
Maliwan	4.36±0.29d	5.32±1.25de	34.84±2.52f	4.80±1.98bc	0.68±0.24g	47.20±11.03h
Manikhan	5.52±0.83cd	7.09±0.45abc	43.98±7.16def	2.76±0.99def	1.01±0.32def	53.98±14.25gh
Mundum	5.28±0.36cd	6.94±0.98bc	55.98±4.76cd	2.68±0.87def	1.32±0.29cde	76.65±13.69de
Nheumkeaw	6.40±0.67bcd	6.60±1.81cd	45.23±2.62def	3.60±1.00cd	1.24±0.22cde	89.64±24.83cd
OP1	10.88±0.32a	10.45±0.61a	74.63±11.68ab	4.96±1.20bc	2.12±0.13bc	101.23±16.35abc
OP2	6.48±0.31bcd	9.48±0.59a	73.87±11.35bc	4.81±2.00bc	2.09±0.32bc	100.98±14.25abc
Patsiam	5.96±0.40cd	6.80±0.36bc	58.80±14.52cd	2.65±0.65de	1.23±0.13cde	65.22±12.18efg
Pongpach	5.08±0.53cd	5.82±0.48cde	38.40±4.34ef	3.00±0.96de	0.84±0.31ef	69.80±14.55ef
Pratadtong	7.40±0.61bcd	6.80±0.48bc	55.20±9.50cd	3.40±1.02cd	1.02±0.13de	89.40±11.47cd
Pretty	5.12±0.33cd	6.62±0.85cd	37.60±4.22ef	3.20±1.03de	0.94±0.09ef	63.80±18.57fg
Redhot	5.68±0.31cd	5.42±0.45de	37.68±3.51ef	3.80±0.88bcd	0.78±0.22f	64.74±7.40fg
Saoykai	5.72±0.51cd	6.63±0.53cd	45.80±3.77def	4.20±1.65bcd	1.08±0.14de	78.66±7.69de
Saoypet	5.12±0.35cd	5.16±1.66de	37.90±8.50ef	3.60±1.32cd	0.86±0.25ef	62.44±14.01fg
Sriphai	9.87±0.51ab	9.24±1.25a	42.74±9.23def	3.40±1.36cd	0.86±0.30ef	59.00±4.99fgh
Top green	6.96±0.34bcd	8.32±1.88ab	47.40±9.76def	2.80±1.30de	0.86±0.11ef	82.00±20.25cd
Top star	6.24±0.31bcd	7.22±0.99abc	40.80±2.49def	5.40±2.01bc	1.02±0.13def	73.00±7.02de
Yhodtong	4.24±0.52d	6.54±0.29cd	45.93±8.11def	1.98±1.00g	1.23±0.24cde	62.71±9.78fg
C.V.	8.76	6.18	13.77	11.54	8.65	10.87

Means in the same column with the same letter(s) are not significantly different by Duncan's New Multiple Range Test (DMRT) at 0.01 probability level

Table 5
Means for leaf and stem characteristics of chilli planted under organic agricultural system

