International Journal of Agricultural Technology 2019 Vol. 15(6):987-996
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Augmented analysis for yield and pod characteristics of yardlong bean (*Vigna unguiculata* (L.) Walp. ssp. *sesquipedalis* Verdc.) lines

Pornsuriya, P.[*], Pornsuriya, P. and Chittawanij, A.

Department of Plant Production Technology, Faculty of Agriculture and Natural Resources, Rajamangala University of Technology Tawan-ok, Bangpra, Sriracha, Chonburi, 20110, Thailand.

Pornsuriya, P., Pornsuriya, P. and Chittawanij, A. (2019). Augmented analysis for yield and pod characteristics of yardlong bean (*Vigna unguiculata* (L.) Walp. spp. *sesquipedalis* Verdc.) lines. International Journal of Agricultural Technology 15(6):987-996.

Abstract The selected forty yardlong bean lines in the sixth generation (F_6) of the cross between two parental cultivars were recorded to compare with four cultivars, viz. Bangpra Purple, Bangpra #2 (parental cultivars), Lamnamchee, and Tarnthong (commercial cultivars). The results showed that the forty lines significantly differed in pod length, number of seeds per pod ($p<0.01$), and yield per hectare ($p<0.05$). The means for pod length and yield of the lines were significantly higher than the control. Eight lines expressed the pod length ranging from 70.35 to 75.85 cm that are longer than the parent (69.50 cm of Bangpra #2) but not significantly different ($p>0.05$). Twenty-one lines possessed pod lengths from 61.41 to 75.85 cm that are significantly different ($p>0.05$) from the commercial cultivar (52.52 cm). The Bangpra #2 cultivar gave the significantly highest yield (19.16 t/ha) compared to the control. There were four promising lines for possessing yields ranging from 20.60 to 22.80 t/h and tended to get more value than the Bangpra #2 cultivar. Most of the selected F_6-lines were proven to have better performance than the commercial cultivars, and some cultivars had better performance than their parents. Thus, these promising lines would be selected for yield trials in the next generation.

Keywords: asparagus bean, cross, generation, performance

Introduction

Yardlong beans (*Vigna unguiculata*) L.) Walp. subsp. *sesquipedalis* (L.) Verdc.) (Stephens, 2003; Porcher, 2005) belong to a member of the Fabaceae family (United States Department of Agriculture, 2007). It is one of the most important vegetable crops widely grown in all seasons throughout Thailand. According to the yearly situation of plant production in Thailand, the Department of Agricultural Extension reported that during the 2017 growing season, yardlong beans were grown on an area of 4,701.1 hectares and a harvesting area of 1,762.3 hectares, yielding pod production of 22,444 tons and

[*] **Corresponding Author:** Pornsuriya, P.; **Email:** pornsuriya@hotmail.com

an average yield of 12.73 tons per hectare of the harvesting area (Department of Agricultural Extension, 2018). Yardlong bean is a highly nutritive vegetable containing digestible protein, thiamin, riboflavin, calcium, phosphorus, sodium, potassium, magnesium, iron, and is also a very good source of Vitamin A and C (National Research Council, 2006). It is considered to provide good income to farmers, resulting that many vegetable farmers in Thailand commonly cultivate it. However, yardlong bean breeding and production presently might not pay sufficient attention to pod quality for fresh pod consumption. Thus, this breeding program will be focused on both pod yield and pod quality of the yardlong bean.

To select new, elite lines from a parental cultivar in a self-pollinated crop such as the yardlong bean is rarely successful because of its homozygosity. Therefore, yardlong bean breeding should be performed by the hybridization of two or more appropriate parental cultivars to create genetic variability for selecting better genotypes resulting from transgressive segregation (Poehlman and Sleper, 1995). The variability existing in a base population of this crop after crossing is significant so that plant breeders can exploit it for crop improvement. In the early stages of plant selection, the expected genetic gains may be increased by screening a larger number of genotypes in contrast to having more precise comparisons of fewer genotypes under several replications (Bos, 1983; Gauch and Zobel, 1996). Moreover, the problem existing in evaluating lines in the early generations selected from a cross is the inadequate quantity of seeds to conduct replicated experiments (Fehr, 1987). Federer (1956 & 1961) and Federer and Ragavarao (1975) proposed augmented designs to solve these problems, where a set of check cultivars is replicated with an equal number of times, and additional sets of new or tested lines are included in the experiment only once.

