EFFECTS OF PLANT POPULATIONS, FERTILIZER RATES ON TOMATO YIELDS ON ROCKDALE SOIL

H. H. Bryan and J. W. Strobel

University of Florida, IFAS
Sub-Tropical Experiment Station
Homestead

J. D. Dalton

Associate County Agent
Agricultural Extension Service
Homestead

Abstract

A replicated factorial experiment using five populations, three fertilizer rates and two tomato breeding lines on black-plastic mulch was conducted in a commercial field on Dade County Rockdale soil in late spring under water stress conditions. The low fertilizer rate (1650 lbs of 8-13-16-2/acre) produced highest early yield, and total marketable yields were not increased by adding more fertilizer. Size of marketable fruit was reduced with higher fertilizer rates. Early and total marketable yields increased with population increments up to 25,000 plants per acre, then dropped. Early fruit size was smaller in plots of 25,000 plants per acre or more, and fruit size for the total yield was largest at 12,000. Plants in plots with low fertilizer rates or high plant populations were chlorotic at final harvest.

Introduction

It has been shown that increasing plant density in crops of tomatoes and other vegetables result in increased yields (2, 4, 5, 6, 10). There has been considerable doubt that this could be accomplished with tomatoes in Florida because of disease problems associated with lush vegetative development and variable conditions resulting from erratic occurrence of excessive rainfall, widely fluctuating temperatures and related climatic factors. Use of plastic mulch as proposed by Geraldson (1) offers a method for avoiding some of these problems. However, with the availability of multiple-disease resistant, determinate tomato varieties (7, 8) and the prospect of even more compact determinates now being developed for machine harvest (9), it has become apparent that increased plant populations will be necessary for profitable yields in the face of increased costs of production and harvesting. Maximum yields will be required for once-over machine harvest to be profitable.

Experimental Methods

A factorial experiment comparing five populations of plants, two tomato stocks and three fertilizer rates was conducted on black plastic mulch in a commercial field on Rockdale soil. Populations were 6,200, 12,400, 18,700, 24,900 and 31,100 plants per acre (1, 2, 3, 4 and 5 rows per bed with plants 12 inches apart in each row). Fertilizer rates were 1650 3300 and 4950 pounds of 8-13-16-2-1-.2 (N-P_2O_5-K_2O-MgO-MnO-B_2O_3) per acre. The tomato stocks tested were 857-9-DBk-DBk-FP9-DBk CAVStW and 183-D2-D3-D3-DBk-DBk CAVStW; the 857 stock is a sister line of Tropi-Red and 183 is related to Tropi-Gro. Treatments were replicated four times with the exception of the high and low plant populations which were replicated only twice.

On January 18, previously formed 4 foot wide beds on seven foot centers were fertilized, drenched with nabam, then fumigated with EDB immediately before mulching with 1.5 mil black polyethylene. The entire amount of fertilizer was broadcast by hand in a 4 foot strip on the bed surface and incorporated with a tractor rototiller. The nabam drench was applied in a three foot band at 90 pounds of nabam in 1000 gallons of water for each broadcast acre. The EDB was injected through five chisels spaced 8 inches apart at a rate of 6 gallons per broadcast acre. Month old plants in peat pots were dipped in a solution of 20-20-20 fertilizer and transplanted through the mulch by hand on January 23 to 25. All operations, except application and incorporation of fertilizer and hand transplanting were standard grower procedures. The grower used 3300 pounds of the fertilizer described above and 8,300 plants per acre for his commercial operation. Weather conditions during the growing season were hot, dry and windy, which made optimum watering impossible.

Florida Agricultural Experiment Stations Journal Series No. 2839.

Table 1. Effects of fertilizer rate, plant population and variety on the yield of tomatoes grown on plastic mulch and on significant treatment interactions.