Variety	Leaf width (cm)	Leaf length (cm)	Canopy width (cm)	Branches/ plant	Stem width (cm)	Plant height (cm)
Black hot	4.12±0.35l	7.77±0.66def	61.78±5.68def	3.43±1.06cd	1.99±0.15c	76.68±12.42cd
Chaiprakan	4.58±0.46k	5.87±0.98ij	59.96±13.58def	2.33±0.36ef	1.85±0.26cde	63.77±12.98ef
Chee	5.60±0.22ghi	4.75±0.73j	88.29±10.68a	5.32±3.58a	2.87±0.08a	107.53±16.35a
Choypach	5.82±0.43fgh	4.75±0.62j	53.95±9.68ef	2.22±0.28ef	1.87±0.18cd	79.61±12.38cd
Dehot	6.32±0.36ef	9.33±0.42bcd	60.59±7.65def	1.75±0.98g	1.82±0.17cde	77.88±11.05cd
Dinamai	6.62±0.60def	8.41±0.52cde	46.60±4.58gh	2.54±1.01ef	1.42±0.19efg	68.88±7.68def
Dumnean	5.35±0.35hij	7.98±0.53de	60.96±13.58def	2.36±1.01ef	1.87±0.12cde	65.43±14.58ef
Haomkeaw	6.22±0.23ef	7.03±0.93fg	52.18±9.58fg	2.32±0.98ef	1.76±0.15de	85.32±22.36bc
Hot het	6.05±0.22efg	7.23±0.48efg	55.71±7.99ef	2.56±0.98ef	1.54±0.02ef	99.98±16.35b
Intira	6.06±0.32efg	6.75±0.72ghi	49.07±8.58fgh	2.32±0.86ef	1.59±0.10ef	56.66±8.32fg
Jindadang	5.33±0.43hij	6.09±0.36hi	43.58±13.25hi	3.15±1.02de	1.52±0.21ef	67.08±9.36ef
Jindadum	5.47±0.52ghij	7.54±0.92efg	72.88±7.68bcd	4.32±1.05bc	1.98±0.32c	89.18±10.82bc
Jomthong	8.34±0.26cd	9.93±0.98abc	78.18±7.98bc	4.43±2.01bc	2.23±0.24bc	63.88±15.71ef
Karang	4.77±0.46jk	10.89±0.99a	75.07±12.85bc	5.32±2.07a	1.63±0.05ef	95.67±14.25b
Keenukaw	5.81±0.38ghi	8.23±1.03cde	66.85±15.99cd	3.43±1.02cd	1.87±0.05cde	73.98±15.88cde
Keenuson	6.16±0.32efg	9.28±0.87cd	68.33±14.67cd	2.32±0.87ef	1.58±0.24ef	62.80±13.20ef
Kungsalad	4.95±0.40jk	7.03±1.23fg	64.08±14.57cd	4.43±1.23bc	1.65±0.23def	72.16±5.69de
Labmeunang	8.45±0.40cd	9.75±0.55bcd	33.81±9.57k	0.55±0.19h	1.24±0.12gh	60.68±8.699efg
Maliwan	4.98±0.32jk	6.34±0.99ghi	41.82±8.57j	4.23±2.07bc	1.21±0.23h	43.88±16.35hi
Manikhan	5.88±0.86fgh	7.12±1.98efg	50.96±2.69fg	2.11±1.06ef	1.57±0.31ef	48.66±15.38hi
Mundum	5.17±0.36ijk	7.36±0.62efg	62.96±8.63cde	2.32±0.96ef	1.88±0.21cd	73.33±14.39cde
Nheumkeaw	6.45±0.69ef	7.67±0.96def	52.21±5.12fg	2.95±0.98e	1.85±0.21cde	86.32±25.35bc
OP1	12.09±0.33a	12.23±0.48a	81.61±3.68bc	4.31±1.55bc	2.68±0.12a	95.91±17.69b
OP2	6.49±0.40ef	10.25±0.53a	80.85±13.58bc	4.16±2.03bc	2.65±0.21ab	96.66±16.35b
Patsiam	5.89±0.51efgh	7.57±0.52efg	65.78±13.58cd	2.00±0.87f	1.79±0.11de	61.90±13.85ef
Pongpach	5.44±0.23hij	6.59±0.98ghi	45.38±16.28ghi	2.35±0.85ef	1.40±0.24fg	66.48±12.02ef
Pratadtong	7.43±0.63def	7.57±0.55def	62.18±5.39cde	2.75±1.02ef	1.89±0.02cd	85.08±19.06bcd
Pretty	5.55±0.40ghij	7.76±0.53def	44.58±10.68hi	2.55±1.03ef	1.50±0.17ef	59.48±8.20fg
Redhot	5.66±0.52ghi	6.19±0.35hi	44.66±5.67hi	3.15±1.11de	1.35±0.09fg	54.42±8.69gh
Saoykai	5.98±0.34efgh	7.87±0.25def	52.78±4.35fg	3.43±1.60cd	1.68±0.21def	71.34±16.35de
Saoypet	5.90±0.53efgh	5.67±0.98ij	44.88±5.31hi	2.95±0.85e	1.46±0.26efg	55.12±10.24gh
Sriphai	9.89±0.40b	10.01±0.99ab	49.72±5.02fgh	2.77±1.12ef	1.42±0.09efg	52.68±9.69gh
Top green	6.98±0.33def	9.77±0.75bc	54.38±9.25ef	2.21±0.85ef	1.45±0.09efg	71.68±11.30de
Top star	6.26±0.60ef	7.92±0.99de	47.78±9.09gh	4.54±2.02bc	1.58±0.24ef	68.68±7.09def
Yhodtong	4.56±0.65k	7.65±0.98def	52.91±3.09ef	1.76±0.96g	1.82±0.08cde	58.39±9.68fg
C.V.	9.73	10.12	11.57	10.44	7.95	11.58