According to the yardlong bean breeding program conducted by the researchers, the cross between two cultivars was performed to create genetic variability for selecting new, elite lines for high yield and good pod quality using the pedigree method (Pornsuriya and Pornsuriya, 2016). In the present study, the forty promising F_6 lines selected from this cross were evaluated in augmented design to compare their yield and pod characteristics with check cultivars and then to select the promising lines for the breeding program in the next generation.

Materials and Methods

The yield trial involving 40 yardlong bean F_6-lines selected from the cross of two parental elite cultivars of the breeding program (Bangpra #2 x Bangpra Purple) was carried out at Department of Plant Production Technology,

Faculty of Agriculture and Natural Resources, Rajamangala University of Technology, Tawan-ok, Chonburi, Thailand, during January – March 2019. The experimental design was augmented in a Randomized Complete Block Design (RCBD) with five replications (blocks), of which each block contained twelve plots. Four check cultivars, namely Bangpra #2, Bangpra Purple (parents), Tarn Thong, and Lamnamchee (commercial cultivars), were randomly planted on plots in each block. The remaining eight plots in each block were assigned to new F_6-lines, eight lines per block. Thus, each block contained four check cultivars and eight F_6-lines and only four check cultivars were replicated in every block.

The experimental plot unit was 1 m x 3 m in size, and 0.5 m width between two adjacent planting beds, and 0.75 m width between blocks. Plants were grown in two-row beds using plastic mulch, with 50 cm hill spacing and 75 cm row spacing, two plants per hill, which totals 24 plants per plot under a trellising system using bamboo stakes. Manures and fertilizers were applied as per the recommended dose. Recommended practices were followed to raise a good crop. Data on the pod characteristics of marketable fresh pods including pod width (cm), pod length (cm), seeds per pod, and pod weight (g) were recorded from ten selected pods from each plot. Pods per plant were averaged from pods per plot. Yield per plot was collected from the pod fresh weight in each plot calculated to yield per hectare (ton/hectare). Fresh pods were harvested on alternate days for five weeks. The data were analysed by following the augmented method of RCBD (Federer, 1956; Federer and Ragavarao, 1975). The means of the tested F_6-lines were adjusted by a block effect value of each block according to the augmented method. Least significant difference at 0.05 level ($LSD_{0.05}$) was calculated for the mean comparison between a pair of check means, F_6-line means, and between an F_6-line and a check means. The means of all F_6-lines and check cultivars were sorted from maximum to minimum to facilitate the comparison between an F_6-line and the highest check cultivar. Relationships among characters were investigated using the Pearson correlation coefficient.

Results

The resulting means indicated that there were significant differences among the treatments, among the check entries, and among the tested entries (F_6-lines) for pod length, seeds per pod, pods per plant, and yield ($p < 0.05$ and 0.01) as shown in Table 1. Check cultivars vs. F_6-lines showed significant differences for pod length, pods per plant, and fresh pod yield ($p < 0.05$ and

0.01). No significant differences were found among treatments for pod width and pod weight ($p > 0.05$).

Table 1. Analysis of variance for pod width (cm), pod length (cm), seeds/pod, pods/plant, pod weight (g) and yield (t/ha) of 40 F6-lines and 4 check cultivars

Source	df	Mean Square					
		Pod width	Pod length	Seeds/pod	Pods/plant	Pod weight	Yield
Block	4	0.002	17.306	1.570	3.754	13.138	7.652
Treatment	43	0.002	78.743**	6.749**	19.957**	23.263	23.507**
Check	3	0.005	394.800**	14.670**	66.406**	36.183	94.345**
Test Entry	39	0.002	52.171**	6.330**	15.553**	22.228	17.605*
Chk. VS Test	1	0.008	167.161**	0.673	52.381**	24.877	41.157*
Error	12	0.001	11.559	1.184	3.138	26.767	4.929
Total	59						

* and ** = significant at $p < 0.05$ and 0.01, respectively

Line comparison and ranking were reported as the pod width. With this, Line No. 40 tended to give the widest pod (0.73 cm) due to its ranking in the first order and followed by Tarn Thong, No. 8 and No. 16 (0.71, 0.70 and 0.70 cm, respectively). Whereas, the parental cultivars, Bangpra Purple and Bangpra #2 gave the pod width of 0.66 and 0.64 cm, respectively (Table 2).

The tested lines gave pod lengths of 61.93 cm, which significantly differed ($p < 0.01$) from the control (58.08 cm). Eight tested lines exhibited the pod length from 70.35 to 75.85 cm, which their ranking numbers were prior appeared to the check cultivar (69.50 cm of Bangpra #2). The parental cultivars and most of tested lines had significantly longer pods than the two commercial cultivars (Table 3).

