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EVALUATION OF 25 ENTRIES OF RACE 3 BACTERIAL SPOT RESISTANT BELL PEPPERS

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Abstract. **Twenty-five cultivars and experimental hybrids of bell peppers (*Capsicum annuum* L) were transplanted in commercial pepper fields in Immokalee and Delray Beach, Fla. to evaluate horticultural characteristics and resistance to race 3 bacterial spot of peppers caused by *Xanthomonas campestris* pv. *Vesicatoria* (Doigde). All cultural and management procedures were based on commercial best management practices. Eighty to 90% of marketable fruits had three or four lobes. Marketable fruit ranged from 894 to 1402 bushels (28-pound)/acre. Entries that had an average of more than 1200 bushels/acre at both locations were PR99R-16 from Pepper Research, 'Crusader' from Syngenta, and lines 8364 and 8338 from Hazera. Due to late natural infection of the field, resistance to bacterial spot did not necessarily correlate with yield and quality measurements. A number of entries had an overall pepper disease ratings >20% but were statistically similar in marketable yields as the top producing entries. Susceptible control 'Jupiter' had a mean foliage disease incident rating of 26% after the final harvest and was surpassed only by 7682 and 8328 from Enza. The most resistant lines with disease ratings of <3% were 5776, 7141, and 8302 from Seminis and 'Telstar' from Hazera.**

Bell pepper is one of the primary vegetable crops grown in South Florida, with approximately 90% of Florida's production located south of Orlando (Aerts and Nesheim, 1999). Florida has also historically been a leader in the production of bell peppers, second only to California in total harvested acres (USDA, 2004) and first in fresh market production with a value of $218 million during the 2003-2004 season (Fla. Agric. Stat. Serv., 2005). During that season 20.2 million bushels were harvested from 18,300 acres, with an average price per bushel of $10.78.

Bacterial spot (*Xanthomonas campestris* pv. *vesicatoria*) is one of the serious diseases affecting bell pepper production in the southeastern United States, especially Florida (Pernezny et al., 2003). Loss in yield due to bacterial spot can be attributed to both defoliation and spotting or rotting of fruit. Currently on the commercial vegetable market there are numerous bell pepper cultivars available to growers that are marketed as having the Bs2 gene, expressing resistance to races 1,2,3 of *X.c* pv. *Vesicatoria.* Unfortunately for the growers, there are additional races, such as 4, 5, or 6, that can overcome the resistance to the Bs2 gene.

The purpose of this study was to evaluate new bell pepper varieties for their yield potential, marketable traits, and resistance to bacterial spot in two growing areas, Delray Beach (southeast Florida) and Immokalee (southwest Florida).

Materials and Methods

Two separate trials were conducted in south Florida during the 2004-2005 growing season. The first was planted near Immokalee in Collier County and second in Delray Beach, Palm Beach County. Transplants of 24 entries (Immokalee) and 25 entries (Delray Beach) were started from seed at the Everglades Research and Education Center (EREC) in Belle Glade using a commercial potting mix and polystyrene trays. Seedlings were transplanted by hand, with dead or dying transplants replaced within 10 d of transplanting. Entries in each location were situated in a randomized complete block design with three replications for evaluation of mature green peppers. An additional single replication was used for evaluation of plant architecture and ripe red or yellow peppers. This replication was not included in the statistical analysis. Blocks were standard, 5 ft wide, single raised beds on 6 ft centers. Beds were fumigated with methyl bromide/chloropicrin prior to being covered with polyethylene mulch (white mulch in Immokalee, black mulch in Delray Beach). Each plot consisted of 10 plants planted in double rows, with in-row plant spacing at 8 inches and between-row spacing at 16 inches. Seedlings were planted in an off-set, staggered planting design.