Means in the same column with the same letter(s) are not significantly different by Duncan's New Multiple Range Test (DMRT) at 0.01 probability level

Table 6
Means for yield components of chilli varieties planted under chemical agricultural system

Variety	Fruit width (cm)	Fruit length (cm)	Fruits/plant (fruit)	Fruit weight (g)	Fruit yield/plant (g)
Black hot	1.01±0.02cde	8.65±0.35de	63.02±6.71hij	8.15±1.12bcd	513.74±80.25cdef
Chaiprakan	0.87±0.01def	8.25±0.85de	58.22±2.70jk	4.35±0.58def	253.26±22.69ef
Chee	0.78±0.06ef	6.54±0.54fg	519.42±14.27a	1.35±0.06i	701.22±18.58a
Choypach	0.86±0.01def	6.77±0.24fg	55.20±1.95jk	2.03±0.25fg	112.06±11.80jk
Dehot	0.75±0.02ef	7.35±0.36efg	60.60±3.90ijk	3.21±0.35ef	194.53±18.68ghi
Dinamai	0.86±0.03def	5.82±0.09fgh	107.42±18.10fg	2.01±0.35fgh	215.70±49.66gh
Dumnean	0.86±0.06def	4.68±0.14hi	100.42±8.05fg	2.36±0.68fg	236.99±31.25efg
Haomkeaw	1.27±0.06cd	10.97±0.25cd	53.46±4.15jk	7.88±1.25cd	421.37±77.98cdef
Hot het	0.61±0.01fg	5.10±0.13ghi	121.20±13.67ef	1.36±0.55i	164.35±60.59hij
Intira	0.56±0.01g	6.35±0.24fg	82.23±7.83ghi	1.32±0.64i	108.54±19.85k
Jindadang	0.77±0.05ef	5.00±0.13ghi	82.80±9.37ghi	1.65±0.25hi	136.62±56.52ijk
Jindadum	0.81±0.04def	5.48±0.15gh	219.32±18.99d	1.65±0.21hi	362.76±31.41def
Jomthong	1.32±0.11cd	12.71±0.65bc	64.27±4.62hij	10.90±1.07b	700.80±71.03a
Karang	0.75±0.11ef	4.12±0.33i	229.20±4.51cd	0.98±0.08j	224.62±28.85fgh
Keenukaw	0.63±0.07fg	8.01±1.02de	186.04±10.07e	1.24±0.24ij	230.69±44.52efgh
Keenuson	0.53±0.05g	5.45±0.17gh	287.35±11.90c	1.32±0.31i	379.30±29.57def
Kungsalad	1.23±0.10cd	11.88±0.24bcd	51.06±3.16kl	10.23±2.02bc	522.34±27.43cde
Labmeunang	0.39±0.02h	4.66±0.24h	27.63±6.10n	1.39±0.36i	38.41±12.25l
Maliwan	1.50±0.07cd	11.89±0.52bc	76.43±4.21hi	8.88±1.06bc	679.00±62.02ab
Manikhan	0.58±0.03g	5.49±0.15gh	139.63±3.71ef	1.97±0.31gh	274.51±58.25def
Mundum	1.42±0.08cd	9.62±0.49cde	82.68±7.89ghi	6.54±1.06cde	540.73±89.55cd
Nheumkeaw	1.33±0.14cd	14.94±0.48a	51.36±2.45kl	12.69±3.20a	651.86±57.36bc
OP1	0.66±0.11fg	6.22±0.61fg	396.76±8.04b	1.56±0.26hi	618.95±32.35bc
OP2	0.66±0.11fg	6.22±0.59fg	380.46±20.18b	1.59±0.31hi	604.93±56.68bcd
Patsiam	0.98±0.03de	8.39±0.11de	84.66±8.11g	1.95±0.31gh	164.92±36.25hi
Pongpach	1.35±0.05cd	7.45±0.19efg	52.35±2.70jkl	5.55±0.87de	290.44±23.54edef
Pratadtong	0.71±0.06ef	11.62±0.30bcd	60.32±9.52ijk	2.35±0.25fg	141.51±19.36ij
Pretty	1.04±0.03cde	11.13±0.37bcd	52.71±3.21jkl	5.57±0.24cde	293.49±29.68def
Redhot	1.24±0.33cd	11.38±0.23bcd	81.65±7.62ghi	1.84±0.19ghi	150.56±18.36hij
Saoykai	0.59±0.03g	5.70±0.14gh	67.32±2.61hij	2.21±0.05fg	148.91±20.68ij
Saoypet	2.21±0.35a	8.25±0.87de	58.82±4.16jk	5.99±1.58cde	352.59±40.15def
Sriphai	1.98±0.13b	6.01±0.98fg	48.32±2.92l	4.35±1.01def	210.19±29.57ghi
Top green	1.22±0.14cd	9.56±0.20cde	30.41±2.55m	4.25±0.82def	129.36±17.58ijk
Top star	1.29±0.05cd	10.56±1.02cd	75.22±9.22hi	5.02±0.67def	377.45±38.66def
Yhodtong	0.98±0.06de	5.70±0.15gh	162.12±15.07e	2.10±0.13fg	340.45±38.74def
C.V.	10.32	9.87	11.45	11.00	12.34

