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EARLY STAMINATE FLOWERING MONOECIOUS LINES HAVE POTENTIAL AS POLLENIZERS FOR GYNOECIOUS HYBRID BITTER GOURD CULTIVARS

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Bitter gourd (*Momordica charantia* L.) is an economically and nutritionally important vegetable in Asia. The objective of this study was to evaluate a diverse collection of bitter gourd germplasm for identifying early staminate flowering monoecious lines for blending with predominantly gynoecious hybrids or gynoecious open pollinated cultivars to provide the pollen necessary for fruit set. We evaluated 186 cultigens (182 monoecious inbred lines, four commercial hybrids, collectively referred to as cultigens) of bitter gourd for early staminate flowering (days from sowing to first open staminate flower) in a two seasons study. The inbred lines were derived from 182 bitter gourd accessions in the collection of AVRDC. Cultigens were transplanted to the field at the two-leaf stage of growth each season with three plants in each of three replications. The cultigens differed significantly in both seasons ($P<0.05$) for mean number of days to first open staminate flowers, which was affected by season (day length). The earliest staminate flowering cultigen was THMC 62 (Philippines); the latest was THMC 17 (Thailand). Days to 50% staminate flowering and pollen viability (%) of the earliest staminate flowering monoecious lines ranged from 61.8% to 73.7% and 96.0% to 98.2%, respectively. The early staminate flowering monoecious lines identified have potential for use as pollenizers to optimize early and total yield of gynoecious hybrids and gynoecious open-pollinated cultivars.
Keywords: *Momordica charantia*, vegetable breeding, flowering, early pollenizer, inbred lines.

INTRODUCTION

Bitter gourd (*Momordica charantia* L.) is a commercially and nutritionally important cucurbitaceous vegetable in South and Southeast Asia where approximately 340,000 hectares are planted annually (McCreight *et al*., 2013). Asian varieties are cultivated in a few African countries, such as in Ghana, Zambia, Congo and Madagascar and fresh fruit is exported to Europe, where it is in demand among expatriate Asian communities. It is also grown on a small scale in the southern United States and Australia (Northern Territory, Queensland, New South Wales, Victoria), using Asian varieties, as a niche product for Asian immigrants (Morgan and Midmore, 2002). Bitter gourd fruits are rich in important nutrients such as vitamin C, folic acid, magnesium, phosphorus, and potassium (Yuwai *et al*., 1991). Bitter gourd fruits are used in folk medicine to manage Type 2 diabetes, a non-communicable disease which presently affects 347 million people worldwide, with 80% of affected individuals living in low-income and middle-income countries (WHO, 2013). Bitter gourd fruit contains compounds that have the potential to improve insulin sensitivity, lower blood glucose, and assist in postprandial/intestinal glucose uptake (Krawinkel and Keding, 2006). Current biogeographic analyses imply that *M. charantia* originated from Africa (Schaefer and Renner, 2010) and in all likelihood was domesticated in eastern India and southern China (Walter and Decker-Walters, 1988). Nearly 60% of the bitter gourd production area in South Asia is planted to open-pollinated cultivars (McCreight *et al*. 2013). Asian seed companies release many bitter gourd hybrid cultivars each year in Asia that are improved for fruit quality and yield compared with open-pollinated cultivars. Modern bitter gourd cultivars are monoecious (bear separate staminate and pistillate flowers on the same plant) and are open-pollinated by bee. Long days cause the staminate flowers to bloom up to two weeks before the pistillate flowers, while the short days have the inverse effect (Huyskens *et al*. 1992). Gynoecious (all pistillate flowers) bitter gourd breeding lines are available (Behra *et al*. 2010). The use of a gynoecious inbred lines in hybrid development reduces the cost of F_1 hybrid seed production and enhances seed purity. Breeders have developed gynoecious inbreds with higher combining ability that has improved early and total fruit yield in bitter gourd hybrids (Dey *et al*. 2010). High yielding gynoecious × monoecious hybrids have recently become available (Behra *et al*., 2010). In some of these hybrid cultivars, pistillate flowers tend to appear earlier than staminate flowers; in some cases, by as much as seven days. For example, the popular bitter gourd cultivar VNR 28, when planted in the last week of March in Chhattisgarh, India in 2012, produced pistillate flowers continuously from the first week of May through the end of May, but staminate flowers did not appear until end of May (P. Agarwal, personal communication, 2015). Likewise, 'Kumaken BP1', an early high yielding bitter gourd hybrid developed in Japan using a gynoecious inbred line as the seed parent, needs a pollenizer for earlier fruit setting (Iwamoto *et al*., 2009). Parthenocarpy (fruit set without pollination) is unknown in bitter gourd (Behra *et al*., 2010). Therefore, fruit yield is dependent on insect pollination (Behera *et al*., 2010). Most cucurbit species typically produce staminate flowers prior to the first pistillate flower. Lack of staminate flowers for pollination at first appearance of open pistillate flowers will, potentially, delay or reduce early and total fruit yield. Thus, adapted monoecious lines blended with gynoecious × monoecious hybrids that produce pistillate flowers earlier than staminate flowers could serve as early pollenizers to increase early and total yield potential of gynoecious hybrids or gynoecious open-pollinated cultivars. Our objective in this study was to evaluate a large collection of bitter gourd germplasm to identify early staminate flowering phenotypes. Additionally, fruit characteristics in these cultigens were evaluated for inclusion with the gynoecious cultivars.

