Journal of Agricultural Science and Technology A and B
& Hue University Journal of Science 7 (2017) 10-16
doi: 10.17265/2161-6256/2017.10.002S

Evaluation of Sponge Gourd (*Luffa cylindrical* L.) Inbred Lines for Growth Potential and Fruit Quality in Thua Thien Hue Province, Central Vietnam

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Abstract: Plants which contain unisexual flowers are subjected to genetic degradation and yield capacity reduction due to the easily cross-pollination. Sponge gourd, one of species of the Cucurbitaceae which is predominantly cross-pollinating, is cultivated to widely use as vegetable in Vietnamese daily meals. The aim of this experiment was to evaluate the growth potential and fruit quality including fruit aroma of sponge gourd inbred lines. Pure line selection has been performed using self-pollinated method, so that sponge gourd lines would be recovered with high yielding and aroma and thereby recommended for further crop system in Thua Thien Hue province, Central Vietnam. The experiment was conducted in a randomized complete block design (RCBD) with three replications during the winter-spring season in 2017. Agronomical data were observed and analyzed on seven inbred lines (1-MN1, 1-MN2, 5-MN1, 7-MN1, 13-MN2, 15-MN1 and 15-MN2) derived from B29 accession (GBVN006904). The results indicated that inbred lines 13-MN2, 1-MN2 and 15-MN1 attained more highly fruit weight and yield compared to the others. Four inbred lines consisting of 5-MN1, 7-MN1, 15-MN1 and 15-MN2 still retained the light aroma after boiling. The inbred lines 1-MN2, 7-MN1, 13-MN2 and 15- MN1 are considered for appropriately using in breeding program of new luffa.

Key words: Sponge gourd, inbred line, growth potential, fruit aroma, Thua Thien Hue.

1. Introduction

Sponge gourd or smooth luffa (*Luffa cylindrical* L.) is a cross-pollinated crop with 13 pairs of chromosomes ($2n$ = 26) [1, 2] and seed-propagated species. Sponge gourds are popularly cultivated for harvesting both of mature-green fruit and dry fruit because of its high nutrient value [3, 4] and tough fibrous vascular system [5-7]. Sponge gourds, which are attributed to hot season crops, are grown extensively in Vietnam and various countries, such as India, China, Taiwan, Korea, America and Nepal [8, 9]. There are about 91.3% households cultivating sponge gourd in their farms in Kaski ecosite of Nepal [9]. Vietnamese farmers commonly cultivate two *Luffa* species, such as *L. cylindrical* (sponge gourd) and *L. acutangula* (ridged gourd), and then harvest fruits as edible vegetables. Customers prefer sponge gourd fruits than ridged gourd ones because of good tasting and aroma.

Sponge gourds are easy to cultivate and maintain seeds, so local farmers may consistently utilize random available seeds from dried old-fruits. Sthapit and Jarvis [10] also emphasized that farmers develop crop seed over many generations of selection without direct inputs of formal plant breeding. Due to the attraction of an aroma aspect, sponge gourds are favored for cooking in Vietnam. The genetic degeneration of sponge gourd which is probably caused by a cross-pollination habit, however occurs. The important characteristics (such as aroma) could

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disappear by the genetic degeneration. Thus, a sponge gourd breeding program using pure line selection method is essential to introduce new line having aroma feature to crop system in Thua Thien Hue province, Central Vietnam. A sponge gourd germplasm consisting of 49 accessions obtained from Center of Plant Genetic Resource of Vietnam was described and reported with significant variation of agronomical characteristics and yield components [11]. Several promising sponge gourd were considered to be grown in local conditions of Thua Thien Hue [12]. Favorable sponge gourd varieties and lines were constantly evaluated and then selected for the procedure of new *Luffa* breeding during the last three years. Sponge gourd inbred lines derived from the fourth generation of promising ones were investigated for agronomical traits in last summer-autumn season [11]. In order to enhance selected ability for the breeding, this experiment was conducted to evaluate the growth potential and yield of sponge gourd inbred lines at Thua Thien Hue during winter-spring season.