Means in the same column with the same letter(s) are not significantly different by Duncan's New Multiple Range Test (DMRT) at 0.01 probability level

Table 7
Means for yield componentst of chilli planted under organic agricultural system

Variety	Fruit width (cm)	Fruit length (cm)	Fruits/plant (fruit)	Fruit weight (g)	Fruit yield/plant (g)
Black hot	0.93±0.02ef	8.63±0.34cde	53.39±5.68hij	8.06±1.21bc	430.32±52.35d
Chaiprakan	0.84±0.02ef	8.21±0.75cdef	46.46±2.35jk	4.23±0.68def	196.53±21.35hij
Chee	0.68±0.03g	6.52±0.54efg	512.69±12.35a	1.23±0.35jk	630.61±16.35a
Choypach	0.75±0.01fg	6.75±0.21efg	43.47±13.25jk	1.93±0.25gh	83.90±10.20l
Dehot	0.62±0.02g	7.31±0.23def	51.86±2.68hij	3.12±1.02efg	161.80±16.38ij
Dinamai	0.82±0.04efg	5.79±0.34fg	96.64±14.35efg	1.94±0.65gh	187.48±43.36ij
Dumnean	0.75±0.05fg	4.66±0.08hi	88.66±7.69efg	2.26±0.36efg	200.37±32.58hi
Haomkeaw	1.14±0.04de	10.95±0.12cde	43.72±3.58jk	7.77±1.69bc	339.70±75.35efg
Hot het	0.51±0.01hi	5.08±0.24gh	101.43±12.20def	1.26±0.09jk	127.80±59.28ijk
Intira	0.47±0.02i	6.33±0.13efg	70.47±2.34fgh	1.23±0.06jk	86.64±14.36l
Jindadang	0.69±0.04g	4.98±0.21gh	74.06±8.36fg	1.53±0.32hij	113.31±54.21jk
Jindadum	0.73±0.06fg	5.46±0.12fgh	187.58±3.35d	1.56±0.06hij	292.62±30.28fgh
Jomthong	1.20±0.08cde	12.61±0.13ab	50.53±4.35ijk	10.12±3.05ab	511.36±70.28bc
Karang	0.65±0.05g	4.10±0.54i	223.46±4.25cd	0.89±0.07l	198.88±26.35hij
Keenukaw	0.45±0.05i	8.00±0.21def	179.33±10.20de	1.15±0.21k	206.23±40.15ghi
Keenuson	0.38±0.08j	5.44±0.98gh	278.63±11.20c	1.33±0.33ijk	370.58±25.36de
Kungsalad	1.13±0.03def	11.85±0.16bcd	43.32±5.36jk	10.13±3.36ab	438.83±24.25cd
Labmeunang	0.33±0.05j	4.64±0.24hi	19.89±5.78n	1.33±0.15ijk	26.45±10.05m
Maliwan	1.41±0.02cd	11.86±0.21abc	59.52±3.54ghi	8.78±1.02bc	522.59±56.38b
Manikhan	0.52±0.02hi	5.46±0.52fgh	120.87±2.54def	1.85±0.25ghi	223.61±54.21gh
Mundum	1.33±0.07cd	9.60±0.12cde	71.95±5.46fgh	6.44±0.98bcd	463.36±87.25c
Nheumkeaw	1.24±0.12cde	14.90±0.42a	40.67±2.01kl	12.61±3.28a	512.85±52.45bc
OP1	0.61±0.11g	6.22±0.98efg	389.02±8.25b	1.47±0.28hijk	571.86±40.12b
OP2	0.60±0.09gh	6.21±0.52efg	366.77±9.02b	1.48±0.67hijk	542.82±40.35b