MATERIALS AND METHODS

One hundred and eighty-six cultigens (182 breeding lines and four commercial hybrids, collectively referred to as cultigens, Table 1) were evaluated for initiation of staminate flowering during two field tests in 2012 and 2013 (designated Season 1 and Season 2, respectively) at the Research & Training Station of AVRDC – The World Vegetable Center East and Southeast Asia, Kasetsart University, Kamphaeng Saen, Nakhon Pathom, Thailand. Transplanting dates for the first and second seasons were 24 December 2012 and 10 June 2013, respectively. The latitude and longitude of the field sites in decimal degrees is 13°98'39", and 99°99'39", respectively and the soil type is clay loam. The breeding lines were drawn from the S_5 generation of genebank accessions and were developed through inbreeding, followed by selection for various horticultural traits including early staminate and pistillate flowering. Three replications containing three plants of each entry were arranged in a randomized complete block design with a row spacing of 1.6 m and within-row spacing of 1 m. Plants were furrow-irrigated, and compound fertilizer (15N- 15P-15K) was applied at an approximate rate of 3.0 g per vine every 2 weeks after planting. Plants were trained on trellises 2 m high and were not pruned during the studies. Flowering date was recorded over a period of 25 days after the opening of the first staminate flower on the earliest plant in each of the two seasons. Number of days from sowing to the first open staminate flower was recorded for each plant. Subsequently, controlled self-pollinations were made on the 15 earliest and nine latest cultigens to observe fruit shape, color, skin pattern and bitterness. The 10 earliest staminate flowering inbreds that were the earliest staminate flowering in both seasons, and five earliest inbreds based on the mean of the two seasons were grown in the field from Dec. 2014 to Feb. 2015 along with two of the four commercial hybrids, 'Benteng 545' and 'Palee'by following the above-mentioned field plot technique with five plants per plot. The following traits were recorded: (1) fruit length/breadth ratio (2) marketable fruit weight (3) number of marketable fruit per plant (4) total staminate flowers per plant and (5) days to 50% staminate flowering after sowing. Five marketable fruits of each entry in each replication were harvested to record data on length, breadth and weight. Marketable fruit size refers to the physiologically immature or unripe stage when fruits are harvested about 12-20 days after fruit set, depending on the cultivar. Immature fruit has a fresh bright appearance and the immature seed coat is creamy white. Mature fruits have yellow flesh with red seed coats. Anthers were stained with 1% acetocarmine solution to estimate pollen viability, and the stained pollen was scored as viable and non-stained as non-viable pollen (Zaman, 2006). Ten female flowers of a bitter gourd gynoecious line '12THBG5-16A5' were pollinated separately with the pollen from the each of the ten earliest staminate flowering inbreds to estimate the fruit set percentage which provided indication of pollen germination and pollen tube growth potential of early staminate flowering inbred lines. Fruit bitterness was determined using three fresh, marketable fruits of each accession that were harvested at market maturity, washed and cut into small (ca. 3 g) pieces, and used for organoleptic assessment by a three-person taste panel. Three categories of bitterness were recorded: high, medium and low. The evaluators rinsed their mouth with water after each sample tasting. Data were subjected to analysis of variance using SAS General Linear Model (GLM) procedure (SAS Institute, Cary, N.C.). Means separation was done using Tukey's HSD at $P<0.05$ or Fisher's least significant differences (LSD) at $P<0.05$ (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

