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Original Article

The effect of genotypic variability on the yield and yield components of okra (*Abelmoschus esculentus* L. Moench) in Thailand

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Abstract

This study was conducted on twenty of okra lines (treatments) at the Thaksin University in two farming systems (conventional and organic cultivations). The experiments of conventional and organic cultivations were carried out in a Randomized complete block design (RCBD) with four replications to evaluate the yield, yield components and genetic variations. The results showed significant variability ($p \leq 0.05$) in the okra lines for fresh important traits of yield; marketable fruits.plant^{-1}, fruit yields.plant^{-1}, seeds.fruit^{-1}, 100 seed weight, 1000 seed weight and harvest index. The number of marketable fruits.plant^{-1} of KN-OYV-02 line showed the number of marketable fruits yield approximately 60.85 and 51.91 fruits.plant^{-1} under the conventional and organic farming systems, respectively. The lowest of marketable fruits.plant^{-1} were investigated in the OP (Open Pollination) line (30.58 and 26.74 fruits.plant^{-1} under the conventional and organic farming systems, respectively). KN-OYV-02 line produced the highest yield of two farming system (1,168.37 g.plant^{-1}). The OP line produced the lowest yield under the organic farming system (505.16 g.plant^{-1}). There were significant interactions between the cropping system and lines for the two system plantations. So, the results indicated that the KN-OYV-02 line showed the highest potential for okra breeding and production in both systems.

Keywords: Gene interactions, Line, Okra, Yield components

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Introduction

Okra or ladies finger was domesticated in West and Central Africa and is now widely cultivated throughout the tropics primarily for local consumption (Kumar et al., 2010; Chinatu et al., 2014). Okra, the most popular vegetable crop in Asia and Africa (Zeshan et al., 2019), is thought to be a native crop extending from Ethiopia to Sudan. Although the early-history and distribution are not known, okra was apparently introduced to Egypt in the seventh century. Okra is considered to be a prized vegetable due to its high nutrient value (Dabire-Binso et al., 2009).

Normally, okra green fruits are rich sources of carbohydrate, protein, dietary fiber, calcium, magnesium, potassium, and vitamins A and C ect. [Water 90%, Energy (kcal) 38, Carbohydrate (g) 7.6, Protein(g) 2.0, Fat (g) 0.1, Fiber (g) 0.9, K (mg) 303, Ca (mg) 81, P (mg) 63, Fe (mg) 0.8, Na (mg) 8, Vitamin A (IU) 660, Thiamine (mg) 0.20, Riboflavin (mg) 0.06, Niacin (mg) 1.00, Ascorbic acid (mg) 21.1 and Vitamin B6 (mg) 0.22]. Okra is also an excellent source of iodine, which is useful for the treatment of goiter (Liu et al., 2005; Benchasri, 2015). The green fruits can be boiled, fried or cooked. In Thailand and Asia, this vegetable is usually boiled in water resulting in viscous soups and sauces, which are relished. The fruits also serve as soup thickeners. The leaves buds and flowers are also edible. Okra seeds can be dried, and the dried seed is a nutritious material that can be used to prepare vegetable curds. The seeds can also be roasted and ground and used as a coffee additive or substitute. Okra leaves are often used as cattle feed, but this use is not the primary use of the plant. The powdered root of okra is consumed with sugar as a treatment for leucorrhoea backache. Okra acts as a tonic for both men and women and enables them to increase their vitality and vigor. Mucilage from the stem and roots is used for purifying sugarcane juice in jaggery manufacturing in many countries. Fully ripened fruits and stems containing crude fiber are used in the paper industry. Okra gum obtained from the seedfruits of *A. esculentus* is an anionic polysaccharide, which can be used as flocculant for the removal of solid wastes from tannery effluent (Moekchantuk and Kumar, 2004; Pendre et al., 2012). Industrially, okra mucilage is typically used to glace certain papers and in confectioneries, among other uses (Markose and Peter, 1990).

Over the past 50 years, high agricultural input levels have been used to maximized yields and profits with the aim of feeding the global population. However, these inputs have generated negative impacts on the atmosphere, hydrosphere, and pedosphere (Osma et al., 2012; Arbenz et al., 2017). The increased chemical composition of vegetables and other foodstuffs has become a substantial issue (Manond et al., 2011; Amalraj et al., 2013; Duman et al., 2018). Therefore, organic farming has long been viewed as a sustainable form of management for mitigating the present and potential risks within agro-ecosystems (Pradeepkumar et al., 2017; Suja et al., 2017). Organic farming systems aim to provide a cleaner environment and more fertile soil for future generations via the maintenance of soil organic matter, recycling of carbon, improvement of soil health, reduction of farm nitrogen and phosphorus, increase in biodiversity, reduction in energy use and improvement in energy efficiency (Ghaouti et al., 2008; Aiyelaagbe et al., 2016).

