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Effect of planting pattern and season on some agronomic performances and yield of sweet potato cv. Japanese Orange

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Abstract

Sweet potato (*Ipomoea batatas* (L.) is one of the most important root crops in the world. It is primarily grown as a second crop during the dry season in Thailand. Several cultivars are produced with some being imported from Japan, especially cv. Japanese Orange, Yellow and Purple which are popular because they have high value and are rich in phytochemicals. Thai farmers use only one planting pattern for production although there are five recommended patterns available. The objectives of this study were to investigate the effect of different planting patterns on yield, agronomic traits, and determine associations among agronomic traits of sweet potato cv. Japanese Orange. The experiments were conducted during the rainy and dry seasons of 2017. An RCBD with 5 planting patterns and 3 replications were used. Tuber yield, no. of tuber/plant, no. of tuber/ha, no. branch/plant, tuber diameter and tuber fresh weight were measured. The results revealed that during the rainy season, pattern 5 (three vines per hole) had highest tuber yield (11.2 ton/ha), no. of tubers/plant (7.7) and number of tubers/ha (408.9×10^3) whereas pattern 3 (one vine) had highest no of branches/plant (4.7) and tuber diameter (36.9 mm). In the dry season, patterns 1, 5 and 3 had the highest yields (7.13, 6.71 and 6.48 ton/ha, respectively) pattern 1 had significantly higher tuber fresh weight (84.17 g) than the other four patterns. Pattern 5 had the highest number of tubers/plant and number of tubers/ha during the dry season. We found positive correlations between tuber yield and number of tuber per plant, number of tuber per ha, vine length, vine girth, number of nodes per plant at 60 and 75 DAP.

Keywords: Agronomic traits, correlation, orange-flesh, yield performance.
Abbreviations: DAP: days after planting; RCBD: randomized complete block design.

Introduction

Sweet potato (*Ipomoea batatas* L.) is classified in the family Convolvulaceae and originated from tropical central America. Currently, sweet potato is cultivated in more than 100 countries, mostly throughout tropical and subtropical Asia (Department of Agriculture, Forestry and Fishery, 2011). Sweet potato ranks as the third most important starchy food, after cassava and potato in the world (FAO stat, 2006) with 75.3 percent being produced in Asia followed by Africa and America. China is the world's biggest producer of sweet potatoes followed by Nigeria, Tanzania, Ethiopia and Indonesia (FAO, 2014). Sweet potato is adaptable to a broad range of agro-ecological conditions and fits into low-input agriculture. It is highly productive even under adverse farming conditions (Prakash, 1994). Sweet potato is cultivated as a valuable source of human food, animal feed and industrial raw material (Egbe et al., 2012). In Thailand, sweet potato is planted as a second crop after rice, cassava, or sugarcane. Generally, the second crop is planted after harvesting the primary crop or before planting the primary crop which is normally during the dry season (October to May). Sweet potato is produced for food, dessert and flour industrial and is exported to other countries. In 2015/16 Thailand produced 360,000 tons of sweet potatoes on 3,251 ha, with an average yield of 2.67 ton/rai or 16.69 ton/ha by 4,317 farmers. Sweet potatoes are widely grown in several parts of Thailand especially in the lower north regions (Ruttarattanamongkol et al., 2016) i.e. Suphan Buri, Nakhon Si Thammarat, Phra Nakhon Si Ayutthaya, Si Sa ket, Trat and Nakhon Ratchasima etc. Local cultivars (Phichit 65-3, Phichit 265-1 and Phichit 64-1) but imported cultivars from Japan and Taiwan (Purple Oginawa, Japanese Orange, Japanese Yellow and Japanese Purple) are attractive for Thai farmers due to their high yield and value, as well as the high levels of carotenoid, anthocyanin and other properties.

