Field Performance of Vegetable Soybean Varieties(lines) in Northeast USA

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Abstract: Vegetable soybean is a special soybean harvested after the R6 and before the R7 growth stage as a fresh green bean. Although vegetable soybean research has been conducted for many years in the USA, fewer varieties are available for commercial production. Twelve vegetable cultivars(lines) were evaluated for their field performance and marketable yield potential at the University of Massachusetts Crop Research and Education Center in Deerfield, Massachusetts, USA. The experiment was arranged in a randomized complete block design with 4 replications. Seven out of twelve varieties or lines had the green seed color, 50% first flowering day, optimum eating day, and harvest maturity were significantly different among varieties. Days from over 50% first flowering to optimum eating day ranged from 20 d to 45 d. The variety "late branch bean" had the highest marketable yield of 7 971 kg·ha^{-1}, while the variety "early branch bean" had the lowest marketable yield of 3 122 kg·ha^{-1}. A higher marketable yield was mostly due to lower unproductive pod percentage, greater seed size and a greater percentage of 2 – seeded pods.

Key words: Edamame; Marketable yield; Pod percentage; Seed size

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美国东北菜用大豆品种(品系)的农艺表现

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摘 要: 菜用大豆是一种特殊的大豆, 它是在植株生育处于 R6 或 R7 时进行采摘, 作为食用的大豆。尽管菜用大豆的研究在美国已进行了多年, 但仍然只有少数菜用大豆品种可用于商业生产。试验在美国麻省大学作物研究和教育中心对 12 个菜用大豆品种(品系)的田间的生育表现及销售产量的潜力进行了评价。试验采用随机区组 4 次重复。研究表明: 12 个品种中, 7 个品种(品系)是绿色种皮。品种间始花期, 最佳可食期及种子成熟收获期存在明显差异。从 50% 以上开花期到最佳可食期及种子成熟收获期变化范围为 20 ~ 45 d。晚枝豆的销售产量最高为 7 971 kg·ha^{-1}, 早枝豆的销售产量最低为 3 122 kg·ha^{-1}。高的销售产量的获得主要是瘪荚率低, 籽粒大及 2 粒荚的比率高。

关键词: 菜用大豆; 销售产量; 荚比率; 籽粒大小

Soybean(*Glycine max*(L.) Merrill), an excellent source of major nutrients, is a highly successful modern-day crop[1]. The average approximate composition is 40% protein, 21% oil, 34% carbohydrates, and 5% ash. There are many grain soybean varieties but only a small number of them can be grown as vegetable soybean[2]. Vegetable soybean or edamame is a special soybean harvested after the R6 and before the R7 growth stage, while the pod is still green and the seeds have developed to fill 80%-90% of the pod width. Relative to soybean used for other purposes, edamame-type soybeans are characterized by having a clear hilum, relatively large, sweet, and tender seed and unique sensory characteristics. Edamame tends to have a mild or neutral yet unique flavor, reportedly derived from a distinctive combination of sweetness, sourness, and bitterness[3]. Edamame is also sold in intact pods, which must lack external defects, be bright green in color,

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have no or translucent pubescence, and contain at least two beans [4]. Because of its excellent nutrition and slightly sweet, mild flavor and nutty texture with less objectionable beany taste, it is preferred over conventional soybean as a fresh green bean (pea). Thus, its utilization is completely different from the grain soybean, and its importance in human nutrition is increasingly recognized in many countries. Although vegetable soybean research has been conducted for many years in the USA, mostly in the west, it was only a dozen years ago that Americans began to learn about vegetable soybean varieties. Additionally, germplasm enhancement and variety development of edamame-type soybeans is relatively new in the US, as most varieties can be traced back to origins in Asia. The purpose of this study was to evaluate the field performance and marketable potential of different vegetable soybean varieties or line in Massachusetts, and for commercialized production in New England, USA.