2. Materials and Methods

The experiment was carried out in a plastic house at Agronomy Faculty, University of Agriculture and Forestry, Hue University from November 2016 to May 2017. B9, seven sponge gourd lines derived from B29 (GBVN006904) [12] having aroma feature, and one local variety, namely, Muop Trau grown as a control were investigated. The different sponge gourd lines were selfing at the fourth generation of B29 designated by 1-MN1, 1-MN2, 5-MN1, 7-MN1, 13-MN2, 15-MN1 and 15-MN2. Hand pollination was used to collect the prior seeds forming these inbred lines.

The collected seeds having black and thick shell in the previous study were treated by using a mix of 2/5 boiled water and 3/5 cool water for pre-sprouting. After that, these seeds were sown in pots, and then seedlings with 1-2 true leaves were transplanted to open experiment. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Each replication was obtained five plants. Area of a plot was 2.5 m^2, allowing the total area of experiment to reach 67.5 m^2.

The experimental soil was treated by lime powder to reduce acidity and made beds with 1 m width. The basal fertilizers for this experiment included 20 tons manure/ha, 120 kg superphosphate ($CaH_4P_2O_8$)/ha and 30 kg potassium (KCl, K_2SO_4, KNO_3)/ha. When sponge gourds reached 20-day old since transplanting, fertilizers were adjusted and supplied for plants every 20 d with 300 kg NPK (16% CH_4N_2O, 16% P_2O_5, 8% KCl)/ha, 200 kg urea/ha and 30 kg potassium/ha by watering. Watering and weeding out were manually served as required.

The evaluated data were recorded on 13 quantitative traits: (1) the days from transplanting to first female flower, (2) the days to first male flower, (3) harvesting days, (4) internode length (cm), (5) leaf width (cm), (6) leaf length (cm), (7) total number of branches per main stem in the growth stage, (8) total number of female flower per plant, (9) total number of fruits per plant, (10) fruit peduncle length (cm), (11) fruit length (cm), (12) fruit diameter (cm) and (13) fruit weight (g) in the flowering and harvesting stages. The data consisting of 14 morphological traits were observed during harvesting time: (1) leaf shape, (2) leaf color, (3) leaf margin, (4) depth of lobbing, (5) leaf pubescence (dorsal face), (6) leaf pubescence (ventral face), (7) fruit shape, (8) fruit color, (9) stem-end fruit shape, (10) blossom-end fruit shape, (11) fruit rib shape, (12) fruit veins color, (13) peduncle transactional shape and (14) peduncle separation from fruit. Qualitative traits, such as aromatic trait, flesh color after boiling and total solid soluble (TSS) (Brix), were also collected. A sensory evaluation by five people was to check the aromatic presence of raw and cooked sponge gourd. Five sliced pieces of each sponge gourd replication were cooked by water to check the change of flesh color. Five random fruits per inbred line were estimated TSS by using spectrophotometer. Fruiting ratio was measured

by Eq. (1):

$$\text{Fruiting ratio} = \frac{\text{number of fruits}}{\text{number of female flowers}} \quad (1)$$

The predicted yield was estimated by number of fruits per plant, fruit weight and plot area.

The data were analyzed to get mean values of five plants by Excel. One-way ANOVA was run to determine the significant difference among available values by Statistix 10.0.

3. Results and Discussion

3.1 Growing Time to Flower Appearance and Harvesting

The number of days to an appearance of the first male flower ranged from 67 d to 75 d (data not shown). The earliest male flower was observed in 15-MN2 line (67 d), whereas the line last produced male flower was B9 (75 d). The appearance of the first female flower was later than the male flower in the ranging of 68-83 d. The line 1-MN2 produced the earliest female flower, whereas 7-MN1 and 13-MN2 produced the last ones. The earliest harvesting time was recorded in 13-MN2, 1-MN2, 15-MN1 and 5-MN1 lines by the 114th day from transplanting time. The number of days to harvesting of 1-MN2 and 15-MN1 were observed later at the 156th day. The last fruits were harvested at the 160th day in 15-MN2, 13-MN2, 7-MN1, 5-MN1 lines and B9. Only 1-MN2 line produced fruits during 114-160 d from transplanting.

