Cucumbers Planted Immediately after the Termination of a Nematode-resistant Tomato Cultivar Produce Higher Yields

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Summary. **In the southern United States, the polyethylene-mulched and drip-irrigated beds remaining after the last harvest of fresh-market tomatoes (Lycopersicon esculentum) offer the potential for producing a cucumber (Cucumis sativus) crop to increase grower profit. A 2-year study of double-cropping cucumbers with 'Celebrity' (nematode-resistant) and 'Heatwave' (nematode-susceptible) tomato cultivars was conducted at the Red River Research Station in northwestern Louisiana to assess the benefits of this system and to determine how soon cucumbers should be planted following the termination of the tomato crop. Results indicated that cucumbers planted after 'Celebrity' produced significantly greater premium and total yields per acre than did cucumbers planted after 'Heatwave'. Plant fresh weight of cucumbers was greater and the percentage of galled roots was smaller when planted after 'Celebrity' than when planted after 'Heatwave'. Planting dates had significant effects on cucumber yield. Cucumbers planted in early July, immediately after the termination of the tomato crop produced the highest yield. Cucumbers planted in early August, 1 month after terminating the tomato crop produced an intermediate yield, and cucumbers planted in September, 2 months after the termination of the tomato crop, produced the lowest yield. A gradual decline of plant fresh weight and a gradual increase of galled-root percentage resulted from delaying cucumber planting beyond the July month. Year of planting had no significant effect on cucumber productivity, but it did influence plant fresh weight and the percentage of galled roots significantly. Average minimum temperature in September was lower than the minimum safe temperature for growing cucumbers. The combined effect of higher temperature and lower percentage of galled roots may have contributed to the increased yield of cucumbers planted in July.**

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Root-knot nematode (Meloidogyne incognita) causes significant losses in cucumber yield. Recent estimates by St. Amand and Wehner (1991) indicated that root knot causes an average annual yield loss of 11% in North Carolina. Development of tomato cultivars resistant to root-knot nematodes has proven to be an effective, economical, and environmentally safe means of reducing loss from this pest. Considerable effort has been dedicated to breeding for similar resistance in cucumbers, but limited progress has been realized (Fassuliotis, 1967, 1970, 1979, 1982; Fassuliotis and Rau, 1963; Walters et al., 1993). Currently, using nematicides is the method of choice to control root-knot nematodes in cucumbers. However, Hanna et al. (1994) found that planting cucumbers following nematode-resistant tomatoes was as good or better than using nematicides to manage this pest.

In the southern United States, thousands of acres (1.0 acre = 0.405 ha) of fresh-market tomatoes are planted annually on polyethylene-mulched and drip-irrigated beds. The spring tomato crop in Louisiana, Mississippi, and Alabama is transplanted in late March or early April and terminated in late June or early July. Producing a second short-season crop such as cucumbers following tomatoes on these beds is feasible and may help tomato growers increase profit from additional use of the irrigation and mulch system already in place.

According to Lorenz and Maynard (1988), cucumber is a warm season crop requiring a temperature range of 60 to 90 °F (15.6 to 32.2 °C) . Hanna et al. (1994) found that cucumbers grown for 74 to 79 d at temperature range of 63.9 to 87.8 °F (17.7 to 31.0 °C) from seeding to termination produced good yields.

Field preparation following the termination of a tomato crop is time consuming and may delay planting cucumbers for weeks or even months. It is not known how long the residual beneficial effect will remain in the soil after terminating a nematode-resistant tomato crop. Also, the growing season following the termination of a tomato crop in late June or early July may not be long enough especially in northern Louisiana, Mississippi, and Alabama for cucumbers to grow under the temperature range defined by Lorenz and Maynard (1998). This study was conducted in 1995 and 1996 to evaluate cucumber yield planted at three dates, separated by 1 month each, following the termination of nematode-resistant and susceptible tomato cultivars.

