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Genetic variability for yield and yield components of Thai chilli (*Capsicum* spp.) landraces under inorganic and organic agricultural systems

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Abstract

Yield components and genetic variation for high yield potential is an essential prerequisite for the development of chilli cultivars with improved production system. The objectives of this study were to evaluate yield and yield component and genotypic variability of chill germplasm. Each experiment was conducted in a Randomized complete block design (RCBD) with four replications of two production systems between December 2012 and June 2013. The results showed that in this germplasm, there were highly significant variability ($p \leq 0.01$) for fruit width, fruit length, number of fruits plant^{-1}, fruit weights fruit^{-1} and fruit yields plant^{-1}. The highest number of quality fruit was found on Chee genotype 519.42±14.27 and 512.69±12.35 fruits plant^{-1} under inorganic and organic agricultural systems, respectively. The lowest number of quality fruit was observed on Labmeunang genotype (27.63±6.10 and 19.89±5.78 fruits plant^{-1} under the inorganic agricultural system and organic agricultural system, respectively). Chee genotype produced the highest yield under the inorganic and organic agricultural system 701.22±18.58 and 630.61±16.35 g plant^{-1}, respectively. Labmeunang genotype produced the lowest yield (26.45±10.05 g.plant^{-1}) under the organic agricultural system. The results indicated that Chee genotype show potential for chilli production in both systems.

Keywords: *Capsicum* spp., Agricultural system, Genotype, Interaction.

Introduction

Chilli hot pepper (*Capsicum* spp.) belongs to the family Solanaceae (Rajamanickam and Sethuraman, 2015). The crop is undoubtedly a native of tropical America and widely distributed throughout Africa and Asia (Jagtap et al., 2012a; Khan et al., 2012). Chilli is an important crop in preparation of many food and many countries such as India, Thailand, Japan, China, Burma, Vietnam, Cambodia and Laos (Sangdee et al., 2011). 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 (Stewart et al., 2005; Jarret, 2008). The nutritive value of chilli is excellent (Pawar et al., 2011; Jagtap 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 (Gurung et al., 2012). 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.

Nowadays, with increase of population, our aim is not only to stabilize agricultural production but also to increase it further in sustainable manner (Sangwankam and Pitakaso, 2014). Excessive use of agro-chemicals like pesticides and fertilizers has affected the soil health, leading to reduction in crop yield and product quality (Sangdee et al., 2011). Hence, a natural balance needs to be maintained at all cost (Ghaouti and Link, 2009; Mehmood et al., 2016).

Chilli cultivars with good adaptation to organic agricultural systems have not been investigated in Thailand. So, it is important to compare the crop performance of chilli cultivars in terms of yield, yield components and combined analysis under both inorganic and organic production systems 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 of combined stability and to identify chilli cultivars that have good adaptation to inorganic and organic agricultural systems. The information obtained in this study will be useful for providing suggestion to chilli growers under inorganic and organic agricultural systems in Thailand or worldwide.

Results

Soil content, plant survival and weather conditions

Soil content for this research is shown in Table 1. The soil had 1.16-1.15% of organic matter, 0.14-0.15% of total nitrogen contents, 34.33-37.01 mg.kg^{-1} of phosphorus, 65.01-82.35 mg.kg^{-1} of potassium, and 0.07 – 0.08 dS.m^{-1} of electric conductivity (EC) for chilli planting under inorganic agricultural system. On the other side, chilli organic agricultural system had organic matter, nitrogen contents, phosphorus, potassium and electric conductivity in before planting 1.02%, 0.15%, 37.33 $mg.kg^{-1}$, 41.67 $mg.kg^{-1}$ and 0.06 $dS.m^{-1}$, respectively.

Thirty five genotypes of hot chilli were evaluated for plant survival at 30 days after transplanting. Survival percentages ranged from 50.00% to 85.71% and 42.86% to 85.71% were recorded under inorganic production system and organic production system, respectively. Top star cultivar had the highest survival percentages of 85.71% under inorganic and organic agricultural systems, whereas Labmeunang had the lowest survival percentages of 50% under inorganic agricultural system and 42.86% under organic agricultural system. Other chilli genotypes with high survival percentages were Hot het, Jindadang, Jindadum, Mundum, Pratadtong, Pretty and Yhodtong (Fig 1). In general, inorganic production system had higher survival percentage than organic production system. Chee had the highest difference (14.28%) between inorganic production system and organic production system.

The meteorological data were shown in Fig 2. The air temperature during 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% (Fig 2A). Rain day ranged from 4 to 23 days, while lowest rainfall was recorded in March 2013 (Fig 2B).