For the Immokalee experiment, seeds were sown on 3 Aug. 2004 and transplanted into the field on 4 Oct. 2004. All of the cultivars are marketed as having resistance to bacterial spot races 1,2,3 except for the open-pollinated variety 'Jupiter'. The soil type was Immokalee fine sand. After transplant, fertilization, pest management, and all other cultural practices were managed by the growers (Collier-Pacific). Plants were staked and tied twice. The first harvest was 57 days after transplant (DAT) on 2 Dec. 2004, with subsequent harvests on 17 Dec. 2004 (72 DAT) and 5 Jan. 2005 (91 DAT).

Seeds for the Delray Beach experiment were sown on 3 Oct. 2004 and transplanted into the field on 23 Nov. 2004. Similar to the Immokalee experiment, all of the cultivars are marketed as having resistance to bacterial spot races 1,2,3 except for the open-pollinated variety 'Jupiter'. The soil type was a Myakka sand. Similar to the Immokalee experiment, the

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trial was managed by the growers (Thomas Produce) after transplant. Plants were also staked and tied twice. The first harvest was on 11 Feb. 2005 (80 DAT) with subsequent harvest on 25 Feb. 2005 (94 DAT) and 11 Mar. (108 DAT).

At each harvest from both locations, fruit considered mature green or turning (red or yellow) were harvested by hand from the entire plot. Fruit from each plot were placed in paper bags and transported back to refrigerated storage at the EREC were they were held until yield and quality measurements were made. Number of marketable fruit, weight, and number of lobes was recorded. Number of culls was also recorded, but weight of culls was not taken. Ten randomly selected fruit were taken from each plot and measured for length and width to evaluate blockiness. Data were expressed as an average length and width ratio per fruit.

Bacterial spot ratings for late-developing infection were performed in Immokalee on 8 Feb. 2005 and in Delray Beach on 23 Feb. 2005. Ratings are defined as "an estimate of the percentage of symptomatic foliar tissue and leaf surface lost due to disease-induced abscission combined into one number representing loss of phytosynthetically active foliage" (Pernezny, pers. comm.).

Results and Discussion

Immokalee, Collier-Pacific Farms. Entries in Table 1 are listed in order according to yield of mature green fruit. Fruits from pepper plants were harvested three times over a period of 34 d. It would have been possible to make an additional harvest of colored fruit; however, due to high market value of colored peppers at the time, the pepper fruit within the trial was harvested by parties other than those involved in the experiment. The additional harvest would have been light, but would have contributed to the overall yield. During the late-fall early-winter months the highest yielding entry was PR99R-16 with an average yield of 1380 bushels/acre. Although only three entries had yields greater than 1300 bushels/acre, there was much statistical variation and eight of the 24 entries were statistically similar to PR99R-16. Of all the entries, only four, 8302, 'Jupiter', PR02R-3, and 774 ('Alexandra'), yielded less than 1000 bushels/acre. While total yield is an extremely important consideration, it is not the only one for choosing pepper cultivars or varieties. Plant architecture, as indicated by fruit placement and set, and fruit size, as indicated by fruit weight, and blockiness (ratio L:W) are also important variables to consider.

With the onset of hybrid varieties over the past 20 years, pepper fruit size has continued to increase (Shuler, 2003). With an increase in fruit size comes an increase in total yield; however, many pepper growers are hesitant to grow peppers that are noticeably larger (or smaller) than those they typically grow. Rather than increase in fruit size, consistency in fruit size may be more important. Very little variation was seen in the Immokalee trial in fruit weight, indicating that the seed companies have developed cultivars that tend to be consistent in weight.

Another trait deemed important and desirable by the pepper industry is blocky or slightly elongated fruit. ACR 252 and PR02R-3 both had relatively high L:W ratios, 1.39 and 1.37, respectively. This indicates a relatively elongated fruit, which is

Table 1. Summary of yield and fruit characteristics for a bell pepper cultivar evaluation, Collier-Pacific, Immokalee, Fla., 2004-2005.