Okra plantation in Thailand, is mostly cultivated in many areas such as Angthong, Bangkok, Kanchanaburi, Nakornprotom, Saraburi, Supanburi, Phatthalung and Phichit provinces, respectively. The area, and productivity of okra in Thailand are approximately 1,996.80 ha and 11,232 tons.ha^{-1}, respectively (Benchasri, 2015). However, okra cultivars with good adaptations to organic farming systems have rarely been reported in Thailand. Thus, comparing the of yield, yield components and variability in genetics under two cropping system of conventional and organic farming are the most important for providing recommendations for okra breeding program and growth in the future. The objectives of this study were to compare the crop performance in difference of okra lines in terms of productivity and reactions of combined analysis of variance after growing in conventional and organic system in Thailand. Finally, selected of suitable genotype of all population with adaptations in both cultivations, identify okra cultivars that exhibit good adaptations to conventional and organic systems. The information data obtained in this study will be useful for providing suggestions for okra breeding program and growth under conventional and organic systems in Thailand.

Material and Methods

Plant materials and experimental conditions

Twenty lines of okra (treatments) including FAK DANG, KN–OYV–01, KN–OYV–02, KN–OYV–03, KN–OYV–04, KN–OYV–11, KN–OYV–12, KN–OYV–13, KN–OYV–14, KN–OYV–16, KN–OYV–25, LUCKYFILE 473, NO–71, OP (Open Pollination, Control line), PC52S5, PJ 03, RED FINGER, RED 322, TVRC 064 and TVRC 064, respectively (Table 1) were selected from different areas. Evaluations of the okra lines were carried out in a randomized complete block design with four replicates in conventional and organic systems at the Department of Plant Science, Faculty of Technology and Community Development, Thaksin University Phatthalung Campus, Phatthalung Province, Thailand between January and June 2018.

Table-1. Line information, source of origins and some characteristics of twenty okra germplasm in the experimental research

No.	Lines/codes	Sources	Original sources	Flower, Stem color, Pod color
1	FAK DANG	Phatthalung Province	Thailand	Red, red, yellow
2	KN-OYV-01	PHRC (India)	India	Light green, green, yellow
3	KN-OYV-02	PHRC	India	Reddish green, green, yellow
4	KN-OYV-03	PHRC	India	Dark green, green, yellow
5	KN-OYV-04	PHRC	India	Light green, green, yellow
6	KN-OYV-11	PHRC	India	Dark green, green, yellow
7	KN-OYV-12	PHRC	India	Light green, green, yellow
8	KN-OYV-13	PHRC	India	Light green, green, yellow
9	KN-OYV-14	PHRC	India	Dark green, green, yellow
10	KN-OYV-16	PHRC	India	Light green, green, yellow
11	KN-OYV-25	PHRC	India	Reddish green, green, yellow
12	LUCKY FILE 473	Bangkok Province	Japan	Light green, white, yellow
13	NO 71	PHRC	India	Dark green, green, yellow
14	OP (CONTROL)	Phatthalung Province	Thailand	Dark green, green, yellow
15	PC 52S5	PHRC	Thailand	Light green, green, yellow
16	PJ 03	PHRC	Thailand	Light green, green, yellow
17	RED FINGER	Beijing	China	Red, red, yellow
18	RED 322	Pahang	Malaysia	Red, red, yellow
19	TVRC 06	PHRC	India	Dark green, green, yellow
20	TVRC 064	PHRC	India	Dark green, green, yellow

PHRC=Phichit Horticulture Research Center

Prior to the start of the experiment, the soil at the two experimental sites was ploughed and sowed with *Crotalaria juncea* L. as a green manure to improve soil conditions and provide fixed nitrogen for the crops. The soil was ploughed again at the flowering of sun hemp or 60 d after sowing. For both trials, seeds (~3 seeds) were directly planted. The plant to plant and row to row spacing were both maintained at 75 cm. The rows were planted in pairs. Therefore, each plot treatment had maintained 12 plants. One week after planting, only one plant was left in each hole. Conventional fertilizer (N-P-K, formula 15-15-15) was pitched to the conventional trial, and compost manure was pitched to the organic trial, at a rate of 650 kg.ha^{-1} (Benchasri, 2015). The full rates of the fertilizers (organic and conventional) were applied in two rounds at the rate of 325 kg ha^{-1} at planting and at 28 day after planting. Weeds were eliminated by manually removing them and by conventional hoeing. Insect and disease infestations were treated with pesticides under the conventional farming system and by biological controls under the organic farming system. Okra fruit harvesting was done when the fruits were still fresh. Fresh fruits (at green state) were picked between 3-5 day after flowering (Benchasri, 2012). The meteorological data between planted shows that air temperatures of okra plantings in the two farming systems ranged from 23.60 to 35.70°C. The average air temperature was 28.44°C. The relative humidity values were between 51.00 and 99.00% and the average relative humidity value was 79.13% (Fig. 1A). The number of rain days ranged from 2 to 19 d.mon^{-1} (Fig. 1B).