Materials and methods

'Celebrity' (nematode-resistant) and 'Heatwave' (nematode-susceptible) tomato cultivars were transplanted on equal numbers of black polyethylene mulched and drip-irrigated plots (raised beds) of size 5 × 33 ft (1.5 × 10 m) in early Apr. 1995 and 1996. Fertilizer rates and other cultural practices consisted of standard recommendations for growing staked tomatoes for fresh market production in Louisiana (Boudreaux, 1998). Following the last harvest of tomatoes in late June, plots were sprayed with glyphosate (a.i.) at 3.0 lb/acre (3.4 kg·ha^{-1}) to kill tomato plants and other existing vegetation. Plots were cleared of plant debris and remained fallow for 0, 1 , and 2 months before planting cucumbers as a second crop. 'Dasher II' cucumbers were seeded at 12- inch (30-cm) in-row spacing during the first week of July, August, and September, 1995 and 1996 on the cleared plots. The experimental design was a 2 × 3 factorial, arranged in a randomized complete block with three replications in each year. Treatments were 1) cucumbers planted after nematode-resistant and-susceptible tomato cultivars and 2) cucumbers planted during the

Table 1. Influence of previous tomato cultivar and planting dates on growth and yield of cucumbers planted as a second crop in 2 years.

Treatment	Yield (tons/acre)[z] Premium	Yield (tons/acre)[z] Total	Culls (%)	Fresh wt (lb/plant)	Galled roots (%)
Previous tomato cultivar (C)					
Nematode-resistant	15.6	19.9	9.5	1.30	40.2
Nematode-susceptible	11.1	14.1	11.6	0.99	58.5
Significance	*	***	NS	**	*
Cucumber planting dates[y] (D)					
July	19.6 a[x]	24.0 a	12.4 a	1.43 a	31.0 c
August	15.4 b	20.0 b	11.3 a	1.29 a	45.4 b
September	5.1 c	7.0 c	7.9 b	0.71 b	71.7 a
Year of planting (Y)					
1995	13.5	16.4	10.7	1.39	54.3
1996	13.2	17.5	10.4	0.90	44.4
Significance	NS	NS	NS	***	**
Interactions					
C × D	NS	NS	*	**	NS
C × D × Y	NS	NS	*	**	NS

[z]1.0 ton/acre = 2.24 t·ha^{-1}; 1.00 lb = 0.45 kg.
[y]Cucumbers were planted during the first week of each month in both years, i.e., soon, 1 month later, and 2 month later following the termination of the tomato crop.
[x]Values followed by the same letter within columns are not significantly different according to the least significant test at $P \leq 0.05$.
[w]Premium = USDA Grade Fancy + USDA Grade No. 1 (USDA, 1958).
[NS,*,**,***]Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

first week of July, August, and September, i.e., after 0 (immediately), 1 month, and 2 months following the termination of the tomato crop in each year. Plants were trained vertically using existing tomato stakes for support (Hanna, 1993) and were fertilized by injecting 12.5 lb/acre (14 kg·ha^{-1}) of N through the drip irrigation system when cucumber plants reached the third-leaf stage. Two more applications of equal amounts were made at 3-week intervals following the first application. Cucumbers were harvested three times each week for 2 to 4 weeks. Fruit were graded according to U.S Dept. of Agriculture (USDA) standards (USDA, 1958) for U.S. Fancy, No. 1, No. 2, and culls. Premium yield was determined by combining the weight of fruit graded Fancy and No. 1. Total yield was the sum of fruit graded Fancy, No. 1, and No. 2 by weight. All plants in each plot were removed without root or fruit after the last harvest and plant fresh weight was determined. The root system of each plant was carefully removed and freed from sand and/or dirt. Healthy roots were separated from galled ones, and the percentage of galled roots was calculated. Data were subjected to analysis of variance (SAS Institute, 1994).

Results and discussion

Cucumbers planted after the nematode-resistant tomato cultivar, Celebrity, produced significantly higher premium and total yields per acre than did those planted after the nematode-susceptible tomato cultivar, Heatwave (Table 1). The percentage of culls was not significantly affected by treatment. Cucumbers planted after the nematode-resistant tomato cultivar produced greater plant fresh weight and a lower percentage of galled roots compared to cucumbers following the nematode-susceptible tomato cultivar (Table 1).