The six tested lines were ranked for the number of seeds per pod which were higher than the Bangpra #2 cultivar that showed the highest check cultivar (control). Seeds per pod of eighteen F_6-lines were significantly higher than both commercial cultivars (Table 4).

Line No. 8 was significantly higher in the number of pods per plant (24.87 pods/plant) than the check cultivar (15.01 pods/plant of Bangpra #2 cultivar) as compared by $LSD_{0.05}$. Both parental cultivars possessed significantly more pods per plant higher than the two commercial cultivars (Table 5).

There were no significant differences in pod weight ($p > 0.05$) among the check cultivars and tested lines. Line No. 26 tended to get the highest pod weight among the tested lines and all cultivars (36.85 g), whereas Bangpra #2 tended to get the highest pod weight (30.40 g) among the check cultivars (Table 6).

Table 2. The adjusted values for pod width (cm) of 40 F6-lines and 4 check cultivars ranking from maximum to minimum

Rank	Lines/ Cultivars	Pod width (cm)	Rank	Lines/ Cultivars	Pod width (cm)	Rank	Lines/ Cultivars	Pod width (cm)
1	No. 40	0.73	16	No. 33	0.66	31	No. 2	0.61
2	**Tarn Thong**	**0.71**	17	No. 35	0.66	32	No. 23	0.61
3	No. 8	0.70	18	**Bangpra Pur.**	**0.66**	33	No. 34	0.61
4	No. 16	0.70	19	No. 9	0.65	34	No. 36	0.61
5	No. 24	0.70	20	No. 32	0.65	35	No. 39	0.61
6	No. 10	0.69	21	No. 13	0.64	36	No. 19	0.60
7	No. 28	0.69	22	No. 15	0.64	37	No. 21	0.60
8	No. 25	0.68	23	No. 18	0.64	38	No. 29	0.60
9	No. 26	0.68	24	No. 20	0.64	39	No. 11	0.59
10	No. 31	0.68	25	No. 27	0.64	40	No. 5	0.58
11	No. 37	0.68	26	**Bangpra#2**	**0.64**	41	No. 6	0.57
12	No. 12	0.67	27	No. 3	0.63	42	No. 22	0.57
13	**Lamnamchee**	**0.67**	28	No. 7	0.63	43	No. 4	0.54
14	No. 14	0.66	29	No. 17	0.63	44	No. 38	0.54
15	No. 30	0.66	30	No. 1	0.62			

C.V. (%) = 5.77

$LSD_{0.05}$ (between an F6-line and a check) = 0.10 cm,

$LSD_{0.05}$ (between F6-lines) = 0.11 cm, $LSD_{0.05}$ (between checks) = 0.05 cm

Table 3. The adjusted values for pod length (cm) of 40 F6-lines and 4 check cultivars ranking from maximum to minimum

Rank	Lines/ Cultivars	Pod length (cm)	Rank	Lines/ Cultivars	Pod length (cm)	Rank	Lines/ Cultivars	Pod length (cm)
1	No. 15	75.85	16	No. 40	64.06	31	No. 29	58.58
2	No. 8	73.57	17	No. 16	64.00	32	No. 21	58.24
3	No. 17	72.54	18	No. 9	63.71	33	No. 2	57.22
4	No. 25	72.13	19	No. 23	63.49	34	No. 4	56.67
5	No. 22	71.84	20	No. 31	62.58	35	No. 12	54.06
6	No. 26	71.13	21	No. 3	61.81	36	No. 34	53.70
7	No. 30	70.53	22	No. 35	61.41	37	**Tarn Thong**	**52.52**
8	No. 10	70.35	23	**Bangpra pur.**	**60.55**	38	No. 6	52.26
9	**Bangpra#2**	**69.50**	24	No. 32	60.48	39	No. 11	50.91
10	No. 33	69.21	25	No. 24	59.64	40	No. 13	49.75
11	No. 18	68.69	26	No. 7	59.47	41	**Lamnamchee**	**49.75**
12	No. 37	68.60	27	No. 1	59.12	42	No. 5	49.22
13	No. 28	67.63	28	No. 39	59.11	43	No. 36	48.45
14	No. 20	66.59	29	No. 14	59.06	44	No. 38	48.16
15	No. 19	64.74	30	No. 27	58.63			

