requirements for near-maximum yield, not delay fruit set, and result in optimum ripe fruit load at harvest.

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Stand Deficiencies and Replanting Effects on Tomato Fruit Yields and Size

Peter J. Stoffella[1]

Agricultural Research and Education Center, IFAS, University of Florida, P.O. Box 248, Fort Pierce, FL 34954

Donald N. Maynard[2]

Gulf Coast Research and Education Center, IFAS, University of Florida, 5007 60th St. E., Bradenton, FL 34203

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Abstract. **The effects of replanting stand-deficient plots on marketable tomato (*Lycopersicon esculentum* Mill.) fruit size and yields were investigated at Bradenton, Fla. during the 1986 spring and fall seasons. Treatments consisted of a control (10-plant plot) and plots with 9, 8, and 7 (10%, 20%, and 30%) missing plants. Other plots with the same stand deficiency were replanted to attain a complete stand 2 or 3 weeks and 1, 2, or 3 weeks after initial transplanting in the spring and fall experiments, respectively. Plots with 30% stand reduction produced a lower weight and number of marketable fruit per hectare than control plots in both seasons. In spring, replanting stand-deficient plots did not increase marketable fruit yields relative to plots not replanted, regardless of the time of replanting or percentage of stand reduction. In fall, under an unfavorable environment due to a late infestation of bacterial spot, replanting plots with 30% stand reduction increased marketable fruit yields over similar plots that were not replanted, when the replanting occurred 1 or 2 weeks after initial transplanting, but not when replanting was delayed 3 weeks. Small, medium, or extra-large marketable fruit weight per hectare were similar in both seasons for plots with 30% stand reduction, whether replanted or not. Mean fruit size (g/fruit) did not differ significantly among treatments in either experiment. These results suggest that replanting improved marketable tomato yields only when the level of stand deficiency reached 30% and only in a stressed environment.**

Tomato plant losses during or shortly after stand establishment can be associated with poor-quality transplants, plant injury by various pests, unfavorable environmental conditions, or inadequate management of cultural practices. However, transplant losses generally are variable within and between commercial tomato fields. Most growers will replant stand-deficient fields within 2 weeks after initial transplanting. The decision to replant is based on the extent of plant losses and the economic climate of the season. Growers usually determine the reduction of stand establishment by subjective visual observations of their fields.

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[1]Associate Professor of Vegetable Crops.

[2]Professor of Vegetable Crops.

Several investigations (1–4, 7, 11–15) have focused on determining optimum plant populations and plant arrangements to achieve maximum tomato fruit quality and yield. The influence of replanting to a complete stand on vegetable crop yields has generally been neglected. Sullivan and Bliss (9) reported that having an additional plant at thinning next to a skip improved the compensation of bean (*Phaseolus vulgaris* L.) seed yields and percent protein as compared with transplanting. Stoffella and Sonoda (8) reported a 7% to 31% tomato yield reduction when one or two transplants, at different positions, were missing from a complete stand of six transplants. However, mean fruit size was the same for plots with complete or incomplete stands.

The purpose of this investigation was to determine if replanting incomplete tomato stands would improve marketable tomato fruit yields and fruit size.

Materials and Methods

Seedlings of the determinate tomato cultivar Sunny were transplanted during the spring and fall seasons of 1986 at the Gulf Coast Research and Education Center, Bradenton, Fla. Soil was characterized as EauGalle fine sand (sandy, silicaceous, hyperthermic Aeric Haplaquod) with a spodic horizon at 0.9 m. Raised beds, 0.2 m in height, were spaced 1.37 m apart (center to center), with each bed 0.76 m wide. Ditches for subsurface irrigation were 12.5 m apart, with seven beds between ditches.

Fertilizer at a rate of 39, 95, and 83 $kg \cdot ha^{-1}$ of N, P, and K, respectively, was broadcast and incorporated into the beds. An additional application of 390 and 730 $kg \cdot ha^{-1}$ of N and K, respectively, was applied on the bed surface, in two bands, 0.3 m from the center of each bed prior to planting. Beds were fumigated with methylbromide–chloropicrin (2:1) at 390 $kg \cdot ha^{-1}$ and immediately covered with black or white polyethylene mulch in the spring or fall seasons, respectively.