Analysis of variance over two seasons revealed highly significant differences ($P<0.01$) among cultigens for mean days to first open staminate flower (Data not presented). Differences between seasons was highly significant ($P<0.01$). Season × cultigen interaction was highly significant ($P<0.01$), but the mean square for cultigens was at least eight times larger than the season × cultigen mean square, which indicated that variation due to genetic causes was more important than the genotype × environment interaction. Significant season × cultigen interaction resulted from

Table 1. List of the bitter gourd (*Momordica charantia*) cultigens evaluated for days to first open staminate flowers.

No.	Cultigen	Origin	No.	Cultigen	Origin	No.	Cultigen	Origin
1	THMC 1	Thailand	33	THMC 33	Philippines	65	THMC 68	Bangladesh
2	THMC 2	Thailand	34	THMC 34	Philippines	66	THMC 70	Bangladesh
3	THMC 3	Thailand	35	THMC 35	Philippines	67	THMC 71	Bangladesh
4	THMC 4	Thailand	36	THMC 36	Philippines	68	THMC 72	Bangladesh
5	THMC 5	Thailand	37	THMC 40	Philippines	69	THMC 73	Bangladesh
6	THMC 6-1	Thailand	38	THMC 41	Philippines	70	THMC 74-1	Bangladesh
7	THMC 6-2	Thailand	39	THMC 42	Philippines	71	THMC 75-1	Bangladesh
8	THMC 7	Thailand	40	THMC 43	Philippines	72	THMC 75-2	Bangladesh
9	THMC 8-1	Thailand	41	THMC 44	Philippines	73	THMC 76	Bangladesh
10	THMC 10	Thailand	42	THMC 45	Philippines	74	THMC 77	Bangladesh
11	THMC 11	Thailand	43	THMC 46	Philippines	75	THMC 78-1	Bangladesh
12	THMC 12	Thailand	44	THMC 47	Philippines	76	THMC 81	Bangladesh
13	THMC 13	Thailand	45	THMC 48	Philippines	77	THMC 82	Bangladesh
14	THMC 15	Thailand	46	THMC 49	Philippines	78	THMC 86	Bangladesh
15	THMC 17	Thailand	47	THMC 52-1	Philippines	79	THMC 87	Bangladesh
16	THMC 18-1	Thailand	48	THMC 52-2	Philippines	80	THMC 88-1	Bangladesh
17	THMC 18-2	Thailand	49	THMC 53-1	Philippines	81	THMC 88-2	Bangladesh
18	THMC 19-1	Thailand	50	THMC 53-2	Philippines	82	THMC 89	Bangladesh
19	THMC 19-2	Thailand	51	THMC 54	Philippines	83	THMC 90	Bangladesh
20	THMC 22	Thailand	52	THMC 55	Philippines	84	THMC 92	Bangladesh
21	THMC 23	Thailand	53	THMC 56	Philippines	85	THMC 93	Bangladesh
22	THMC 24	Thailand	54	THMC 57	Philippines	86	THMC 94	Bangladesh
23	THMC 25	Thailand	55	THMC 58	Vietnam	87	THMC 95	Bangladesh
24	THMC 26-1	Thailand	56	THMC 59-1	Vietnam	88	THMC 96-1	Bangladesh
25	THMC 26-3	Thailand	57	THMC 60-1	Vietnam	89	THMC 96-2	Bangladesh
26	THMC 27	Thailand	58	THMC 62	Vietnam	90	THMC 97	Bangladesh
27	THMC 28-1	Philippines	59	THMC 63	Vietnam	91	THMC 98	Bangladesh
28	THMC 28-2	Philippines	60	THMC 64	Vietnam	92	THMC 99	Bangladesh
29	THMC 29	Philippines	61	THMC 65	Vietnam	93	THMC 108	Indonesia
30	THMC 30	Philippines	62	THMC 66	Bangladesh	94	THMC 110	Indonesia
31	THMC 31	Philippines	63	THMC 67-1	Bangladesh	95	THMC 111	Indonesia
32	THMC 32	Philippines	64	THMC 67-2	Bangladesh	96	THMC 112	Indonesia
97	THMC 101	Taiwan	127	THMC 153	India	157	THMC 281	India
98	THMC 102-1	Taiwan	128	THMC 155	India	158	THMC 288	India