Main Effects	Mature-green		Pink	Total	Cull
	Early	Total		Marketable[†]	
Fertilizer Rate	(cwt/A)	(cwt/A)	(cwt/A)	(cwt/A)	(cwt/A)
(lb/acre)	**L-12				
1650	136	265	46	311	43
3300	127	275	51	326	45
4950	112	263	50	313	37
Population					
(plants/acre)	**Q	**Q	**I		**Q
6,200	49	183	30	213	23
12,400	124	275	32	307	42
18,700	141	284	47	331	47
24,900	159	300	57	357	48
31,100	101	240	89	329	36
Variety		*	*I		**
857	129	276	53	329	43
183	120	259	45	304	36

Significant Interactions (I) PINK YIELD (cwt/acre) - Variety X Population

Variety Population:	6,200	12,400	18,700	24,900	31,100
857	32	32	47	62	108
183	29	32	47	51	70

† Analysis of variance not determined for total marketable yield.

* Significant at the 5% level.

** Significant at the 1% level: negative linear (L^-) and quadratic (Q) responses (Table 5).

Table 2. Effects of fertilizer rate, plant population and variety on the size and leaf chlorosis of tomatoes grown on plastic mulch.

Main Effects	Mature-green		Pink	Total	Leaf
	Early	Total		Marketable†	Chlorosis
Fertilizer Rate	(lb/frt)	(lb/frt)	(lb/frt)	(lb/frt)	(rating)††
(lb/acre)		**L⁻.005			**
1650	.271	.236	.232	.235	1.8
3300	.266	.231	.238	.232	3.9
4950	.266	.225	.230	.226	5.0
Population					
(plants/acre)	*L⁻.005				**
6,200	.271	.223	.235	.224	4.5
12,400	.276	.235	.235	.235	3.8
18,700	.270	.232	.232	.232	3.6
24,900	.260	.231	.229	.230	3.2
31,100	.258	.226	.239	.229	2.8
Variety					
857	.269	.233	.232	.233	3.5
183	.266	.228	.235	.229	3.7

† Analysis of variance not determined for total marketable size.

†† Rating: 1 = yellow (very chlorotic), 3 = greenish yellow, 5 = dark green (no chlorosis).

* Significant at the 5% level.

** Significant at the 1% level: negative linear (L⁻) and Quadratic (Q) responses (Table 5).

Mature-green, pink, marketable and cull fruit were harvested, counted and weighed April 5, 17 and May 2. Post-harvest ripening studies on mature-green tomatoes harvested April 17 were conducted at Gainesville. Fruit were ripened at 68F for 21 days and observed at three day intervals. Ripe fruit were evaluated externally for blotch, desiccation, and black shoulder, and internally for puffiness, green-gel, green-wall, white-wall and black seeds.

Leaf chlorosis ratings were made after the final harvest. Samples were taken from soil under the planting hole and from soil under the mulch two months after the final harvest to

Table 3. Effect of fertilizer rate and variety on the incidence of puffy and blotched fruit grown on plastic mulch.

Main Effect	Puffy Fruit		Blotched Fruit	
Variety:	857	183	857	183
Fertilizer Rate	(%)	(%)	(%)	(%)
(lb/acre)				
1650	2	37	13	31
3300	3	28	13	25
4950	2	19	10	26
Variety means:	2	28	12	27

determine residual nutrient levels. Four samples, 0 to 4 inches deep, from each sampling site in each plot were combined for the analyses.

Results and Discussion

Highest early yields were from plants grown at the low fertilizer rate (1650 lbs/arce) and marketable yields were not increased by adding more fertilizer (Table 1). Yields decreased 1200 pounds per acre for every 1650 lb/acre increase in fertilizer. Mature-green, total and cull yields increased significantly with population increments up to 24,900 plants/acre then decreased in a quadratic response, but pink yields increased

Table 4. Effect of fertilizer rate and location of soil sample on the soil analysis (water extraction) 2 months after the last harvest of tomatoes grown on plastic mulch.

Main Effect	Nutrient Levels			Soil Reaction
	NO_3-N	P	K	
Fertilizer Rate	(ppm)	(ppm)	(ppm)	(pH)
(lb/acre)				
1650	68	9	214	7.5
3300	110	10	326	7.5
4950	234	16	834	7.4
Sample Location				
Planting hole	27	10	43	7.6
Under mulch	248	14	873	7.3
Adequate soil levels *	65 to 75	5 to 10	150 to 175	

* Adequate soil levels according to Llewellyn (3).