Fruit yield and yield components of chill between two production systems

In this study, chilli genotypes cultivated in organic and inorganic farming systems responded significantly different ($p \leq 0.01$). The fruit width, fruit length, fruit number, fruit weight and fruit yield responded significantly different under the inorganic agricultural system. 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. Numbers of $fruit.plant^{-1}$ ranged from 27.63±6.10 fruits in Labmeunang to 519.42±14.27 fruits in Chee. The fruit weights ranged from 0.98±0.08 g in Karang to 12.69±3.20 g in Nheumkeaw. The highest fruit yield of 701.22±18.58 g was calculated from Chee and the lowest fruit yield of 38.41±12.25 g was harvested from Labmeunang. Under organic production system, chilli genotypes were also significantly different ($p \leq 0.01$) for fruit width, fruit length, fruit numbers, fruit weight and fruit yield. 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 number of 512.69±12.35 $fruits.plant^{-1}$, and Labmeunang was the genotype of lowest fruit $numbers.plant^{-1}$ (19.89±5.78 fruits). Nheumkeaw was the genotype with the highest fruit weight (12.61±3.28 g) and Karang was the genotype with the lowest fruit weight (0.89±0.07 g). The highest fruit yield (630.61±16.35 g) was obtained from Chee and the lowest fruit yield (26.45±10.05 g) was obtained from Labmeunang (Table 2). Inorganic production system had higher fruit number and fruit yields than organic production system for all genotypes. The differences between production systems for fruit numbers were between 5.74 $fruits.plant^{-1}$ in Karang and 31.74 fruits in Jindadum, whereas the differences between production systems for fruit yields were between 8.72 g in Keenuson and 189.44 g in Jomthong. It is interesting to note that Chee had the highest fruit numbers and fruit yield but the differences between inorganic and organic production system for fruit number and fruit yield were rather low in this genotype (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 (Table 3).

Combined analysis of variance in different systems

Combined analysis of variance indicated that differences between systems (S) and among genotypes (G) were significant for fruit width, fruit length, number of $fruits.plant^{-1}$, fruit $weights.fruit^{-1}$ and $yields.plant^{-1}$. There were also significant interactions between system and genotypes (S x G) for fruit width, fruit length, number of fruits, fruit weight and fruit yields for organic and inorganic production systems while, the variation of replication (Blocks) within the system for all traits were non-significant (Table 4).

Mean analysis and comparison

Mean analysis of fruit width, fruit length, number of $fruits.plant^{-1}$, fruit $weights.fruit^{-1}$ and fruit yield have shown significant differences between system productions. There were also significant 328.20 and 273.73 g under inorganic and organic agricultural system, respectively. However, all characteristics of organic agricultural system were lower than inorganic agricultural system in all genotypes (Table 5).

Discussion

The present study quantitatively compared the influence of temperature, the level of relative humidity and raining on development times of chilli growth during the experimental period from December 2012 to June in 2013. We found that the highest average temperature in May was 33.89°C, whereas the highest humidity in December was 96.13%. However, the average temperature levels were recorded between 27.35 and 29.61°C and the average relative humidity was obtained between 78.27 and 86.86 percent. We found that Chee genotype has the highest seed germination percentage about 94.23 and 95.19% (data not shown) under inorganic agricultural system and organic agricultural systems, respectively. The percentage of regeneration system under inorganic agricultural system test showed a higher percentage than organic agricultural system, because the seed is protected by the substance that prevents fungus and insects into ruin, while the system of organic agricultural production in not allowed (Trewavas, 2004; Yadav et al., 2013). These substances kill insects, diseases and/or prevent their easy access to plants which promote the ability of plants to sprout (Sangdee et al., 2011). In addition, chilli planting phase and environmental factors can affect seed germination and growth of plants (Datta et al., 2011; Dahanayake et al., 2012; Rajamanickam and Sethuraman,

Table 1. Soil chemical properties of the experiment.

Soil properties	Inorganic		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^{-1})	0.08	0.07	0.06	0.07	

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

Table 2. Yield and yield components of chill planted between two systems.

