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Productivity of Asian varieties of cucumber (*Cucumis sativus* L.), bitter melon (*Momordica charantia* L.), and eggplant (*Solanum melongena* L.) in coastal Mississippi

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Abstract

Ethnicity plays a strong role in niche market development, and the market for specialty Asian crops is currently under-served. As Asian populations continue to grow in the southern United States, especially along the Gulf Coast, it is important for producers to recognize this opportunity. Fruits and vegetables desired by the diverse Asian population are often completely unavailable or of poor quality due to shipping distance. This market need can be met by local growers with a greater potential return on investment greater than traditional vegetables. This paper summarizes results of variety trials of Asian vegetables conducted during 2003 -2005 growing seasons at Mississippi State University, Coastal Research and Extension Center's Beaumont Horticultural Unit (USDA Hardiness Zone 8a). These trials evaluated yield performance of Asian varieties of cucumber (*Cucumis sativus* L.), bitter melon (*Momordica charantia* L.) and eggplant (*Solanum melongena* L.) under coastal Mississippi environmental conditions. Cucumbers: 'Natsuhikari', 'Tasty Queen', 'Crisp Petrel', 'Tokiwa', 'White Sun', and 'Summer Express'; bitter melon: 'Large Top', 'Taiwan Large', 'Japan Long', 'Thailand Star' and eggplants: 'Round Green', 'Orient Charm', 'Ichiban', 'Millionaire', 'Green Giant', 'Purple Ball', 'Kurume', 'Purple Excel', 'Ping Tung Long', 'Mangan', 'Long Green', and 'Orient Express' were grown conventionally on raised beds using drip irrigation and plastic mulch. Results indicated that cucumber varieties performed well, though their yield might have been affected by environment conditions. Average total yield and fruit numbers in 2004 were 65.5 and 56.1 % higher, respectively, compared to 2005. Marketable yield of Asian bitter melon varieties 'Large Top', 'Taiwan Large', and 'Japan Long', were higher than 'Thailand Star'. Total eggplant yield varied greatly among varieties. Total yield of 'Round Green' in 2003 was highest compared to all other cultivars.

Key words: Asian varieties, cucumber, bitter melon, *Momordicak charantia* L., eggplant, *Solanum melongena* L., fruit yield.

Introduction

Census results from 2010 (U. S. Census Bureau, 2012) show a thriving Asian population in the southern U.S., especially along the Gulf Coast. Asian nationalities make up approximately 0.9 % of the population of Mississippi and 2 % of the 3 coastal counties of Mississippi: Hancock (1.0 %), Harrison (2.9 %), and Jackson (2.2 %) (U.S. Census Bureau, 2011). Coastal communities in Alabama and Louisiana are also home to significant Asian populations (Zip Atlas, 2012). According to census data, the Asian population grew faster than any other race group in the United States between 2000 and 2010. This was observed for the population reporting Asian alone, which increased 43 % and 38.2 %, respectively for the United States and Mississippi, as well as for the population who reported Asian alone or in combination with another race, which increased 46 % and 39.9 %, respectively for US and for Mississippi (Hoeffel *et al.*, 2012). The Vietnamese population is the 4th largest among the Asian population groups in the United States. Between 2000 and 2010, the Vietnamese population in Mississippi increased by 30 % (US Census, 2010).

There is increasing demand for Asian vegetables (Jia *et al.*, 1996) because of an increasing ethnic population in the Gulf South. Addition of Asian varieties of cucumber (*Cucumis sativus* L.), bitter melon (*Momordica charantia* L.) and eggplant (*Solanum melongena* L.) to a farmer's crop mix can provide new market niches by meeting the need for these products. Development of production recommendations for these high value vegetable crops is important to generate additional income for producers. Some popular Asian vegetables crops include varieties of eggplant, cucumber, melon, and beans (Coker *et al.*, 2007) which can be grown productively in Gulf Coast. For example, Asian eggplant varieties have been successful crops for vegetable growers in Mississippi (Evans *et al.*, 2009).