Thai farmers use a cultivation practice of planting one cutting vine (slip) per hole because it is convenient and economical

(15-30 cutting vines per US dollar). However, the Department of Agriculture of Thailand recommends five different planting patterns for sweet potato production with each pattern producing different tuber yield and size. The common pattern does not necessarily give the highest tuber yield. The objective of this study was to investigate the effect of planting patterns on yield and agronomic traits and also determine the association among agronomic traits of sweet potato cv. Japanese Orange. The results can then be demonstrated to growers to update recommendations on cultivation of sweet potato in Thailand.

Results and Discussion

Analysis of variance among seasons

Combined analysis over seasons indicates that all characteristic was affected by season except number of branches/plant at 60 DAP and tuber wide (Table 1). As stated earlier, planting pattern was not significantly different in vine girth, and vine length, at 60 and 75 days and tuber length. Season × planting pattern interactions were significantly different for number of branches and nodes per plant at 60 DAP, number of branches per plant at 75 DAP, number of tubers per plant, tuber fresh weight and tuber yield. The combine analysis indicated that season main effects were significant for many traits. These results show the importance of evaluating planting patterns for each planting season individually.

The average tuber yield during the rainy season was higher than the dry season (8.07 and 6.12 ton/ha, respectively) with planting pattern 5 having the highest tuber yield in both seasons. (Figure 1). The rainy season produced a higher number of tubers per plant than the dry season (5.2 and 2.6 tubers, respectively), however, the dry season produced a higher tuber fresh weight than rainy season (53.59 and 28.35 g, respectively) with pattern 1 having an amazingly higher tuber fresh weight than others four pattern (56.71 g). Generally, the number of tubers per hectare during the rainy season was higher than the dry season (297.0×10^3 and 116.7×10^3 tubers, respectively).

Agronomic performances

Generally, pattern 1 of planting slips is used for cultivation of sweet potato due to ease in management and cost savings. In this study the effects of various planting patterns on tuber yield and others agronomic traits were investigated to determine whether the recommended procedures of the Department of Agriculture (1999) would give the highest tuber yield and the biggest tuber size. No significant differences were found among treatments for vine length or vine girth in either growing season or date of sampling.

Rainy season

In rainy season, we found significant differences among planting patterns for tuber yield (Figure 1), the number of branches per plant at 75 DAP, and tuber diameter, number of tuber per plant, number of tubers per hectare and tuber fresh weight (Table 2).

Planting pattern 3 had the highest number of branches per plant at day 75 (4.7 branches), followed by pattern 2 (3.4). Dumbuya et al. (2016) reported that sweet potato had 4.20 and 5.97 branches per plant at 30 and 60 days after planting. Ogbe et al. (2012) reported branch number per plant of 11 cultivars ranged from 3.83 to 4.83 which is similar to our results. Mekonnen et al. (2015) reported that the number of branches/plant of an orange fleshed variety ranged from 29.29 to 41.41 branches which is almost ten times greater than our study and we are assuming that it was due to differences in climate, soil type, agricultural practices and location.

The pattern 3 had the highest tuber diameter (36.9 mm) followed by patterns 5 and 2 (35.3 and 31.7 mm, respectively) (Table 2). Ogbe et al. (2012) found significant differences in both tuber length and tuber diameter but our study found differences only in tuber diameter. They also reported tuber diameter of the 11 cultivars ranged between 3.85 and 8.23 cm which is higher than our study.

Pattern 5 gave the highest number of tubers /plant and number of tubers/ha (7.7 and $408.9\text{x}10^3$ tubers, respectively) (Table 1). Dumbuya et al. (2016) studied the response of phosphorus rates on growth and yield of sweet potato cv. Okumkom and their results showed that the number of marketable roots per plant ranged from 3.20 to 4.63 which is much lower than our study. Dumbuya et al. (2016) reported that 11 sweet potato cultivars had number of roots ranging between 4,642 to 121,817 tubers/ha.

Pattern 3 had the highest tuber fresh weight (31.40 g) but it was not significantly different from pattern 1 and 2 (29.3 and 28.7 g, respectively) (Table 2). This result is similar to the report from the Department of Agriculture (1999). Yooyongwech et al. (2017) reported that tuber fresh weight of sweet potato cv. Japanese Yellow under favorable conditions was 21.23 g and 31.46 g for cv.Tianung 57. Our study used cv. Japanese Orange and had higher tuber yield than their cv. Japanese yellow, and lower than Tianung 57.