Genotypes	Yield component of inorganic agricultural system (Mean±SE)					Yield component of organic agricultural system (Mean±SE)				
	Fruit width (cm)	Fruit length(cm)	Fruit numbers. plant^{-1} (fruit)	Fruit weight (g)	Fruit yields.plant^{-1} (g)	Fruit width(cm)	Fruit length(cm)	Fruit number. plant^{-1}(fruit)	Fruit weight(g)	Fruit yields.plant^{-1}(g)
Black hot	1.01±0.02cde	8.65±0.35de	63.02±6.71hij	8.15±1.12bcd	513.74±80.25cdef	0.93±0.02ef	8.63±0.34cde	53.39±5.68hij	8.06±1.21bc	430.32±52.35d
Chaiprakan	0.87±0.01def	8.25±0.85de	58.22±2.70jk	4.35±0.58def	253.26±22.69ef	0.84±0.02ef	8.21±0.75cdef	46.46±2.35jk	4.23±0.68def	196.53±21.35hij
Chee	0.78±0.06ef	6.54±0.54fg	519.42±14.27a	1.35±0.06i	701.22±18.58a	0.68±0.03g	6.52±0.54efg	512.69±12.35a	1.23±0.35jk	630.61±16.35a
Choypach	0.86±0.01def	6.77±0.24fg	55.20±1.95jk	2.03±0.25fg	112.06±11.80jk	0.75±0.01fg	6.75±0.21efg	43.47±13.25jk	1.93±0.25gh	83.90±10.20l
Dehot	0.75±0.02ef	7.35±0.36efg	60.60±3.90ijk	3.21±0.35ef	194.53±18.68ghi	0.62±0.02g	7.31±0.23def	51.86±2.68hij	3.12±1.02efg	161.80±16.38ij
Dinamai	0.86±0.03def	5.82±0.09fgh	107.42±18.10fg	2.01±0.35fgh	215.70±49.66gh	0.82±0.04efg	5.79±0.34fg	96.64±14.35efg	1.94±0.65gh	187.48±43.36ij
Dumnean	0.86±0.06def	4.68±0.14hi	100.42±8.05fg	2.36±0.68fg	236.99±31.25efg	0.75±0.05fg	4.66±0.08hi	88.66±7.69efg	2.26±0.36efg	200.37±32.58hi
Haomkeaw	1.27±0.06cd	10.97±0.25cd	53.46±4.15jk	7.88±1.25cd	421.37±77.98cdef	1.14±0.04de	10.95±0.12cde	43.72±3.58jk	7.77±1.69bc	339.70±75.35efg
Hot het	0.61±0.01fg	5.10±0.13ghi	121.20±13.67ef	1.36±0.55i	164.35±60.59hij	0.51±0.01hi	5.08±0.24gh	101.43±12.20def	1.26±0.09jk	127.80±59.28ijk
Intira	0.56±0.01g	6.35±0.24fg	82.23±7.83ghi	1.32±0.64i	108.54±19.85k	0.47±0.02i	6.33±0.13efg	70.47±2.34fgh	1.23±0.06jk	86.64±14.36l
Jindadang	0.77±0.05ef	5.00±0.13ghi	82.80±9.37ghi	1.65±0.25hi	136.62±56.52ijk	0.69±0.04g	4.98±0.21gh	74.06±8.36fg	1.53±0.32hij	113.31±54.21jk
Jindadum	0.81±0.04def	5.48±0.15gh	219.32±18.99d	1.65±0.21hi	362.76±31.41def	0.73±0.06fg	5.46±0.12fgh	187.58±3.35d	1.56±0.06hij	292.62±30.28fgh
Jomthong	1.32±0.11cd	12.71±0.65bc	64.27±4.62hij	10.90±1.07b	700.80±71.03a	1.20±0.08cde	12.61±0.13ab	50.53±4.35ijk	10.12±3.05ab	511.36±70.28bc
Karang	0.75±0.11ef	4.12±0.33i	229.20±4.51cd	0.98±0.08j	224.62±28.85fgh	0.65±0.05g	4.10±0.54i	223.46±4.25cd	0.89±0.07l	198.88±26.35hij
Keenukaw	0.63±0.07fg	8.01±1.02de	186.04±10.07e	1.24±0.24ij	230.69±44.52efgh	0.45±0.05i	8.00±0.21def	179.33±10.20de	1.15±0.21k	206.23±40.15ghi
Keenuson	0.53±0.05g	5.45±0.17gh	287.35±11.90c	1.32±0.31i	379.30±29.57def	0.38±0.08j	5.44±0.98gh	278.63±11.20c	1.33±0.33ijk	370.58±25.36de
Kungsalad	1.23±0.10cd	11.88±0.24bcd	51.06±3.16kl	10.23±2.02bc	522.34±27.43cde	1.13±0.03def	11.85±0.16bcd	43.32±5.36jk	10.13±3.36ab	438.83±24.25cd
Labmeunang	0.39±0.02h	4.66±0.24h	27.63±6.10n	1.39±0.36i	38.41±12.25l	0.33±0.05j	4.64±0.24hi	19.89±5.78n	1.33±0.15ijk	26.45±10.05m
Maliwan	1.50±0.07cd	11.89±0.52bc	76.43±4.21hi	8.88±1.06bc	679.00±62.02ab	1.41±0.02cd	11.86±0.21abc	59.52±3.54ghi	8.78±1.02bc	522.59±56.38b
Manikhan	0.58±0.03g	5.49±0.15gh	139.63±3.71ef	1.97±0.31gh	274.51±58.25def	0.52±0.02hi	5.46±0.52fgh	120.87±2.54def	1.85±0.25ghi	223.61±54.21gh
Mundum	1.42±0.08cd	9.62±0.49cde	82.68±7.89ghi	6.54±1.06cde	540.73±89.55cd	1.33±0.07cd	9.60±0.12cde	71.95±5.46fgh	6.44±0.98bcd	463.36±87.25c
Nheumkeaw	1.33±0.14cd	14.94±0.48a	51.36±2.45kl	12.69±3.20a	651.86±57.36bc	1.24±0.12cde	14.90±0.42a	40.67±2.01kl	12.61±3.28a	512.85±52.45bc
OP1	0.66±0.11fg	6.22±0.61fg	396.76±8.04b	1.56±0.26hi	618.95±32.35bc	0.61±0.11g	6.22±0.98efg	389.02±8.25b	1.47±0.28hijk	571.86±40.12b
OP2	0.66±0.11fg	6.22±0.59fg	380.46±20.18b	1.59±0.31hi	604.93±56.68bcd	0.60±0.09gh	6.21±0.52efg	366.77±9.02b	1.48±0.67hijk	542.82±40.35b
Patsiam	0.98±0.03de	8.39±0.11de	84.66±8.11g	1.95±0.31gh	164.92±36.25hi	0.89±0.02ef	8.38±0.12cde	73.92±8.57fg	1.81±0.78ghi	133.80±32.05ijk
Pongpach	1.35±0.05cd	7.45±0.19efg	52.35±2.70jkl	5.55±0.87de	290.44±23.54edef	1.31±0.05cd	7.43±0.26def	41.67±2.35jkl	5.44±2.06cd	226.68±15.08gh
Pratadtong	0.71±0.06ef	11.62±0.30bcd	60.32±9.52ijk	2.35±0.25fg	141.51±19.36ij	0.58±0.05hi	11.50±0.23bcd	50.57±8.65ij	2.26±0.14efg	114.24±26.87jk
Pretty	1.04±0.03cde	11.13±0.37bcd	52.71±3.21jkl	5.57±0.24cde	293.49±29.68def	0.95±0.03def	11.07±0.34bcd	44.93±3.36jk	5.45±2.05cd	244.87±14.58fgh
Redhot	1.24±0.33cd	11.38±0.23bcd	81.65±7.62ghi	1.84±0.19ghi	150.56±18.36hij	1.15±0.21de	11.31±0.64bcd	70.92±7.35fgh	1.76±0.28hij	124.82±21.06ijk
Saoykai	0.59±0.03g	5.70±0.14gh	67.32±2.61hij	2.21±0.05fg	148.91±20.68ij	0.49±0.25i	5.67±0.12fgh	57.58±4.21ghi	2.11±0.38efg	121.49±40.15jk
Saoypet	2.21±0.35a	8.25±0.87de	58.82±4.16jk	5.99±1.58cde	352.59±40.15def	2.16±0.12a	8.23±0.58cde	46.03±2.15jk	5.91±0.09cd	272.04±24.58fgh
Sriphai	1.98±0.13b	6.01±0.98fg	48.32±2.92l	4.35±1.01def	210.19±29.57ghi	1.88±0.09b	5.99±0.57fg	37.53±2.36l	4.24±0.58def	159.13±16.58ijk
Top green	1.22±0.14cd	9.56±0.20cde	30.41±2.55m	4.25±0.82def	129.36±17.58ijk	1.23±0.04cde	9.55±0.16cde	22.67±3.58m	4.17±1.25def	94.53±13.26kl
Top star	1.29±0.05cd	10.56±1.02cd	75.22±9.22hi	5.02±0.67def	377.45±38.66def	1.23±0.05cde	10.51±0.25cde	67.48±8.62fgh	4.94±2.08def	333.35±32.05efg
Yhodtong	0.98±0.06de	5.70±0.15gh	162.12±15.07e	2.10±0.13fg	340.45±38.74def	0.86±0.03ef	5.64±0.36fgh	154.38±12.03de	2.04±0.24fgh	314.94±65.35fg
C.V.(%)	10.32	9.87	11.45	11.00	12.34	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.

