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Row Arrangement, Plant Spacing, and Nitrogen Rate Effects on Zucchini Squash Yield

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Additional index words. *Cucurbita pepo*, plant density

Abstract. **Two field studies were conducted in Fall 1982 and Spring 1983 to evaluate two row arrangements (single vs. double rows per bed), four within-row plant spacings (0.30, 0.45, 0.60, and 0.75 m), and three N rates for zucchini squash (*Cucurbita pepo* var. *melopepo* L.) grown on sandy soils. Rates of 67, 134, and 202 kg N/ha were used in the fall, while 134, 202, and 268 kg N/ha were used in spring to determine the optimum levels of N for the higher population densities. Early and total marketable yields were higher with double rows in the spring experiment. Decreasing in-row plant spacing from 0.75 to 0.30 m increased total yield in both experiments, but decreased early yield in the fall experiment. Total yields increased as the N rate increased from 67 to 202 kg·ha^{-1}, but then decreased at 268 kg·ha^{-1}. Combinations of row arrangements and within-row plant spacings allowed testing of seven populations ranging from 11,111 to 55,556 plants/ha. The overall response of yield to increasing plant densities was linear in the fall, but quadratic in the spring, when the higher rates of N were used.**

Although summer squash is commonly grown with plant spacing ranging from 0.30 to 0.60 m and row spacing of 0.9 to 1.2 m (11), little has been reported concerning the effect of spacing (plant density) on squash yield. Brown (5), working with crookneck squash, planted at four densities that ranged from 0.23 to 0.58 m^2/plant and found that the higher the plant density, the higher the marketable yield obtained; however, early yield was lowest with 0.23 m^2/plant. Bradley and Rhodes (3) reported larger marketable yields of summer squash with spacings of 0.30 and 0.60 m between plants in the row than with a 0.90-m spacing. The relationship between plant density and yield of fruiting crops was classified as parabolic (8): Yield increased to a maximum but decreased at a very high plant density. Several researchers have reported increased squash yield with increases in fertilizer rates (3, 13–15). Robertson and Young (12) reported maximum squash yield with the application of 146 kg N/ha on a Norfolk loamy fine sand. We evaluated row arrangement, plant spacing, nitrogen rate, and population density on zucchini squash yield.

Experiments were conducted at the IFAS Horticultural Unit, Gainesville, Fla. on a Mulat fine sand (loamy, siliceous, Thermic Typic Ochraguult) in Fall 1982 and Spring 1983. We used a factorial combination of two row arrangements, four plant spacings, and three N rates in a randomized complete block design with four replicates in the fall and three replicates in the spring. Treatment plots were 5 m long by 1.2 m wide. Soils were fumigated 3 weeks before planting with DD 1,2-dichloropropane, 1,3-dichloropropene (DD) at 55 liters·ha^{-1}.

In fall all of the fertilizer was applied preplant at rates of 67, 134, or 202 kg N/ha plus 88 kg P and 168 kg K/ha. In spring, 134, 202, or 268 kg N/ha plus 88 kg P and 168 kg K/ha, with 60% of the N applied preplant and the remainder applied 4 weeks postplanting on bed shoulders 0.20 m from center was applied. The fertilizer was derived from ammonium nitrate, triple superphosphate, and potassium sulfate. Beds 0.20 m high, 0.61 m wide, spaced 1.2 m center to center, were prepared before planting. Seeds of 'Senator' squash were planted on 21 Sept. 1982 for the fall experiment and on 17 Apr. 1983 for the spring experiment. Single rows were planted by hand with two seeds per hill. Double-row treatments were planted similarly, with the rows spaced 0.30 m apart and the seed hills staggered. The hills were thinned to a single plant 21 days after planting. Spacings were 0.30, 0.45, 0.60, and 0.75 m between plants within rows. Irrigation was provided by overhead sprinkler to supple-

Table 1. Effects of row arrangement, plant spacing, and rate of N application on early and total marketable yield of zuccini squash.