Pattern 5 (11.2 ton/ha) gave the highest tuber yield during the rainy season but was not significantly different from pattern 2 (9.27 ton/ha) (Figure 1A). Kongisro (2012) reported that tuber yield of various cultivars using pattern 1 ranged from 1.21 to 5.27 ton/ha which is by far lower than our study. Their study was also conducted in rainy season, however, it was conducted in South Thailand with a different environment, soil type and agricultural meteorology.

Tuber yield of the current study in both seasons were lower than average storage yield of sweet potato that was studied in Ethiopia (Ali et al., 2015). Mwanja et al. (2017) reported that population density had an effect on yield of sweet potato in Nigeria where the yield ranged between 8.25 to 47.89 ton/ha (density 28,570 to 50,000 plants/ha) which was higher than a recent study (44,444 holes/ha).

Pattern 3 had highest tuber fresh weight tuber fresh weight (31.4 g) followed by pattern 1 and 2 (29.3 and 28.7 g respectively) which is similar to the results of the Department of Agriculture (1999).

Dry season

In dry season the number of branches and number of nodes/plant at 60 days after planting were significantly different with patterns 1, 2 and 3 having the highest number of

Table 1. Analysis of variance results (F-statistics) for agronomic performances of 5 planting patterns of sweet potato under two seasons (wet and dry) in 2017 at Mahasarakham University.

	F		
Effect	Season	Planting pattern	Season × planting pattern
Vine length 60 DAP	**	*	ns
Vine girth 60 DAP	**	ns	ns
Number of branches/plant at 60 DAP	ns	**	**
Number of nodes/plant 60 DAP	**	ns	**
Vine length 75 DAP	**	ns	ns
Vine girth 75 DAP	*	ns	ns
Number of branches/plant 75 DAP	**	**	**
Number of nodes/plant 75 DAP	**	ns	ns
Number of tubers/plant	**	**	**
Tuber fresh weight	**	**	**
Number of tuber/ha	**	**	ns
Tuber wide	ns	*	ns
Tuber length	**	ns	ns
Tuber yield	**	**	**

*,** and ns; significant at α =0.05, 0.01 and ns = not significant, DAP; days after planting.

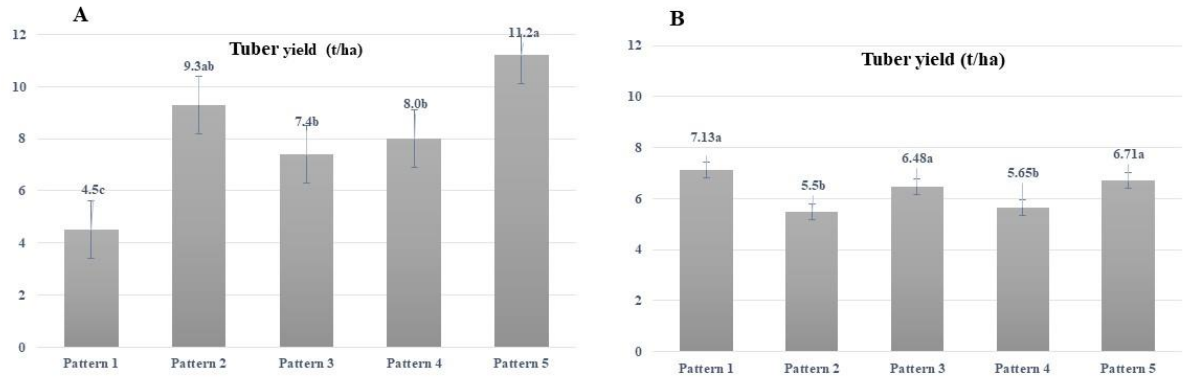

Fig 1. Tuber yield of sweet potato during rainy (a) and dry (b) season 2017 at Mahasarakham, Thailand using 5 planting patterns.