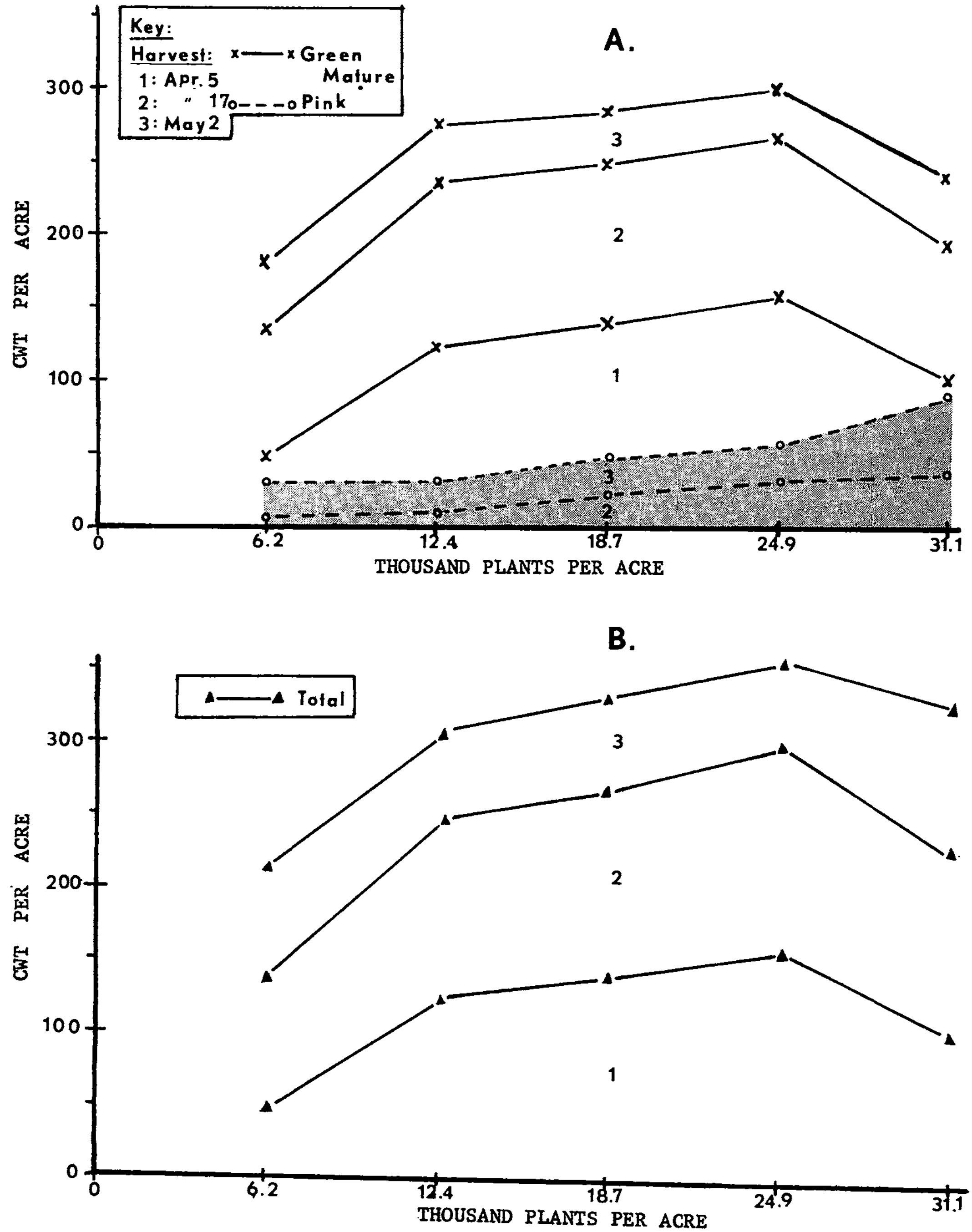

Fig. 1.—Mature green, pink and total marketable tomato yields for 3 harvest dates at 5 plant populations.