In general, the time to terminate growth stages was increased compared to the results of previous studies. Sponge gourd accessions grown in Ha Noi took 43-62 d from transplanting to produce the first male flower, whereas promising sponge gourd accessions grown in Hue took 46-65 d from sowing to appear the first one [12, 13]. The first fruit could early harvest from 72 d to 87 d in Ha Noi. The times were delayed probably due to environmental conditions. An exposing of seedlings under cold temperature in winter period presumably prolonged vegetative process.

3.2 Growth Potential

The results of some quantitative traits are presented in Table 1. The internode length ranged from 17.76 cm (15-MN1) to 21.29 cm (control). The internode lengths of B9, 5-MN1, 7-MN1 and 13-MN2 were not significantly decreased as compared to those of control. The lines of 15-MN1, 1-MN2, 1-MN1 and 15-MN2 had shorter internodes than control. The widest leaf reached 29.48 cm in control, whereas the

Table 1 The quantitative traits of sponge gourd inbred lines.

Inbred line	Internode length (cm)	Leaf width (cm)	Leaf length (cm)	No. of branches per main stem	No. of female flowers per plant	Total No. of harvested fruits per plant	Fruit length (cm)	Fruit width (cm)	Fruit peduncle length (cm)
1-MN1	18.40^{cd}	19.02^{e}	14.86^{d}	2.60^{d}	17.33^{a}	6.67^{ab}	20.50^{c}	5.28^{bc}	8.94^{c}
1-MN2	19.73^{abcd}	22.32^{cde}	17.03^{cd}	3.00^{cd}	18.67^{a}	8.00^{ab}	22.83^{bc}	5.11^{bcd}	13.21^{ab}
5-MN1	20.81^{ab}	25.17^{abc}	18.84^{bc}	3.80^{bcd}	20.00^{a}	4.67^{b}	26.63^{b}	5.59^{b}	10.73^{bc}
7-MN1	20.53^{abc}	23.07^{cde}	19.25^{bc}	2.80^{d}	19.67^{a}	5.67^{b}	25.20^{b}	5.52^{b}	9.15^{c}
13-MN2	19.53^{abcd}	26.75^{abc}	23.77^{a}	4.20^{bc}	18.33^{a}	7.33^{ab}	24.65^{bc}	6.73^{a}	9.61^{c}
15-MN1	17.76^{d}	24.56^{bcd}	17.94^{cd}	4.13^{bc}	18.67^{a}	6.33^{ab}	25.50^{b}	6.64^{a}	8.25^{c}
15-MN2	18.98^{bcd}	20.36^{de}	16.37^{cd}	3.80^{bcd}	22.33^{a}	6.00^{ab}	22.84^{bc}	4.45^{d}	12.81^{ab}
B9	21.15^{ab}	28.89^{ab}	22.96^{a}	4.33^{b}	23.00^{a}	9.33^{a}	34.61^{a}	4.80^{cd}	13.56^{a}
Control	21.29^{a}	29.48^{a}	21.29^{ab}	8.00^{a}	-	-	-	-	-
$LSD_{0.05}$	2.21	4.69	3.18	1.22	6.70	3.53	4.47	0.69	2.66

Means in the same column with different letters are significantly different at $P < 0.05$.

-: no data observed.

smallest leaf width was recorded in 1-MN1 line by 19.02 cm. Leaf widths of 15-MN2, 7-MN1, 1-MN2, 15-MN1 and 1-MN1 lines were not significantly decreased as compared to that of control. The longest leaf was obtained in 13-MN2 line by 23.77 cm, and the following was in B9 by 22.96 cm. 1-MN1 showed the shortest leaf by 14.86 cm. The leaf lengths of 1-MN1, 1-MN2, 15-MN1 and 15-MN2 were significantly decreased as compared to control. Leaf lengths of sponge gourd landraces in Bara, Nepal varied from 11.3 cm to 22 cm [14].

