Evaluating the Impact of Transplanting Depth on Bell Pepper Growth and Yield

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Abstract. ‘Jupiter’ and ‘Verdel’ bell pepper (*Capsicum annuum* L.) transplants set to the depth of cotyledon leaves or to the first true leaf yielded more fruit than transplants set to the top of the rootball. Increased yields and early stand establishment criteria (number of leaves, leaf area, plant weight, and plant height) suggest that planting pepper transplants deeper than is now common is commercially beneficial in Florida. Deeper plantings may place pepper roots in a cooler environment and reduce fluctuations in soil temperature. Moderated soil temperature, in conjunction with earlier fertilizer and water acquisition, may give deeper-planted pepper plants a competitive edge in growth.

Information on the effects of planting depth on growth is readily available for fruit trees (Lyons et al., 1983; Rogers and Parry, 1968), seed (Mack et al., 1984; Redman and Qi, 1992; Wilson et al., 1990), asparagus (*Asparagus officinalis* L.) (Lindgren, 1990), and Brodiaea corms (Han et al., 1991); however, little information exists on vegetable transplant planting depth. Watson (1865) indicated, “it is the general rule to set the plants of cabbages [*Brassica oleracea* Capitata Group], peppers, and other plants that form a stem one to two inches deeper than they have previously stood.” Planting bare-rooted tomato (*Lycopersicon esculentum* Mill.) transplants slightly deeper than their plant bed depth was a tradition in the early 1900s (Tracy, 1908; Work, 1945). More recently, research on cabbage transplant depth was conducted by Miller et al. (1969) who found higher yields but inconsistent head size with deeper transplanting. Kwapata (1991) noted that, in tomato, yields could be increased by grass mulch, but mulch depths >10 cm did not further increase yields more than shallower mulch depths. Weed control in bare-ground production of commercial vegetables, sometimes accomplished by mechanical hoeing, often buries existing stem

(and leaf) structures, resulting in deeper plantings. Whether planting depths are intentional or the result of soil tillage, more information on the consequences of different planting depths is needed. Our study was designed to analyze the effect of transplanting depth on pepper growth and yield under subsurface seepage irrigation and polyethylene mulch culture in Florida.

Materials and Methods

Bell pepper transplants were commercially grown (Collier Gro, Immokalee, and LaBelle Plant World, LaBelle, Fla.) in Heco plug mix (Southern Importers, Greensboro, N.C.) in 26-cm³ inverted pyramid containerized cells (Todd, Plant City, Fla.). Plants were grown in greenhouses under natural light and seasonal temperature. They received 75 mg N/liter from 20N–4P–17K daily. Each season of commercial transplant production resulted in different size plants available for testing; therefore, anatomical designations were used as a planting depth determinant rather than measured distances above the rootball.

‘Jupiter’ bell pepper transplants were planted on 10 Sept. 1991 in Immokalee, Fla., either to the top of the rootball (rootball depth) or to the base of the cotyledon leaves (cotyledon-leaf depth). Further trials were planted to the top of the rootball, the cotyledons, and the first true leaf at the soil surface (true-leaf stage) in Immokalee, Fla. (13 Feb. and 15 Sept. 1992), and Boynton Beach, Fla. (17 Aug. 1992). ‘Verdel’ bell pepper was planted on 29 Dec. 1992 in Jupiter, Fla., to the rootball, cotyledons, first true leaf, and to a position

between the rootball and the cotyledon leaves. This latter position was termed “grower’s depth” because it approximated the standard transplant depth used on that farm.