Patsiam	0.89±0.02ef	8.38±0.12cde	73.92±8.57fg	1.81±0.78ghi	133.80±32.05ijk
Pongpach	1.31±0.05cd	7.43±0.26def	41.67±2.35jkl	5.44±2.06cd	226.68±15.08gh
Pratadtong	0.58±0.05hi	11.50±0.23bcd	50.57±8.65ij	2.26±0.14efg	114.24±26.87jk
Pretty	0.95±0.03def	11.07±0.34bcd	44.93±3.36jk	5.45±2.05cd	244.87±14.58fgh
Redhot	1.15±0.21de	11.31±0.64bcd	70.92±7.35fgh	1.76±0.28hij	124.82±21.06ijk
Saoykai	0.49±0.25i	5.67±0.12fgh	57.58±4.21ghi	2.11±0.38efg	121.49±40.15jk
Saoypet	2.16±0.12a	8.23±0.58cde	46.03±2.15jk	5.91±0.09cd	272.04±24.58fgh
Sriphai	1.88±0.09b	5.99±0.57fg	37.53±2.36l	4.24±0.58def	159.13±16.58ijk
Top green	1.23±0.04cde	9.55±0.16cde	22.67±3.58m	4.17±1.25def	94.53±13.26kl
Top star	1.23±0.05cde	10.51±0.25cde	67.48±8.62fgh	4.94±2.08def	333.35±32.05efg
Yhodtong	0.86±0.03ef	5.64±0.36fgh	154.38±12.03de	2.04±0.24fgh	314.94±65.35fg
C.V.	9.58	10.21	10.24	11.03	10.98

Means in the same column with the same letter(s) are not significantly different by Duncan's New Multiple Range Test (DMRT) at 0.01 probability level

both production systems (chemical and organic), ranging from 2.08% in Chee and Pratadtong to 31.25% in Top star and Labmeunang under chemical production system and 6.25% in Chee to 37.50% in Top star and Labmeunang under organic production system (Figrue 2a).

In general, organic production system had slightly higher percentages of root and stem rot disease than chemical production system. Similar to disease incidence, ratings of leaf damage by piercing-sucking insect pests were low under both production systems, ranging from 0.09 in Chee to 2.06 in Labmeunang under chemical production system and 0.02 in Chee to 2.37 in Labmeunang under organic production system (Figure 2b).

Weather conditions

The meteorological data were shown in Table 8 temperatures chilli planting between December 2012 and June 2013 were 24.39°C to 33.89°C. Average air temperatures were 28.45°C. The relative humidity values were between 63.07% and 96.13% and the average relative humidity value was 81.34%. Rain day ranged from 4 to 23 days, while lowest rainfall was recorded in March 2013.