Entry	Source	Marketable yield[z] (bu/acre)	Fruit/plant (no.)	Fruit wt. (oz)	Ratio L:W[x]	Lobes (no.)	Bacterial spot[w] (%)
PR99R-16	Pepper Research	1380 a[y]	4.3 a	8.2 b-g	1.28 cd	3.59 b-f	7.25 g-f
8338	Enza	1314 ab	3.8 a-d	8.9 a-c	1.12 h-j	3.63 b-f	18.20 c-e
Crusader	Syngenta	1310 ab	4.3 a	7.7 e-j	1.04 jk	3.68 a-d	13.80 d-f
8364	Enza	1225 a-c	4.0 ab	7.6 f-j	1.13 g-i	3.38 gh	11.00 d-h
ACX 248	Abbott & Cobb	1201 a-d	3.9 a-c	8.1 c-g	1.17 e-h	3.54 c-g	20.80 b-d
5776	Seminis	1174 a-e	3.4 b-f	8.4 a-f	1.16 f-h	3.74 ab	2.00 h
Brigadier	Syngenta	1158 a-e	3.7 a-d	7.9 e-i	1.10 h-j	3.53 d-g	9.50 e-h
PR02R-2A	Pepper Research	1152 a-e	3.5 a-f	8.3 a-f	1.23 d-f	3.73 a-c	5.50 g-f
7682	Enza	1147 a-e	3.3 b-f	8.4 a-f	1.16 f-h	3.66 b-e	32.50 a
ACR 275	Abbott & Cobb	1130 b-e	3.6 a-e	8.0 c-h	1.25 c-e	3.69 a-d	3.25 g-f
7602	Seminis	1123 b-f	3.3 b-f	8.9 a-c	1.00 k	3.64 b-f	4.00 g-f
959 (Golden Sun)	Hazera	1121 b-f	4.0 ab	7.0 i-k	1.31 bc	3.33 h	9.00 e-h
8328	Enza	1103 b-f	3.2 b-f	8.6 a-e	1.27 cd	3.62 b-f	30.80 ab
2506 (Telstar)	Hazera	1084 b-f	3.6 a-e	7.4 g-k	1.26 cd	3.47 e-h	2.20 h
ACR 252	Abbott & Cobb	1067 c-f	3.6 a-f	7.4 g-k	1.39 a	3.47 f-h	12.50 d-h
ACR 272	Abbott & Cobb	1061 c-f	3.1 c-f	8.8 a-d	1.21 d-g	3.69 a-d	3.25 g-f
Legionnaire	Syngenta	1039 c-f	3.2 b-f	7.7 e-j	1.25 cd	3.32 h	13.20 d-g
7141	Seminis	1037 c-f	2.9 ef	9.2 a	1.13 g-i	3.64 b-f	2.75 gh
2513	Hazera	1030 c-f	3.7 a-d	6.9 jk	1.10 h-j	3.74 ab	12.50 d-h
Boynton Bell	Pepper Research	1016 c-f	3.6 a-f	7.0 i-k	1.13 g-i	3.31 h	7.25 g-f
8302	Seminis	987 d-f	2.8 f	9.0 ab	1.07 i-k	3.74 ab	2.25 h
Jupiter	Syngenta	966 ef	3.4 b-f	7.3 h-k	1.15 f-i	3.30 h	26.20 a-c
PR02R-3	Pepper Research	948 ef	3.0 d-f	7.9 e-i	1.37 ab	3.71 a-d	2.75 gh
774 (Alexandra)	Hazera	894 f	3.5 b-f	6.6 k	1.05 jk	3.86 a	12.20 d-h

[z]Bushel = 28 lb; one acre = 7,260 linear ft of bed with beds spaced on 6 ft centers. Cwt = 100 lb.
[y]Mean separation in columns by Duncan's multiple range test, 5% level, when applicable.
[x]Length to width ratio. Scale: 1.00 = blocky, length same as width.
[w]Evaluated and rated 8 Feb. 2005 visual rating of percent loss of photosynthetic material.

not desired by produce brokers. An ideal ratio would roughly be between 1.00-1.20, a range that the majority (14) of these entries exhibited. Pepper fruit should also have between three and four lobes, with the preference towards four lobes and distinct indentations at the blossom end. Fruit with two lobes tend to be pointed with little indentations and may or may not be saleable depending on the market. Five-lobed fruit also tend to lose lobe distinction and although they are usually saleable, they are desired less by the industry and the public.