Research shows that soil fertility level greatly affects cucumber (Ahmed and Shalaby, 2012; Eifediyi and Remison, 2010; Esawy *et al.*, 2009; Motior *et al.*, 2011; Onyia *et al.*, 2012), bitter melon (El-Gengaihi *et al.*, 2007; Huyskens *et al.*, 1992) and eggplant (Abbas *et al.*, 2011; Agbo *et al.*, 2012; Aminifard *et al.*, 2010; Cardoso *et al.,* 2009; Moraditochaee *et al.*, 2011; Ravella *et al.*, 2013; Sarhan *et al.*, 2011; Suge *et al.*, 2011) yields. However, there is little information on the production and potential yield of Asian vegetable varieties in the soil-climatic conditions of Mississippi. Therefore, the objective of these field experiments was to evaluate productivity of Asian varieties of cucumber, bitter melon and eggplant under coastal Mississippi environmental conditions which are characterized by prolonged high air temperature in the summer season. In this paper, we concentrate on yield value of these crops as a function of natural field environmental conditions.

Materials and methods

Field experiments were conducted during the 2003 - 2005 growing seasons at Mississippi State University, Coastal Research and Extension Center's Beaumont Horticultural Unit in Perry County, MS (31.25˚N, 88.92˚W; USDA Hardiness Zone 8a) to evaluate yield performance of Asian vegetables varieties under coastal Mississippi environmental conditions. Four bitter melon varieties: 'Large Top', 'Taiwan Large', 'Japan Long', and 'Thailand Star'; 12 eggplant varieties: 'Round Green', 'Orient Charm', 'Orient Express', 'Ichiban', 'Millionaire', 'Green Giant', 'Purple Ball', 'Kurume', 'Purple Excel', 'Ping Tung Long', 'Mangan', 'Long Green', and 6 cucumber varieties: 'Natsuhikari', 'Tasty Queen', 'Crisp Petrel', 'Tokiwa', 'White Sun', and 'Summer Xpress' were evaluated.

Asian cucumber, eggplant and bitter melon transplants were grown in the greenhouse in 72 cell plastic trays using professional soilless growing mix (Metro-Mix, Scotts Co., Marysville, OH) for 5-6 weeks prior to being transplanted to the field. In spring, the experimental site was disked and raised beds were prepared using a press pan bed shape mulch layer machine (Kennco Manufacturing, Inc., Ruskin, FL.), which also placed black plastic and irrigation tape prior to transplanting. Asian vegetables seedlings were transplanted by hand in staggered double rows into field plots which were 6.1 m long and were spaced 1.83 m on centers (from bed center to bed center). Cucumber plots consisted of 10 plants at a spacing of 60 cm, eggplant plots consisted of 6 plants at a spacing of 90 cm, and bitter melon plots consisted of 20 plants at a spacing of 30 cm. Bitter melon and cucumber plants were grown on a vertical trellis approximately 2 m high, constructed from stakes 1.5-2 m apart. Plastic netting was used to support climbing vines and lateral stems. Fertilization was based on soil test recommendations from the Mississippi State University Soil Testing and Plant Analysis Laboratory and irrigation was provided as needed using drip tape. Weeds were not present in plots due to use of plastic mulch. Insect and disease pests were controlled according to vegetable crop guidelines for the Southeastern U.S. (Sanders, 2005). Fruit were harvested in their commercial mature stage. Cucumbers were harvested by hand, three times weekly for 6 weeks (May-June) in 2004 and two times weekly for 6 weeks (June–July) in 2005. Eggplants were harvested once each week July-September for 12 weeks in 2003 and two times weekly July-August period for 4 weeks in 2004. Bitter melon was harvested twice a week for 6 weeks (August-September) in 2003. Fruit were hand-sorted by quality, counted, weighed and yield results were combined over all harvests.

Plots for this experiment were arranged in a randomized complete block design with four replications. Yield data were compared using one-way analysis of variance (ANOVA) and differences between treatments effects were determined using Duncan's multiple range test at a significance level of 0.05.