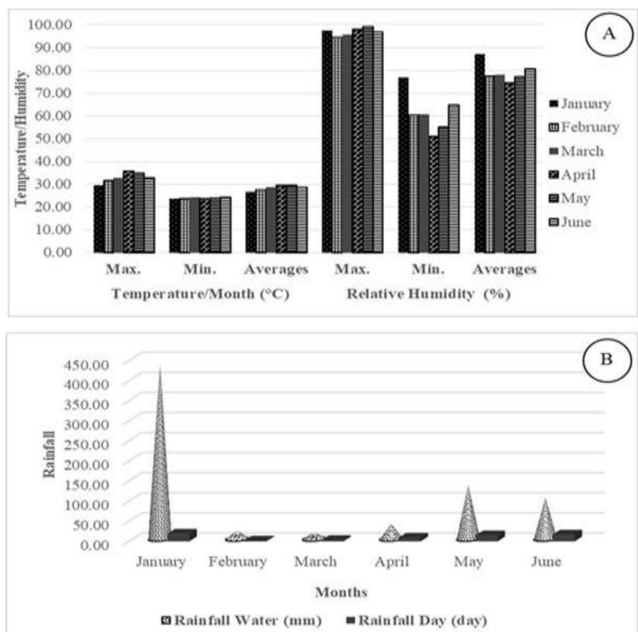

Figure-1. Weather conditions during plantation of twenty okra

Data collection

Soil and meteorological conditions

The survival percentage of plant was recorded at 28 day after planting from a total of 48 plants in each treatment. The chemical properties and soil contents were analyzed. The weather conditions for this experiment, including humidity, rainfall, and air temperature (minimum, maximum and average air temperature), were also recorded monthly between planting.

Yield and important of young fruit trials

The important morphological characteristics of green okra such as plant height (8th week after planting), first day of flowering, number of branches.plant^{-1}, stem diameter, fruit length, fruit circumference, marketable fruits.plant^{-1}, seeds.fruit^{-1}, 100 seed weight and 1,000 seed weight were manually analyzed of 80 fruits.treatment^{-1}. In addition, fresh fruit yield and harvest index were also recorded for the twenty lines. Okra fruit should be harvested at horticulture maturity state or green fruit while still tender, which is usually 3-5 day after flowering. Fresh fruits length around 4-10 cm were harvested in each treatment. Okra should be harvested two to three times a week. Regular picking increases yield.

Statistical analysis

Randomized complete block design was investigated in this research (Table 2). Statistical Package for Social Science for Windows were used all analyses. Significant differences between the treatments were applied using the Duncan Multiple Range Test at a 0.05 probability level. Each system (conventional and organic) were statistically analyzed for fruit yield and yield components traits in Table 3. Error of variances were proved for homogeneity with Bartlett's Test as described by Gomez and Gomez (1984). The variance of combined analysis was investigated for the two environments (production farming systems) using to a statistical model (Freeman, 1973).

Results

Soil content, plant survival and weather conditions

The soil content for this research is shown in Table 4. Under the conventional farming system, the soil had 1.15% organic matter, 0.16-0.14% total nitrogen content, 35.33-36.01 mg.kg^{-1} phosphorus, 81.35-63.01 mg.kg^{-1} potassium, and 0.08 dS.m^{-1} electric conductivity (EC). Under the organic farming, the soil had organic matter, nitrogen contents phosphorus, potassium and electric conductivity before planting of 1.14%, 0.16%, 39.58 mg.kg^{-1}, 43.67 mg.kg^{-1} and 0.08 dS.m^{-1}, respectively.

Table-2. Statistical model of variance in the study

Variation source	Degrees of Freedom	Sum of Square	Mean of Square	F
Treatment	t-1	SST)= $T_1^2+T_2^2+\ldots+T_t^2$/(b-CF	SST) /t-1(	MST/MSE
Block	b-1	SSR) = $B_1^2+B_2^2+\ldots B_b^2$/(t-CF	SSR)/b-1(	MSR/MSE
Error	)t-1)(b-1(	SSE =Total SS –SST –SSR	SSE)/t –1)(b – 1(	
Total	t.b-1	Total SS = $\sum$) X_{ij}^2 - (CF		

Table-3. Combined analysis of variance for twenty okra lines in conventional and organic cropping system.

Source of variances	DF	MS	Expected Mean Square
Systems (S)	s-1	MS (System)	$\sigma_\varepsilon^2 + l\sigma_{r/s}^2 + lr\sigma_s^2$
Blocks. Within S	s(r-1)	MS (Blocks within S)	$\sigma_\varepsilon^2 + l\sigma_{r/s}^2$
Lines (L)	l-1	MS (Line)	$\sigma_\varepsilon^2 + r\sigma_{ls}^2 + rs\sigma_l^2$
S x L	(s-1)(l-1)	MS (System x Line)	$\sigma_\varepsilon^2 + r\sigma_{ls}^2$
Pooled error	s(r-1)(l-1)	MS (Error)	σ_ε^2
Total	slr-1		

Table-4. Soil chemical properties.