Table 2. Agronomic performances of sweet potato cv. Japanese using 5 planting patterns during the rainy season of 2017 at Mahasarakham University.

Planting pattern	Vine length (cm)	Vine girth (mm)	branches /plant	no. of nodes/plant	branches /plant	No. of nodes/plant	number of tubers/plant	tuber fresh weight (g)	Tuber length (cm)	Tuber diameter (mm)
	60 days after planting				75 days after planting		harvest day			
Pattern 1	84.3	5.49	1.3	26.8	2.8b	27.0	4.1bc	29.3ab	9.1	30.9bc
Pattern 2	112.4	5.44	3.2	32.5	2.4b	25.7	7.3a	28.7ab	9.6	31.7abc
Pattern 3	95.3	5.68	1.9	32.0	4.7a	25.5	4.5b	31.4a	11.8	36.9a
Pattern 4	114.8	5.44	4.1	27.4	2.5b	26.6	2.5c	24.8c	9.8	27.2c
Pattern 5	102.4	5.81	2.5	26.2	2.6b	26.8	7.7a	27.6bc	10.4	35.3ab
F-test	ns	ns	ns	ns	**	ns	**	*	ns	*
CV (%)	13.2	9.9	17.3	7.4	17.0	17.2	20.0	7.0	11.2	9.5

*,** and ns significant at P<0.05, 0.01 and not significant probability levels, respectively, mean in the same column followed by the same letter(s) are not significantly different by LSD.