Treatment	Fall yield (t·ha^{-1}) Early	Fall yield (t·ha^{-1}) Total	Spring yield (t·ha^{-1}) Early	Spring yield (t·ha^{-1}) Total
Row arrangement				
Single row	5.4	11.2	7.5	19.4
Double row	5.6	11.9	9.7	24.0
F value	NS	**	**	**
Plant spacing (m)				
0.30	5.2	12.0	8.2	23.1
0.45	5.5	11.7	8.4	22.2
0.60	5.5	11.4	8.7	21.2
0.75	5.8	11.1	9.1	20.5
F value	L**	L**	NS	L*
Nitrogen rate (kg·ha^{-1})				
67	5.0	8.7	---	---
134	5.4	12.0	7.6	18.0
202	6.2	14.0	9.1	24.9
268	---	---	9.2	22.5
F value	L**	L**	L**	L**Q**
Interactions				
Row × spacing	NS	NS	NS	NS
Row × nitrogen	**	**	NS	NS
Spacing × nitrogen	NS	**	NS	NS
Row × spacing × nitrogen	NS	NS	NS	NS

NS,*,**Effects were nonsignificant or significant at the 5% (*) or 1% (**) levels, respectively. For plant spacing and nitrogen rate, the effects were linear (L) or quadratic (Q).

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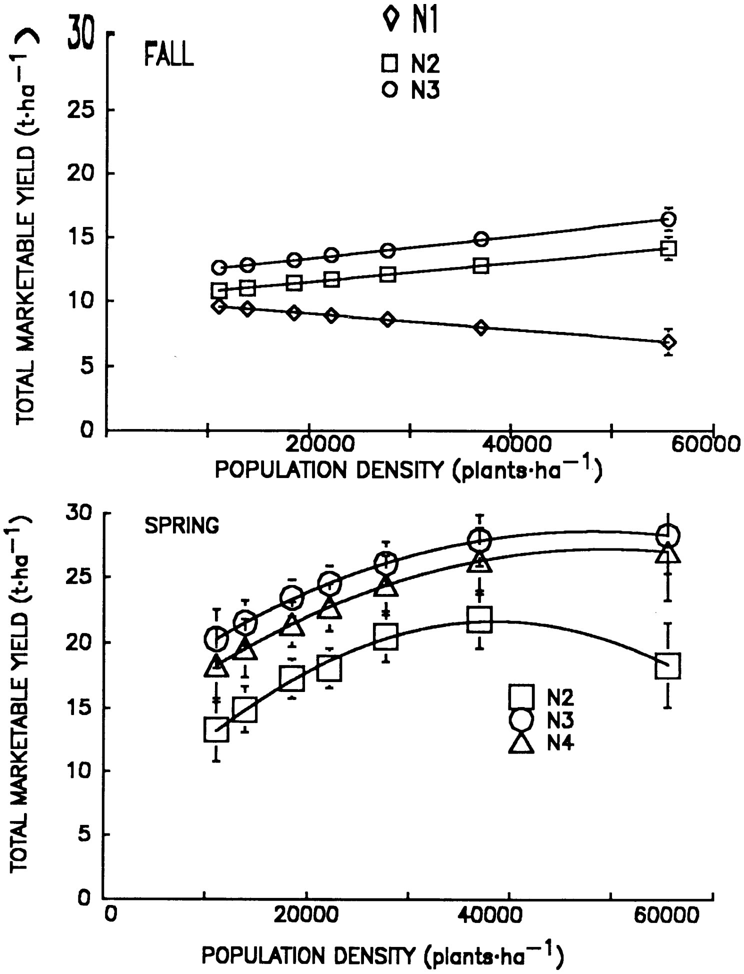

Fig. 1. Relationships between plant populations and total marketable yield in response to various rates of N in experiments conducted in fall and spring. N1, 2, 3 and 4: 67, 134, 202, and 268 kg N/ha, respectively. Regression equations for the lines shown were as follows: Fall: N_1: $y = 10.2 - 0.00006x$, ($R^2 = 0.37$); N_2: $y = 9.9 + 0.00008x$, ($R^2 = 0.52$); N_3: $y = 11.6 + 0.00009x$, ($R^2 = 0.64$). Spring: N2: $y = 4.9 + 0.0009x - 0.000000012x^2$, ($R^2 = 0.54$); N3: $y = 14.5 + 0.0006x - 0.00000000061x^2$, ($R^2 = 0.61$); N4: $y = 12.4 + 0.0006x - 0.0000000060x^2$, ($R^2 = 0.51$).