Soil properties	Conventional		Organic	
	Before	**After**	**Before**	**After**
Nitrogen (N)	0.16%	0.14%	0.16%	0.15%
Organic matter	1.15%	1.15%	1.14%	1.16%
P_2O_5 (mg kg^{-1})	35.33	36.01	39.58	39.98
K (mg kg^{-1})	81.35	63.01	43.67	37.99
pH (H_2O)	4.57	4.58	4.57	4.59
EC (dS.m^{-1})	0.08	0.08	0.08	0.09
Soil texture	clay loam	clay loam	clay loam	clay loam

Twenty lines of okra were evaluated for plant survival 28 day after planting. The survival percentages ranging from 79.97 to 96.17% and 72.01 to 94.12% were recorded under the conventional and organic farming systems, respectively. KN-OYV-02 had the highest survival percentages with 96.17 and 94.12% under the conventional and organic farming systems, respectively. NO 71 had the lowest survival percentages with 79.97% under conventional farming system and 72.01% under the organic farming system. Other lines are shown in Fig. 2. In general, the conventional farming system had a higher survival percentage than the organic farming system. Because insect pest and disease infestations were treated with pesticides under the conventional farming system, on the other hand biological controls were treated under the organic farming system. NO 71 exhibited the highest difference (7.96%) between the conventional and organic farming systems.

Fruit yield and yield components of okra

The important characteristics of okra lines cultivated in the organic and conventional farming systems were significantly different (p≤0.05) in almost traits. Plant height, first day of flowering, lateral branches.plant^{-1}, stem diameter, fruit circumference, marketable fruits.plant^{-1}, 100 seed weight, seeds.fruit^{-1}, 1,000 seed and fruit harvest index under the conventional farming system are presented in Table 5.

In the organic farming system, okra lines were also significantly different (p≤0.05) for plant height, first day of flowering, lateral branches.plant^{-1}, stem diameter, fruit circumference, marketable fruits.plant^{-1},seeds.fruit^{-1}, 100 seed weight, 1,000 seed and harvest index. The yield.plant^{-1} was also significantly different (p≤0.05). NO 71 had the highest 100 seed weight (8.43g), white PJ03 had the lowest 100 seed weight (4.47g) (Table 6). However, middle fruit circumferences were not statistically significantly different between the systems.

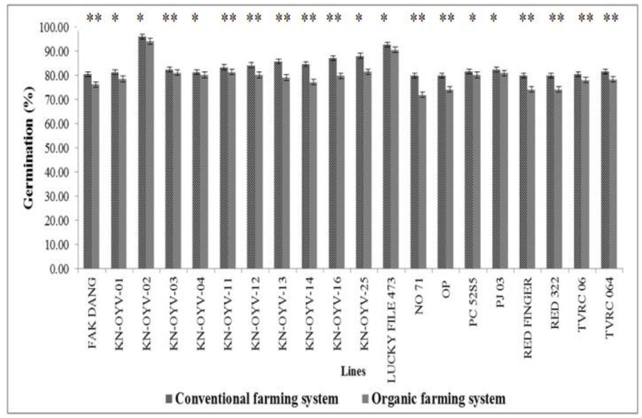

Figure-2. Okra survival percentage (%)

*Significant difference at P ≤ 0.05, ** significant difference at P ≤ .0.01

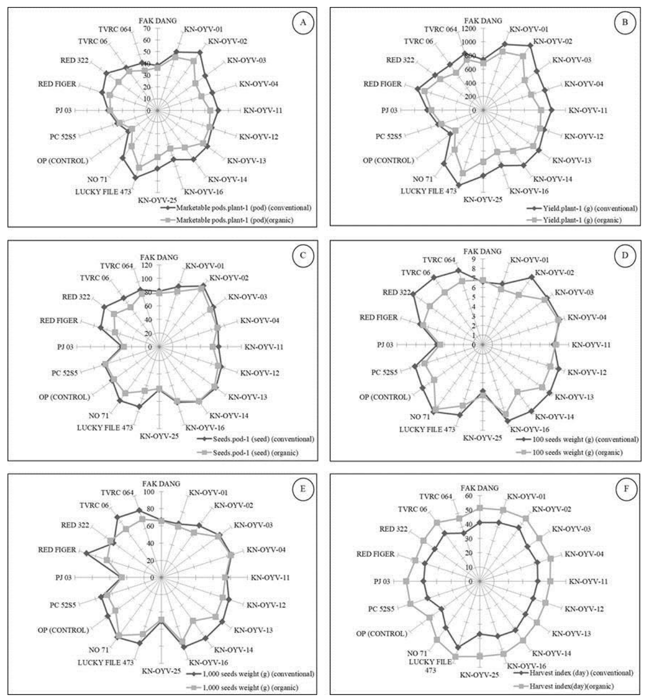

Figure-3. Graphical representation of yield and yield components in 20 okra seed for different cropping

At the termination of the experiment in each system, marketable fruits.plant^{-1}, yield.plant^{-1}, seeds.fruit^{-1}, 100 seed weight, 1,000 seed weight and the harvest index were estimated in each production system. The results showed that the conventional farming system had higher marketable fruits.plant^{-1}, yield.plant^{-1} and seeds.fruit^{-1} than the organic farming system across all lines. The one exception was that the harvest index in the conventional farming system was lower than that in the organic farming system in across all lines. On the other hand, 100 seed weight and 1,000 seed weights were distributed (Fig. 3).

