Cultivar and Plant Arrangement Effects on Yield and Fruit Quality of Bell Pepper

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Abstract. Single- and double-row arrangements of a fixed population (one plant every 0.285 m²) were compared in factorial combination with two (2002) or five (2003) cultivars for effects on yield and fruit quality of bell pepper (Capsicum annuum L.). Arrangements for 2002 were S30, single rows 0.95 m apart, plants within rows 30 cm apart; D30, 1.9 m between centers of double-row beds, double rows 30 cm apart on beds, plants within rows 30 cm apart; S37.5, single rows 0.76 m apart, plants within rows 37.5 cm apart; and D37.5, 1.52 m between centers of double-row beds, double rows 24 cm apart on beds, plants within rows 37.5 cm apart. Only the S30 and D30 arrangements were used in 2003 after 2002 results showed almost no differences between S30 and S37.5 or between D30 and D37.5. Choice of cultivar was more critical in Texas, where 'X3R Wizard' consistently outperformed 'King Arthur', than in Oklahoma. Single rows resulted in more full-season total marketable fruit weight than double rows in three experiments out of four, primarily as a result of an increased weight of U.S. No. 1 fruit with single rows. Average weight per marketable fruit was consistently unaffected by plant arrangement. Single rows also resulted in a greater full-season weight of sunburned fruit than double rows in two experiments out of four. Cultivar × plant arrangement interactions were not evident in Oklahoma and never involved full-season marketable fruit weights at either location in either year. Given the tested population, a single-row arrangement is likely to result in increased full-season production of U.S. No. 1 bell pepper fruit compared with a double-row arrangement, despite an increased potential for sunburned fruit with single rows.

In a competitive marketplace, total yield may be less important than yield of a high-quality, premium product. Selection of adapted cultivars and appropriate cultural practices are important steps toward this goal.

Many studies have been published on plant populations for bell peppers (Ahmed, 1984; Batal and Smittle, 1981; Gaye et al., 1992; Locascio and Stall, 1994; Stoffella and Bryan, 1988). Specific recommendations for optimal plant population density vary. One reason may be that, as pointed out by Willey and Heath (1969), plant population density consists not only of plant number, but also plant arrangement. Plant arrangement has received relatively little attention in the solanaceous fruits and particularly in bell pepper. In theory, equidistant spacing of plants within the row and between rows (that is, an arrangement approaching a square) should maximize the yield per plant by optimizing canopy exposure to light and by providing a more uniform area for water and mineral uptake by the roots compared with standard rectangular planting (Sayre, 1959). Sayre (1959) compared tomatoes (Lycopersicon esculentum Mill.) in twin rows with those in standard single rows at similar plant population densities and found that the pattern in which the plants were more equally spaced produced the largest yield. Sayre (1959) also reported plants in the twin rows produced a high-quality crop with few fruit defects. This was attributed to plants having grown more erect in the twin rows and shading the fruit better than in the single rows.

The current study was designed to determine whether different arrangements of a given plant population would affect yield of premium (U.S. Fancy and U.S. No. 1) bell pepper fruit. The comparison of single- and double-row arrangements also tested the hypothesis that use of double rows might reduce the number of cull fruits. Yield and grade-out of different cultivars were also examined, and possible cultivar × plant arrangement interactions were tested.

Materials and Methods

Studies were conducted at the Oklahoma Vegetable Research Station, Bixby, and at the Texas Agricultural Experiment Station, Uvalde, in 2002 and 2003. The soil at Bixby was a Severn very fine sandy loam [coarse–silty, mixed (calcareous), thermic Typic Udic Haplustalf] and at Uvalde was a Uvalde silty clay loam [fine–silty, mixed, hyperthermic Aridic Calciustoll]. No plastic mulches were used at either location. Weeds were controlled with herbicides supplemented by hand and machine cultivation. Plant water requirements were met with rainfall supplemented by overhead sprinkler irrigation at Bixby and by surface drip irrigation at Uvalde. Standard foliar insecticides, fungicides, and bactericides were applied as needed.