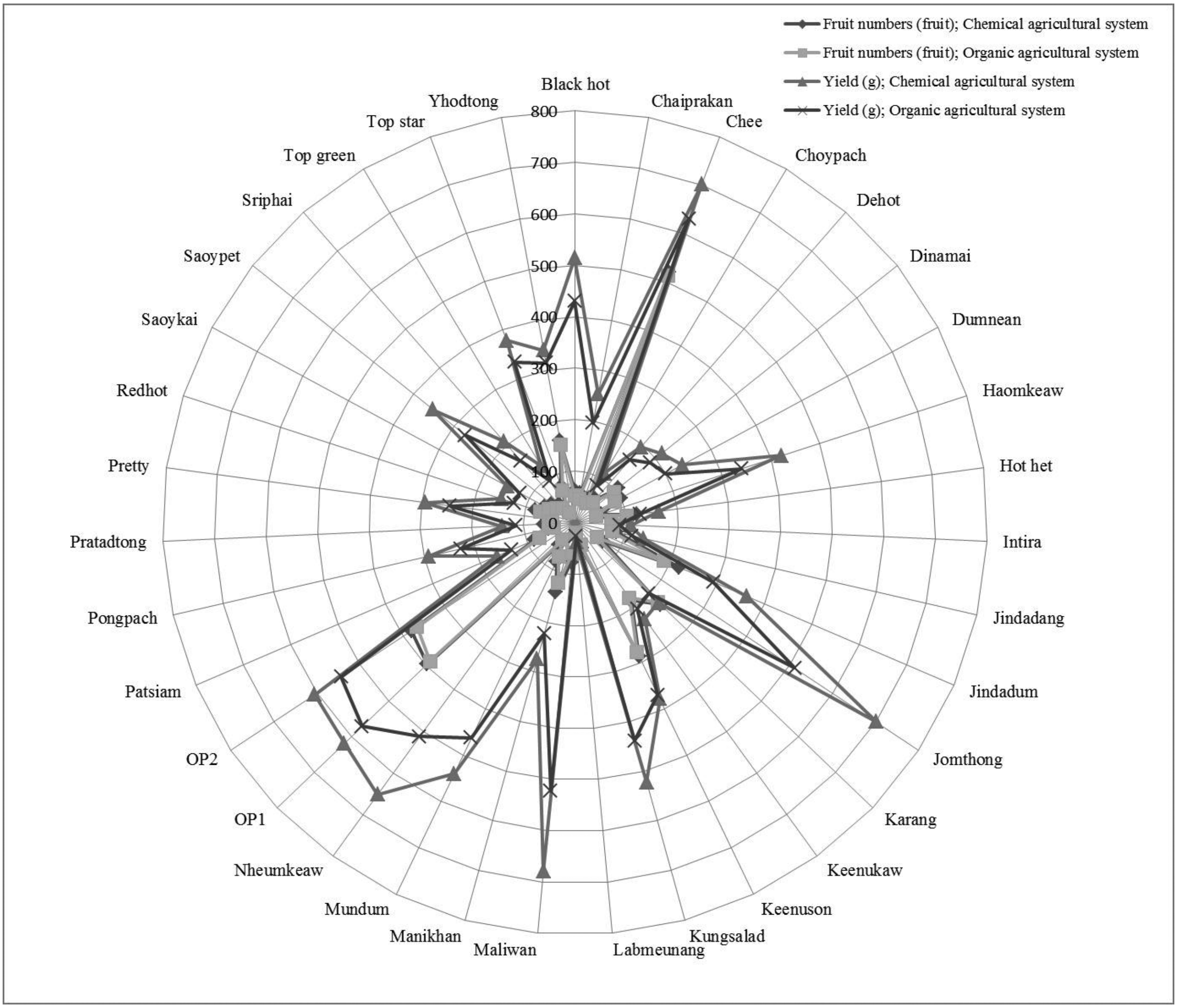
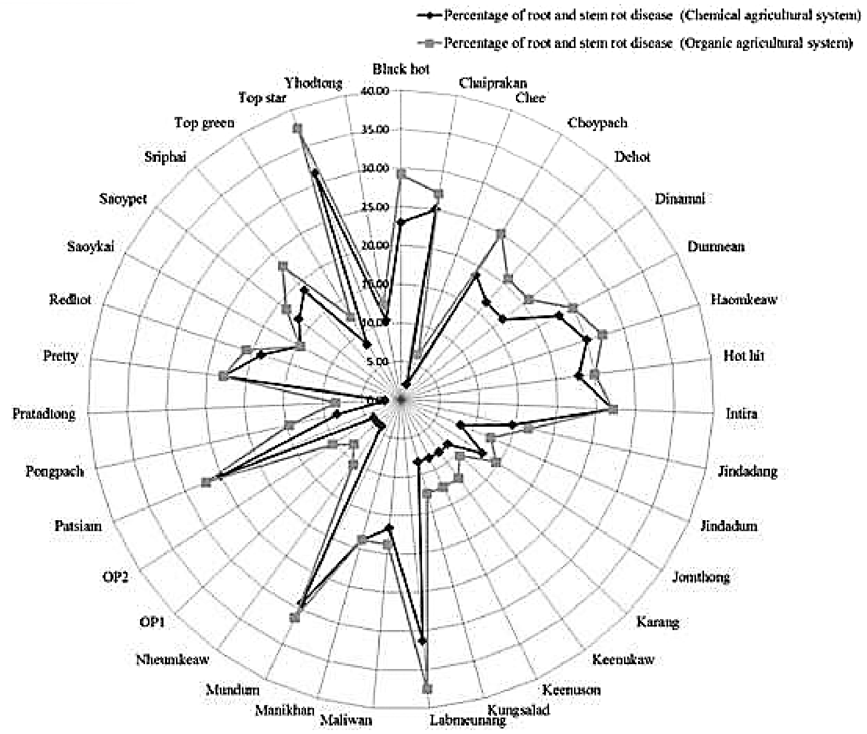