Air, soil temperature and rainfall were recorded during the research period for each year of this study (Table 1). Weather conditions at the beginning of vegetable growth and development were similar in each study year and were favorable for the growth of Asian vegetable plants. Average maximum and minimum air temperature during vegetative growth of plants in May ranged from 29.9 to 30.7 and 14.2 to 17.6 ºC respectively. Average maximum and minimum soil temperatures in May were 28.7 to 32.2 and 20.9 to 22.6 ºC respectively. Average maximum and minimum air temperature during reproductive stages in July 2004 and 2005 were higher (33.8 ºC) than in 2003. Although precipitation during the experimental period was regular in each month, amount of precipitation overall during May-September was 1.4 times higher in 2003 compared to 2004 and 2005.

Soil samples were analyzed for nutrient content using the Lancaster soil test method (Cox, 2001) and the concentrations of nutrients in soil extracts were measured with an inductively coupled argon plasma spectrometer by the Mississippi State University Soil Testing and Plant Analysis Laboratory. Soil at the experiment site was McLaurin sandy loam, containing on average 0.93 % organic matter, available phosphorus (P) 202, potassium (K) 269, sulfur (S) 150, and zinc (Zn) 3.6 kg ha^{-1} with a pH value of 6.7 at a soil depth of 0-15 cm.

Results and discussion

Cucumber: Total yield for cucumber varieties in the 2004 growing season ranged from 137.2 to 196.4 lbs/plot**,** whereas in 2005, yield of cucumber ranged between 86.7 and 123.7 lbs/plot. Cull fruit numbers were 133 % higher in 2005 than in 2004. Differences in yield were observed among varieties in this study. Yield of 'Natsuhikari' was highest at 196.4 lbs/plot, and was significantly greater than 'White Sun' and 'Summer Express', respectively, in 2004. The total yield of 'Tasty Queen' also was significantly greater than 'White Sun' and 'Summer Express', respectively in 2004. In 2005, highest total yield was produced by variety 'Tasty Queen'. This yield was significantly greater than that for 'Tokiwa' and 'White Sun' in 2005. There was not a significant difference in cucumber yield among 'Natsuhikari', 'Tasty Queen', 'Crisp Petrel' and 'Tokiwa' or among 'White Sun' and 'Summer Express' in 2004; nor were there significant differences among 'Natsuhikari', 'Tasty Queen', 'Crisp Petrel', and 'Summer Express', or 'Tokiwa' and 'White Sun' in 2005 (Table 2).

Bitter melon: Bitter melon marketable yield varied from 22.7 to

Table 1. Air, soil temperatures, and monthly precipitation at the Beaumont Horticultural Unit in Perry County, MS collected between 2003 and 2005

Month	Average Air Temperature (ºC)[z]						Average Soil Temperature (ºC)[z]						Precipitation (mm)		
	2003		2004		2005		2003		2004		2005		2003	2004	2005
	Max[y]	Min[x]	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min			
May	30.7	17.6	29.9	16.3	30.0	14.2	31.8	22.6	28.7	20.9	32.2	20.9	116.6	196.1	79.0
June	32.0	20.7	31.4	20.8	32.6	19.7	33.5	25.2	31.9	24.3	34.2	25.1	291.6	367.0	119.9
July	32.7	20.8	33.8	21.2	33.8	21.9	35.0	25.7	34.2	25.4	33.7	26.8	285.5	106.7	162.6
August	33.5	21.4	32.4	19.7	33.8	21.8	33.6	26.4	33.7	24.9	32.0	26.7	263.9	68.8	315.5
September	31.4	17.8	32.7	18.5	34.3	19.3	33.0	23.9	32.0	23.8	29.9	26.9	106.9	56.6	16.3

[z](ºC) = temperature Celsius = (F-32) x 5/9. [y]Max = Maximum temperature. [x]Min = Minimum temperature. [w]mm = millimeters of precipitation, 1 mm = 0.0394 in.