1 Materials and methods

Studies were conducted during the growing season from May 23 to October 10, 2004 at the University of Massachusetts Crop Research and Education Center in Deerfield, Massachusetts on a Hadley fine sandy loam (Typic Udifluvent). The previous crop was silage corn. Twelve Asian varieties or lines of edamame (table 1) were planted at the rate of 150 000 seeds per hectare on May 23, 2005 and arranged in a randomized complete block design with 4 replications. Each plot consisted of 6 rows 65cm apart and 5 meter-long. Manual weeding was applied during the growing season. The number of days to flowering was recorded, data on yield and yield components were collected and agronomic characters were examined. Data for yield and agronomic characters were observed and taken from the center 2 rows. Ten sample plants per plot were randomly selected from the center 2 rows to determine pod number, percentage of different seeded pods, fresh pod weight, and hundred seed fresh weight. At harvest, pods in 2 m^2 from each treatment plot were weighed for the marketable and non-marketable yield. The pods having two and three seeds were considered marketable, while pods with one or, without seeds, and those with pod discoloration, small seeds, insect damaged and abnormal pods were classified as cull types or unmarketable pods. Seed protein and oil content was also measured.

Table 1 Code number provided for varieties or lines

No.	Varieties (lines)	No.	Varieties (lines)	No.	Varieties (lines)
1	Black bean	5	Light Green bean	9	Green leaves bean
2	Green bean	6	Early Green bean	10	Space infinite bean
3	Late Branch bean	7	Middle Sapporo bean	11	Sapporo green
4	Early Branch bean	8	14×42	12	Space finite bean

2 Results

2.1 Seed color, flowering and days to eating maturity

Among the twelve varieties/lines, seven had green seed color, two had yellow seed color, two had brown color and only one variety was black (Table 2). Signifi cant differences were found among varieties in terms of days to 50% flowering, eating maturity, and harvest maturity. The earliest varieties with over 50% flowering days were varieties 4, 5 and 6 on July 6, while variety 3 was the latest (July 27). Although flowering days of variety 4, 5, and 6 were the same, the days to eating maturity was July 25 for variety 4 and 6, while for variety 5 it was extended to August 5, ten days later. Varieties 1, 2 and 3 had the latest eating maturity day (September 10). Days from over 50% first flowering to day of eating maturity ranged from 20 d to 45 d, which allows producers to harvest and sale the product over an extended period if different varieties are planted on a same farm. The early varieties 4, 5 and 6, were mature for dry seed harvested on August 20 while the latest harvest day was October 2 for variety 2.

Table 2 Mature seed color, days to flowering and days to eating maturity and day of dry seed harvest maturity of the tested vegetable soybean lines

Variety code number	Seed color	Flower color	Day of >50% flowering	Eating maturity day	Day of dry seed harvest
1	Black	White	July 25	Sept. 10	Sept. 28
2	Green	Purple	July 22	Sept. 10	Oct. 2
3	Brown	Purple	July 27	Sept. 10	Sept. 28
4	Brown	White	July 6	July 25	Aug. 20
5	Green	White	July 6	Aug. 5	Aug. 20
6	Green	White	July 6	July 25	Aug. 20
7	Green	White	July 12	Aug. 5	Sept. 13
8	Green	Purple	July 24	Aug. 25	Sept. 28
9	Green	White	July 20	Aug. 20	Sept. 20
10	Yellow	White	July 22	Aug. 25	Sept. 28
11	Green	White	July 14	Aug. 15	Sept. 13
12	Yellow	White	July 20	Aug. 25	Sept. 28