C.V. (%) = 5.61

$LSD_{0.05}$ (between an F6-line and a check) = 8.83 cm,

$LSD_{0.05}$ (between F6-lines) = 10.19 cm, $LSD_{0.05}$ (between checks) = 4.56 cm

Table 4. The adjusted values for number of seeds per pod of 40 F6-lines and 4 check cultivars ranking from maximum to minimum

Rank	Lines/ Cultivars	Seeds per pod	Rank	Lines/ Cultivars	Seeds per pod	Rank	Lines/ Cultivars	Seeds per pod
1	No. 15	23.03	16	No. 1	18.50	31	**Lamnamchee**	**16.44**
2	No. 22	21.90	17	No. 40	18.31	32	No. 32	16.25
3	No. 27	20.46	18	No. 18	18.20	33	**Tarn Thong**	**16.04**
4	No. 11	20.23	19	No. 33	18.10	34	No. 17	15.71
5	No. 21	20.20	20	**Bangpra pur.**	**17.92**	35	No. 3	15.61
6	No. 2	19.90	21	No. 34	17.90	36	No. 39	15.60
7	**Bangpra#2**	**19.82**	22	No. 10	17.73	37	No. 26	15.35
8	No. 28	19.56	23	No. 38	17.50	38	No. 23	15.30
9	No. 19	19.40	24	No. 9	17.03	39	No. 31	14.85
10	No. 13	19.23	25	No. 24	17.01	40	No. 14	14.73
11	No. 25	19.06	26	No. 30	16.85	41	No. 5	13.30
12	No. 16	19.03	27	No. 12	16.83	42	No. 35	12.50
13	No. 8	19.00	28	No. 4	16.81	43	No. 7	12.41
14	No. 20	18.90	29	No. 36	16.81	44	No. 29	10.05
15	No. 37	18.71	30	No. 6	16.61			

C.V. (%) = 6.24

$LSD_{0.05}$ (between an F6-line and a check) = 2.82 seeds/pod,

$LSD_{0.05}$ (between F6-lines) = 3.26 seeds/pod, $LSD_{0.05}$ (between checks) = 1.46 seeds/pod

Table 5. The adjusted values for number of pods per plant of 40 F6-lines and 4 check cultivars ranking from maximum to minimum

Rank	Lines/ Cultivars	Pods per plant	Rank	Lines/ Cultivars	Pods per plant	Rank	Lines/ Cultivars	Pods per plant
1	No. 8	24.87	16	No. 17	12.77	31	No. 21	8.77
2	No. 10	18.87	17	No. 40	12.23	32	No. 15	8.70
3	No. 1	18.74	18	No. 22	11.98	33	**Lamnamchee**	**8.58**
4	No. 38	18.65	19	**Bangpra Pur.**	**11.83**	34	No. 37	8.15
5	No. 6	16.44	20	No. 2	11.69	35	No. 29	8.06
6	No. 25	15.93	21	No. 28	11.51	36	No. 26	7.81
7	No. 36	15.86	22	No. 19	11.10	37	No. 18	7.31
8	**Bangpra#2**	**15.01**	23	No. 30	10.76	38	No. 4	7.16
9	No. 3	14.50	24	No. 32	10.76	39	No. 27	7.10
10	No. 9	13.91	25	No. 23	10.68	40	**Tarn Thong**	**6.75**
11	No. 33	13.90	26	No. 7	10.50	41	No. 20	6.18
12	No. 5	13.79	27	No. 11	9.79	42	No. 13	4.87
13	No. 24	13.60	28	No. 16	9.50	43	No. 12	3.83
14	No. 34	13.44	29	No. 39	9.40	44	No. 31	3.56
15	No. 35	13.44	30	No. 14	9.00			

C.V. (%) = 15.87

$LSD_{0.05}$ (between an F6-line and a check) = 4.60 pods/plant

$LSD_{0.05}$ (between F6-lines) = 5.31 pods/plant, $LSD_{0.05}$ (between checks) = 2.38 pods/plant

Table 6. The adjusted values for pod weight (g) of 40 F6-lines and 4 check cultivars ranking from maximum to minimum