Plants in Immokalee (Immokalee fine sand—sandy, siliceous, hyperthermic, Arenic Haplaquod) were transplanted into raised beds (20 cm) on 1.8-m centers, two rows to the bed, with ≈25 cm between rows and between plants (5.57 m²/replication). The Immokalee crops received (in kg·ha⁻¹) 224 N, 291 K, and P by soil test (56 P in fall, 78 P in spring) plus basic micronutrients. Sixty-seven kilograms each of total N and K used per hectare and all the P plus micronutrients were broadcast-applied on flat ground and then covered by a soil bed 12 to 15 cm deep. The remaining N and K were applied in two narrow bands on top of the bed, 17 cm to either side of the bed crown. The soil was simultaneously fumigated with 98% methyl bromide : 2% chloropicrin at 314 kg·ha⁻¹ while the final bed was shaped. The beds were then covered with 0.03-mm polyethylene mulch (black in spring, white in fall). At the Boynton Beach site (Riviera sand—loamy, siliceous, hyperthermic Arenic Glossaqualfs), the transplants received (in kg·ha⁻¹) 349 N, 433 K, and 63 P. Plant spacing in Boynton Beach was 23 cm between plants and 46 cm between rows within the bed (5.57 m²/replication). The pepper transplants at the Jupiter site (Basinger fine sand—siliceous, hyperthermic Spodic Psammaquents) received (in kg·ha⁻¹) 329 N, 400 K, and 70 P. Jupiter transplants were spaced 20 cm between plants and 46 cm between rows (5.57 m²/replication). Fertilizer application and bedding procedures in Boynton Beach and Jupiter were similar to those in Immokalee. Subsurface seepage irrigation (based on need) was used at all sites.

For the Immokalee 1992 trials only, a 12-plant transplant sample per treatment was taken at 30 and 60 days after transplanting (DAT). The 30 DAT sample measurements included the number of leaves, leaf area and weight, plant height, and dry matter accumulation. The 60 DAT plant sample was used to determine dry weight (minus fruit) only.

First harvest and total yield by weight were measured at all sites. Average individual fruit weight also was determined at each harvest. Harvest dates were 13 Nov. and 3 and 23 Dec. 1991 and 7 and 12 Dec. 1992 in Immokalee; 15 and 28 Oct., 13 and 26 Nov., and 11 Dec. 1992 in Boynton Beach; and 1, 9, and 27 Mar.; 13 Apr.; and 1 June 1993 in Jupiter. Planting depths were replicated six times in Fall 1991 and nine times in Fall 1992 trials in Immokalee and four times each season in Boynton Beach and Jupiter.

Due to the varying number of treatments, replications, harvests, and sites in this study, separate analysis of variance (ANOVA) were performed for each season and site for the harvest data. However, the plant characteristic data for spring and fall at Immokalee were combined and analyzed by ANOVA to test for differences among the depths, seasons, and depth × season interaction. All mean comparisons were identified by Fisher’s LSD.

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Table 1. Transplant planting depth and pepper planting characteristics 30 and 60 days after transplanting (DAT) in Immokalee, Fla. (trials in Spring and Fall 1992).

Variable	30 DAT				60 DAT
	Stem length (cm)	No. leaves/plant	Leaf area (cm ²)	Shoot dry wt ^z	Shoot dry wt ^y
Depth					
True leaf	12.6 b ^x	50.5 a	807 a	3.3 a	30 a
Cotyledon	13.7 b	48.7 a	705 a	3.2 a	28 a
Rootball	15.6 a	38.6 b	423 b	2.4 b	26 b
Season					
Spring	13.2 a	38.2 b	314 b	2.0 b	28 a
Fall	14.6 a	51.1 a	870 a	4.6 a	30 a
Depth	*	*	*	*	*
Season	NS	*	*	*	NS
Season × depth	NS	NS	NS	NS	NS

^zShoot measured from cotyledon leaf.^yShoot measured from ground level.^xMean separation by Fisher's LSD.NS, * Nonsignificant or significant at $P \leq 0.05$, respectively.

Table 2. Pepper yields as affected by transplant planting depth during fall and spring at three sites in southern Florida.