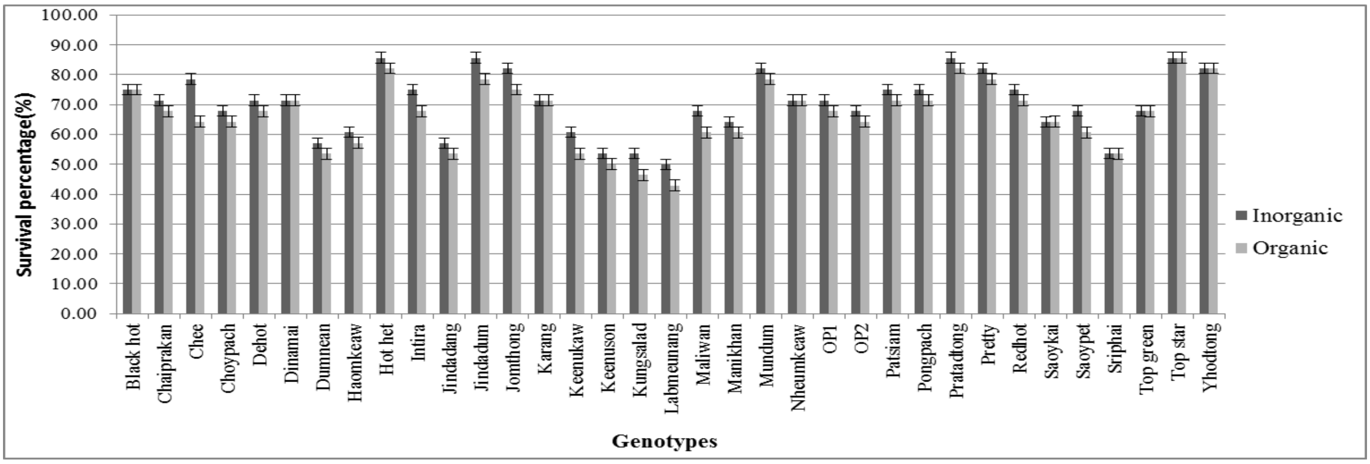

Fig 1. Survival percentage (%) of chilli genotypes under the fields.