Rank	Lines/ Cultivars	Pod weight (g)	Rank	Lines/ Cultivars	Pod weight (g)	Rank	Lines/ Cultivars	Pod weight (g)
1	No. 26	36.85	16	No. 9	28.85	31	No. 23	24.35
2	No. 15	35.85	17	No. 29	28.85	32	**Lamnamchee**	**24.20**
3	No. 33	35.10	18	No. 31	28.85	33	No. 14	23.85
4	No. 25	34.85	19	No. 17	28.35	34	No. 6	23.35
5	No. 30	34.85	20	No. 18	28.35	35	No. 7	22.85
6	No. 37	33.10	21	No. 27	27.85	36	No. 12	22.85
7	No. 28	32.85	22	**Bangpra Pur.**	**27.60**	37	No. 1	22.35
8	No. 32	32.85	23	No. 21	26.35	38	No. 34	19.10
9	No. 10	31.85	24	No. 22	26.35	39	No. 39	19.10
10	No. 20	31.35	25	No. 35	26.10	40	No. 2	18.85
11	**Bangpra#2**	**30.40**	26	No. 8	25.92	41	No. 5	18.85
12	No. 40	30.10	27	No. 3	25.85	42	No. 13	18.85
13	No. 19	29.35	28	No. 16	25.85	43	No. 36	18.10
14	No. 24	29.35	29	No. 4	24.85	44	No. 38	17.10
15	**Tarn Thong**	**29.20**	30	No. 11	24.85			

C.V. (%) = 19.02

$LSD_{0.05}$ (between an F6-line and a check) = 13.43 g

$LSD_{0.05}$ (between F6-lines) = 15.51 g, $LSD_{0.05}$ (between checks) = 6.94 g

Table 7. The adjusted values for yield (tons/ha) of 40 F6-lines and 4 check cultivars ranking from maximum to minimum

Rank	Lines/ Cultivars	Yield (t/ha)	Rank	Lines/ Cultivars	Yield (t/ha)	Rank	Lines/ Cultivars	Yield (t/ha)
1	No. 8	22.80	16	No. 30	14.18	31	No. 26	10.68
2	No. 10	22.16	17	No. 2	14.08	32	No. 14	10.50
3	No. 1	22.01	18	No. 5	14.03	33	No. 21	10.49
4	No. 25	20.60	19	No. 34	13.80	34	No. 28	10.40
5	**Bangpra#2**	**19.16**	20	No. 23	13.59	35	No. 29	10.14
6	No. 3	18.22	21	No. 24	13.01	36	No. 16	10.09
7	No. 9	17.40	22	**Bangpra Pur.**	**12.75**	37	No. 11	9.57
8	No. 35	17.27	23	No. 32	12.74	38	No. 4	9.03
9	No. 33	17.13	24	No. 19	12.65	39	**Tarn Thong**	**8.98**
10	No. 38	17.04	25	No. 39	12.43	40	No. 27	7.43
11	No. 6	16.54	26	No. 7	12.33	41	No. 20	7.11
12	No. 22	15.07	27	No. 15	12.32	42	No. 13	4.88
13	No. 17	14.98	28	**Lamnamchee**	**11.43**	43	No. 12	4.57
14	No. 40	14.73	29	No. 18	11.40	44	No. 31	2.90
15	No. 36	14.19	30	No. 37	10.82			

C.V. (%) = 16.93

$LSD_{0.05}$ (between an F6-line and a check) = 5.76 t/ha,

$LSD_{0.05}$ (between F6-lines) = 6.66 t/ha, $LSD_{0.05}$ (between checks) = 2.98 t/ha

The averaged yield of 40 tested lines was 13.13 t/ha, significantly different ($p < 0.05$) from the control (13.08 t/ha), whereas all cultivars had an averaged yield of 13.12 t/ha. Among the check cultivars, Bangpra #2 gave the highest yield of 19.16 t/ha. Considering the tested lines, lines No.8, No.10, No.1 and No.25 yielded 22.80, 22.16, 22.01, and 20.06 t/ha, respectively, which are a higher ranking number than the Bangpra #2 cultivar, but they were not significantly different from the Bangpra #2 cultivar. However, they were significantly different and higher than the mean of the check cultivars (13.08 t/ha) (Table 7).

The relationship between a pair of characteristics was determined by Pearson correlation coefficient, as shown in Table 8. Correlation coefficient values indicated the positive correlation of pod width with pod length and pod weight, and pod length with pod weight. Only two pod characteristics, pod length and pods per plant, were positively correlated with yield.