Five-week-old commercially grown seedlings were transplanted on 10 Feb. 1986 and 22 Aug. 1986 at 0.61 m between plants in a single row placed in the center of each bed. Population was equivalent to 11,959 plants/ha. Each experimental plot contained 10 plants, with four plants separating each plot within the row.

In both experiments, treatments consisted of a control (10-plant plot) and three plots each of 9, 8, or 7 plants. The incomplete stands were established at the time of initial transplanting. The fifth, third, and seventh, or second, fifth, and eighth plant of a 10-plant plot were never transplanted and represented a 10%, 20%, or 30% reduction in stands, respectively. One plot of each stand reduction treatment was planted to a complete stand 2 or 3 weeks following initial transplanting and one plot of each stand-reduction treatment was never replanted to a complete stand. In fall, an additional plot of each stand-reduction treatment was incorporated to allow planting to a complete stand 1 week after initial transplanting. The design resulted in 10 and 13 treatment combinations for the spring and fall experiments, respectively. A randomized complete block design with treatments replicated four times was used for each experiment. In both experiments, seedlings used for replanting were from the original transplant lot, which is the usual grower's practice. Tomato plants were staked and tied three times in each experiment. Standard pesticide and cultural practices (6) were followed throughout the season.

Fruits were harvested manually three times at 10-day intervals during the spring experiment. Bacterial spot disease incited by *Xanthomonas campestris* pv. *vesicatoria* Dye late in the season caused sufficient leaf damage to preclude a third harvest in the fall experiment. Only fruit that were at the breaker to red-ripe stages (10) were harvested. Fruit of marketable size, but green, also were picked in the last harvest of each experiment. Fruit for each harvest were graded for diameter into small (<60 mm), medium (60–65 mm), large (65–70 mm), and extra-large (>70 mm) sizes, counted, and weighed. Misshapen, diseased, or undersized (<54 mm) fruits were considered culls. Weights of marketable fruit in each size category were summed for all harvests in each experiment. Total marketable fruit weight and numbers were expressed on a per-hectare and per-plant basis. Mean fruit size (g/fruit) was calculated as total marketable weight/total marketable number.

Analysis of variance was performed for each measured and calculated variable with the Statistical Analysis System (SAS) (5) software program. Main effects of treatments were partitioned into single-degree-of-freedom (orthogonal) contrasts. Comparisons between the control and each treatment were also obtained.

Table 1. Marketable tomato fruit yields as influenced by replanting plots with stand deficiencies during the spring season, 1986.

Stand reduction (%)	Time of replanting (PL) (weeks)[z]	Marketable fruit yield per ha t	per ha No. × 1000	per plant kg	per plant No.
0 (control)		114	758	9.5	63
10	NPL[y]	106	690	9.9	64
10	2	114	769	9.5	64
10	3	104	706	8.7	59
20	NPL	98	634[x]	10.3	66
20	2	117	779	9.8	65
20	3	107	708	8.9	59
30	NPL	94[x]	610[x]	11.3[x]	73
30	2	107	706	8.9	59
30	3	99	632[x]	8.3	53
Orthogonal contrasts					
10% skips NPL vs. 10% PL 2 weeks		NS	NS	NS	NS
10% skips NPL vs. 10% PL 3 weeks		NS	NS	NS	NS
20% skips NPL vs. 20% PL 2 weeks		NS	*	NS	NS
20% skips NPL vs. 20% PL 3 weeks		NS	NS	NS	NS
30% skips NPL vs. 30% PL 2 weeks		NS	NS	**	*
30% skips NPL vs. 30% PL 3 weeks		NS	NS	**	**

[z]Weeks following initial transplanting.
[y]NPL = Not replanted.
[x]Significantly different from the control at the 5% level.
NS,*,**Nonsignificant or significant at the 5% or 1% levels, respectively.