Table-5. Phenotypic traits of 20 okra lines from conventional and organic cropping systems, respectively

No.	Lines	Plant height (cm)	First day flowering (day)	Lateral branches.plant^{-1} (branch)	Stem diameter (cm)	Fruit length (cm)	Fruit circumference (cm)		
							Head	Middle	Tail
1	FAKDANG	154.25bcd	42.25bc	5.36bcd	6.16bc	8.54bcde	4.61def	2.19	0.98ancd
2	KN-OYV-01	171.49ab	42.05bc	5.01cd	6.17bc	8.40bcd	5.14cde	2.83	1.00abcd
3	KN-OYV-02	159.35bcd	40.68cd	5.01cd	5.80c	8.07bcde	5.27cde	2.79	0.97abcd
4	KN-OYV-03	157.58bcd	43.58b	4.31de	6.25bc	8.47bcd	6.63ab	2.87	0.87cd
5	KN-OYV-04	165.58bc	40.68cde	5.61bcd	6.31ab	7.40de	6.00bc	2.83	0.87cd
6	KN-OYV-11	173.59a	40.68cde	5.13cd	6.17bc	7.90cde	4.60def	2.9	1.03abcd
7	KN-OYV-12	171.59ab	40.68cde	5.53bcd	6.43a	8.46bcde	4.04d	2.17	0.63e
8	KN-OYV-13	170.36ab	42.01c	4.11de	6.19bc	8.90bcd	4.83def	2.63	0.98abcd
9	KN-OYV-14	167.68bc	40.68cde	3.31f	6.23ab	8.83bcd	4.85def	2.67	0.98abcd
10	KN-OYV-16	171.96ab	40.32de	6.14b	6.20bc	8.20bcde	5.23cde	2.73	0.84d
11	KN-OYV-25	163.39bcd	44.63b	6.01b	6.49a	9.00abd	5.20cde	2.77	0.97abcd
12	LUCKYFILE 473	187.58a	43.36bc	6.18b	6.16bc	12.45a	6.97a	2.96	1.43a
13	NO 71	151.25cd	41.65cd	4.45cde	6.30ab	9.47ab	6.23ab	2.93	1.23ab
14	PC 52S5	134.48de	45.68ab	4.78cde	6.48a	7.90ced	5.00cde	2.57	0.83d
15	PJ 03	69.58f	44.58b	5.74bcd	6.21bc	9.17abc	4.23ef	2.27	0.97abcd
16	RED FINGER	157.18bcd	40.28de	5.68bcd	6.18bc	9.47ab	5.20cde	2.25	0.98abcd
17	RED 322	156.88bcd	40.58cde	5.78bc	6.20bc	9.46ab	5.13cde	2.64	0.99abcd
18	TVRC 06	152.25cd	41.69cd	6.11b	6.27ab	10.00a	4.24ef	2.45	0.82d
19	TVRC 064	99.58e	42.25bc	5.59bcd	6.21ab	11.45a	6.07abc	2.83	1.03abcd
20	OP (CONTROL)	177.35a	48.63a	8.88a	6.17bc	7.23e	5.13cde	2.69	0.98abcd
	C.V.	10.25	10.25	9.31	14.02	12.47	9.67	-	9.28
		Mean phenotypic effects from the organic farming system							
No.	Lines	Plant height (cm)	First day flowering (day)	Lateral branches.plant^{-1} (branch)	Stem diameter (cm)	Fruit length (cm)	Fruit circumference (cm)		
							Head	Middle	Tail
1	FAKDANG	164.35cd	44.35bcd	5.39de	6.18bc	8.54bcde	4.62de	2.12	0.98abcd
2	KN-OYV-01	162.96cd	43.59bcd	5.75d	6.27bc	8.41bcde	5.17cde	2.84	1.01abcd
3	KN-OYV-02	168.8bcd	44.22bcd	5.33e	5.89c	8.08bcde	5.29cde	2.85	0.99abcd
4	KN-OYV-03	163.72cd	44.23bcd	4.82f	6.27bc	8.48bcde	6.66ab	2.88	0.89cd
5	KN-OYV-04	172.96bc	42.25bcd	6.29c	6.341ab	7.41de	6.02bc	2.84	0.88cd
6	KN-OYV-11	177.05ab	41.36cd	6.23c	6.27bc	7.93cde	4.61def	2.92	1.03abcd
7	KN-OYV-12	178.05ab	42.36bcd	6.06c	6.83a	8.47bcde	4.05d	2.18	0.64e
8	KN-OYV-13	174.72abc	43.36bcd	5.32ef	6.26bc	8.93cd	4.84def	2.64	0.98abcd
9	KN-OYV-14	171.68bcd	42.58bcd	4.35g	6.27ab	8.89bcd	4.87def	2.69	0.99abcd
10	KN-OYV-16	172.05bcd	43.65bcd	6.72bc	6.21bc	8.21bcde	5.24cde	2.74	0.84d
11	KN-OYV-25	175.29ab	45.87b	7.31b	6.69a	9.04abc	5.22cde	2.8	0.99abcd
12	LUCKYFILE 473	189.18a	44.02bcd	7.24b	6.19bc	12.55a	6.99a	2.99	1.46a
13	NO 71	153.58d	42.41bcd	5.23ef	6.32ab	9.49ab	6.25ab	2.95	1.25ab
14	PC 52S5	147.69e	46.02b	4.82f	6.63a	7.92cde	5.04cde	2.59	0.84d
15	PJ 03	78.65g	44.98bc	6.76bc	6.51bc	9.18abc	4.24ef	2.27	0.99abcd
16	RED FINGER	164.58cd	41.25d	5.87d	6.20bc	9.48ab	5.21cde	2.26	0.9abcd
17	RED 322	168.14bcd	41.98cd	5.98d	6.21bc	9.48ab	5.14cde	2.66	0.99abcd
18	TVRC 06	161.01cd	43.68bcd	6.15c	6.30ab	10.49a	4.25ef	2.45	0.84d
19	TVRC 064	105.24f	42.32bcd	5.98cd	6.29ab	11.55a	6.08abc	2.84	1.01abcd
20	OP (CONTROL)	182.96a	49.25a	8.84a	6.20bc	7.24e	5.13cde	2.71	0.99abcd
	C.V.	10.25	12.25	10.13	12.02	11.47	10.12	-	11.41