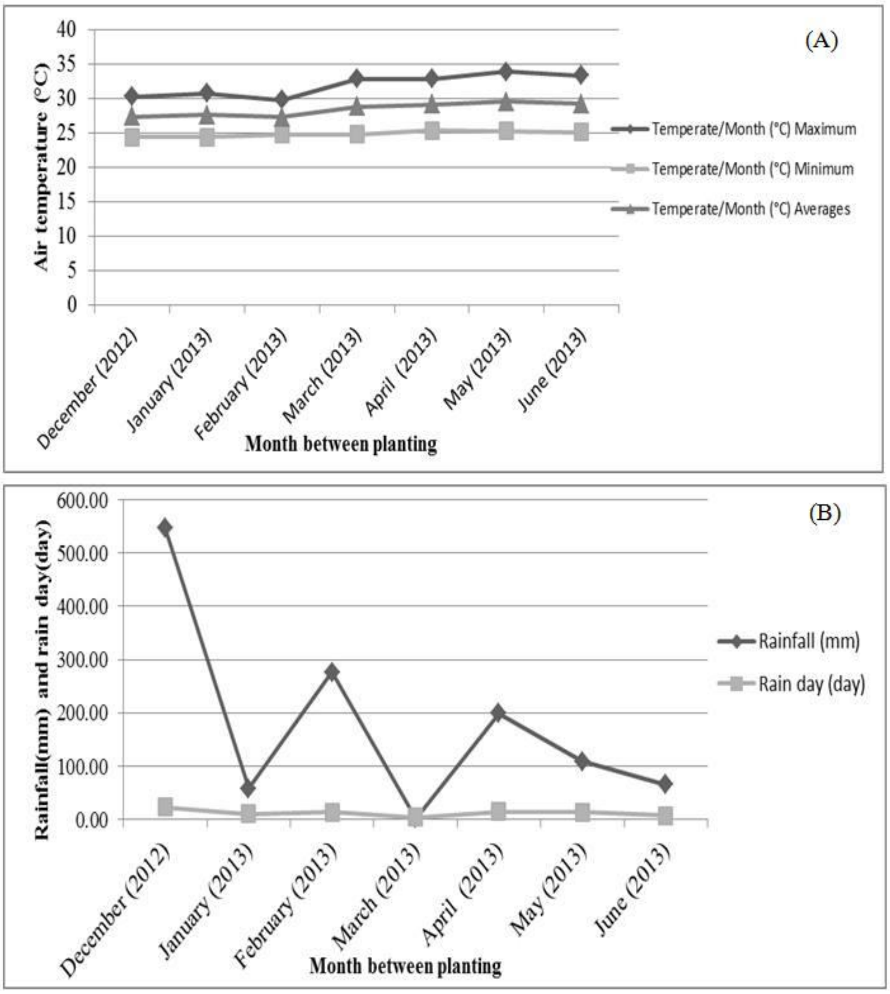

Fig 2. Temperature, relative humidity and rainfall in Phatthalung province.

Table 3. Means for the differences for these traits between two production systems.

Genotypes	Fruit numbers.plant^{-1}(fruit) Inorganic system	Fruit numbers.plant^{-1}(fruit) Organic system	Fruit numbers.plant^{-1}(fruit) Difference[1]	Fruit yields.plant^{-1}(g) Inorganic system	Fruit yields.plant^{-1}(g) Organic system	Fruit yields.plant^{-1}(g) Difference[1]
Black hot	63.02^{hij}	53.39^{hij}	+9.63	513.74^{cdef}	430.32^{d}	+83.42
Chaiprakan	58.22^{jk}	46.46^{jk}	+11.76	253.26^{ef}	196.53^{hij}	+56.73
Chee	519.42^{a}	512.69^{a}	+6.73	701.22^{a}	630.61^{a}	+70.61
Choypach	55.20^{jk}	43.47^{jk}	+11.73	112.06^{jk}	83.90^{l}	+28.16
Dehot	60.60^{ijk}	51.86^{hij}	+8.74	194.53^{ghi}	161.80^{ij}	+32.73
Dinamai	107.42^{fg}	96.64^{efg}	+10.78	215.70^{gh}	187.48^{ij}	+28.22
Dumnean	100.42^{fg}	88.66^{efg}	+11.76	236.99^{efg}	200.37^{hi}	+36.62
Haomkeaw	53.46^{jk}	43.72^{jk}	+9.74	421.37^{cdef}	339.70^{efg}	+81.67
Hot het	121.20^{ef}	101.43^{def}	+19.77	164.35^{hij}	127.80^{ijk}	+36.55
Intira	82.23^{ghi}	70.47^{fgh}	+11.76	108.54^{k}	86.64^{l}	+21.90
Jindadang	82.80^{ghi}	74.06^{fg}	+8.74	136.62^{ijk}	113.31^{jk}	+23.31
Jindadum	219.32^{d}	187.58^{d}	+31.74	362.76^{def}	292.62^{fgh}	+70.14
Jomthong	64.27^{hij}	50.53^{ijk}	+13.74	700.80^{a}	511.36^{bc}	+189.44
Karang	229.20^{cd}	223.46^{cd}	+5.74	224.62^{fgh}	198.88^{hij}	+25.74
Keenukaw	186.04^{e}	179.33^{de}	+6.71	230.69^{efgh}	206.23^{ghi}	+24.46
Keenuson	287.35^{c}	278.63^{c}	+8.72	379.30^{def}	370.58^{de}	+8.72
Kungsalad	51.06^{kl}	43.32^{jk}	+7.74	522.34^{cde}	438.83^{cd}	+83.51
Labmeunang	27.63^{n}	19.89^{n}	+7.74	38.41^{l}	26.45^{m}	+11.96
Maliwan	76.43^{hi}	59.52^{ghi}	+16.91	679.00^{ab}	522.59^{b}	+156.41
Manikhan	139.63^{ef}	120.87^{def}	+18.76	274.51^{def}	223.61^{gh}	+50.90
Mundum	82.68^{ghi}	71.95^{fgh}	+10.73	540.73^{cd}	463.36^{c}	+77.37
Nheumkeaw	51.36^{kl}	40.67^{kl}	+10.69	651.86^{bc}	512.85^{bc}	+139.01
OP1	396.76^{b}	389.02^{b}	+7.74	618.95^{bc}	571.86^{b}	+47.09
OP2	380.46^{b}	366.77^{b}	+13.69	604.93^{bcd}	542.82^{b}	+62.11
Patsiam	84.66^{g}	73.92^{fg}	+10.74	164.92^{hi}	133.80^{ijk}	+31.12
Pongpach	52.35^{jkl}	41.67^{jkl}	+10.68	290.44^{edef}	226.68^{gh}	+63.76
Pratadtong	60.32^{ijk}	50.57^{ij}	+9.75	141.51^{ij}	114.24^{jk}	+27.27
Pretty	52.71^{jkl}	44.93^{jk}	+7.78	293.49^{def}	244.87^{fgh}	+48.62
Redhot	81.65^{ghi}	70.92^{fgh}	+10.73	150.56^{hij}	124.82^{ijk}	+25.74
Saoykai	67.32^{hij}	57.58^{ghi}	+9.74	148.91^{ij}	121.49^{jk}	+27.42
Saoypet	58.82^{jk}	46.03^{jk}	+12.79	352.59^{def}	272.04^{fgh}	+80.55
Sriphai	48.32^{l}	37.53^{l}	+10.79	210.19^{ghi}	159.13^{ijk}	+51.06
Top green	30.41^{m}	22.67^{m}	+7.74	129.36^{ijk}	94.53^{kl}	+34.83
Top star	75.23^{hi}	67.48^{fgh}	+7.75	377.45^{def}	333.35^{efg}	+44.10
Yhodtong	162.12^{e}	154.38^{de}	+7.74	340.45^{def}	314.94^{fg}	+25.51
C.V.(%)	11.45	10.24		12.34	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. [1]+ indicates that inorganic system was higher than organic system.