The bell pepper cultivars King Arthur and X3R Wizard were used both years. Additional cultivars in 2003 were Boynton Bell, Karma, and Lafayette. Transplants were commercially grown in 2002 and grown on-site in 2003. In both cases, transplants were produced in flats with inverted pyramid cells (200 cells per flat; volume, 18 cm³ per cell). Single- and double-row arrangements of a fixed population (one plant every 0.285 m²) were compared. This population was chosen as a rough average of recommended plant population densities for Oklahoma and Texas. Arrangements for 2002 were S30, single rows 0.95 m apart, plants within rows 30 cm apart; D30, 1.9 m between centers of double-row beds, double rows 30 cm apart on beds, plants within rows 30 cm apart; S37.5, single rows 0.76 m apart, plants within rows 37.5 cm apart; and D37.5, 1.52 m between centers of double-row beds, double rows 24 cm apart on beds, plants within rows 37.5 cm apart. Only the S30 and D30 arrangements were used in 2003 after 2002 results showed almost no differences between S30 and S37.5 or between D30 and D37.5.

The experimental design was a split plot. In 2002, arrangements were main plots in a 4 × 4 Latin square; cultivars were subplots. In 2003, cultivars were main plots in a randomized complete block with four replications; arrangements were subplots.

Plot lengths varied by plant arrangement. In 2002, single-row treatments had 32 plants per row (16 per cultivar). Double-row treatments had 20 plants per row (10 per cultivar). In 2003, S30 had 16 plants per row and D30...
had 10 plants per row. In all cases, areas containing 12 plants per plot were designated for data collection, and appropriately spaced guard rows separated the main plots.

Selective hand harvests of mature green fruits were made periodically. Fruits were classified as U.S. Fancy, U.S. No. 1, U.S. No. 2, and culls, according to U.S. Dept. of Agriculture grading standards. Cull fruits were further classified by predominant reason for culling as follows: blossom-end rot, sunburn, or other defects (such as seriously misshapen or insect damaged).

Cultural Practices

*Bixby, 2002.* The soil was prepared with a broadcast preplant-incorporated application of 31N–14P–26K kg ha⁻¹, plus trifluralin [2,6-dinitro-N,N-dipropyl-4-(trifluoromethyl) benzenamine at 560 g ha⁻¹] for weed control. Transplants were set in the field by hand on 17 Apr. Each plant received ≈240 ml starter solution providing 1079N–941P–895K mg L⁻¹, plus diazinon ([O,O-diethyl O-(6-methyl-2-(1-methylethyl)-4-pyrimidineyl)phosphorothioate at 300 mg L⁻¹]. Plants were top dressed with urea to supply 56 kg ha⁻¹ N per application on 15 May and 4 June.

A total of 10 harvests were made beginning on 3 July and ending on 26 Aug. “Early harvest” was defined as the first four picks. On 27 Aug., three plants per plot were measured for plant height, cut, and defruited as in Oklahoma. Sampled plants were dried for 6 d at 65 °C, and weighed.

*Bixby, 2003.* The soil was prepared with a broadcast preplant-incorporated application of trifluralin 560 g ha⁻¹. Transplants were set in the field by hand on 22 Apr. Each plant received starter solution as in 2002. Preplant N had not been applied, so a top dressing with urea to supply 56 kg ha⁻¹ N was made on 29 Apr. Adequate P and K were available from fertilization of previous trials. Plants also were top dressed with urea to supply 56 kg ha⁻¹ N per application on 21 May and 19 June, and to supply 28 kg ha⁻¹ N on 21 July. A total of five harvests were made beginning on 24 June and ending on 28 July. “Early harvest” was defined as the first two picks. On 1 Aug., three plants per plot were measured for height and cut for dry weight determination as in 2002.

*Uvalde, 2002.* The soil was prepared with a broadcast preplant-incorporated application of 70N–50P–0K-2Zn kg ha⁻¹. Transplants were set in the field by hand on 3 Apr. The herbicide S-metolachlor (1.28 kg ha⁻¹) was applied on 4 Apr. Fertilizer (ammonium nitrate and phosphoric acid sources) was applied through the drip system on 22 Apr., 2 May, and 2 June to supply a supplemental total of 45N–30P kg ha⁻¹. A total of nine harvests were made beginning on 17 June and ending on 18 Sept. “Early harvest” was defined as the first four picks. On 4 Aug., four plants per plot were measured for height and cut for dry weight determination as in 2002.

**Results**

*Early harvest, 2002.* ‘King Arthur’ had more early fruit production than ‘X3R Wizard’ in Oklahoma, but not in Texas (Table 1). Single rows resulted in a greater overall total early fruit weight than double rows in Oklahoma, but not in Texas, and this was attributed to a greater weight of U.S. No. 1 fruit from single rows in Oklahoma (Table 1). No differences were found between the S30 and S37.5 arrangements, nor between the D30 and D37.5 arrangements. Only one interaction was evident, affecting early cull fruit weight in Texas. Both single-row arrangements of ‘King Arthur’ led to higher early cull weights than the D30 arrangement of ‘King Arthur’ and ‘X3R Wizard’ in Texas. The S30 arrangement of ‘King Arthur’ also led to a higher early cull weight than the S37.5 arrangement of ‘X3R Wizard’ (interaction means not presented).