Results and Discussion

Spring experiment. Stand-deficient plots, regardless of replanting, and the control plot (a complete stand) produced similar yields of marketable fruit weight per hectare or per plant (Table 1). Only plots with stand reductions of 30% had significantly lower marketable fruit weights and numbers per hectare, but higher marketable fruit weights per plant, than the control plot. Plots with 10%, 20%, or 30% stand reductions replanted 2 or 3 weeks after initial transplanting generally did not produce more marketable fruit weight or number per hectare than with stand-deficient plots that were not replanted (Table 1). The exception was a significantly higher marketable fruit number per hectare in plots with stand reduction of 20% that were replanted 2 weeks after initial transplanting than in plots with 20% missing plants that were not replanted. We attribute this difference to the production of more medium-sized fruit in plots with 20%

Table 2. Tomato fruit size as influenced by replanting plots with stand deficiencies during the spring season, 1986.

Stand reduction (%)	Time of replanting (weeks)[y]	Weight (t·ha⁻¹) Fruit size categories[z] Small	Medium	Large	Extra-large	Mean fruit size (g/fruit)
0 (control)		6.5	32	35	41	150
10	NPL[x]	4.0[w]	27	35	40	154
10	2	4.9	29	37	43	150
10	3	6.4	30	32	36	145
20	NPL	4.5[w]	23[w]	34	38	154
20	2	5.3	32	36	44	150
20	3	4.4[w]	26	35	42	150
30	NPL	4.2[w]	29	30	31	154
30	2	4.7	29	34	39	150
30	3	3.4[w]	25	30	40	160
Orthogonal contrasts						
10% skips NPL vs. 10% PL 2 weeks		NS	NS	NS	NS	NS
10% skips NPL vs. 10% PL 3 weeks		*	NS	NS	NS	NS
20% skips NPL vs. 20% PL 2 weeks		NS	*	NS	NS	NS
20% skips NPL vs. 20% PL 3 weeks		NS	NS	NS	NS	NS
30% skips NPL vs. 30% PL 2 weeks		NS	NS	NS	NS	NS
30% skips NPL vs. 30% PL 3 weeks		NS	NS	NS	NS	NS

[z]Size categories for small, large, and extra-large are 54–60, 60–65, 65–70, and >70-mm-diameter fruit, respectively.
[y]Weeks following initial replanting.
[x]NPL = Not replanted.
[w]Significantly different from the control at the 5% level.
NS,*,**Nonsignificant or significant at the 5% or 1% levels, respectively.

Table 3. Marketable tomato fruit yields as influenced by replanting plots with stand deficiencies during the fall season, 1986.

Stand reduction (%)	Time of replanting (PL) (weeks)[z]	Marketable fruit yield per ha t	No. × 1000	per plant kg	No.
0 (control)		65	448	5.5	37
10	NPL[y]	71	471	6.6	44
10	1	74	482	6.2	40
10	2	52	364	4.4	30
10	3	57	384	4.7	32
20	NPL	57	384	5.9	40
20	1	64	422	5.3	35
20	2	58	387	4.9	32
20	3	56	376	4.7	31
30	NPL	45[x]	293[x]	5.3	35
30	1	61	396	5.1	33
30	2	54	352	4.5	29
30	3	47	324	3.9	27
Orthogonal contrasts					
10% skips NPL vs. 10% PL 1 week		NS	NS	NS	NS
10% skips NPL vs. 10% PL 2 weeks		*	**	**	**
10% skips NPL vs. 10% PL 3 weeks		NS	*	*	**
20% skips NPL vs. 20% PL 1 week		NS	NS	NS	NS
20% skips NPL vs. 20% PL 2 weeks		NS	NS	NS	*
20% skips NPL vs. 20% PL 3 weeks		NS	NS	NS	*
30% skips NPL vs. 30% PL 1 week		*	**	NS	NS
30% skips NPL vs. 30% PL 2 weeks		*	**	NS	NS
30% skips NPL vs. 30% PL 3 weeks		NS	NS	*	*

[z]Weeks following initial transplanting.
[y]NPL = Not replanted.
[x]Significantly different from the control at the 5% level.
NS,*,**Nonsignificant or significant at the 5% or 1% levels, respectively.

stand reduction that were replanted than in plots that were not replanted (Table 2).

Marketable fruit weights and numbers per plant were higher in the 30% stand-reduction plots that were not replanted than in comparable plots replanted 2 or 3 weeks after initial transplanting (Table 1). These greater yields per plant provided sufficient yield compensation so that fruit weights and numbers per hectare were about the same as those of 30% stand-reduction plots that were replanted. However, 30% stand-deficient plots that were not replanted still produced lower yields per hectare than those of control plots with complete stands.