Table 2. Average marketable yield per plot[z] of Asian cucumber at the Beaumont Horticultural Unit in Perry County, Mississippi in 2004 and 2005

Variety	2004		2005	
	Marketable Number	Marketable Weight	Marketable Number	Marketable Weight
White Sun	174.50bc[y]	138.50b	119.25bc	94.10b
Summer Express	157.25c	137.20b	147.75ab	113.09ab
Tasty Queen	229.75a	187.96a	152.00a	123.73a
Crisp Petrel	213.75ab	178.55ab	127.00abc	97.83ab
Natsuhikari	243.5a	196.39a	127.50abc	96.78ab
Tokiwa	197.50abc	164.61ab	105.73c	86.70b

[z]Plots consisted of staggered double rows which were 6.1 m long and were spaced 1.83 m on centers (from bed center to bed center); 10 plants per plot.

[y]Means within columns followed by different letters are significantly different according to Duncan's Multiple Range Test at the 5 % level.

75.8 lbs/plot in 2003. Marketable weights were not significantly different for "Japan Long', 'Large Top', and 'Taiwan Large'. However, yields were significantly less for 'Thailand Star' (Table 3). There were no differences in weight of culled fruit, regardless of cultivar, but 'Taiwan Large' did have a higher number of culled fruit compared to 'Large Top' or 'Japan Long'. These results suggest that 'Taiwan Large' fruit were generally smaller compared to culled fruit from 'Large Top' or 'Japan Long'.

Eggplant: In 2003 (Table 4), total fruit yield of 'Round Green' eggplant (99.9 lbs/plot) was significantly higher compared to 'Orient Charm', 'Ichiban', 'Millionaire', 'Green Giant', 'Purple Ball', 'Kurume', 'Purple Excel', 'Ping Tung Long', 'Mangan', and 'Long Green'. There was no significant differences in fruit yield among 'Orient Charm', 'Ichiban', 'Millionaire', and 'Green Giant' or ' Purple Ball', 'Kurume', 'Purple Excel', 'Ping Tung Long', 'Mangan', and 'Long Green'. Total fruit yield of 'Orient

Table 3. Average marketable yield per plot[z] bitter melon at the Beaumont Horticultural Unit in Perry County, Mississippi in 2003

Variety	Marketable Weight
Japan Long	67.9a[y]
Large Top	75.8a
Taiwan Large	72.5a
Thailand Star	22.7b

[z]Plots consisted of staggered double rows which were 6.1 m long and were spaced 1.83 m on centers (from bed center to bed center); 20 plants per plot.

[y]Means within columns followed by different letters are significantly different according to Duncan's Multiple Range Test at the 5 % level.

Charm', 'Ichiban', Millionaire', and 'Green Giant' ranged from 74.6 to 66.4 lbs/plot, and were, on average, 72 lbs/plot lower than 'Round Green'. Total fruit yield of 'Purple Ball', 'Kurume', 'Purple Excel', 'Ping Tung Long', 'Mangan', and 'Long Green' was also 51 % lower on average than 'Round Green'.

Environmental conditions greatly affected eggplant productivity in 2004 resulting in low yields for all tested varieties. Highest yield was obtained from 'Orient Express' at 22.9 lbs/plot. Yield for 'Orient Express' was similar to that of 'Millionaire'. Significant differences were not observed among 'Millionaire', 'Long Green', 'Purple Excel', 'Green Giant', 'Orient Charm', 'Ichiban', and 'Ping Tung Long' in 2004 (Table 5).

Variation observed in these results are similar to results reported by Eifediyi and Remison (2009) and Olaniyi *et al.* (2009) for cucumber; Morgan and Midmore (2002) and Rahayu *et al.* (2011)

Table 4. Average yield (number and weight) per plot[z] of Asian eggplant varieties grown at the Beaumont Horticultural Unit in 2003