The control produced the highest number of branch per main stem by 8.0, whereas 1-MN1 produced the lowest one by 2.6 branches. There was significantly different in branch number between the inbred lines (such as 15-MN2, 13-MN2, 7-MN1, B9, 5-MN1, 15-MN1 and 1-MN2) and control. Other greenhouse studies indicated that distillate flower development would hasten when first 4-6 lateral shoots are removed [15]. No significant difference was observed in total number of female flower among inbred lines. The lowest one was obtained in 1-MN1 inbred line by 17.33 flowers, whereas the highest one was attained in B9 by 23.00 flowers. Total number of fruit per plant ranged from 4.67 fruits to 9.33 fruits. The number of fruit of 5-MN1 and 7-MN1 was significantly decreased as compared to B9.

Fruit size is one of important supplements which conceive the expected actual yield. Sponge gourd size is also considered as a determining factor to predispose what products can be made from a particular sponge gourd [15]. Fruit lengths of mature-green harvested fruits ranged from 20.50 cm (1-MN1) to 34.61 cm (15-MN2). There were significantly different in fruit length between sponge gourd inbred lines and B9. The biggest fruit width was recorded 13-MN2 by 6.73 cm. The fruit width of remained lines, except 15-MN1 was significantly decreased as compared to 13-MN2. The smallest fruit was obtained in 15-MN2. Sponge gourd is an annual vine with tendrils and large [16], so it needs a supporting frame as trellis system to grow and spread. Harvesting was more easily carried out when fruit peduncle recorded as long as well. The longest fruit peduncle (13.56 cm) was obtained in B9, followed by 13.21 cm in 1-MN2. The observation of the shortest one was 8.25 cm in 15-MN1.

3.3 Morphological Traits

The morphological traits of leaf and stem are displayed in Table 2. The orbicular leaves were detected in 15-MN2 and 1-MN1, whereas the reniform leaves were observed in 13-MN2, 7-MN1, 1-MN2, 15-MN1 and 5-MN1 similar to control. Only B9 obtained ovate leaves. All inbred lines obtained the dented leaves. Dark green leaves were found in 5-MN1 and control, whereas light green leaves were observed in 1-MN2, 13-MN1 and B9. The remained lines obtained green leaves. According to Bal et al. [2], the depth of lobbing is corresponding to the leaf shape. Control and

Table 2 Leaf traits and stem shape of sponge gourd inbred lines.

Inbred line	Leaf shape	Leaf color	Leaf margin	Depth of lobbing	Leaf pubescence (dorsal face)	Leaf pubescence (ventral)	Stem shape
1-MN1	Orbicular	Green	Dented	Shallow	Medium	Low	Angular
1-MN2	Reniform	Light green	Dented	Medium	Medium	Low	Angular
5-MN1	Reniform	Dark green	Dented	Medium	Medium	Low	Angular
7-MN1	Reniform	Green	Dented	Medium	Medium	Low	Angular
13-MN2	Reniform	Light green	Dented	Medium	Medium	Low	Angular
15-MN1	Reniform	Green	Dented	medium	Medium	Low	Angular
15-MN2	Orbicular	Green	Dented	Shallow	High	Low	Angular
B9	Ovate	Light green	Dented	Deep	High	Medium	Angular
Control	Reniform	Dark green	Dented	Deep	High	Medium	Angular

B9 lines revealed deep depth of lobbing, whereas 15-MN2 and 1-MN1 exposed low depth of lobbing. The remained inbred lines were assembled in medium depth of lobbing. The high leaf pubescence (dorsal face) was detected in 15-MN2, B9 and control, and the medium leaf pubescence was observed in the remained inbred lines. All inbred lines, however, indicated low leaf pubescence (ventral face), whereas control and B9 obtained the medium one. The angular stem shape was recorded in all sponge gourds.