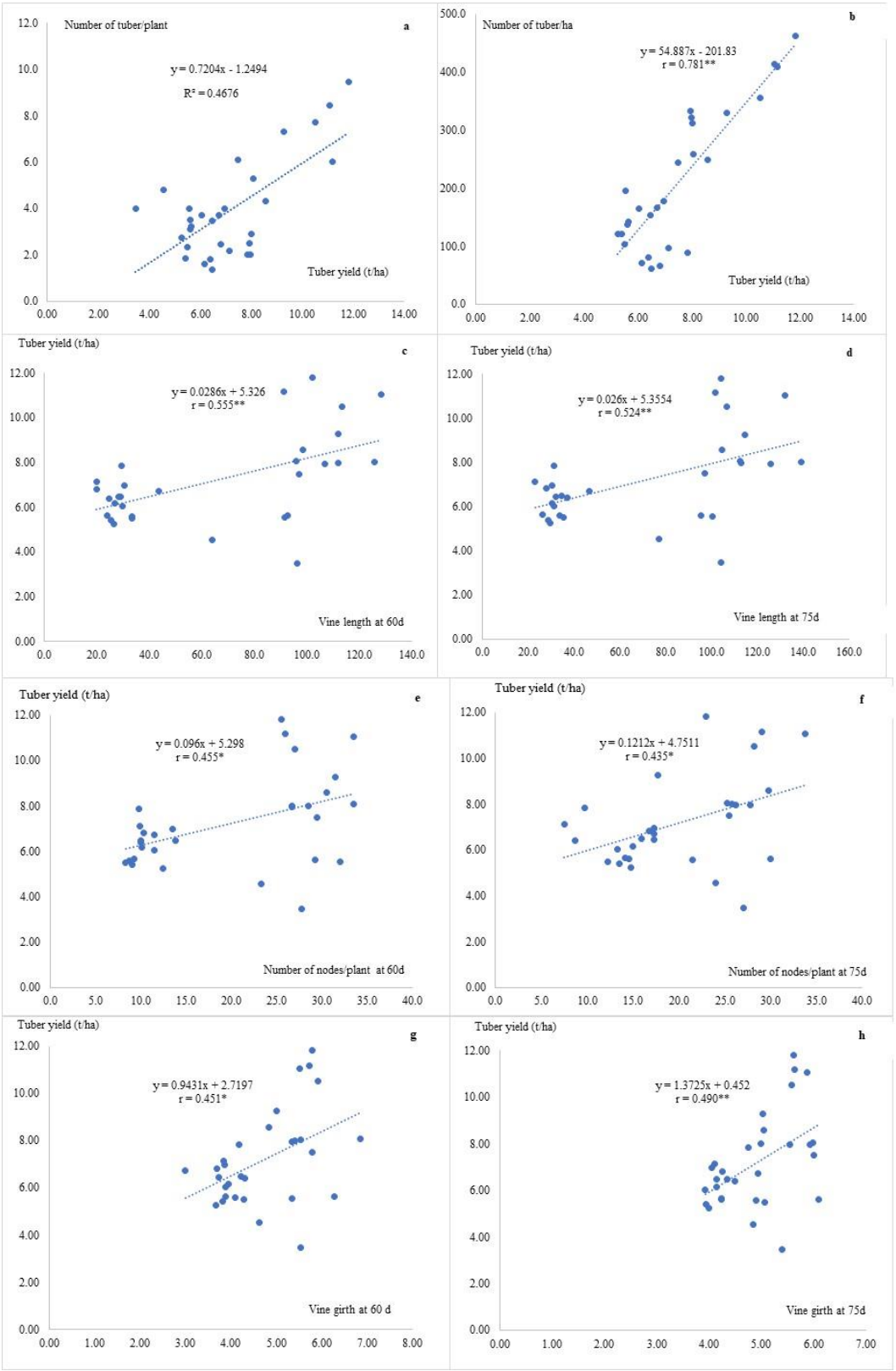

Fig 2. Correlation coefficients between tuber yield and some agronomics traits of sweet potato grown during the wet and dry seasons at Mahasarakham, Thailand in 2017.

Table 3. Agronomic performances of sweet potato cv. Japanese using 5 planting patterns during the dry season of 2017 at Mahasarakham University.

Planting pattern	vine length (cm)	vine girth (mm)	branches /plant	no. of nodes/plant	branches /plant	no. of nodes/plant	no. of tubers/plant	tuber fresh weight (g)	tuber length (cm)	tuber diameter (mm)
	60 days after planting				75 days after planting		harvest day			
Pattern 1	24.8	4.11	3.6a	9.9bc	3.9bc	8.7c	2.0c	84.17a	10.6	37.0
Pattern 2	30.7	4.10	3.3a	8.7c	4.5b	13.4b	2.4bc	53.50b	12.4	36.0
Pattern 3	25.2	4.00	3.2a	10.1b	3.3c	15.9a	1.8c	52.78b	11.5	34.9
Pattern 4	26.7	3.81	2.4b	11.1b	4.4bc	14.1b	3.2ab	40.03b	11.6	32.9
Pattern 5	34.0	3.53	2.4b	12.9a	7.2a	17.3a	3.7a	37.47b	12.3	39.0
F-test	ns	ns	**	**	**	**	**	**	ns	ns
CV (%)	17.0	8.1	14.4	7.0	12.6	6.8	16.8	16.6	9.4	7.0

** and ns significant at P<0.01 and not significant probability levels, respectively, mean in the same column followed by the same letter(s) are not significantly different by LSD.

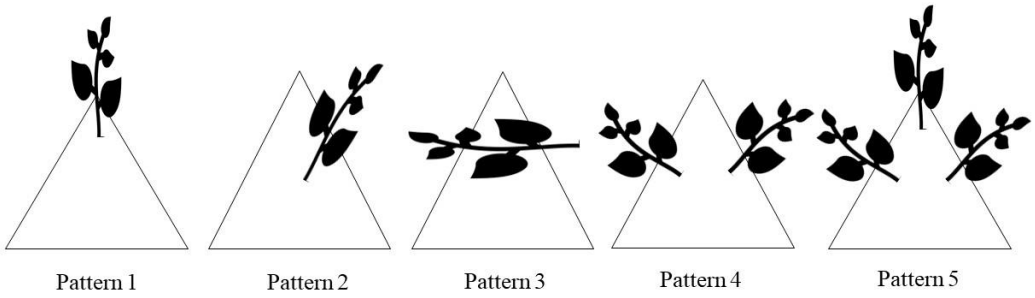

Fig 3. Five planting patterns of sweet potato used as treatments at Mahasarakham, Thailand during the wet and dry seasons of 2017.