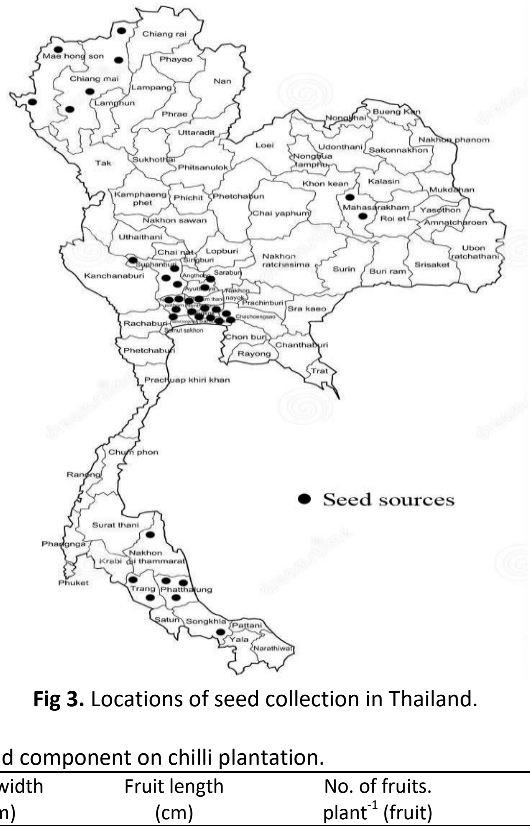

Fig 3. Locations of seed collection in Thailand.

Table 4. Mean squares for yield and yield component on chilli plantation.

Source of variances	DF	Fruit width (cm)	Fruit length (cm)	No. of fruits. plant^{-1} (fruit)	Fruit weight. fruit^{-1} (g)	Fruit yields. plant^{-1} (g)
Systems (S)	1	129.57ns	725.49*	873.58**	851.38**	10,867.68**
Blocks. Within S	6	76.11ns	331.72ns	245.01ns	237.86ns	1,424.15ns
Genotypes (G)	34	267.58**	979.12**	1,452.58**	1,002.14**	29,542.25**
S x G	34	203.55**	887.51**	1,384.67**	958.14**	24,054.68**
Pooled error	204	38.68	186.36	129.13	124.52	872.58

*, ** significant difference at P ≤ 0.05 and P ≤ 0.01 levels, respectively.