Entries having a high level of bacterial spot did not always demonstrate a decrease in yield, indicating that the disease was late in developing or the majority of harvestable fruit was during the first or second pick. ACX 248 and 7682 both had a bacterial spot rating greater than 20%, with 7682 having a rating of 32% which was higher than 'Jupiter' and considered to be highly susceptible. However, both ACX 248 and 7682 had yields greater than 1145 bushels/acre.

Delray Beach, Thomas Produce. Similar to Table 1, entries in the Delray Beach experiment are listed in order according to yield of mature green fruit (Table 2). Compared to Immokalee, the Delray Beach experiment took more days to mature from transplant to first harvest. In Immokalee, the first harvest was 57 DAT, compared to 80 DAT in Delray Beach. Pepper fruit from the Delray Beach experiment was also harvested three times over a period of 28 d. The third harvest was primarily colored fruit and probably could not have been harvested an additional time. The difference in DAT and harvest period between the two locations clearly indicates the variation between growing seasons and locations. In Immokalee, where temperatures were warmer and days longer during the experiment, the plants tended to have an early fruit set that was not heavy in weight, but continued to produce fruit over a longer period of time. In contrast, the Delray Beach experiment was primarily conducted during the winter months when temperatures were lower and day length shorter. This resulted in a longer amount of time to first harvest (heavier initial harvest) as well as less time between the first and last harvests. These distinctions are important to growers and the allied industry in that certain cultivars or varieties may be best suited to fit into these market windows.

Of the 10 highest yielding entries, only one, 5776, had a bacterial spot rating less than 10%. The other nine entries had ratings higher than 11%, with three of those exhibiting a rating above 30% ('Legionnaire' at 31%; 8338 at 36%; 8328 at 41%). The Immokalee location also exhibited poor correlation between disease and yield, indicating that fruit set and/or size was not negatively affected by bacterial spot.

Despite a more than 200 bushels/acre variation in yield among the top 10 producing entries, substantial statistical differences in yield were not found. In fact, the top producing entry, 5776, which yielded over 1400 bushels/acre, was found to be statistically similar to the next nine top producing entries (Table 2). Very little difference was seen between entries in number of lobes and blockiness, although three entries had a ratio less than 1.00, indicating that the majority of the fruit sampled were somewhat flattened in shape.

In conclusion, when planted in Immokalee during the late-fall early-winter season, PR99R-16, 8338, and 'Crusader' were the highest yielding entries. Of these three, only PR99R-16 had a bacterial spot rating less than 10%. When planted on

Table 2. Summary of yield and fruit characteristics for a bell pepper cultivar evaluation, Thomas Produce, Delray Beach, Fla., 2004-2005.