99	THMC 102-2	Taiwan	129	THMC 156	India	159	THMC 289	India
100	THMC 103-1	Taiwan	130	THMC 157	India	160	THMC 290	India
101	THMC 103-2	Taiwan	131	THMC 159	India	161	THMC 291	India
102	THMC 104	Taiwan	132	THMC 160	India	162	THMC 292	India
103	THMC 107	Taiwan	133	THMC 161	India	163	THMC 293	India
104	THMC 114	Lao PDR	134	THMC 162	India	164	THMC 294	India
105	THMC 115	Cambodia	135	THMC 163	India	165	THMC 295	India
106	THMC 116	Cambodia	136	THMC 164	India	166	THMC 296	India
107	THMC 118	Cambodia	137	THMC165	India	167	THMC 297	India
108	THMC 122	Cambodia	138	THMC 166	India	168	THMC 298	India
109	THMC 126	Cambodia	139	THMC 167	India	169	THMC 299	India
110	THMC 131	Sri Lanka	140	THMC 169	India	170	THMC 300	India
111	THMC 132	Pakistan	141	THMC 170	India	171	THMC 301	India
112	THMC 134	India	142	THMC 171	India	172	THMC 302	India
113	THMC 137	India	143	THMC 172	India	173	THMC 303	India
114	THMC 138	India	144	THMC 173	India	174	THMC 304	India
115	THMC 139	India	145	THMC 174	India	175	THMC 305	India
116	THMC 140	India	146	THMC 175	India	176	THMC 306	India
117	THMC 141	India	147	THMC 177	India	177	THMC 307	India
118	THMC 142	India	148	THMC 178	India	178	THMC 308	India
119	THMC 143	India	149	THMC 179	India	179	THMC 309	India
120	THMC 144	India	150	THMC 181	India	180	THMC 310	India
121	THMC145	India	151	THMC 182	India	181	THMC 311	India
122	THMC 148	India	152	THMC 183	India	182	THMC 113	Belize
123	THMC 149	India	153	THMC 184	India	183	Palee	East-West Seeds
124	THMC 150	India	154	THMC 185	India	184	Prachi	East-West Seeds
125	THMC 151	India	155	THMC 186	India	185	Benteng 545	East-West Seeds
126	THMC 152	India	156	THMC 187	India	186	Nagesh	Rasi Seeds

changes in entry ranking between seasons of some cultigens and changes in the magnitude of differences between cultigens. Therefore, mean values are presented here by season. Sex expression in cucurbits is influenced by environmental factors such as day length and temperature (Staub *et al*., 2008). Mean day length during crop growth and development at the experimental site in December (first season) and June (second season) plantings was 11.27 and 12.45 hours, respectively. This relatively small day length difference (1.18 hours) may have caused the significant season × cultigen interaction. Mean number of days to first open staminate flower for the 186 cultigens was 41.0 over the two seasons of experimentation and was 42.3 and 39.7 for Season 1 and Season 2, respectively. The first open staminate flower was earlier in Season 2 than in Season 1 for 154 of the 186 cultigens. One to two hour differences in day length affects male flowering pattern of some bitter gourd, bottle gourd (*Lagenaria siceraria* L.) and sponge gourd (*Luffa cylindrica* L.) genotypes in some areas of the tropics (Prashant Kumar, Rasi Seeds, personnal communication, 2015). One hundred twenty-four of the cultigens (66.6%) produced their first open staminate flower 38 to 47 days after sowing (Fig. 1).