Table 4. Meteorological data at the location of the wet and dry season sweet potato experiment (Mahasarakam, Thailand) between August 14, 2017 and February 2, 2018.

Month	Average temp. (°C)	Average humidity (%)	Wind speed (km/hr)	Monthly rain (mm)	Aggregate rain (mm)
Aug 2017	29.4	78.8	2.11	0	532.8
Sept 2017	28.4	77.2	1.80	0.08	533.1
Oct 2017	26.8	67.3	2.50	0.02	537.9
Nov 2017	24.2	64.8	2.60	0.2	539.4
Dec 2017	25.4	63.5	2.00	0	539.4
Jan 2018	24.9	63.5	2.20	0	539.4
Feb 2018	28.2	60.5	2.10	0	539.4

branches per plant (3.6, 3.3 and 3.2 branches, respectively) (Table 2). Bassey (2017) showed significant differences among treatments at 9 weeks after planting with ranges in 2013 between 0.3 to 15.2 and 2014 ranged between 0.3 to 15.3 branches/plant. However, Ali et al. (2015) and Dumbuya et al. (2016) reported no significantly differences for branches/plant at different days after planting. Pattern 5 had the highest number of nodes per plant (12.9 nodes) followed by patterns 4 and 3 (11.1 and 10.1, respectively). At 75 DAP, number of branches and nodes per plant were significantly different. Pattern 5 had highest number of branches/plant (7.2 branches). Bassey (2017) reported that number of branches/plant at 12 weeks after planting ranged between 1.3 and 18.3 in 2013 and between 3.1 and 24.3 in 2014. Patterns 5 and 3 had the highest number of nodes/plant (17.3 nodes and 15.9 nodes, respectively) (Table 3). Patterns 5 and 4 gave the highest number of tubers/plant (3.7 and 3.2) and number of tubers/hectare (165.7 tubers and 142.8 $x10^3$ respectively), which was similar to the rainy season. However, pattern 1 had the highest tuber fresh weight (84.17g) whereas in rainy season there was less separation among treatments.

Significant differences were observed in tuber yield of sweet potato during the dry season with patterns 1, 3 and 5 giving the highest yields, (7.13, 6.48, 6.71 ton/ha, respectively) (Figure 1B). Ruttanaprasert et al. (2017) evaluated 5 sweet potato cultivars during the dry season (October to January) and their tuber yield ranged between 3.5 and 10.0 ton/rai which was higher than our study, probably due to the

differences in cultivars, environment factors, sand oil properties. Generally, most of previous studies did not study cultivation of sweet potato during the dry season. However, farmers in the Northeast par of Thailand usually plant sweet potato as a second crop during the dry season after harvesting their main crop (November to December).

Relationship between tuber yield and other agronomic performances

Tuber yield was correlated with number of tuber/plant (r=0.686**) and number of tubers/ha (r=0.781**) (Figure 2a,b respectively) which was similar to Egbe et al. (2012) who reported that root weight was correlated with number of root (r=0.727**). Also Bassey (2017) reported that tuber yield was strongly correlated with number of marketable tubers per plot (r=0.94**). Harriman et al. (2017) showed that root yield was correlated to total root number per plant (0.73**) and Ruttanaprasert et al. (2017) showed that tuber fresh weight was moderately correlated with number of tuber/plant. They also found that root yield was highly correlated with root weight/plant (0.99**) which we did not find.

Vine length at 60 and 75 DAP was correlated with tuber yield (r=0.555** and 0.524**, respectively) (Figure 2c, d). Bassey (2017) and Ogbe et al. (2012) did not find any association between vine length and other traits in their studies. On the other hand, Ruttanaprasert et al. (2017) reported that vine length was negatively correlated with tuber fresh weight and tuber dry weight (r=-0.68* and -0.59* respectively) which is in contrast with our study.