2.2 Yield and yield components

Yield and yield component data presented in Tables 3, 4 and 5 showed that there were significant differences among tested varieties. The highest marketable yield of 7 971 kg·ha^{-1} was obtained in variety 3, while variety 4 gave the lowest marketable yield at 3 122 kg·ha^{-1}. Variety 7 gave the second highest marketable yield at 7 667 kg·ha^{-1} with lowest non-marketable yield of 528 kg·ha^{-1} (Table 3). Although variety 2 had the greatest total pod number of 69 per plant, its marketable yield was only 7 288 kg·ha^{-1} due to its high non-marketable yield of 4 845 kg·ha^{-1}. No difference was found among the tested varieties for percentage of 1-seed pod, while the percentage of 2-seed pod, 3-seed pod and unproductive pod was significantly different (Table 4). Varieties with higher marketable yield in general had the lowest unproductive pod percentage. The hundred seed fresh weight ranged from 45.9 g to 79.6 g (Table 5). Varieties 3, 7, and 12 had the greatest seed size at 792 mg, 796 mg and 785 mg respectively, and their marketable yield was also the greatest (Table 3). Thus, higher marketable yield in varieties was mostly due to a lower unproductive pod percentage, greater seed size and greater percentage of 2-seed pods. The average protein and fat content for the tested varieties was 44.57%, 18.36% respectively (Table 3). The highest protein content was 46.16% in variety 10, while the highest fat content was 20.26% in variety 8. Variety 3 had the lowest fat content at 16.50% although it had the greatest marketable yield (Table 3). Although the length of 1-seeded pods, 2-seeded pods, 3-seeded pods and 4-seeded pods increased from 3.8 cm (1-seeded pods) to 6.7 cm (4-seeded pods), the width of the different seeded-pods had almost no change (Table 6).

Table 3 Marketable/non-marketable yield and seed quality

Variety	Marketable yield/kg·ha^{-1}	Non-marketable yield/kg·ha^{-1}	Protein/%	Fat/%
1	6175bc	2659c	44.67b	18.66b
2	7288b	4845a	44.86b	17.27c
3	7971a	1920c	44.66b	16.50c
4	3122d	839d	43.86c	17.29c
5	6945b	1132c	44.39b	19.13b
6	3971d	854d	46.13a	18.09bc
7	7667a	528d	43.48c	19.21b
8	5871c	1085c	44.05b	20.26a
9	3496d	634d	42.42c	19.70ab
10	6641b	3638b	46.16a	16.63c
11	4968c	1238c	44.69b	19.69ab
12	7628a	1104c	45.43ab	17.91bc
Mean	5985	1706	44.57	18.36

Means followed by the same letter in the column are not significantly different at 5% level of significance.

Table 4　Total pod number and percentage of different seeded-pods

Variety	Total pod number	1-seed pod		2-seed pod		3-seed pod		4-seed pod		Unproducitve	
		Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
1	50.8b	13.2a	26ns	31.4a	62a	2.03c	4c			4.1	8a
2	69.0a	15.0a	22	37.4a	55b	10.6b	15b	1.2	1	4.8	7a
3	43.2c	11.0ab	25	23.6b	55b	7.2b	17b	0.4	1	0.9	2c
4	21.2d	5.6c	27	11.2c	53b	3.0c	14b			1.3	6a
5	39.0c	8.8b	23	24.4b	62a	5.0c	13b			0.8	2c
6	25.0d	6.2c	25	12.8c	51b	4.0c	16b			2.0	8a
7	35.6c	7.0c	20	11.2c	31c	6.4bc	18b			0.4	1c
8	33.8c	8.2b	24	17.6bc	52b	7.0b	21b			1.0	3c
9	23.4d	4.7c	20	11.5c	49b	4.9c	21b			2.3	10a
10	62.0a	9.9b	16	21.0b	34c	24.2a	39a	3.7	6	3.1	5b
11	34.6c	9.7b	28	18.3bc	53b	5.5c	16b			1.0	3b
12	31.8c	6.4c	20	20b	63a	4.5c	14b			1.0	3b
Mean	39.1	9	23	19	51.8	6.8	17.4	1.7	2.7	1.9	5

Means followed by the same letter in the column are not significantly different at 5% level of significance, ns means not significant at 5% level of significance for the column.