Bajracharya et al. [17] emphasized that fruit traits, such as shape, size and color, are important to distinguishing varietal character of sponge gourd often used by farmers. The morphological traits of fruits were indicated in Table 3. The elongate slim fruits are initiated in 15-MN2, 7-MN1, 1-MN2 and 15-MN1, whereas the elliptical ones were detected in 13-MN2, 1-MN1, 5-MN1 and B9. In the study of Yadav et al. [14], 36% of fruit shape was found elongated. Fruit color ranged from light green in 1-MN1 and B9, green in 15-MN2, 7-MN1, 1-MN2 and 5-MN1 to dark green in 13-MN2 and 15-MN1. All inbred lines assembled round stem-end fruit, pointed blossom-end, round fruit rib shape and round peduncle transactional shape. Fruit vein color consisting of light green in B9, green in 15-MN2, 13-MN2 and 1-MN1, and dark green in 7-MN1, 1-MN2, 15-MN1 and 5-MN1, was observed. Peduncle separation from fruit was easy in 1-MN1, 1-MN2, 13-MN2, 15-MN1 and 15-MN2 lines.

3.4 Yield and Yield Components

The values of yield and yield components of sponge gourd inbred lines are presented in Table 4. Fruit-set is a crucial supplement influences yield of every fruit

Table 3 Morphological traits of sponge gourd fruits.

Inbred lines	Fruit shape	Fruit color	Blossom-end fruit shape	Stem-end fruit shape	Fruit rib shape	Fruit veins color	Peduncle transactional shape	Peduncle separation from fruit
1-MN1	Elliptical	Light green	Round	Pointed	Round	Green	Round	Easy
1-MN2	Elongate slim	Green	Round	Pointed	Round	Dark green	Round	Easy
5-MN1	Elliptical	Green	Round	Pointed	Round	Dark green	Round	Difficult
7-MN1	Elongate slim	Green	Round	Pointed	Round	Dark green	Round	Difficult
13-MN2	Elliptical	Dark green	Round	Pointed	Round	Green	Round	Easy
15-MN1	Elongate slim	Dark green	Round	Pointed	Round	Dark green	Round	Easy
15-MN2	Elongate slim	Green	Round	Pointed	Round	Green	Round	Easy
B9	Elliptical	Light green	Pointed	Pointed	Round	Light green	Round	Difficult

Table 4 Yield components and yield of sponge gourd inbred lines.

Inbred lines	Fruit-set ratio (%)	Number of fruit per plant (fruit)	Mean fruit weight (g)	Predicted yield (ton/ha)	Actual yield (ton/ha)
1-MN1	38.67^{ab}	1.33^{ab}	232.44^{a}	6.21^{ab}	5.83^{b}
1-MN2	43.24^{a}	1.60^{ab}	261.50^{a}	8.33^{ab}	7.44^{ab}
5-MN1	23.22^{c}	0.93^{b}	290.00^{a}	5.20^{b}	4.65^{b}
7-MN1	28.60^{bc}	1.13^{b}	271.11^{a}	6.02^{ab}	5.73^{b}
13-MN2	39.67^{ab}	1.47^{ab}	290.56^{a}	9.01^{ab}	7.40^{ab}
15-MN1	32.16^{abc}	1.27^{ab}	265.00^{a}	6.67^{ab}	6.40^{ab}
15-MN2	26.59^{c}	1.20^{ab}	273.89^{a}	6.66^{ab}	5.45^{b}
B9	40.83^{a}	1.87^{a}	286.67^{a}	10.48^{a}	9.60^{a}
Control	-	-	-	-	-
$LSD_{0,05}$	11.41	0.70	69.70	4.92	3.60

Means in the column with different letters are significantly different at $P < 0.05$.

-: indicate no data observed.

Table 5 Brix, aroma feature and flesh color of sponge gourd lines.