Entry	Source	Marketable yield[z] (bu/acre)	Fruit/plant (no.)	Fruit wt. (oz)	Ratio L:W[x]	Lobes (no.)	Bacterial spot[w] (%)
5776	Seminis	1402 a	5.0 a	9.0 a-c	1.05 f-k	3.75 b-d	7.75 g-i
8364	Enza	1271 ab	4.5 ab	7.4 ef	1.21 b-d	3.45 b-g	17.5 e-h
7682	Enza	1252 a-c	3.4 c-e	9.2 ab	1.15 c-h	3.49 b-g	25.00 b-e
PR01Y-5	Pepper Research	1247 a-c	4.2 a-c	8.8 a-d	1.16 c-h	3.63 b-g	13.25 e-i
Crusader	Syngenta	1234 a-c	3.6 c-e	8.8 a-d	0.92 k	3.68 b-f	19.50 c-g
PR99R-16	Pepper Research	1231 a-c	3.4 c-e	9.3 a	1.18 c-g	3.48 b-g	15.00 d-i
Legionnaire	Syngenta	1229 a-d	3.8 b-d	8.2 c-d	1.18 c-f	3.28 d-g	31.25 a-c
8338	Enza	1209 a-e	3.8 b-d	8.9 a-d	1.04 h-k	3.89 b	35.75 ab
PR02R-2A	Pepper Research	1206 a-e	3.8 b-d	8.0 d-f	1.24 a-c	3.65 b-g	11.25 g-i
8328	Enza	1190 a-e	3.3 de	9.2 ab	1.18 c-f	3.73 b-e	41.25 a
Brigadier	Syngenta	1183 b-e	3.4 c-e	8.5 a-d	0.94 jk	3.53 b-g	16.50 e-h
2506 (Telstar)	Hazera	1170 b-f	3.6 c-e	8.2 c-d	1.07 e-j	3.30 d-g	15.00 d-i
ACX 248	Abbott & Cobb	1148 b-g	3.5 c-e	8.3 c-d	1.20 b-d	3.24 fg	20.75 c-f
8302	Seminis	1106 b-h	3.0 de	8.9 a-d	1.06 e-k	3.48 b-g	7.00 hi
774 (Alexandra)	Hazera	1100 b-h	3.5 c-e	8.1 de	1.00 i-k	3.78 bc	24.00 b-e
7602	Seminis	1093 b-h	3.2 de	8.6 a-d	1.32 ab	3.46 b-g	5.50 hi
ACR 275	Abbott & Cobb	1079 b-h	3.3 de	8.4 a-d	1.26 a-c	3.44 b-g	13.00 e-i
2513	Hazera	1062 b-h	3.3 de	8.3 c-d	1.05 g-k	3.58 b-g	26.25 b-d
7141	Seminis	1049 c-h	3.0 de	8.8 a-d	1.19 b-e	3.55 b-g	4.25 i
Boynton Bell	Pepper Research	1013 d-h	3.2 de	8.2 c-d	1.07 e-j	3.29 d-g	27.00 b-d
PR02R-3	Pepper Research	995 e-h	3.1 de	8.2 c-d	1.10 d-i	3.58 b-g	14.00 e-i
959 (Golden Sun)	Hazera	959 f-h	3.4 c-e	7.2 f	1.14 c-h	3.18 g	16.25 d-i
ACR 252	Abbott & Cobb	956 f-h	3.4 c-e	8.1 de	1.35 a	3.27 e-g	23.75 b-e
ACR 272	Abbott & Cobb	949 gh	3.1 de	8.1 de	0.97 i-k	4.40 a	6.25 hi

[z]Bushel = 28 lb; one acre = 7,260 linear ft of bed with beds spaced on 6 ft centers. Cwt = 100 lb.
[y]Mean separation in columns by Duncan's multiple range test, 5% level, when applicable.
[x]Length to width ratio. Scale: 1.00 = blocky, length same as width.
[w]Evaluated and rated 25 Feb. 2005 visual rating of percent loss of photosynthetic material.

the east coast of Florida (Delray Beach) during the winter months, a number of entries performed exceptionally well with the top three producing entries being 5776, 8364, and 7682. In both locations, low resistance to bacterial spot did not necessarily correlate to decreases in yield and horticultural quality. Entries 7682, 8338, and ACX 248 all yielded well at both locations despite having relatively high bacterial spot ratings. Conversely, some entries that had an elevated level of bacterial spot did show below average yields. Further research is needed to determine if a correlation between lower yield and bacterial spot exists for these entries.

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