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

Combined analysis of variance in different systems

The results of combined analysis of variance indicated that the differences between systems (S) and among Lines (L) were significant for marketable fruits.plant^{-1}, yield.plant^{-1}, seeds.fruit^{-1}, 100 seed weight, 1,000 seed weight and the harvest index. There were also significant interactions between the systems and lines (S x L) for the marketable fruits.plant^{-1}, yield.plant^{-1}, seeds.fruit^{-1}, 100 seed weight, 1,000 seed weight and harvest index for the conventional and organic farming systems (Table 7). The variation of replications within the systems for all traits was non-significant. In the results of the okra cultivations at different farming system of; conventional and organic, showed the yield generally of organic treatment lower than conventional system. But the interaction between the farming system and okra germplasms also detected from the experiments. The interactions showed the superior yield of KN-OYV-02 line in conventional farming, of KN-OYV-02 line' in organic farming, because of the better marketable fruits.plant^{-1}and higher yield.plant^{-1}.

Table-6. Mean performance of marketable fruit yield and physical components of 20 okra after cultivated in conventional and organic systems

		Conventional farming system					
N0.	**Lines**	**Marketable fruits.plant^{-1} (fruit)**	**Yield.plant^{-1} (g)**	**Seeds.fruit^{-1} (seed)**	**100 seed weight (g)**	**1000 seed weight (g)**	**Harvest index(d)**
1	FAKDANG	38.28ef	741.10ef	81.46d	6.58def	66.86d	41.15abc
2	KN-OYV-01	52.35ab	1013.49ab	92.55bc	6.68def	65.68d	43.25ab
3	KN-OYV-02	60.85a	1168.37a	110.21a	8.72a	74.55cd	46.41ab
4	KN-OYV-03	49.91abc	966.25bc	98.21ab	8.33bc	83.83bc	41.12abc
5	KN-OYV-04	48.81bcd	944.96bc	90.25bcd	8.45bc	85.55abc	42.34ab
6	KN-OYV-11	51.38ab	994.70b	86.98cd	7.44cde	75.74cd	40.45bcd
7	KN-OYV-12	48.25bcd	934.12bc	95.47abc	8.34bc	82.48bc	39.15cde
8	KN-OYV-13	52.11ab	999.84bc	102.25ab	8.65ab	87.58ab	39.34cde
9	KN-OYV-14	51.75ab	999.88bc	99.68ab	8.65abc	87.35ab	42.33abc
10	KN-OYV-16	44.01de	852.03def	85.67cd	8.46bc	85.12abc	40.48bcd
11	KN-OYV-25	49.68bcd	961.80bc	63.12de	4.92ef	50.94e	36.82de
12	LUCKYFILE 473	60.35a	1158.06a	92.48bcd	7.79cde	80.64bc	48.61a
13	NO 71	50.21ab	972.06bc	97.57abc	8.74a	86.14abc	40.08bcd
14	PC 52S5	35.68ef	690.76ef	84.01cd	7.45cde	73.21cd	38.19cde
15	PJ 03	42.01de	813.31def	54.34e	4.75f	46.55e	39.12cde
16	RED FINGER	49.35ab	1003.49ab	89.68cd	6.87def	90.75a	40.11bcd
17	RED 322	53.75ab	867.89de	98.68ab	8.98a	68.26d	38.57cde