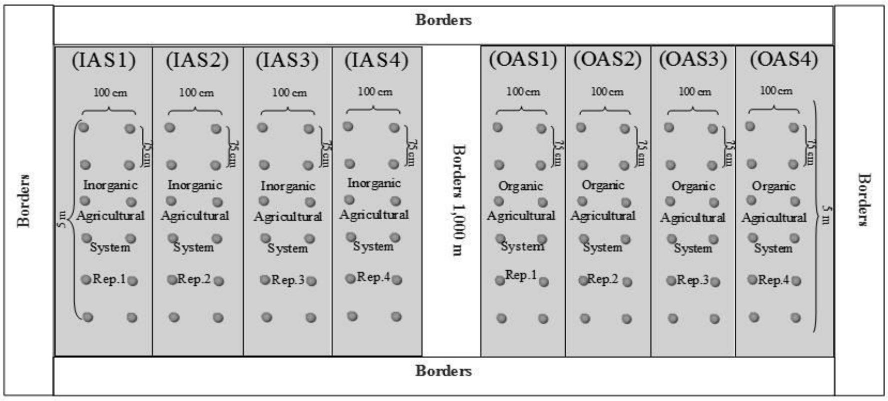

Fig 4. RCBD experimental plotting design.

Table 5. Means for fruit width, fruit length, number of fruits.plant^{-1}, fruit weight and fruit yield of chilli grown at two growing systems.

Systems	Fruit width (cm)	Fruit length (cm)	No. of fruits. plant^{-1} (fruit)	Fruit weights . fruit^{-1}(g)	Fruit yields. Plant^{-1}(g)
Inorganic	0.98ns	7.98a	122.00a	3.95a	328.20a
Organic	0.90ns	7.91b	110.92b	3.82b	273.73b
Means	0.94	7.95	116.46	3.89	300.97

Means in the same column followed by the same letter(s) are not significantly different at P≤0.05 by DMRT.

Table 6. Thirty five genotypes of hot chilli used in the experiment.

Genotypes	Canopy size	Characteristics	Original sources	
Black hot	medium size	medium plant	normal market	Bangkok province
Chaiprakan	medium size	short plant	normal market	Samut Prakan province
Chee	big size	high plant	local genotype	Phatthalung province
Choypach	medium size	medium plant	normal market	Supan buri province
Deehot	medium size	medium plant	normal market	Supan buri province
Dinamai	small size	medium plant	normal market	Nakhon Pathom province
Dumnean	medium size	short plant	normal market	Samut Prakan province
Haomkeaw	medium size	medium plant	normal market	Samut Prakan province
Hot het	medium size	high plant	normal market	Samut Prakan province
Intira	small size	short plant	normal market	Bangkok province
Jindadang	small size	medium plant	normal market	Mae Hong Son province
Jindadum	medium size	medium plant	normal market	Chiang Mai province
Jomthong	big size	short plant	normal market	Chiang Mai province
Karang	big size	medium plant	local genotype	Mae Hong Son province
keenukaw	medium size	medium plant	local market	Phatthalung province
Keenuson	medium size	short plant	local market	Phatthalung province
Kungsalad	medium size	medium plant	normal market	Maha Sarakham province
Labmeunang	small size	short plant	normal market	Maha Sarakham province
Maliwan	small size	short plant	normal market	Suphan Buri province
Manikhan	medium size	short plant	normal market	Suphan Buri province
Mundum	medium size	medium plant	normal market	Samut Prakan province
Nheumkeaw	medium size	medium plant	normal market	Samut Prakan province
OP1	big size	high plant	local genotype	Trang province
OP2	big size	high plant	local market	Trang province
Patsiam	medium size	short plant	normal market	Pathum Thani province
Pongpach	small size	short plant	normal market	Pathum Thani province
Pratadtong	medium size	medium plant	normal market	Nonthaburi province
Pretty	small size	short plant	normal market	Nonthaburi province
Redhot	small size	short plant	normal market	Nakhon Pathom province
Saoykai	medium size	medium plant	normal market	Songkhla province
Saoypet	small size	short plant	normal market	Nakhon Pathom province
Sriphai	small size	short plant	normal market	Nakhon Pathom province
Top green	medium size	medium plant	normal market	Chiang Mai province
Top star	small size	medium plant	normal market	Chiang Mai province
Yhodtong	medium size	short plant	normal market	Nakhon Si Thammarat

Table 7. Analysis of variance by Randomized Complete Block Design (Fixed model).

Sources	DF	SS	MS	F
Treatment	t-1	SSTr $=(T_1^2+T_2^2+\ldots+T_t^2)/r$-CF	SSTr/(t-1)	MSTr/MSE
Rep or Block	r-1	SSR = $(R_1^2+R_2^2+\ldots R_r^2)/t$-CF	SSR/(r-1)	MSR/MSE
Error	(t-1)(r-1)	SSE = Total SS – SSTr – SSR	SSE/(t – 1)(r –1)	
Total	t.r-1	Total SS = $\sum(X_{ij}^2)$ - CF		

Table 8. Combined analysis sources.