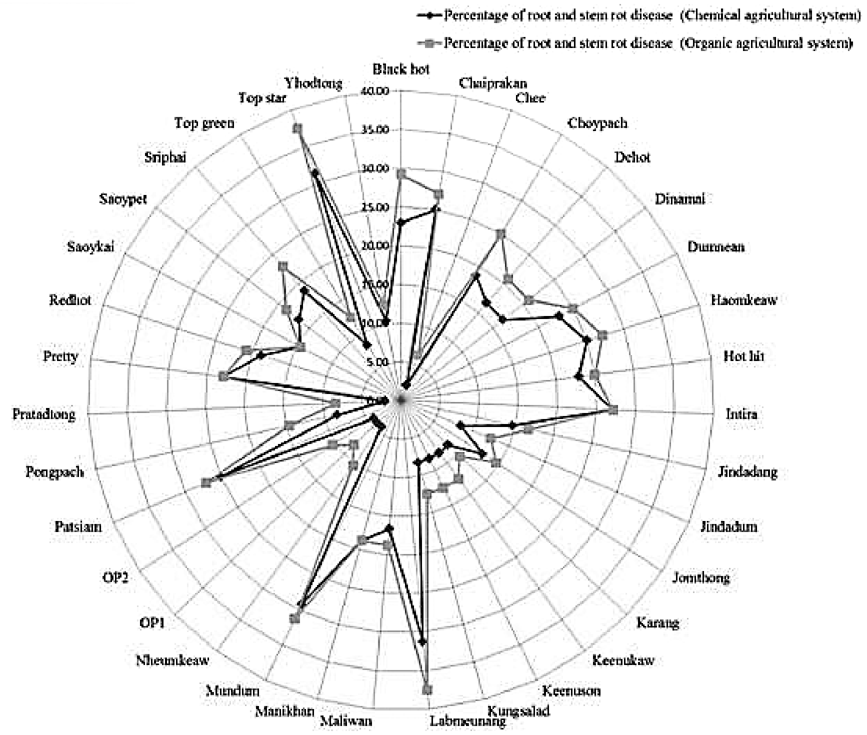