18	TVRC 06	45.01cde	822.99def	87.69cd	8.67ab	86.24abc	41.58abc
19	TVRC 064	42.51de	871.39de	87.36cd	8.17cde	82.17bc	35.47e
20	OP (CONTROL)	30.58f	592.03f	84.44cd	7.78cde	76.28cd	32.82e
	CV.	8.25	12.54	11.05	9.58	9.58	10.24
		Organic farming system					
No.	**Lines**	**Marketable fruits.plant^{-1}(fruit)**	**Yield.plant^{-1} (g)**	**Seeds.Fruit-1 (seed)**	**100 seed weight (g)**	**1000 seed weight (g)**	**Harvest index(d)**
1	FAKDANG	36.28cde	685.32ef	78.36cd	6.78cde	65.96de	51.35bc
2	KN-OYV-01	47.71ab	901.24ab	85.15bc	6.12de	62.34e	52.58abc
3	KN-OYV-02	51.91a	980.59a	105.25a	6.43cde	64.48e	54.47a
4	KN-OYV-03	39.41cde	744.45def	92.24ab	8.01b	81.22ab	51.25bc
5	KN-OYV-04	38.87cde	734.24def	89.25bc	8.32a	84.64a	51.81bc
6	KN-OYV-11	44.49ab	840.41cde	78.24cd	7.62bc	74.11bc	49.15bcd
7	KN-OYV-12	46.12ab	871.28cde	90.54abc	7.43bc	74.86bc	48.15bcd
8	KN-OYV-13	47.57ab	898.61bc	99.75a	7.66bc	77.72bc	49.05bcd
9	KN-OYV-14	39.07cde	738.03def	98.51a	6.17cde	62.34e	51.09bce
10	KN-OYV-16	34.25de	646.82efg	83.51bc	7.68bc	78.36b	53.42abc
11	KN-OYV-25	39.81cde	752.19df	61.46de	5.35ef	49.07f	52.57abc
12	LUCKYFILE 473	51.27a	968.49a	68.25de	6.77cde	69.34cd	55.35a
13	NO 71	37.64cde	711.96ef	84.25bc	8.43a	83.44ab	50.57bcd
14	PC 52S5	34.07de	643.58fg	82.25bc	6.43cde	65.86de	50.82bcd
15	PJ 03	40.25cd	760.25de	51.55f	4.47f	45.81g	51.28bc
16	RED FINGER	42.715ab	900.01ab	67.68de	6.58cde	66.16de	47.18cd
17	RED 322	41.06bcd	775.64de	81.25bc	6.87cde	72.74c	48.57bcd
18	TVRC 06	41.15bcd	674.56ef	71.12cde	6.78cde	69.93cd	50.81bcd
19	TVRC 064	35.71de	777.35de	81.24bc	7.01c	71.25c	46.31cd
20	OP (CONTROL)	26.74f	505.16g	81.24bc	6.32cde	65.62de	43.15de
	CV.	9.18	103.64	12.58	12.04	9.09	14.05

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

Table-7. Mean squares for yield and yield component on okra plantation.

Source of variances	**DF**	**Marketable fruits.plant^{-1} (fruit)**	**Yield.plant^{-1} (plant)**	**Seeds.fruit^{-1} (seed)**	**100 seed weight (g)**	**1000 seed weight (g)**	**Harvest index (d)**
Systems (S)	1	2,098.49*	26,867.68*	4,498.87*	2,289.38*	2,494.35*	3,895.54*
Blocks. Within S	6	275.27ns	854.15ns	209.25ns	66.11ns	324.16ns	305.02 ns
Lines (L)	19	2,142.51*	28,248.25*	4,005.94*	1,067.98*	2,287.26*	3,632.55*
S x L	19	958.51*	22,454.68*	2,915.14*	1,537.94*	2,032.55*	3,438.51*
Pooled error	114	164.63	725.48	114.82	48.74	287.45	121.23

*significant difference at P ≤ 0.05, ns = not statistically significantly different.

Table-8. Comparison fruit components of 20 okra lines grown from conventional and organic farming.