Table 5　Fresh pod weight in different seeded-pods

Variety	Total fresh pod weight/g	Hundred seed fresh weight/g	1-seeded pod/g	2-seeded pod/g	3-seeded pod/g	4-seeded pod/g
1	92.7b	65.0b	18.0a	60.0b	5.0d	–
2	128.0a	55.9bc	18.4a	74.7a	2.83d	2.83
3	103.9b	79.2a	17.7a	60.6b	23.3b	1.69
4	41.6d	59.7b	8.7c	23.5d	9.36c	–
5	84.9c	69.8ab	11.4b	56.3b	16.8bc	–
6	50.7d	61.2b	8.9bc	30.1c	11.7c	–
7	86.2c	79.6a	4.9c	56.2b	24.5b	–
8	73.1c	67.8b	10.7b	39.1c	22.7b	–
9	43.4c	54.1c	5.4c	22.0d	14.8c	–
10	107.8b	45.9c	4.7c	15.5d	54.4a	4.2
11	65.2c	61.0c	10.3b	34.2c	18.1b	–
12	91.8b	78.5a	10.3b	59.8b	20.5b	–
Mean	80.8	64.8	10.8	44.8	18.7	2.9

Means followed by the same letter in the column are not significantly different at 5% level of significance

Table 6　Pod length and width in different seeded pods

Variety	1-seed pod		2-seed pod		3-seed pod		4-seed pod	
	Length/cm	Width/cm	Length/cm	Width/cm	Length/cm	Width/cm	Length/cm	Width/cm
1	4	1.3	5	1.4	5.4	1.3	–	–
2	3.6	1.3	4.6	1.3	5.7	1.3	6.3	1.3
3	4	1.5	4.7	1.4	5.8	1.4	6.7	1.4
4	4	1.4	4.7	1.3	5.7	1.5	–	–
5	3.6	1.5	5.3	1.4	6.2	1.6	–	–
6	3.7	1.3	4.8	1.3	5.8	1.4	–	–
7	3.9	1.6	6	1.5	7.2	1.8	–	–
8	3.5	1.3	4.7	1.4	5.9	1.4	–	–
9	3	1.3	5	1.3	5.5	1.5	–	–
10	3.5	1	4.5	1.1	5.5	1.2	6	1.1
11	3.8	1.6	4.7	1.5	5.9	1.5	–	–
12	4.9	1.6	6.1	1.5	6.9	1.6	–	–
Mean	3.8	1.4	5	1.4	6	1.5	6.3	1.3

3 Discussion and Conclusions

Significant difference among varieties in eating maturity provides producers more flexible time to sale their products when diverse varieties are planted on the same farm[6]. In this observation, the day of eating maturity can extend to 45 d if appropriate varieties are chosen. 2-seed pod accounts for the majority of the total pod, which is in consistent with general observation[7]. Wang et al reported that majority of vegetable soybean varieties were green and yellow color[8], 9 out of 12 genotypes tested belong to this group in current investigation. Hundred fresh grain weight of vegetable soybean in Shenyang was 58.1 – 63.7g, and pod length and width was ranged from 5.87 – 6.54 cm and 1.31 – 1.59 cm separately[9], our observation found a greater range of hundred fresh grain weight from 54.1 – 79.6 g, similar results in pod length and width. Negative relationship has been found between protein and oil content[10], our result indicated this relationship had an exception, for instance variety 8 had highest oil content of 20.26% but also higher protein content of 44.05%, and thus the relationship between the two traits needs further investigation. Marketable yield of 7 543 – 11 068 kg · ha^{-1} was reported in south China by Li et al[11]. However, for the tested varieties, the marketable yield in northeast USA was ranged from 3 122 – 7 667 kg · ha^{-1}, and variety 3, "late branch bean" had the highest marketable yield among the tested varieties and its fat content was the lowest. This variety together with the Japanese varieties "space finite bean" (12) and "Middle Sapporo bean (7)" had the highest yields and a good spread in days of eating maturity from August 5 to September 10. Current result also found that marketable yield was correlated to the seed size, lower unproductive pod percentage, and percentage of 3-seed and 2-seed marketable pods. Further research should be conducted to determine preferred planting dates and planting population for conditions in Massachusetts.

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