Mean fruit size was similar for stand-deficient plots, whether replanted or not, regardless of the percentage of stand reduction or time of replanting (Table 2). However, plots with a stand reduction of 10% that were replanted 3 weeks after initial transplanting produced more weight of marketable small fruit than similar plots that were not replanted (Table 2). Weights per hectare of marketable large or extra-large fruit were similar in stand-deficient plots whether they were replanted or not (Table 2).

The spring experiment was grown in a favorable environment for tomato fruit production due to the absence of disease. Replanting incomplete stands in an environment favorable for plant growth did not improve tomato yields as compared to not replanting.

Fall experiment. Plots with stand reductions of 30% yielded significantly less marketable fruit weight and fewer fruit per hectare than control plots (Table 3). Marketable fruit weight and number per hectare were higher in plots with 30% stand reduction that were replanted 1 or 2 weeks after initial transplanting than in plots with 30% stand reduction that were not replanted (Table 3). We attribute the higher marketable fruit yields per hectare to more plants per plot with similar fruit yields per plant rather than higher yields per plants. Perhaps in the environment unfavorable for plant growth due to the presence

Table 4. Tomato fruit size as influenced by replanting plots with stand deficiencies during the fall season, 1986.

Stand reduction (%)	Time of replanting (weeks)[y]	Weight (t·ha⁻¹) Fruit size categories[z] Small	Medium	Large	Extra-large	Mean fruit size (g/fruit)
0 (control)		3.1	18	29	15	145
10	NPL[x]	2.9	17	32	17	150
10	1	2.9	15	31	26	154
10	2	3.1	17	21	11	145
10	3	2.5	14	25	15	145
20	NPL	1.8	15	27	14	145
20	1	1.8	15	29	19	150
20	2	2.1	14	27	16	150
20	3	2.7	15	25	14	145
30	NPL	1.9	11[w]	18[w]	14	150
30	1	1.8	13	26	20	154
30	2	1.9	14	22	16	154
30	3	2.3	13	19	12	141
Orthogonal contrasts						
10% skips NPL vs. 10% PL 1 week		NS	NS	NS	NS	NS
10% skips NPL vs. 10% PL 2 weeks		NS	NS	**	NS	NS
10% skips NPL vs. 10% PL 3 weeks		NS	NS	*	NS	NS
20% skips NPL vs. 20% PL 1 week		NS	NS	NS	NS	NS
20% skips NPL vs. 20% PL 2 weeks		NS	NS	NS	NS	NS
20% skips NPL vs. 20% PL 3 weeks		NS	NS	NS	NS	NS
30% skips NPL vs. 30% PL 1 week		NS	NS	*	NS	NS
30% skips NPL vs. 30% PL 2 weeks		NS	NS	NS	NS	NS
30% skips NPL vs. 30% PL 3 weeks		NS	NS	NS	NS	NS

[z]Size categories for small, large, and extra-large are 54–60, 60–65, 65–70, and >70-mm-diameter fruit, respectively.
[y]Weeks following initial transplanting.
[x]NPL = Not replanted.
[w]Significantly different from the control at the 5% level.
NS,*,**Nonsignificant or significant at the 5% or 1% levels, respectively.

of bacterial spot, the remaining plants in plots with stand deficiencies were not able to sufficiently compensate for fruit size or number per plant to obtain marketable yields per hectare equivalent to those in stand-deficient plots that were replanted. Replanting plots with a 30% stand reduction 3 weeks after initial transplanting did not improve marketable yields per hectare and reduced per-plant yields as compared with plots not replanted. This result suggests that the replants used 3 weeks after initial transplanting were acting as plant competitors (weeds), rather than as yield-contributing plants. These plants produced few or no marketable fruit, since the unfavorable environment apparently reduced plant growth and productivity, particularly late in the season, when these plants should have been at the peak of their fruit productivity. Plots with 10% stand reduction that were replanted 2 weeks after initial transplanting produced less marketable fruit weight and fewer fruits per hectare than plots with 10% stand reduction that were not replanted.