Table 8. Correlation coefficients among pod width, pod length, seeds/pod, pods/plant, pod weight and yield of 40 F_6-lines and 4 check cultivars

Characters	Pod length	Seeds/pod	Pods/plant	Pod weight	Yield
Pod width	0.395**	0.025	-0.062	0.528**	-0.021
Pod length		0.289	0.141	0.759**	0.314*
Seeds/pod			0.072	0.183	0.059
Pods/plant				-0.119	0.924**
Pod weight					0.047

* and ** = significant at $p < 0.05$ and 0.01, respectively

Discussion

Most studied characters of the F_6-lines showed transgressive segregation; that there were some segregating genotypes falling outside the range of the parents, which known as transgressive segregates (Poehlman and Sleper, 1995). The results from the analysis showed significant differences among the control samples for pod length, seeds per pod, pods per plant, and yield, but it was not significant for pod width and pod weight. Consequently, the check cultivars could not display differences when compared to the F_6-lines for pod width and pod weight. The pod width and pod weight were not significantly different in the characteristics that should have the most consideration for affecting and influencing yield, including pod length and number of pods per plant, as confirmed by their positive correlation with yield. Kanhong and Pornsuriya (2014) also reported that pod length and number of pods per plant result in a highly significant positive relation with the yields of forty yardlong bean lines, whereas Sarutayophat and Nualsri (2010) reported that highly positive

correlation was found between pod number per plant and pod yield in two populations of yardlong bean F_4 progenies. However, line No.8 that expressed both long pods and the greatest number of pods per plant was not considered to select for the next generation because it showed non-uniformity of pod length during the harvesting period. Thus, the present study confirmed the lines No. 1, 3, 9, 10, 17, 18, 23, 25, 30 and 33 are the most promising genotypes to select for the yield trial under multi-environments in the next generation.

Acknowledgement

This experiment is a part of the research project entitled "Development of Yardlong Bean Cultivar for High Yield and Pod Quality" supported by Agricultural Research Development Agency (Public Organization) (ARDA) through the Grant Agreement No. PRP6205030420. The authors also wish to deliver their thanks to research assistants and field workers of the Department of Plant Production Technology, RMUTTO, for their help and cooperation.

References

Bos, I. (1983). Optimum number of replications when testing lines of families on a fixed number of plots. Euphytica, 32:311-318.

Department of Agricultural Extension. (2018). Information technology system for agricultural production. Retrived from http://production.doae.go.th/report/report_main2.php?report.

Federer, W. T. (1956). Augmented (or hoonuiaku) designs. Hawaiian Planters' Record, 55:191-208.

Federer, W. T. (1961). Augmented designs with one-way elimination of heterogeneity. Biometrics, 17:447-473.

Federer, W. T. and Raghavarao, D. (1975). On augmented designs. Biometrics, 31:29-35.

Fehr, W. R. (1987). Principles of cultivar development. Vol. I. Theory and Techniques. Macmillan Publishing Company, N York, USA.

Gauch, H. G. and Zobel, R. W. (1996). Optimal replication in selection experiments. Crop Science, 36:838-843.

Kanhong, A. and Pornsuriya, P. (2014). Yield trial of 40 yard long bean lines. Khon Kaen Agriculture Journal, 42:634-640.

National Research Council (2006). Lost crops of Africa, Vol. II: Vegetables. The National Academies Press, Washington, DC.

Poehlman, J. M. and Sleper, D. A. (1995). Breeding field crops: Fourth Edition. Iowa State University Press, Ames.

Porcher, M. H. (2005). Sorting Vigna names. The University of Melbourne. Retrieved from http://www.plantnames.unimelb. edu.au/Sorting/Vigna.html. March 10, 2007.

Pornsuriya, P. and Pornsuriya, P. (2016). Variations of pod characters in F_2 progenies of crosses between yardlong bean lines. VIIth Conference of Plant Genetic Conservation Project under the Royal Initiation of Her Royal Highness Princess Maha Chakri Sirindhorn (RSPG). Khon Kaen University, Khon Kaen.

Sarutayophat, T. and Nualsri, C. (2010). The efficiency of pedigree and single seed descent selections for yield improvement at generation 4 (F_4) of two yardlong bean populations. Kasetsart Journal (Natural Science), 44:343-352.

Stephens, J. M. (2003). Bean, Yard-Long--*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc. University of Florida IFAS Extension, Publication #HS562. Retrieved from http://edis.ifas.ufl.edu/MV029.

United States Department of Agriculture (2007). *Vigna unguiculata* (L.) Walp. subsp. *sesquipedalis* (L.) Verdc. Retrieved from http://www.ars-grin.gov/cgi-in/npgs/html/taxon.pl?41646.

(Received: 29 July 2019, accepted: 31 October 2019)