Source of variances	DF	MS	Expected Mean Square
Systems (S)	s-1	MS(system)	$\sigma_{\varepsilon}^{2} + g\sigma_{r/s}^{2} + gr\sigma_{s}^{2}$
Blocks. Within S	s(r-1)	MS(Blocks within s)	$\sigma_{\varepsilon}^{2} + g\sigma_{r/s}^{2}$
Genotypes (G)	g-1	MS(genotype)	$\sigma_{\varepsilon}^{2} + r\sigma_{gs}^{2} + rs\sigma_{g}^{2}$
S x G	(s-1)(g-1)	MS(system x genotype)	$\sigma_{\varepsilon}^{2} + r\sigma_{gs}^{2}$
Pooled error	s(r-1)(g-1)	MS(error)	σ_{ε}^{2}
Total	sgr-1		

2015). Morphological characters in the chilli genotypes varied significantly between all lines of chilli. The significant variation in fruit width, fruit length, fruit numbers, fruit weight and yields.plant^{-1} might 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 such as El-Tohamy et al. (2006), Jarret (2008), Nkansah et al. (2011), and Payakhapaab et al. (2012) who reported significant differences in plant heights leaf width, leaf length canopy and yields.plant^{-1} in some other crops due to genetic and environmental conditions (Bulluck et al., 2002).

In this study, chilli genotypes grown through organic agricultural system had lower fruit width, fruit length, number of fruits.plant^{-1}, fruit weight and yields.plant^{-1}, compared to genotypes grown through inorganic agricultural system. The results were similar to those reported by Deore et al., (2010) and Mcsorley (2011). It was found that the average yield and yield components of plants tested under the inorganic 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). Evaluation of total yield showed that the production under inorganic agricultural system had more yield than organic agricultural system, about 20-65% higher. Saleque et al. (2004), Bulluck et al. (2002), Naik et al. (2012) and Yadav et al. (2013) reported that there is cost of organic manure and chemical fertilizers for organic and inorganic agriculture, respectively. However, profit comparisons between planted under chemical and organic farming show that plant grown under organic agricultural system are more profitable than chemical (inorganic) agricultural system (Naik et al., 2012). Moreover, organic agricultural system is also safe to the consumer and environment (Bhattacharya and Chakraborty, 2005; Naik et al., 2011; Singh et al., 2014; Campiglia et al., 2015).

The significant interaction between S (system) × G (genotype) effects indicated that genotype responded differently to changes in environments (production system). High proportion of variation on yield and yield components were found for the genotype effect; therefore, more testing sites are needed or the environments in locations need to be controlled (Gurung et al., 2012). Many researchers reported that yield and yield components content were affected by genetic and environment conditions (Contreras-Padilla and Yahia, 1998; Zewdie and Bosland, 2000). Moreover, Gurung et al. (2012) reported that environment had stronger effect on yield. In contrast, Gurung et al. (2012) found that genotype played a major role in yield contents as more than 70% of the variation was due to cultivar effect although G×S was significant. A large source of variation due to genotype was also reported by Nkansah et al. (2011). However, our genotypes were local varieties in countries. Therefore, even with diverse environments, genotypes had more effect on yield rather than plantation system. This experiment suggests that Chee genotype should be used for further breeding or plant in commercial genotypes. The outcome of the study may be used as guidance for chilli production in Thailand.

Materials and Methods

Plant materials and experiment conditions

Thirty five landraces of chilli used in this study. They were selected from different areas in Thailand (Table 6, Fig 3). The chilli genotypes were planted in a Randomized Complete Block Design with four replications in two agricultural systems (inorganic and organic) at the Department of Plant Science, Faculty of Technology and Community Development, Thaksin University Phatthalung Campus, Phatthalung province, Thailand (7° 37' 0" N, 100° 5' 0" E) (between December 2012 and June 2013). The soil type was Phatthalung series (Yt: Fine, kaolinitic, isohyperthermic, plinthic, paleaquults). Prior to the start 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 (Fig 4). Soil preparation and crop management for organic trail followed the regulations of the Organic Agriculture Certification Thailand (ACT, 2012) and the International Federation of Organic Agriculture Movements (IFOAM, 2005).

Briefly, the one month-old seedlings of 35 genotypes were transplanted into the field. Inorganic fertilizer (formula 15-15-15 of NPK) was applied to the inorganic 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} (Benchasri, 2015). 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. 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 inorganic and organic systems, and inorganic control of insects and diseases was practiced under inorganic system only (Benchasri, 2015), whereas biological control was practiced under organic farming systems (Oyesola and Obabire, 2011).

Data collection

Soil and meteorological conditions

Survival percentage was recorded at 30 days after transplanting from total number of 28 plants in each plot. Soil contents and chemical properties were analyzed. Weather condition about rainfall, humidity, air temperature such as maximum, minimum and average air for this experiment were also recorded monthly from transplantation to harvest by a weather station located 100 m away from the experimental field.

Yield and yield component traits

Important morphological characteristics of chilli such as fruit width, fruit length fruit number and fruit weight were measured for 60 fruits per treatment. In addition, yields.plant^{-1} were also recorded all genotypes. 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.

Statistical analysis

Data for separate locations were analyzed statistically according to a randomized complete block design. All analyses were done using the statistical programme of SPSS (Statistical Package for 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. Yield and yield components traits were statistically analyzed for each system (Table 7). Error variances were tested for homogeneity with Bartlett's test as described by Gomez and Gomez (1984). Combined analysis of variance was done for two environments (production systems) according to a statistical model explained by Freeman (1973) (Table 8).

Conclusion

Morphological characters yield and yield components in the chilli genotypes significantly varied between all lines of chilli managed under the inorganic agricultural system which produced a higher yield than the organic agricultural system. However, Chee genotype recorded the highest yield in two systems. Then we recommended that Chee genotype should also be used for further breeding programs.

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