with increasing population increments up to 31,100 plants/acre. Estimates from the regression equations indicate maximum mature-green and cull yields at about 21,000 plants per acre (Table 5). A significant variety x population size interaction was detected for pink yield (Table 5). The highest population for each variety yielded the greatest weight of pink fruit; however, pink yields of 857 increased more rapidly (in a quadratic trend) with increasing population above 18,700 plants/acre than 183, which showed a more linear increase in yield with increasing population size (Table 1). No interactions occurred for other yield data (Table 5). Variety 857 had higher yields than 183 (Table 1). Yield: Population curves for mature-green and total yields at each harvest date were almost parallel (Figure 1), thus, a destructive machine harvest any time between the first and the third harvests should provide the same general yield response to various populations.

Average mature-green fruit size decreased linearly at the rate of 0.005 pound/fruit for every 1650 lbs/acre of added fertilizer (Table 2). Early mature-green fruit decreased linearly at the rate of 0.005 pound/fruit for each 6200 plants/acre increment increase. Largest marketable fruit were produced with 12,400 plants/acre and fruit size decreased gradually with increasing populations. Small fruit size at higher populations was probably due to overcrowding and increased competition for light, nutrients and water (factors that may also account for increased yields of pink fruit). Small fruit size at the low plant density was likely due to moisture deficiency resulting from fewer planting holes in the mulch through which water could enter. Since horizontal water movement through Rockdale soil is insignificant, it is important to provide for water entry through the mulch, but not to the extent that excessive fertilizer leaching occurs. No interaction of treat-

Table 5. Analysis of variance - mean squares - for the effects of fertilizer rate, plant population and variety on the yield, size and leaf chlorosis of tomatoes grown on plastic mulch (and coefficients for the regression equation ($Y=\beta_0+\beta_1 Z+\beta_{11} Z^2$) for significant fertilizer and population responses.

Source	df	Yield				Fruit Size +			Leaf Chlorosis
		Mature-Green				Mature-Green			
		Early	Total	Pink	Cull	Early	Total	Pink	
Replicate	3	3899.8**	2398.3	482.7	354.4	4.113	3.515	16.007	0.89
Fertilizer(F)	2	4776.3**	1239.9	184.4	618.6	2.592	9.608**	4.872	61.64**
Population(P)	4	27435.5**	31936.2**	7902.0**	1538.5**	11.183*	3.563	2.198	4.73**
Variety(V)	1	1709.7	7176.0*	1487.4*	3383.5**	3.028	4.662	1.222	0.51
F x V	2	214.2	803.6	99.4	117.6	1.055	0.627	1.012	0.20
P x V	4	920.1	1010.7	670.8*	26.3	0.780	1.428	4.294	0.11
F x P	8	363.4	1146.8	219.4	90.0	0.877	0.404	3.355	1.91
V x F x P	8	723.2	1363.2	108.9	63.5	1.056	0.618	9.212	0.09
Error	63	437.1	1114.3	228.4	213.9	3.452	1.719	6.389	0.36

Coefficients for Regression Equations

	A. Fertilizer Rate			Stationary Point	B. Population Size			Stationary Point
	b_0	b_1	b_{11}		b_0	b_1	b_{11}	
Yield								
Early Mat.-Gr.:	124.7	-12.1			152.3	14.5	-18.4	21143 Max.
Total " " :					298.4	13.7	-20.5	20783 Max.
Cull :					49.04	2.94	- 4.75	20622 Max.
Size								
Early Mat.-Gr.:					.268	-.005		
Total " " :	.231	-.005			.234	-.0008	.002	18359 Max.