Variety	Marketable Number	Marketable Weight	Cull Number	Cull Weight (lbs)
Mangan	84.75d[y]	47.49d	33.75c	14.51ab
Kurume	148.00c	54.77dc	61.75b	16.29a
Ichiban	199.14ab	73.88b	62.88b	16.80a
Purple Excel	164.75bc	52.95d	41.75c	11.28bc
Orient Charm	209.50ab	74.59b	90.25a	18.38a
Green Giant	77.75d	66.43bc	9.25d	6.49cd
Ping Tung Long	172.25bc	49.00d	49.00bc	9.04cd
Long Green	138.25c	46.57d	35.75c	8.26cd
Round Green	230.75a	99.88a	49.75bc	16.68a
Purple Ball	177.00bc	55.24cd	15.00d	5.56d
Millionaire	168.50bc	73.64b	31.50c	11.05bc

[z]Plots consisted of staggered double rows which were 6.1 m long and were spaced 1.83 m on centers (from bed center to bed center); 6 plants per plot

[y]Means within columns followed by different letters are significantly different according to Duncan's Multiple Range Test at the 5 % level.

Table 5. Average yield (number and weight) per plot[z] of Asian eggplant varieties grown at the Beaumont Horticultural Unit in 2004

Variety	Marketable Number	Marketable Weight (lbs)	Cull Number	Cull Weight (lbs)
Kurume	19.25a[y]	6.13b	0.00a	0.00
Ichiban	30.75a	9.55ab	1.50a	0.00
Purple Excel	33.00a	12.70ab	0.50a	0.00
Orient Charm	50.50a	12.11ab	4.75a	0.13
Green Giant	14.50a	12.23ab	0.50a	0.23
Ping Tung Long	23.50a	6.58ab	1.00a	0.00
Orient Express	59.75a	22.85a	1.00a	0.24
Millionaire	52.75a	20.69a	2.50a	0.75
Long Green	70.00a	13.94ab	3.00a	0.00

[y]Means within columns followed by different letters are significantly different according to Duncan's Multiple Range Test at the 5 % level.

[z]Plots consisted of staggered double rows which were 6.1 m long and were spaced 1.83 m on centers (from bed center to bed center).

for bitter melon; and by Ramesh *et al.* (2013) for eggplant. It appears that high air temperature greatly influenced eggplant yields and produced a minor response in cucumber yield. Monthly average maximum air temperatures during the cucumber reproductive period in June-July 2005 were higher than in May-June 2004. Daily average maximum air temperatures were 35 ºC on June 16 and 36.1 ºC on July 4 in 2005. Cull fruit numbers for cucumber increased by 133 % on an average in 2005 (Table 2). Prolonged high air temperature conditions during eggplant and cucumber pollen formation presumably negatively affected crop fertilization and fruit set. In particular, saturated humidity causes loss of germination power of cucumber pollen as rapidly as dry conditions (0-30 % relative humidity) at 30 ºC (Hiroshi, 1960), and cucumber male sterility, as a high-temperature injury occurs at temperatures over 30 ºC (Masahumi *et al.*, 2011). These results are similar to those reported by Karni and Aloni (2002) in bell pepper, Song *et al.* (2002) in tomato, Reddy and Kakani (2007) in *Capsicum* species, and Endo *et al.* (2009) in rice, which revealed the negative high temperature effects on pollen germination.

Results from yield analysis of Asian vegetable varieties of cucumber (*Cucumis sativus* L.), bitter melon (*Momordica charantia* L.) and eggplant (*Solanum melongena* L.), grown in open field conditions, revealed that many of these varieties could be potentially valuable additions to currently grown vegetable crops in coastal Mississippi and other regions with similar soil

and climatic conditions. Cucumber varieties Natsuhikari, Tasty Queen, Crisp Petrel, Tokiwa, and Summer Express, eggplant varieties Round Green, Orient Charm, Ichiban, Millionaire, Green Giant, and bitter melon varieties Large Top, Taiwan Large and Japan Long demonstrated high productivity compared to other varieties and performed well in Mississippi soil-climatic environment conditions. However, the productivity of all Asian eggplant varieties was low in 2004, presumably due to prolonged high air temperature during the peak production period. Yield results from these Asian varieties of cucumber, bitter melon and eggplant could also benefit breeding programs focused on development of high temperature tolerant vegetable varieties.

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