*Full-season yields, Oklahoma, 2002.* ‘King Arthur’ produced higher marketable and overall total weights of fruit than ‘X3R Wizard’, and the average weight per marketable fruit also was greater for ‘King Arthur’ than for ‘X3R Wizard’ (Table 2). Plant arrangement effects were evident only for cull fruit production. Single rows led to higher cull weights than double rows. Effects were seen for both sunburned fruit and fruit with blossom-end rot (Table 2). No differences were found between the S30 and S37.5 arrangements, nor between the D30 and

Table 1. Bell pepper fruit yields from early harvest as affected by cultivar and plant arrangement, Bixby, Okla. (OK) and Uvalde, Texas (TX), 2002.*

| Treatment factor | Marketable fruit wt | Overall total fruit wt |
|-----------------|---------------------|-----------------------|
|                 | U.S. Fancy (Mg ha⁻¹) | U.S. No. 1 (Mg ha⁻¹) | Premium (Mg ha⁻¹) | U.S. No. 2 (Mg ha⁻¹) | Total (Mg ha⁻¹) | Average (g/fruit) | Cull fruit wt (Mg ha⁻¹) | Overall total fruit wt (Mg ha⁻¹) |
| Cultivar        | OK | TX | OK | TX | OK | TX | OK | TX | OK | TX | OK | TX | OK | OK |
| King Arthur     | 0.7 | 6.4 | 2.9 | 7.1 | 2.9 | 0.9 | 1.0 | 8.0 | 3.9 | 156 | 99 | 1.0 | 1.4 | 8.9 | 5.3 |
| X3R Wizard      | 0.1 | 2.1 | 3.5 | 2.2 | 3.5 | 0.3 | 1.2 | 2.5 | 4.7 | 140 | 106 | 0.3 | 1.2 | 2.9 | 5.9 |
| Significance    | *** | NS | NS | ** | NS | NS | ** | NS | ** | NS | NS | NS | NS | *** | *** |
| Plant arrangement⁠ | Single vs. double rows | NS | * | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| S30             | 0.3 | 5.1 | 3.3 | 5.4 | 3.3 | 0.6 | 1.2 | 6.0 | 4.5 | 150 | 101 | 0.9 | 1.7 | 6.8 | 6.3 |
| D30             | 0.4 | 3.8 | 2.9 | 4.2 | 2.9 | 0.6 | 0.8 | 4.9 | 3.7 | 149 | 102 | 0.7 | 0.7 | 5.6 | 4.4 |
| S37.5           | 0.4 | 4.4 | 3.2 | 4.8 | 3.2 | 0.7 | 1.5 | 5.5 | 4.5 | 142 | 106 | 0.5 | 1.4 | 6.1 | 5.9 |
| D37.5           | 0.4 | 3.8 | 3.6 | 4.2 | 3.6 | 0.5 | 1.0 | 4.6 | 4.6 | 152 | 103 | 0.5 | 1.3 | 5.1 | 6.0 |

*In Oklahoma, early harvest occurred on 3, 8, 12, and 17 July. None of the measured variables showed a significant (P ≤ 0.05) cultivar × plant arrangement interaction. In Texas, early harvest occurred on 19 June and 8 July. Only cull fruit weight showed a significant (P = 0.028) cultivar × plant arrangement interaction.

Overall total = U.S. Fancy + U.S. No. 1 + U.S. No. 2 + all culls.

†Premium = U.S. Fancy + U.S. No. 1.

‡Total marketable = U.S. Fancy + U.S. No. 1 + U.S. No. 2.

§There were no U.S. Fancy fruit at early harvest in Texas.

†Significant (P = 0.05) cultivar × plant arrangement interaction; see text for details.

§S30 = single rows 0.95 m apart; plants 30 cm apart within rows; D30 = double rows 30 cm apart on beds, 1.9 m between centers of beds; plants 30 cm apart within rows; S37.5 = single rows 0.76 m apart; plants 37.5 cm apart within rows; D37.5 = double rows 24 cm apart on beds, 1.52 m between centers of beds; plants 37.5 cm apart within rows.

Contrasts for S30 vs. S37.5 and for D30 vs. D37.5 were ns for all variables in this table.

NS, *, ** Not significant or significant by F test at P ≤ 0.05 or ≤0.01 respectively.