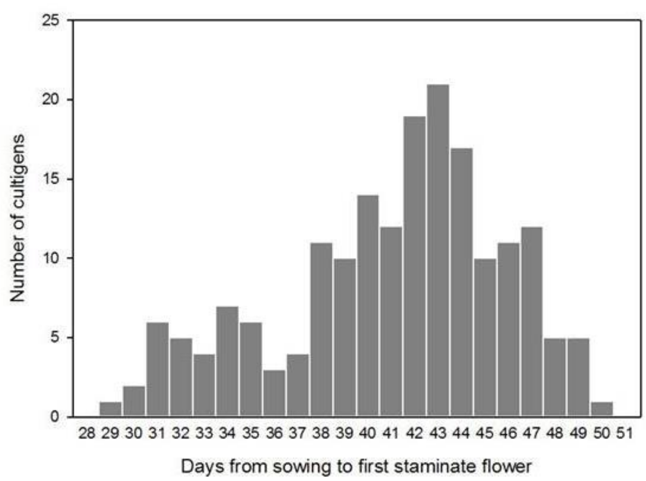

Figure 1. Frequency distribution of mean number of days to first staminate flower for 182 bitter gourd cultigens and four commercial hybrid cultivars in two field experiments conducted in two seasons at Kamphaeng Saen, Thailand.

Mean number of days to first open staminate flower ranged from less than 30 to nearly 50 days among the 182 monoecious bitter gourd inbred lines. Mean number of days to first open staminate flower for the 10 earliest staminate flowering inbreds was 30.6 over the two seasons, and was 31.4 and 29.8 for Season 1 and Season 2, respectively. Line THMC 62 was the earliest staminate flowering cultigen (28.7 days from sowing to first open staminate flower), but it was not significantly different from 14 other cultigens (Table 2). In contrast, the latest male flowering cultigen was THMC 17 (49.8 days) and the four check cultivars were in the mid-range of days when compared to first staminate flower opening (Table 2). Twelve of the 15 earliest staminate flowering cultigens originated in Southeast Asia: Cambodia (4), Philippines (6) and Vietnam (2); the other three were from Bangladesh (1) and India (2). It has been observed during farm field surveys in Vietnam that bitter gourd hybrids produce the first open staminate and pistillate flowers 30 to 35 days after sowing (N.P.S. Dhillon, unpublished data). The nine cultigens with the most number of days to opening of first open staminate flower in this study originated from Bangladesh (1), India (2), Sri Lanka (1) and Thailand (6).