The number of nodes per plant at 60 and 75 DAP was moderately correlated with tuber yield (r=0.455* and 0.435* respectively) (Figure 2e, f). There are no other reports of this association in the literature. Vine girth at 60 and 75 days after planting was moderately correlated with tuber yield (r=0.451* and 0.490* respectively) (Figure 2g, h respectively). Edbg et al. (2012) reported that vine girth had no correlation with tuber yield or others characteristics, however, root diameter was correlated with number of root and root weight (r=0.772** and 0.626**). The low correlation coefficients between these traits and tuber yield in our study probably attributed to the lack of significant differences between planting treatments for the vine characteristics.

Conclusion

There was significant season by planting pattern interaction effects for tuber yield in our experiment. During the rainy season pattern 5 with three vine cuttings had the highest tuber yield, number of tubers per plant and number of tubers per ha. Pattern 2 (with one cutting at an angle) had the second highest yield and pattern 3 (one cutting sideways) had highest number of branches per plant and tuber diameter. During the dry season, patterns 1, 5 and 3 had the highest yields. Pattern 1 had the highest tuber fresh weight, and patterns 4 and 5 had the highest number of tubers per plant and number of tubers per ha. Positive correlations were significant between tuber yield and number of tuber per plant, number of tuber per ha, vine length, vine girth, number of nodes per plant at 60 and 75 DAP. We would recommend patterns 5 and 2 for rainy season, however pattern 2 could save production cost because of using only one branch per hole for planting. In dry season we recommend patterns 1, 5, and 3 for sweet potato while again patterns 1 and 3 could save production costs over pattern 5.

Materials and methods

Plant materials

Vine cuttings (slips) of cultivar Japanese Orange was used. Tubers were germinated and vine cuttings were consistently cut at approximately 40-50 cm long with 10 nodes for use in transplanting for the five planting methods.

Lay out

The experiment was laid out in randomized complete block design (RCBD) with three replications and five patterns of planting as the treatments that were recommended by Department of Agriculture, Ministry of Agriculture and Cooperative, Thailand (Figure 3) (Department of Agriculture, 1999). For planting patterns 1, 2 and 3 one vine cutting was planted in the hole but at different angles. Treatment 4 used two vine cuttings and treatment 5 used three vine cuttings. The experiment was conducted during the wet and dry seasons of 2017 at the Department of Agricultural Technology Faculty of Technology Mahasarakham University, Mahasarakham province Thailand. It is located in 16° 11' 5" N / 103° 18' 2" E, altitude 130-150 m above sea level.

First season was the rainy season in which the sweet potato treatments were planted in August 14, 2017. In the dry season, the sweet potato treatments were planted in late November 2, 2017. A spacing of 30 cm was between plants within the row and 75 cm between rows. There were four rows in each plot at 2.1 m length, and the total plot size was 6.2 m^2 (32 holes per plot). All data was collected within the interior 3.1 square meters (12 holes a plot). Land preparation was done by tractor and then manually ridging using hoes. Chemical fertilizer N-P-K formula 15-15-15 was used at a rate of 312.5 kg/ha at planting and then again at the same rate after planting 45 days DAP. Weeds were removed by hand weeding at 45 and at 60 days after planting. In rainy season, irrigation was not necessary. However, in dry season furrow irrigation was used once a week. The properties of the soil were: pH = 6.82, organic matter =0.621%, EC=0.04 ds/cm, nitrogen=0.03%, phosphorus=2.50 ppm, and potassium=0.004%. Agricultural meteorology data is shown on Table 5.

Data collection

Four plants from each plot were selected and tagged for data collection. Data was collected two times for vine length, vine girth, branches per plant and number of nodes per plant (60 and 75 days after planting). The yield was recorded at 110-120 days after planting within the center 3.1 m^2. The number of tubers per plant, number of tubers per hectare, tuber fresh weight (g) were recorded. Tuber length and tuber diameter were also measured by sampling 5 tubers a plot.

Statistical analyses

Analysis of variance (ANOVA) was conducted on the collected data using STATISTICS 9 and treatment means were separated using least significant difference (LSD) at 5 % probability level. Main treatments and interactions were determined and the correlation of the tuber yield with some of the other agronomic performances were performed.

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