+ Mean squares must be multiplied by 10^{-4}

* Statistically significant at the 5% level

** Statistically significant at the 1% level

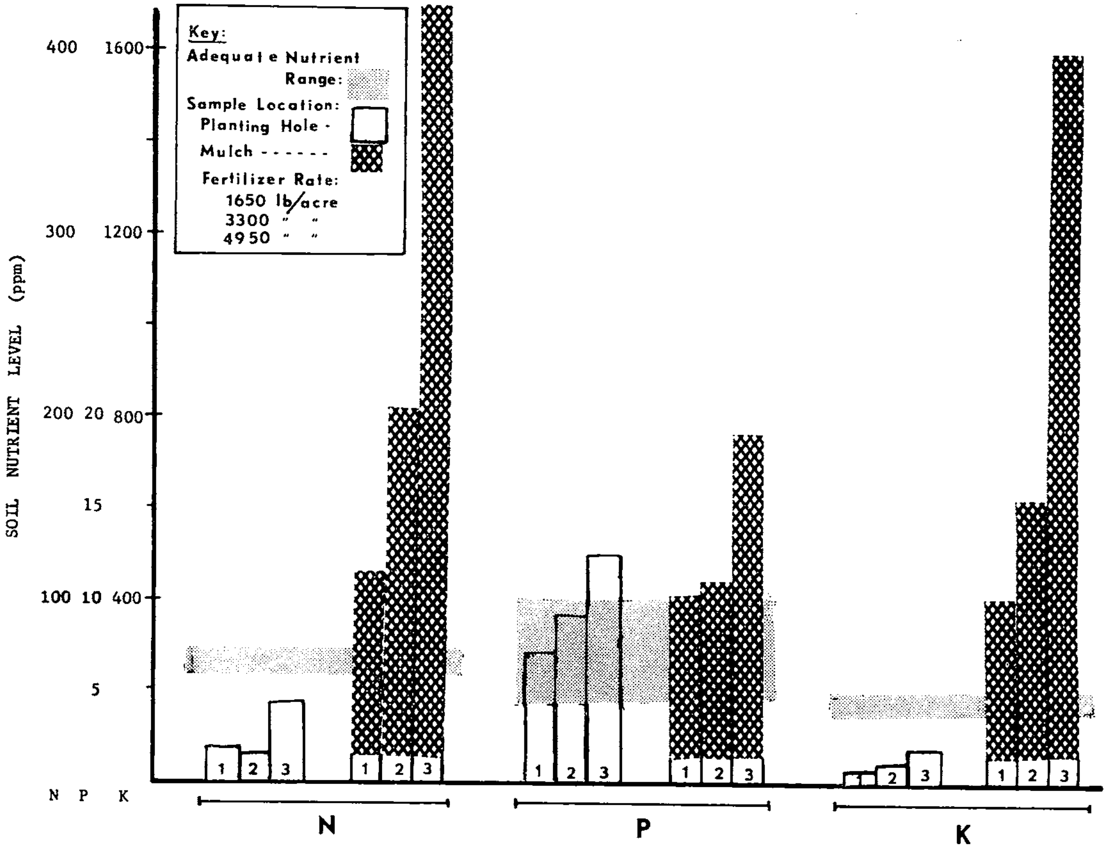

Figure 2. Effect of fertilizer rate and soil sample location on the soil nutrient level 2 months after final harvest.

ments occurred for fruit size (Table 5).

More puffy (air pockets in locular areas) fruit occurred in stock 183 grown at the low fertility rate than at higher fertility rates and there were more puffy and blotched 183 fruit than 857 fruit (Table 3). Amounts of fruit desiccation, black-shoulder, green-gel, green-wall, white-wall and black seed were disorders not affected by treatments. Treatments had no effect on fruit ripening.

Plants in plots with low fertility and high plant populations were chlorotic after final harvest (Table 2), indicating depletion of available nutrients for this crop. However, high yield and large fruit size from low fertility plots indicated that enough nutrients were present for fruit production, but higher nutrient levels provided better vine growth, later fruit maturity and smaller fruit size. Analysis of soil samples taken two months after harvest showed that sufficient nutrients remained under the mulch for a second crop for all fertilizer treatments (Figure 2 and Table 4). The soil pH was lower under the mulch than it was under the planting hole. Nitrogen and potassium were 9 and 20 times greater, respectively, under the mulch than under the planting hole (Table 4). Enough fertilizer remained under the mulch to allow luxury nutrient consumption of N, P and K for a second crop at all fertilizer rates according to levels suggested by Llewellyn (3). A second crop is planted at this time.