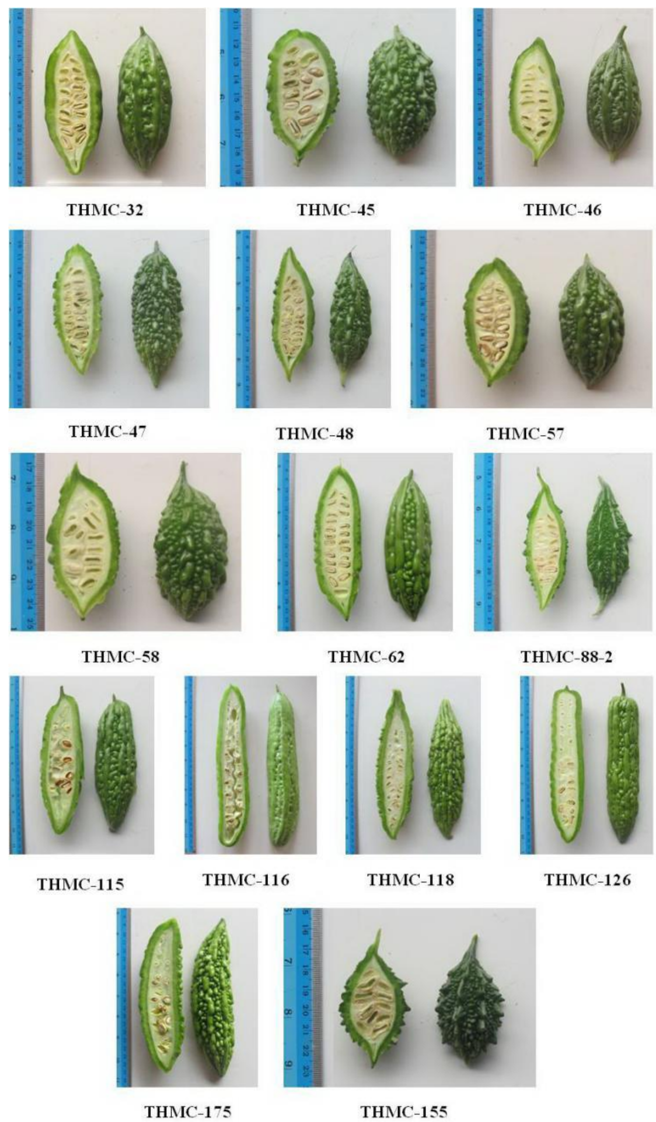

Figure 2. Fruit type of 15 earliest staminate-flowering inbred lines of bitter gourd.

The earliest staminate flowering monoecious lines were diverse in their fruit color (light green or green to dark green), skin pattern (spiny to ribbed), shape (spindle or elliptical to cylindrical) characteristics and bitterness (low or medium to high) (Table 3) and belong to different market types preferred by consumers in Asia. Anthesis of the staminate flowers of these lines started between 0050 and 0930 and the anthers dehisced 2 hours before opening, similar to the floral phenology pattern reported in some commercial bitter gourd cultivars (Pal and Singh, 1972). Days to 50% staminate flowering of these earliest staminate flowering monoecious lines ranged from 61.8 to 73.7, compared with 68.6 and 71.2 days, respectively, for 'Benteng 545' and 'Palee'. This means adequate pollen availability will be provided by the earliest staminate flowering monoecious lines if used as blends in gynoecious hybrid cultivars. Number of staminate flowers per plant was higher on the 11 earliest staminate flowering lines (which ranged from 1192.0 to 4330.9 flowers per plant) than on 'Benteng 545' and 'Palee', (872.2 and 864.5 flowers per plant, respectively). Pollination of 10 female flowers of each gynoecious line with the 10 earliest staminate flowering lines resulted in a mean fruit set of 84%, which ranged from 80% to 90% (data not presented). In commercial bitter gourd varieties, mean fruit set observed in insect-pollinated and hand-pollinated flowers was 78% and 80%, respectively (Deyto and Cervancia, 2009). Mean pollen viability of the 10 earliest staminate-flowering lines was 97.1% and the means ranged from 96% to 98.2%. Thus, these earliest staminate

Table 2. Mean number of days from sowing to the first open staminate flower of the 15 earliest and nine latest staminate-flowering inbreds of bitter gourd (*Momordica charantia*) derived from 182 AVRDC bitter gourd accessions and four commercial bitter gourd cultivars, evaluated at Kamphaeng Saen, Thailand in two seasons: 2012 and 2013.