Table 2. Early and total marketable yield for fall crop of zuccini squash as a function of row arrangement and nitrogen levels[z].

Nitrogen rate	Early yield (t·ha⁻¹)			Total yield (t·ha⁻¹)		
	Row arrangement			Row arrangement		
(kg·ha⁻¹)	Single	Double	LSD[y]	Single	Double	LSD[y]
67	5.1	4.8	1.2	9.0	8.3	2.1
134	4.9	5.9	0.9	11.2	12.8	1.9
202	6.1	6.2	1.0	13.3	14.7	1.4
LSD[y]	1.1	1.1		1.6	1.9	

[z]Interaction was significant at the 1% level.
[y]LSD values at the 0.05 level.

Table 3. Total marketable yield for fall crop of zuccini squash as a function of row arrangement and nitrogen levels[z].

Plant spacing	Nitrogen level (kg·ha⁻¹)			
(m)	67	134	202	LSD[y]
		Total marketable yield (t·ha⁻¹)		
0.30	7.3	13.1	15.6	1.2
0.45	9.0	12.2	14.0	1.2
0.60	9.2	11.5	13.6	2.1
0.75	9.2	11.3	12.7	1.7
LSD[y]	2.1	1.9	1.4	

[z]Interaction was significant at the 1% level.
[y]LSD values at the 0.05 level.

ment rainfall. Seven harvests were made between 26 Oct. and 16 Nov., while 11 harvests were made between 21 May and 12 June. Early yield comprised the first three harvests in both experiments. Only marketable squashes were included in the yield data.

Row arrangement. Row arrangement did not affect the early yield in spring (Table 1), most likely due to low temperatures during the harvest season. However, early yield from double rows in fall was higher than that from single rows. The total yield harvested from double rows was higher than from single rows in both seasons. This may have been the result of double rows more closely approaching the square plant arrangement found to produce highest yields (16).

In-row plant spacing. Early yield in spring decreased linearly as the interplant spacing decreased from 0.75 to 0.30 m (Table 1). Early yield in fall followed a similar trend, but differences were not significant. Although the effect of in-row plant spacing on early yield of zucchini squash does not seem to have been tested by others, similar decreases in early yield with decreased plant spacing have been reported for cucumber (9) and broccoli (6). These results suggest that closer plant spacing increases competition for nutrients and other factors that influence fruit maturation (1, 7, 10). Total yield increased linearly in both experiments as the interplant spacings decreased from 0.75 to 0.30 m. (Table 2). These results agree with those of Bradley and Rhodes (3), who found that marketable squash yield increased as interplant spacings decreased from 0.90 to 0.30 m. Similar results were reported with other crops (4, 6, 9).

Nitrogen rate. Early yield in fall increased linearly as applied N increased from 67 to 202 kg·ha⁻¹, and in spring it increased as N increased from 134 to 202 kg·ha⁻¹, but leveled off thereafter (Table 1).

The total yield response was linear to N rates in fall, but quadratic in spring (Table 1). Total yield in spring was highest with the intermediate rate of N (202 kg·ha⁻¹) and lower at the other rates (134 and 268 kg·ha⁻¹). Other workers have reported decreases in yield of squash and other crops with the highest rates in their studies (2, 9, 12–15).

Interactions. There were interactions between row arrangement and N rate for early and total yields in fall (Table 2). Early yield increased significantly at a lower N rate with double rows than with single rows as N rates were increased. Total yields increased as N rates increased with both row arrangements, but the response was more dramatic with double rows than with single rows. These results may be explained by the greater supply of increased competition for N per plant at the high plant density.