Inbred lines	TSS (°Bx)	Aroma feature		Grey level of flesh color
		Raw	After boiling	
1-MN1	2.93^{cd}	No	No	Disappear
1-MN2	3.03^{bcd}	Yes	No	Disappear
5-MN1	2.95^{cd}	Yes	Yes	Disappear
7-MN1	3.36^{ab}	Yes	Yes	Disappear
13-MN2	3.13^{abcd}	Yes	No	Disappear
15-MN1	3.18^{abc}	Yes	Yes	Disappear
15-MN2	2.81^{d}	Yes	Yes	Disappear
B9	3.40^{a}	No	No	Disappear
Control	-	-	-	-
$LSD_{0.05}$	0.36			

Means in the column with different letters are significantly different at $P < 0.05$.

crops. The number of harvested fruits divided by number of female flowers per plant is generally considered a fruit-set ratio. The results indicated that fruit-set ratio of sponge gourd lines ranged from 23.22% to 43.24%. Sponge gourds 1-MN2, B9 and 13-MN2 reached high fruit-set ratio at 43.24%, 40.83% and 39.67%, respectively. The fruit-set ratio of 5-MN1 and 15-MN2 were 23.22% and 26.59%, respectively, and they were significantly decreased as compared to that of previous mentioned lines. The number of fruits per plant varied from 0.93 fruits (5-MN1) to 1.87 fruits (B9). Sponge gourd grown in summer-autumn season produced higher number of fruits per plant than that in spring-winter season. Mean fruit weight was observed as the maximum in 13-MN2 (290.56 g), which was not significantly different than all other inbred lines. The minimum fruit weight was detected in 1-MN1 line by 232.44 g. The results of fruit weight were found similar in the previous study when other sponge gourd inbred lines investigated from May to November 2016 that ranging from 190.2 g to 264.2 g [11]. The values were not significantly different among last six sponge gourd inbred lines [11]. Predicted yield was measured by mean fruit weight, number of fruits per plant and plant density. The predicted yield was reported the maximum at 10.48 tons/ha in B9, followed by 13-MN2 line in 9.01 tons/ha. The minimum predicted yield was observed in 5-MN1 by 5.2 tons/ha and was significantly different as compared to the maximum one. The highest actual yield was recorded in B9 (9.6 tons/ha), followed by 1-MN2 (7.44 tons/ha), 13-MN2 (7.40 tons/ha) and 15-MN1 (6.40 tons/ha), respectively. No significant difference in actual yield was released in these inbred lines. The lowest actual yield was observed in 5-MN1 inbred line by 4.65 tons/ha.

3.5 Fruit Quality

The evaluation on fruit quality of this experiment is revealed with TSS, aroma feature and flesh color after boiling (Table 5). TSS was observed the maximum at 3.40 °Bx in B9, followed by 3.36 °Bx in 7-MN1, and the minimum at 2.81 °Bx in 15-MN2. Aroma feature was an essential trait to evaluate sponge gourd quality for the study. This trait, however, was identified by smelling of each person, which leading a reliant accuracy. Only 1-MN1 inbred line and B9 had no aroma either before or after boiling. The inbred lines, namely 5-MN1, 7-MN1, 15-MN1 and 15-MN2 still retained aroma feature until boiled. In Bara of Nepal, the moderate aroma was found in only Basmatia landrace [14]. Flesh color is one of the characters that customers pay attention to. A dish decoration is better through fresh flesh and the color is not changed to dark. Grey level of flesh color was disappeared in all sponge gourd inbred lines after boiled. This result was in an agreement with the previous results that

indicated no change in flesh color was observed for sponge gourd inbred lines.

4. Conclusions

The evaluation of sponge gourd inbred lines for growth potential and yield was performed under plastic house during winter-spring season. The results indicated that all inbred lines could grow well under plastic house conditions. The inbred lines, such as 1-MN2, 7-MN1, 13-MN2 and 15-MN1 were considered promising sponge gourd inbred lines, due to more high yield and revealing aroma appearances that will be using like a valuable resource for sponge gourd breeding program in Vietnam in general and in Hue particular. Inbred lines 7-MN1 and 15-MN1 should be utilized for seed retaining and developing new aroma *Luffa* inbred line in next seasons.

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