Season 1			**Season 2**			**Mean of two seasons**		
Rank	**Cultigen**	**First staminate flower (days)**	**Rank**	**Cultigen**	**First staminate flower (days)**	**Rank**	**Cultigen**	**First staminate flower (days)**
Earliest			Earliest			Earliest		
1	THMC 155	27.3	1	THMC 62	27.4	1	THMC 62	28.7
2	THMC 47	30	2	THMC 49	28.9	2	THMC 47	29.5
3	THMC 62	30	3	THMC 47	29	3	THMC 32	29.9
4	THMC 32	30.7	4	THMC 32	29.2	4	THMC 58	30.8
5	THMC 46	31.3	5	THMC 175	29.8	5	THMC 175	30.9
6	THMC 45	31.7	6	THMC 58	29.9	6	THMC 57	31.0
7	THMC 48	31.7	7	THMC 57	30.0	7	THMC 118	31.2
8	THMC 58	31.7	8	THMC 116	30.1	8	THMC 45	31.4
9	THMC 118	31.7	9	THMC 96-2	30.7	9	THMC 116	31.4
10	THMC 152	31.7	10	THMC 118	30.8	10	THMC 46	31.5
11	THMC 57	32	11	THMC 126	30.8	11	THMC 48	31.6
12	THMC 88-2	32	12	THMC 40	31.1	12	THMC 88-2	31.6
13	THMC 175	32	13	THMC 45	31.2	13	THMC 126	32.1
14	THMC 116	32.7	14	THMC 88-2	31.2	14	THMC 155	32.4
15	THMC 52-1	33	15	THMC 108	31.2	15	THMC 115	32.8
Latest			Latest			Latest		
177	THMC 163	50.0	178	THMC 93	46.7	178	THMC 153	47.7
178	THMC 114	50.0	179	THMC 299	46.8	179	THMC 93	47.8
179	THMC 23	50.3	180	THMC 156	46.8	180	THMC 15	48.3
180	THMC 18-1	51.3	181	THMC 104	47.0	181	THMC 131	48.5
181	THMC 17	51.3	182	THMC 6-2	47.0	182	THMC 23	48.7
182	THMC 5	51.7	183	THMC 23	47.0	183	THMC 18-1	48.8
183	THMC 19-2	51.7	184	THMC 25	47.6	184	THMC 12	48.9
185	THMC 12	52.3	185	THMC 131	48.0	185	THMC 5	49.1
186	THMC 302	52.7	186	THMC 17	48.2	186	THMC 17	49.8
Checks			Checks			Checks		
69	Palee	41.3	87	Palee	38.4	66	Palee	39.9
184	Prachi	52.0	128	Prachi	33.7	114	Prachi	42.8
33	Benteng 545	36.7	78	Benteng 545	35.2	33	Benteng 545	35.9
63	Nagesh	41.3	105	Nagesh	37.4	59	Nagesh	39.4
Grand mean		42.3			39.7			41.0
CV (%)		8.2			8.4			6.7
Tukey's HSD (*P*=0.05)		13.2			12.5			9.0

Table 3. Mean numbers ± S.E. of staminate flowers per bitter gourd (*Momordica charantia*) plant, number of days to 50% staminate flowering, and seven fruit characteristics of the 10 earliest staminate-flowering inbreds, the five earliest staminate-flowering inbreds based on mean values of the two seasons (2012, 2013), and two commercial hybrids.