Systems	Marketable fruits.plant^{-1} (fruit)	Yield.plant^{-1} (plant)	Seeds.fruit^{-1} (seed)	100 seed weight (g)	1000 seed weight (g)	Harvest index(d)
Conventional	47.84a	918.43a	89.11a	7.72a	76.80a	40.37b
Organic	40.80b	775.51b	81.55b	6.86b	69.26b	50.45a
Means	44.32	846.97	85.33	7.29	73.03	45.41

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

Mean analysis between systems

Mean analysis of marketable fruits.plant^{-1}, yields.plant^{-1}, seeds.fruit^{-1}, showed significant differences between the conventional and organic farming systems. There were also significant differences in 100 seed weight and 1,000 seed weights under the conventional and organic farming systems, respectively. The conventional farming system generated higher yields than the organic farming system across all lines. However, the harvest index period in the organic farming system was longer than that in the conventional farming system across all okra lines (Table 8).

Discussion

Germination percentage is an estimate of the viability of the population on okra seeds. The present study of germination percentage for okra under the conventional farming system was higher than that under an organic farming system. Abouziena and Haggag (2016) had reported that weed control, disease and pest infestations were treated by chemical pesticides of okra production under the conventional farming systems. On the other hand, the main principle of organic okra production was the avoidance of synthetic pesticides to protect okras from pests and diseases. As a physical control measure and biological control were evaluated under field conditions (Afe and Oluleye, 2017).

The yield components of okra lines cultivated in the organic and conventional farming systems were significantly different ($p \leq 0.05$) in almost traits. The conventional farming system had higher the plant height, first day of flowering, lateral branches.plant^{-1}, stem diameter and fruit circumference than the organic farming system across all lines. The one exception was that the harvest index in the conventional farming system was lower than that in the organic farming system in across all lines. The harvest index might be attributed to the variation environmental factors, the genetic potential of the lines, or the differential ability of the lines to absorb nutrients (Yadav et al., 2013). The results of this study are consistent with work by Shivaramegowda et al. (2016), who reported significant differences in plant height, leaf length, canopy and yield.plant^{-1} in okra crops due to genetic factors and environmental conditions. All data information, farmers can able to decide the production system according to their needs in the future (Benchasri, 2015).

Okra lines grown through organic agricultural system had lower important morphological characteristics of green okra such as marketable fruits.plant^{-1} and yield.plant^{-1}. This difference most likely, arises because the okra production under the conventional farming system was protected by pesticides, which prevented damage by fungal pathogens and insects, while the unprotected system of organic agricultural production reduced the ability of plants to growth (Döring et al., 2012). These results were similar to those reported by Benchasri and Pruthikanee (2018). Average yield and yield components of plants tested under the inorganic and organic systems were significantly different (Narkhede et al., 2011). Total yields revealed that production under the inorganic agricultural system was approximately 20-65% higher than that under the organic agricultural system. However, Yadav et al. (2013) observed that the costs of organic manure and chemical fertilizers were different. When profits between conventional and organic farming are compared, plants grown under an organic agricultural system were more profitable than those grown under a conventional (inorganic) agricultural system (Naik et al., 2012). Moreover, organic agricultural systems are also safe to consumers and the environment (Campiglia et al., 2015).

The analysis of variance revealed that the lines under study were significant for all characteristics. Generally, the significant differences revealed among the morphological traits may be diverse source of materials and also the result of environmental influence affecting okra lines this corroborates findings of Chaukhande et al. (2011) and Kumar et al. (2019) who mentioned the role of environmental factors as well as differences in the genetic makeup of different varieties in yield determination of okra. While, the significant interaction effects between system×line indicated that the lines responded differently to changes in the farming system (conventional versus organic). High variation in yield and yield components was detected for different lines. Thus, more testing sites, environments, or locations are in need of evaluation (Gurung et al., 2012). Many scientists have reported that yield and yield components were affected by genetic and environmental conditions (Benchasri and Simla, 2017). Prakash and Pitchaimuthu (2010) reported that the environment had a stronger effect on yield relative to line. In contrast, Gurung et al. (2012) found that line played a major role in yield contents, as more than 70% of total variation in yield was due to the effect of cultivar, although the SxL effects were significant. A large source of variation due to genotype was also reported by Yadav et al. (2016).

Conclusion

The current research found that okra line grown through the organic farming system had marketable fruits.plant^{-1}, yield.plant^{-1}, seeds.fruit^{-1}, 100 seed weight and 1,000 seed weight less than okra grown through the conventional farming system. Total yields showed that production under the inorganic agricultural system were approximately 20-65% higher than under the organic agricultural system. The significant interaction effects between system x line indicated that lines responded differently to changes in the environment (production system). There was a strong effect of line on the variation in yield and yield components. Therefore, even with diverse environments, lines had a larger effect on yield than the production system. KN-OYV-02, LUCKYFILE 473, KN-OYV-01 and RED FINGER lines should also be used for further breeding or planting as commercial genotypes under field conditions. The outcome of this study should be used to guide okra breeding in Thailand.

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Benchasri S: Conceived idea, designed research methodology, literature review, data collection, data interpretation, manuscript writing and final approbation of the version to be published.
Simla S: Data collection and data interpretation.
Harakotr B: Literature review and data interpretation.