Per-plant marketable fruit weight and number in plots with 10% stand reduction that were replanted 2 or 3 weeks after initial transplanting and plots with 30% stand reduction that were replanted 3 weeks after initial transplanting were lower than in corresponding plots that were not replanted (Table 3). In plots with 20% stand reduction that were replanted 2 or 3 weeks after initial transplanting, only marketable fruit number per plant was lower than in similar plots that were not replanted. Mean fruit size was similar for plots with stand deficiencies whether they were replanted or not (Table 4). Weight per hectare of marketable large fruit was lower in plots with stand reduction of 10% that were replanted 2 and 3 weeks after initial transplanting than in corresponding plots that were not replanted (Table 4). Plots with stand reduction of 30% that were replanted 1 week after initial transplanting produced a higher weight per hectare of marketable large fruit than corresponding plots that were not replanted. Weights per hectare of marketable small, medium, or extra-large fruit were similar for plots with stand deficiencies whether they were replanted or not, regardless of the percentage of missing plants or time of replanting (Table 4).

The results obtained in spring suggest that replanting stands with deficiencies of 10% to 30% does not significantly improve marketable fruit weight, number, or size in environmental conditions favorable for tomato production as compared to not replanting. However, in a stressful environment, as occurred in fall, replanting stands with deficiencies of 30% 1 or 2 weeks after initial transplanting increased marketable tomato fruit weight and number per hectare as compared to not replanting. However, even in these condition, cost : benefit ratios should be calculated prior to implementation. Although input costs of replanting are relatively fixed, income is extremely variable within a production season and may or may not fluctuate with fruit size and grade. Therefore, these cost : benefit ratios must be calculated for several projected incomes.

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Influence of Orientation and Position of Fruiting Laterals on Canopy Light Penetration, Yield, and Fruit Quality of 'Granny Smith' Apple

D. Stuart Tustin and Peter M. Hirst
Division of Horticulture and Processing, Department of Scientific and Industrial Research, Private Bag, Havelock North, New Zealand

Ian J. Warrington
Plant Physiology Division, Department of Scientific and Industrial Research, Private Bag, Palmerston North, New Zealand

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Abstract. **Fruiting laterals were tagged within the inner and outer canopy zones of the basal, mid, and upper tiers of dormant, mature central-leader 'Granny Smith' apple (*Malus domestica* Borkh.) trees and were classified into pendant (>120°), horizontal (30°–120°), and vertical (0°–30°) types. Transmission of photosynthetic photon flux (PPF) to spur sites on tagged laterals was measured in mid-season and fruits from these sites were harvested at commercial maturity for assessment of fresh weight, soluble solids concentration (SSC), starch pattern index, and background color. Pendant laterals produced fewer, smaller, and greener fruit per flowering spur than horizontal or vertical laterals. Fruit fresh weight and soluble solids concentration increased with increasing height in the canopy and were higher in the outer compared with the inner horizontal canopy position. Background color followed a trend opposite to that of fresh weight and soluble solids concentration, with fruit from the lower inner canopy regions being greenest. Both fresh weight and SSC showed highly positive correlations with the percentage transmission of PPF. Fruit set showed a positive correlation with PPF, although the relationship was weaker than that for fresh weight or SSC. PPF penetration was lower to pendant laterals than to horizontal and vertical laterals and declined from upper to lower and from outer to inner canopy positions. Pendant fruiting laterals received <15% of PPF, irrespective of location within the canopy.**

'Granny Smith' is the most significant export cultivar in the New Zealand apple industry and accounts for >35% of production (19). Much of the production is derived from semi-intensive orchards, 10 to 20 years old, and trained as tiered central leaders (14, 15). The efficient production of uniformly high-quality fruit has become a major priority. With fewer new plantings and much of the crop now coming from mature orchards, the greatest opportunity for improving fruit quality lies in optimizing the performance of existing orchards.

The relationship between light interception, fruit quality, and yield of apples has been variously described (1, 6, 7, 9, 10, 16, 23, 25). Differences in fruit tree canopy form due to pruning and training methods can substantially modify light transmission to the various regions of the canopy (3, 4, 11, 21, 24). Fruit quality and yield have been found to vary with position in the canopy and to be closely correlated with light transmission

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