An interaction between plant spacings and N rates also influenced total yields in fall (Table 3). Differences in response to N rate became more pronounced as plant spacing decreased. With 67 kg N/ha, yields gradually decreased as spacing decreased from 0.75 to 0.30 m. In contrast, yields tended to increase with decreasing plant spacing for N at rates of 134 and 202 kg·ha^{-1}. A rate of 67 kg N/ha, rate apparently was insufficient to meet the nutritional requirement of the plants as plant density increased. The lower N rate at higher plant densities may also have affected the balance between vegetative and reproductive growth. No significant interactions occurred in spring.

Overall response to plant populations. The combinations of two row arrangements and four plant spacings formed seven plant populations ranging from 11,111 to 55,556 plants/ha. A simple regression analysis of total yield on plant population density was made for each N rate in both experiments (Fig. 1). The overall response was linear in fall and quadratic in spring. The slight decline in the slope of line N1 (67 kg N/ha) indicates that the amount was insufficient at the higher populations. The decidedly positive slope of the N3 (202 kg N/ha) line confirmed the expected increase in yield at higher populations with higher N rates. The linear response suggests potentially higher yields with higher rates than we used. The higher N rates (134, 202, and 268 kg N/ha) that we used in spring resulted in a quadratic relationship, as also reported by others (1, 7, 8). In spring, a maximum yield was achieved at about 37,000 plants/ha.

The overall difference between yields in the two experiments can be attributed partly to length of harvest season, as previously noted, but the difference in fertilizer regime also may have been a factor. All the fertilizer in fall was applied preplant so that spring leaching late in the season may have resulted in reduced yields. In contrast, the split application used in spring would have minimized such an effect.

Yields were optimized in this study with a plant density of about 37,000 plants/ha (obtained by planting in double rows 0.30 m apart with 0.45 m between plants staggered within rows), in combination with the application of 202 kg N/ha used as a split with 60% applied preplant and the remainder as a sidedressing 4 weeks later.

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Transplant Age and N and P Nutrition Effects on Growth and Yield of Tomatoes

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Additional index words. *Lycopersicon esculentum*, transplanting, nitrogen, phosphorus, plant age, fertilizers

Abstract. **'Pik-Red' tomato (*Lycopersicon esculentum* Mill.) transplants grown in the greenhouse were fertilized with three levels of N and P. Nitrogen at 400 mg·liter^{-1} and P at 30 mg·liter^{-1} had produced the largest transplants at 5 weeks after sowing. Nitrogen at 100 mg·liter^{-1} produced the largest root : shoot ratio. Phosphorus had no effect on root : shoot ratios. Plants fertilized with moderate and high N levels in the greenhouse produced larger early yields in the field, but there was no effect of N or P level applied in the greenhouse on total yield. Four- and 5-week-old plants produced greatest total yields.**

Fresh-market tomatoes are commonly grown from transplants in Michigan. High-quality transplants are essential for successful tomato production because plant condition at field-setting affects stand, early and total yields, and fruit size (2, 9, 11, 12).

Several factors that are known to affect tomato vegetable transplant size, quality, and growth in the field are root container size (4, 9, 12, 15), seedling nutrition before and after transplanting (3, 7, 8), plant age (2), and storage practices (8, 13). Depending on the crop, these cultural practices may or may not have significant effects on total yielding ability of the transplant. Currently, there is minimal information available on the effect of age of tomato plants grown in cells on growth and yield in the field.

Nitrogen and P are important elements in production of tomato transplants. In our previous studies, the fertilization regime during transplant production in the greenhouse affected transplant size and subsequent yielding ability (15). Jaworski and Webb (7) reported that highest yields were obtained with field-grown tomato transplants fertilized with low N–low P or high N–high P, but yields were reduced with high N–low P. In another experiment, they reported no effect of P levels during transplant production on yield (6). Gulmon and Turner reported that tomato seedlings grown with a low nutritional status had greater root : shoot ratios than plants grown with high nutrition, but they did not identify the specific nutrients that caused these differences (5). The experiments reported in this paper were conducted to determine the effect of transplant age and N and P nutrition during greenhouse transplant production on transplant growth and yield in the field.

Greenhouse experiment. The greenhouse experiment was initiated on 29 Mar. 1981. A 1 sphagnum peat : 1 vermiculite mix (v/

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