Depth	Yield (t·ha ⁻¹)		Avg fruit wt (g)	
	First harvest	Total season	First harvest	Total season
<i>Fall 1991 season, Immokalee, Fla.</i>				
Cotyledon	17.2 a ^z	37.5 a	161 a	155 a
Rootball	13.7 b	32.1 b	161 a	154 a
F test (depth) ^y	**	**	NS	NS
<i>Fall 1992 season, Immokalee, Fla.</i>				
True leaf	17.0	22.3	203	188
Cotyledon	14.4	19.5	194	178
Rootball	16.0	19.7	204	190
F test (depth)	NS	NS	NS	NS
<i>Fall 1992 season, Boynton Beach, Fla.</i>				
True leaf	17.3 a	51.0 a	165 a	132 a
Cotyledon	16.7 a	51.2 a	165 a	132 a
Rootball	13.7 b	45.0 b	157 b	127 a
F test (depth)	**	*	**	NS
<i>Spring 1993 season, Jupiter, Fla.</i>				
True Leaf	25.7 a	67.4 a	185 a	149 a
Cotyledon	19.6 b	65.0 ab	170 b	141 b
Grower's ^y	16.5 b	60.8 b	172 b	139 b
Rootball	16.3 b	59.9 b	167 b	139 b
F test (depth)	**	*	**	**

^zMean separation by Fisher's LSD.^yGrower's planting depth was midway between the rootball and the cotyledon leaves.NS, *, ** Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

Results and Discussion

Pepper transplants benefited from deeper planting during stand establishment in spring and fall (Table 1). After 30 days in the field, peppers planted to the first true leaf or cotyledon leaves had more leaves, a larger leaf area, and more shoot dry matter accumulation than plants set at rootball depth. By 60 DAT, increased dry matter accumulation trends with deeper plantings were still evident. Seasonal effects on pepper morphology also were evident (Table 1). Peppers planted in the fall had more leaves, larger leaf area, and higher shoot dry weight (30 DAT) than peppers planted in the spring. Deeper plantings also resulted in earlier bloom and reduced lodging (data not shown).

The advantage of deeper planting was obvious not only on plant structure but also on

first harvest (Table 2). In Fall 1991, total fruit weight from the first harvest was 26% higher with pepper transplanted to cotyledons rather than the rootball depth. Also, transplanting to the cotyledon-leaf depth resulted in a >17% total yield increase. Individual fruit weight was unaffected by planting depth in 1991.

An infestation of pepper weevil (*Anthonomus eugenii* Cano) in Immokalee in the Spring 1992 study caused severe fruit loss, nullifying planting depth yield effects. The Fall 1992 trial in Immokalee became infested with bacterial spot [*Xanthomonas campestris* pv. *vesicatoria* (Doidge) Dye.]. Although disease negated treatment differences, a trend toward higher total yield was noted with the first true-leaf planting compared to either the rootball or cotyledon depths.

The Fall 1992 trial at Boynton Beach showed that deeper planting depths improved

yield and first harvest individual fruit weight of bell pepper when compared to shallower planting (Table 2). First harvest, total season yield, and individual fruit weight were similar for plants set at cotyledon or true-leaf depth (58% and >31%, respectively). However, in Spring 1993 in Jupiter (Fla.), the true-leaf depth led to significantly more fruit weight at first harvest than the cotyledon-leaf or rootball depth (58% and >31%, respectively). Furthermore, plants set to the true-leaf depth consistently produced a heavier pepper when averaged across harvests. Although the yield from the cotyledon-leaf depth was similar to that from the rootball depth, the trend for higher yield was apparent. No benefit in yield or individual fruit weight was found with the grower's standard planting technique compared to peppers planted to the rootball depth.

The larger and earlier yield from deeper transplant depth that we obtained in Florida may be the result of improved temperature conditions for root growth. Deeper plantings may place pepper roots in a cooler environment with less radical temperature swings (White, 1937). This factor would be of considerable importance in late summer and early fall plantings grown under plastic mulch. Other explanations for increased yields with deeper planting may include earlier fertilizer and water acquisition and reduced transplant shock from wind displacement. Adventitious root sprouting along the main stem is minimal (C.S.V., unpublished) in pepper, and it is unclear how such roots are involved in early stand establishment. Further research is necessary to test these hypotheses.

Deeper planting seems to hasten maturity, as the early yield increases seen with deeper transplanting diminish with extended harvests. For example, plants set to the true-leaf depth averaged 30% more yield vs. planting at the rootball depth at first harvest, but at final harvest, the former averaged only 13% more yield. Despite various cultural regimes and soil types, deeper planting of pepper transplants grown with subsurface irrigation and plastic mulch in the subtropics leads to increased yields and fruit size, providing a competitive marketing edge for the grower.

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