Fig. 1. Mean for fruit number and fruit yield per plant between two production systems



a)



b)

Fig. 2. Percentage of root and stem rot disease (a) and ratings of leaf damage (b)

Table 8
Temperature, humidity, rainfall and rain

	Temperature/Month (°C)			Relative Humidity/Month (%)			Rainfall (mm)	Rain (day)
	Maximum	Minimum	Averages	Maximum	Minimum	Averages		
December (2012)	30.32	24.40	27.36	96.13	77.58	86.86	547.30	23.00
January (2013)	30.80	24.39	27.60	93.61	71.10	82.36	58.40	10.00
February (2013)	29.85	24.84	27.35	91.18	71.75	81.47	276.70	13.00
March (2013)	32.88	24.85	28.87	93.32	65.84	79.58	1.40	4.00
April (2013)	32.88	25.39	29.14	94.57	66.23	80.40	198.80	15.00
May (2013)	33.89	25.32	29.61	95.90	65.03	80.47	109.40	14.00
June (2013)	33.35	25.14	29.25	93.47	63.07	78.27	65.60	7.00

Discussion

The survival percentage in the trial natural field at Thaksin University was found that chemical agricultural system test has a higher percentage of survival then organic agricultural system, because the seedling is protected by the use of the substance prevents fungus and insects into ruin, while the system of organic agricultural production is not allowed (Trewavas, 2004; Yadav et al., 2013) then caused the destruction of insects, diseases and access them easily, which affect the ability of plants to sprout (Benchasri and Bairaman, 2013). In addition chilli planted phase environmental factors can affect seed germination and growth of plants (Datta et al., 2011; Dahanayake et al., 2012).

In general morphological characters in the chilli varieties varied significantly between all lines of chilli. The significant variation in chilli height, leaf width, leaf length canopy width, branches/plant, stem width, fruit width, fruit length, fruits/plant and yields/plant may be attributed to their genetic potential as well an environmental factors and ability to absorb nutrients (Yadav et al., 2013).

The results of this study agrees with work done by many researchers and many plant such as Vos and Frinking (1997), El-Tohamy et al. (2006), Jarret (2008), Nkansah et al. (2011), Butt et al. (2016) who reported significant differences in plant heights leaf width, leaf length canopy and yields/plant in other crops due to genetic and environmental conditions (Bulluck et al., 2002). The results of yields and pod numbers of chilli found that the plant tested under the chemical agricultural system had higher yield than chilli production under organic agricultural system (Deore et al., 2010; Mcsorley, 2011), this is consistent with reports of growing plants during the growing season. It was found that the average yield and yield components of plants tested under the chemical and organic system (Datta et al., 2011; Narkhede et al., 2011) or the yield of green beans had the same effect (Naeem et al., 2006). For comparison total yields showed that the production yields under chemical agricultural system had more yield than organic agricultural system about 20-65%. Similar to Saleque et al. (2004), Bulluck et al. (2002), Naik et al. (2012) and Yadav et al. (2013) who observed that cost value of organic manure and chemical fertilizers. However, when calculating profits between planted under chemical and organic farming found that plant grown under organic agricultural system are more profitable than chemical agricultural system (Naik et al., 2012). Moreover, organic agricultural system is also safe to consumer and environment (Bhattacharya and Chakraborty, 2005; Petlamul et al., 2009; Campiglia et al., 2015).

When compared damage from diseases and insect pests between the chilli grown under chemical and organic agricultural systems showed that all chilli varieties produced under the chemical had lower percentage of diseases and insect pests than the chilli produced under organic agricultural system. Due to chilli grown under the chemical agricultural system can be used insecticides, herbicides, hormones and GMO (Genetically Modified Organisms) seeds to control insects, weeds, funguses, and diseases, but chilli grown under organic farming system do not allowed those substances. Therefore, diseases and insects are easy to damage or *destroy* (Pandey et al., 2006; Naik et al., 2011).

Temperature had a direct influence on root and stem rot disease and insect pest development. The environment is an important factor because the environment will be added to the destruction of a diseases and insects or reduces the level of diseases or insects (Dahanayake et al., 2012). However, compare the incidence of this experiment. Environment is a contributing factor to the diseases and insects due to the temperature and high humidity (Chiranjeevi et al., 2002; Benchasri, 2015). So, this experiment is to study the diseases and insects in real conditions and Chee variety should also be used for further breeding or plant in commercial variety. The outcome of the study may be used as guidance for chilli production in Thailand.

Conclusions

In general yield and yield components in the chilli varieties varied significantly between all genotypes of chilli produced and managed under the chemical agricultural system produced a higher yield per plant than the organic agricultural system. However, Chee variety recorded the highest yield in two systems. Moreover, Chee variety is the most resistant to disease and insect pests both chemical and organic agricultural systems. Then we recommended that Chee variety should also be used for further breeding, physiological as well as pungency studies.

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