ACKNOWLEDGMENTS

The authors wish to acknowledge and express appreciation for the fertilizer, equipment, material, land, and cultural practices provided by Mr. Robin Bryant; the post-harvest evaluations made by Dr. D. D. Gull, Associate Horticulturist, Vegetable Crops Department, University of Florida, and the statistical analysis provided by Dr. F. G. Martin, Statistics Department, University of Florida.

LITERATURE CITED

1. Geraldson, C. M. 1962. Growing tomatoes and cucumbers with high analysis fertilizer and plastic mulch. Proc. Fla. Sta. Hort. Soc. 75: 253-260.

2. Halsey, L. H., 1959. Watermelon spacing and fertilization. Proc. Fla. Sta. Hort. Soc. 72: 131-135.

3. Llewellyn, W. R. 1963. Soil testing in southern Dade County. Agric. Ext. Ser., County Agents Office, Homestead, 16 pages.

4. MacGillivray, J. H., et al. 1952. Spacing effect on the yield of green lima beans for freezing. Proc. Am. Soc. Hort. Sci. 60: 330-334.

5. Peterson, L. E. 1961. The varietal response of sweet potatoes to changing levels of irrigation, fertilizer and plant spacing. Proc. Am. Soc. Hort. Sci. 77: 452-457.

6. Reeve, E. and W. A. Schmidt. 1952. Influence of plant spacing on canning tomato yields. Proc. Am. Soc. Hort. Sci. 59: 384-388.

7. Strobel, J. W., J. M. Walter, N. C. Hayslip. 1967. 'Tropi-Red' a determinate tomato with excellent color and multiple disease resistances. U. of Fla. Agr. Exp. Sta. Circ. S-182.

8. Strobel, J. W. 1967. 'Tropi-Gro' a determinate tomato with a new combination of disease resistances. U. of Fla. Agr. Exp. Sta. Circ. S-183.

9. Strobel, J. W. 1967. Breeding fresh market tomato varieties for mechanical harvest. Sunshine State Agricultural Research Report (In press).

10. Vittum, M. T. and W. T. Tapley. 1953. Spacing and fertility level studies with a determinate-type tomato. Proc. Am. Soc. Hort. Sci. 61: 339-342.

EFFICACY OF SOME EXPERIMENTAL NEMATICIDES APPLIED IN-THE-ROW ON VEGETABLES

H. L. RHOADES
Central Florida Experiment Station
Sanford

J. F. BEEMAN
Sylvania Electric Products Inc.
Towanda, Pennsylvania

ABSTRACT

Several experimental nematicides were applied in-the-row on cabbage, celery, cucumbers, snap beans, and sweet corn in comparison with a standard broadcast application of D-D and untreated check plots. Those that gave effective nematode control and increased crop yields on one or more crops were Dasanit, Niagara 10242, Thimet, Temik, TH 336-N, and Zinophos.

INTRODUCTION

Dichloropropene-dichloropropane (D-D) and ethylene dibromide (EDB) became available in the mid 1940's and dibromochloropropane (DBCP) in the early 1950's as soil fumigant type nematicides. Since their introductions, these three materials have been the primary nematicides used in vegetable production.

Both D-D and EDB are highly effective nematicides but are relatively expensive and special injection equipment is required for their application. Also, they are generally phytotoxic and a waiting period of two weeks or more is usually required after application to allow them to escape from the soil before planting.

DBCP is relatively non-phytotoxic to most crops and can, therefore, be applied pre-plant, at the time of planting, or post-plant. However, it has been less consistent than D-D or EDB in its performance and is phytotoxic to certain crops including onion, pepper, and potato.

In 1957, the American Cyanamid Company produced a highly effective (5) experimental nematicide numbered EN 18133 (eventually given the trade name of Zinophos). Since that time, several other chemical companies have made available for research purposes effective and essentially non-phytotoxic experimental nematicides. The purpose of the experiments reported here was to determine the efficacy of several of the more promising of these experimental nematicides when applied at low rates in-the-row just prior to planting various vegetable crops.

MATERIALS AND METHODS

All experiments were conducted on the Central Florida Experiment Station research farm at Sanford, Florida on Leon fine sand, or a very similar series, infested with one or more of the following nematode species: sting (*Belonolai-*

Florida Agricultural Experiment Stations Journal Series No. 2811.