Cultigen	Staminate flowers		Fruit characteristics						
	No. per plant	Days to 50% flowering	Color	Skin pattern	Shape	Bitterness	L/B ratio	Weight (g)	No./plant
Earliest in both seasons									
THMC 62	1192.0±227.7	61.8±0.4	Green	Ribbed	Elliptical	Medium	0.33±0.02	113.3±11.5	105.5±0.7
THMC 47	3802.2±965.4	69.9±1.8	Green	Spiny	Spindle	Medium	0.28±0.01	56.3±12.7	323.0±19.8
THMC 32	3236.1±189.2	71.9±1.0	Green	Ribbed	Spindle	Low	0.34±0.01	41.0±10.1	121.0±19.5
THMC 58	2225.8±92.2	71.5±1.5	Dark green	Spiny	Spindle	Low	0.26±0.01	39.2±3.8	188.7±23.2
THMC 175	399.4±46.4	63.3±1.2	Green	Spiny	Spindle	Low	0.37±.0.05	128.5±2.1	63.3±14.4
THMC 57	1325.3±128.9	67.7±.07	Green	Spiny	Spindle	Low	0.24±0.01	36.0±11.3	203.0±30.5
THMC 118	2279.7±339.1	70.1±2.0	Light green	Ribbed	Elliptical	Low	0.33±0.02	101.7±4.7	57.0±13.5
THMC 45	1980.7±189.1	72.9±1.3	Light green	Ribbed	Spindle	Low	0.24±0.01	66.7±20.8	125.0±14.5
THMC 116	1795.9±401.4	68.4±1.4	Light green	Ribbed	Cylindrical	Low	0.49±0.04	221.7±48.0	38.0±2.6
THMC 88-2	1749.7±98.9	72.8±0.9	Dark green	Spiny	Spindle	Medium	0.34±0.03	40.0±0.0	145.0±20.5
Earliest based on mean values of the two seasons									
THMC 46	4330.9±493.5	73.7±0.6	Green	Ribbed	Spindle	Low	0.22±0.02	39.2±12.8	142.3±15.8
THMC 48	1336.5±152.1	71.4±0.6	Light green	Spiny	Spindle	Medium	0.32±0.03	99.0±15.6	163.0±47.9
THMC 126	710.7±90.0	63.5±0.8	Light green	Ribbed	Cylindrical	Low	0.47±0.03	175.3±23.7	62.70±9.80
THMC 155	576.2±69.3	68.3±2.0	Dark green	Spiny	Elliptical	Low	0.17±0.01	14.0±1.0	332.7±67.7
THMC 115	480.2±64.6	65.9±1.5	Light green	Ribbed	Cylindrical	Low	0.54±0.01	140.0±28.3	37.30±5.90
Commercial hybrids									
Benteng 545	872.2±77.4	68.6±1.4	Light green	Ribbed	Cylindrical	Low	0.47±0.02	193.5±19.1	60.3±10.8
Palee	864.5±68.9	71.2±1.8	Green	Spiny	Elliptical	Low	0.56±0.02	143.0±32.1	81.7±10.6
Grand mean	1749.1	68.9					0.35	95.7	128.9
CV (%)	19.10	1.9					6.40	20.8	20.3
LSD (*P*=0.05)	579.1	2.3					0.04	36.3	44.9

flowering lines possess normal pollen viability, germination and growth like commercial bitter gourd cultivars. Gynoecious bitter gourd open-pollinated cultivars produce none or a few staminate flowers. Predominantly gynoecious cultivars have a relatively high pistillate to staminate flower ratio (1:15-23) and the first staminate flowers open 7 to 10 days after the first pistillate flowers, in many instances (Iwamoto *et al*., 2009). Thus, early and total yield potential are compromised by the absence or paucity of staminate flowers. Mechanical blending of a monoecious pollenizer into packages of gynoecious hybrids is a practical and economically feasible means for ensuring adequate pollen for early fruit set. This is commonly done with gynoecious cucumber hybrids (Miller, 1976). Fifteen of the 182 monoecious bitter gourd inbred lines were identified as potentially suitable for blending into gynoecious hybrids or gynoecious open-pollinated cultivars. The monoecious pollenizer should have fruit characteristics in common with the predominant gynoecious hybrid so that its fruits may be included in the marketable yield. For example, cultigen THMC 62 has potential for blending with a gynoecious hybrid for production in Vietnam, where green, ribbed and elliptical fruits with medium bitterness are desired (Table 4). Similarly, THMC 47, THMC 57, THMC 58, and THMC 175 have the potential for blending with a gynoecious hybrid targeted for south Asia market where consumers prefer spiny, green to dark green fruits. Open-pollinated, high yielding, early maturing, predominantly gynoecious or gynoecious bitter gourd cultivars with extended harvest time are highly suitable for home gardens and net house cultivation (pesticide-free culture, honey bees for pollination). These types of cultivars produce fruit for a longer period than monoecious cultivars. Use of an early staminate flowering pollenizer for blending in packages of gynoecious cultivars helps to ensure early and high total fruit yield.

***Conclusion*:** Fifteen early staminate flowering monoecious bitter gourd lines of various market segments have been identified as potential pollenizers for blending into packages of gynoecious hybrids to ensure early and high total fruit yield for commercial production.

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Note: Seed of the early staminate flowering lines can be acquired from the corresponding author at AVRDC-The

World Vegetable Center East and Southeast Asia, Thailand by following AVRDC rules of germplasm transfer.

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