Premium and total yields of cucumber decreased and percentage of galled roots increased significantly as time of planting was delayed 1 or 2 month(s) following the termination of the tomato crop. Percentage of culls and fresh weight per plant also declined significantly but only when cucumber was planted 2 months later, i.e., in September (Table 1). Cucumbers planted immediately (July) after the termination of the tomato crop yielded more than cucumbers planted 1 month later (August). Cucumbers planted 2 months later (September) produced the least premium and total yields, percentage of culls, fresh weight, and the highest percentage of galled roots (Table 1).

The year of planting cucumber had no significant effect on their yield

Table 2. Planting and termination dates, length of growing period, and prevailing air temperature during cucumber production in 2 years.

Planting[y] dates	Termination dates	Growing period (d)	Air temp (°F)[z] Avg min 1995	Avg min 1996	Avg max 1995	Avg max 1996	Range 1995	Range 1996
July	8–11 Sept.	70–73	72	71	96	91	63–104	59–99
August	10–13 Oct.	71–74	66	66	92	87	45–104	49–95
September	1–7 Nov.	62–68	56	57	84	80	35–104	36–94
Safe temperature range[x]							60–90	60–90

[z]°C = 5/9(°F – 32).
[y]Cucumbers were planted during the first week of each month in both years.
[x]After Lorenz and Maynard, 1988.

or production of culls. However, cucumbers produced heavier plants and more galled roots in 1995 compared with 1996 (Table 1).

There were no previous tomato cultivar × cucumber planting date significant interactions except for percentage of culls and plant fresh weight. Three way interactions of previous tomato cultivar × cucumber planting date × year of planting followed the same trend (Table 1).

Weather data in Table 2 indicate that the average, minimum, and maximum temperatures for the July crop in northwestern Louisiana were higher than for August or September crop. In fact, cucumbers planted in August were exposed to temperatures (°F) in the 40s (4.4 to 9.4 °C) for a few days and cucumbers planted in September were exposed to temperature in the 30s (–1.1 to 3.9 °C) (Table 2). Prevalent low temperatures for July were very close to the lower end of the range defined by Lorenz and Maynard (1988). Subjecting August and September crops to low temperatures even for a short time may have contributed to the yield decline. Also, the increased percentage of galled roots as the time of planting cucumber was delayed beyond July was a good indication that cucumber protection offered by the previous nematode-resistant tomato crop was weakening. The increase in galled roots may have reduced cucumber growth and yield (Table 1).

Average maximum temperature in 1995 was some what higher than in 1996 (Table 2) and that may have helped cucumbers to overcome the effect of more root galling in 1995 and produce heavier plants.

Considerable effort has been made to breed for root-knot nematode resistance in Cucumis species, but limited progress has been made (Fassuliotis, 1967; Nugent and Dukes, 1997). Other alternatives to chemical control of root-knot nematode in Cucumis species are needed. Those alternatives include improved cultural methods. The results of this study and a previous study (Hanna et al., 1994) indicate that double-cropping cucumbers with a nematode-resistant tomato cultivar can be an effective cultural method to improve cucumber yields in soils that have a history of root-knot nematode infestation. It appears from these studies that cucumbers planted immediately after terminating the tomato crop realized the maximum benefit from the previous nematode-resistant tomato cultivar. It is also obvious that cucumbers given enough time to complete their life cycle under a higher temperature range produced more yield than did cucumbers that completed their life cycle under a cooler range. Cucumbers planted in September were subject to the lowest temperature and produced the least healthy roots, fresh weight, and yield.

Results of this study should encourage tomato growers to consider the numerous benefits of planting cucumber as a second crop following nematode-resistant tomatoes in soils susceptible to nematode infestation. Benefits include improving cucumber yield without chemical control, reduced overhead costs by using the polyethylene mulch, drip irrigation, and trellising system for both crops. Residual fertilizer remaining in the soil after the termination of tomato harvest can be used by the cucumber crop and reduces the need for additional application. Cucumber growers should make every effort to plant cucumbers following nematode-resistant tomatoes as early as possible in July to maximize cucumber yields.

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